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Advances in Materials Technology: MONITOR

Issue Number 8 1987/1

Dear Reader,

This is the eighth issue of UNIDO's state-of-the-art series in the field of materials entitled Advances in Materials Technology: Monitor. This issue is devoted to Materials Testing and Quality Control and is addressed to a select target audience of policy-makers, scientists, technologists and industrialists in developing countries.

In each issue of this series, a selected material or group of materials will be featured and an expert assessment made on the technological trends in those fields. In addition, other relevant information of interest to developing countries will be provided. In this manner, over a cycle of several issues, materials relevant to developing countries could be covered and a state-of-the-art assessment made.

UNIDO has received good response on the content of the past issues, which covered materials like steel, ceramics, fibre optics, powder metallurgy, composites, plastics and aluminium alloys. In preparing the Monitors, the Department for Industrial Promotion, Consultations and Technology is receiving valuable help from experts in and outside of UNIDO. We hope to have their co-operation in our future issues as well.

This issue contains an article written for UNIDO by Dr. Wolfgang Neumann. It contains furthermore articles referring to materials testing experience in Japan and in the United Kingdom, as well as articles devoted to materials testing for plastics, composites and ceramics. Of course, the sections "Current Awareness", "Marketing", "UNIDO's Activities", "Publications", a list of centres doing materials testing and research on quality control as well as a list of "Future Meetings - Past Events relating to Materials" are covered in this issue again. We realize that the subject of testing and quality control is as wide as the field of materials itself and we have tried to make a selection which we hope will be interesting.

The UNIDO Secretariat would welcome information on materials and suggestions on the format and content of the Monitor from readers and would appreciate being included in your mailing list, if available, to obtain without charge more information on the development of new materials.

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CONTENTS

TESTING OF MECHANICAL AND THERMOPHYSICAL PROPERTIES OF MATERIALS

written for UNIDO by
Dr. Wolfgang Neumann

CONTENTS

INTRODUCTION

Modern quality control is always concentrated on the investigation of a material's properties in relation to the field of application of the specific material. For specialized fields it is therefore necessary to develop new methods or modify and improve those already existing. In this study it is not possible to describe all the recently developed or modified methods owing to the large number of tests resulting from the increasing number of more specific applications.

In order to give an idea of the interesting and specific trends, two sets of investigation and tests are reported on in detail, both identifying developments in this field.

The properties may be divided into

- Mechanical
- Electrical
- Optical and thermophysical properties

The various trends may broadly be explained by a description of the first (mechanical) and the last (thermophysical) groups of properties.

The methods for determining the mechanical properties are well established, even for advanced materials and a large number of international standard tests already exist. Considerable efforts are being made to adapt these tests to specific areas and to achieve a fully automatic testing procedure.

The chapter on mechanical tests therefore includes general trends and gives some examples of interesting specific methods which may be applied to various types of material.

The second chapter concerns thermophysical properties and gives a general description of the development of the methods used. One of the main tasks in this area is the improvement of experimental equipment to achieve higher accuracy rates, i.e. more reliable data.

In the past simple experimental arrangements were sufficient, but nowadays engineers and designers need more accurate data necessitating more sophisticated equipment. In particular, when considering problems of energy saving, slight improvements in isolation have to be measured as these can result in a remarkable economic effect.

There are only a few methods which have been accepted as international standards but the number of standard tests is increasing.

In this report the subject of the development of measuring methods shall be described extensively in order to illustrate the trends in quality control. It is also anticipated that these methods will run fully automatically some time in the future.

I. MECHANICAL PROPERTIES

Mechanical properties are still one of the most important aspects of quality control because resistance to mechanical impact usually determines the object's longevity.

Accordingly, tests to measure tensile strength, hardness, ductility, etc. were developed long ago and are now routinely used, but in spite of more modern methods they are likely to continue to be used in the future.

Mechanical tests also play an important role in the quality control of advanced materials. Due to the specialities of these materials, their structure, specific properties and fields of appplication, it is often necessary to adapt or modify the existing methods to their special requirements. There are a great many of these modifications, when taking into consideration the different types of advanced materials such as fibre-reinforced composites, brittle ceramics, glass fibre-reinforced plastics, high temperature resistant and high ductile metallic alloys and so forth. Therefore in this paper some typical methods, which probably are of a more general interest, are described.

Independent of the material to be examined recent developments in the field of mechanical testing have been concentrated on two tasks:

One such task is to test the materials under conditions which are very close to those the materials will be used for, i.e. on the one hand to experimentally determine the properties under conditions such as high temperatures or corrosive atmospheres and on the other hand to test not only small specimens of material but structural elements such as tubes or even more complex elements. The reason for this recent trend is the increasing safety and economic considerations. The more reliable the data, the more accurate are the calculations for design and structure and therefore the smaller the safety factor.

The second, which is in some way also connected to safety considerations, is the intention to achieve a fully automatic control of the measuring procedure. Apart from economic reasons, which are probably not valid for developing countries, the reason for automatic control is the better reproducibility of the test procedure. Therefore, as in other fields of science and technology, computers and data acquisition systems are becoming more and more important in quality control.

The application of microcomputers in data acquisition and evaluation for materials testing have changed the methods and apparatus used. Nowadays automatic measuring procedures, data acquisition and evaluation can be afforded by even quite small laboratories. In addition the application of microelectronics enables the design of compact portable apparatus which can also be used outside the laboratories. Time-consuming procedures such as calibration of measurement systems and compensation of disturbing influences can be carrried out by suitable software which is now available.

There are four main tasks which may be carried out by electronic equipment:

The first and most important is data acquisition. An automatic data acquisition system is most valuable or even necessary when handling very large numbers of measuring points and/or a large quantity of data. Second is the evaluation of the data, which includes its reduction, calculations using predetermined formulae and the documentation of process parameters, and the results. For these two tasks personal computers are mainly used. Third is an automatic control which is necessary to make the test performances reproducible. The controlling parameters may be time, certain test parameters, temperature, stress and given limits. Fourth is the control of the process parameters, i.e. the stabilization of temperature, the control of a temperature programme, load cycles, gas composition and so on.

In addition there is another positive aspect for using data acquisition systems in materials testing. When connected with a central or main frame computer the data can be transferred and stored there and be recalled by other technical or administrative departments. For instance the production units can get a quick response to queries on the product's quality.

A. Tensile test

This test is the well-known standard test for measuring mechanical properties.

By means of up-to-date electronic equipment this test has not changed in principle but the evaluation of stress-strain diagrams is now much easier to carry out and it is therefore possible to draw more information from the results of this simple test procedure. Computers control the test procedure, calculate the characteristic values such as tensile strengths, fracture toughness and so on, store the data, compare them with other results and perform statistical calculations. Statistics are very important when obtaining information on the reliability of average values and the scattering band.

B. Notched bar impact test

The impact test measures the fracture toughness very quickly. Unfortunately, the results obtained in the impact test are often not able to characterize the bulk material quantitatively. Therefore the use of the impact test is mainly reduced to the investigation of sheet materials, in which area it is also used as a standard test.

In order to obtain more reliable information from this test a recent trend in this well-established method is to be found in the development of the instrumentation often used in the test. Instrumentation raises a new problem in that disturbing vibrations with high frequencies are superimposed on the transient load-time or load-deflection record. The problem was investigated and it was shown for instance that the predominant vibration modes of a hammerblade are the longitudinal vibrations between the tup and the back of the blade. Because of these results a modified hammerblade was designed with a special precaution given to increased damping of the disturbing vibrations. It could be shown in an experiment that most of the disturbing vibrations had been removed. This finding will lead to an improvement of the evaluations of the transient load-deformation-diagram of an instrumented notched bar impact test as the characteristic points of the diagram can be better identified.

C. Hardness test

The most well-known of these tests are the Rockwell, Vickers and Brinell tests. These are very commonly used as they can characterize mechanical properties very simply and quickly, and therefore there are not expected to be any remarkable changes in these tests in the future. Nevertheless the equipment has been improved and specialized for up-to-date requirements. Microprocessors and computers are also applied to hardness tests and fully automatic tests are available. A further improvement is the reduction in weight of the equipment making it easier to transport. Such devices are particularly suitable for the running of rapid and reliable hardness tests, i.e. on-site testing of large and heavy work pieces or fixed installation components; during the production process and especially during mass production; for machines already installed at material storage depots; for the identification of materials at not easily accessible locations and in cramped space conditions; and for testing variations in hardness of especially large work pieces. In addition to the experimental improvements great efforts are being made to obtain the maximum amount of information from the simple hardness test. Formulae and calculations are therefore being developed to show the most characteristic value of the material as obtained from the geometric dimensions of the characteristics of the test piece.

The investigation of micro-hardness is also becoming more popular. Because of the measuring requirements needed for such investigations, tests were developed to run under fully automatic conditions. The experiments were so successful that there is now an automatic apparatus commercially available.

D. Creep and fatigue

Continuous deformation can occur in materials and particularly in metals and alloys subjected to high temperatures and to constantly applied force. This time-dependent deformation is called creep. The criteria for alloy development for high-temperature application, e.g. for gas turbines, are mainly the creep properties. When the creep characteristics of a material are well established, an engineering component can usually be designed to achieve the required life under specified operating conditions without failure due to creep.

The most widely used technique for providing engineering data involves the tensile creep rupture test machine. This consists of a dead weight applied to a lever system acting on a tensile cylindrical or sheet-shaped test-piece with the gauge portion heated by a resistance furnace. Temperature, load, rupture time and rupture elongation are the parameters measured.

If strain versus time relationships have to be measured a strain recording system is needed. For this purpose test-pieces with ledges at the two ends of the gauge length are usually adapted. The relative displacement of the ledges is transferred out of the furnace and then measured. High sensitivity inductive or capacitor transducers have replaced mechanical and optical systems, thereby facilitating automatic data logging and their computer elaboration. If fast strain variations or a highly disturbed strain signal have to be measured a continuous recording, usually by a chart recorder, is better than logging pairs of discrete values of strain and time. Fatigue data currently obtained and used in engineering design and performance assessment are endurance data, usually in the form of an S-N (S = stress, N = number of cycles) or ε-N (ε = strain) curve. Endurance curves are derived from constant amplitude tests on plain specimens or structural features.

Recently hydraulic closed-loop and computer-controlled machines for mechanical testing have become available. This modern, versatile and precise equipment permits complex tensile, compression and bending stress cycles to be carried out and is widely used for fatigue and creep at variable loads, for creep fatigue and stress relaxation tests.

A further aspect directed to lifetime prediction is thermal fatigue. Most low-cycle fatigue problems in high-temperature machinery involve thermal as well as mechanical loadings. Thermal loading means that the material is subjected to cyclic temperature simultaneously to cyclic stress. Analysis of these loadings and consideration of the attendant fatigue becomes very complex. Recent advances in analysis methods, e.g. finite element computer programmes and testing equipment e.g. servohydraulic test systems, help to solve these problems.

E. Acoustic emission

Acoustic emission is called quasi non-destructive testing as there may be elements in the specimen which could lead to damage of the material. Nevertheless it is being used more often in material testing. In general, acoustic emission can be defined as an elastic wave generated by the release of energy internally stored in a structure. Acoustic emission "sources", which can be described as different processes emitting elastic waves, can be classified into four different groups:

- Dislocation movements
- Phase transformations
- Friction mechanisms
- Crack formation and extensions.

With regard to mechanical properties crack formation and extension is the most important of these groups.

The highest amplitudes of the emitted signal are also generated from crack formation. It occurs at surface notches or at points inside a material where local stresses exceed the fracture stress. Crack formation results in the creation of new surfaces and strain energy is released which is partly transformed to acoustic emission signals. If the source emits a spherical wave packet, it will be propagated as such only in an infinite isotropic, homogeneous, ideally elastic medium. In real structures the propagation will be effected by surfaces, grain boundaries, microcracks, inclusions etc., anisotropy, inhomogenities and non-linear elastic behaviour.

When the emitted stress wave reaches the transducer the stress-strain condition has to be converted into an electrical signal which can be treated electronically. After amplification and a proper evaluation of the signal a more detailed knowledge of the nature of the source can be obtained. A detailed analysis of the waveform, the frequency spectrum and the amplitude distribution is often necessary.

Some of the advantages of the method are remote detection and location of flaws, and high sensitivity and detection of active flaws. On the other hand some of the limitations are a high dependence on materials and coupling methods, difficulties in detecting spurious sources and limited information on the types of flaw. Because of the potentials of the method it is already used in testing different kinds of advanced materials.

A separate and very important field of quality control is testing by non-destructive methods (NDT), but due to the wide scope of this field it is not possible to delve into it in this report. The great number of tests used in this field, which is still increasing, may be divided according to the physical properties the tests are based on:

- Optical methods (holographic methods)
- Radiological methods (absorption, diffraction, transmission, reflection of particles and radiation)
- Nuclear physics methods (activation analysis)
- Elastic oscillation (acoustic waves, ultrasonic tests)
- Magnetic and electrical methods (scattering and diffraction of microwaves or magnetic fields, eddy current tests).

For more details the relevant literature should be referred to.

II. THERMOPHYSICAL PROPERTIES

A. Density and porosity

Density and porosity are important parameters when determining the condition of a material. Often the knowledge of theoretical density and porosity is sufficient for a rough estimate of the properties of porous materials but many properties are influenced by porosity, e.g. thermal conductivity, electrical conductivity, some mechanical properties, etc. Particularly with regard to advanced materials, such as high-tech ceramics and powder metallurgy (P/M) do the values of porosity play an important role and indicate the quality of the product.

At the outset, the definition of density and porosity should be noted:

- Bulk density: the mass of the material divided by its bulk volume, i.e. its total volume including internal pores;
- True density: the mass of the material divided by the volume of solid material, excluding open porosity;
- Theoretical density: the density of the material, excluding all forms of porosity;
- Total porosity: the volume of void space within the material divided by the bulk volume, expressed as a fraction or percentage;
- Open porisity: the volume of void space within a material accessible from the exterior, divided by the bulk volume; and
- Closed porosity: the volume of void space within the material inaccessible from the exterior, divided by its bulk volume.

The bulk density of samples of simple geometric forms such as cylinders or cubes can be easily determined by their dimension and weight.

To determine the true density, the displacement principle is used. Modern pycnometry represents a refinement of the displacement principle and often uses a gas as the displaced medium. In gas pycnometry the volume displacement is determined from the pressure-volume relationship of a gas under controlled conditions. Helium is recommended instead of a liquid because it does not adsorb to most materials, can penetrate pores as small as 0.1 mm and behaves as an ideal gas. Furthermore, there are no problems with wetting, interfacial tension and evaporation.

Another method for density measurement is based on the absorption of a mono-energetic X-ray or γ-radiation. The rate of absorption depends on the thickness of wave length, atomic number of the sample material and its density. Wave length, atomic number and thickness can be kept constant. The resulting constant (K) can be determined by calibration with a material of well-known density. The density of the specimen material can be calculated by the following expression:

$$d = \frac{\ln (I/Io)}{-K}$$

I = intensity of radiation

Io = initial intensity of radiation

It is possible to calculate the theoretical density of cystalline materials from the characteristics of the elementary cell, that is the number of their atoms (Z) and structure type, the distance between atomic planes (a) and the atomic weight (A). For a cubic crystal the theoretical density (d) is given by the expression

$$d = \frac{A.Z_3}{N.a}$$

where A/N is the weight of one single atom (N = Loschmitt number). The required structure data are obtained by X-ray structure analysis.

A more specific method is the levitation method which is used to measure the density of powders and small particles. The material is dispersed in a liquid of which the density is continuously changed by the addition of a second liquid of a different density. Levitation of the particles indicates that their density is equal to the density of the liquid mixture. The latter can easily be measured by determining volume and weight.

Total porosity is difficult to measure. One approach is to grind the material to a powder finer than the smallest inter-space distance and comparing the powder density with the bulk density. When measuring the density of the generated powder one has to take care that the fine powder particles do not trap bubbles during immersion in the liquid of the pycnometer. Another way to determine total porosity is to compare the bulk density with the theoretical value measured on the same material or taken from the relevant reference literature. Alternatively, total porosity can be estimated by a line intercept or area counting method of a carefully prepared and polished cross-section

A suitable method for measuring open porosity, and one which is gaining popularity, is mercury porosimetry. This method uses the penetration of porous solids by mercury under pressure in order to determine the pore volume and pore size distribution of interconnected pores ranging from 500 to 0.003 m in diameter. The porous material to be analysed is placed into a mercury porosimeter in which the volume of mercury absorbed by pores is measured as a function of the pressure applied to the mercury. The technique has been applied to a variety of porous materials such as concrete, bricks and tiles, engineering ceramics, porous metals and powders. The method is based on the following equation:

$$D = \frac{-4\gamma \cos\theta}{p}$$

Where p is the pressure required to force the mercury through a pore of diameter D., θ is the contact angle between the mercury and the porous material. γ is the surface tension of mercury. Mercury is used as the intrusion liquid because it does not wet most materials, a fundamental requirement of the method.

B. Thermal conductivity and diffusivity

Heat flow and temperature distribution determine energy consumption. Due to the importance of energy conservation, thermo-physical properties are becoming increasingly important and considerable effort is being made to accurately measure the thermal conductivity of insulating material and conductive materials.

In the experimental determination of the thermal conductivity of solids, a number of different measuring methods are required for different degrees of temperature and classes of materials with differing rates of thermal conductivity values. A particular method may therefore be preferable to others for a given material and temperature range, and no one method is suitable to all the required conditions of measurement. The appropriateness of a method is further determined by such considerations as the physical nature of the material, the geometry of available samples, the required accuracy of results and the speed of operation.

Two measuring principles are the basis for all methods of conductivity determination. First, the method with a steady state heat flow in which the test specimen is subjected to a temperature profile which is time invariant. The thermal conductivity is determined directly by measuring the rate of heat flow per unit area and by measuring the temperature gradient after equilibrium has been reached. Second, the non-steady state method in which the temperature in the specimen varies with time. Using this method, the rate of temperature change is measured. From the data and geometric dimensions obtained the thermal diffusivity can be determined. The thermal conductivity K is then calculated from the thermal diffusivity a, the density d, and the specific heat Cp of the material according to the formula:

$$K = a.d.Cp$$

Some of the methods commonly used in order to determine the conductivity of advanced materials are described in more detail.

Guarded hot plate

This steady state method is more commonly used for low-conductive materials such as fibre insulating material, highly porous samples and compacted powders.

The shape and size of specimens used in various apparatus are different, but in general the specimen length-to-width ratio is small, because the smaller this ratio the smaller the ratio of lateral heat losses of the heat flow to the specimen. The absolute value of the diameter of a disk-shaped specimen commonly used may even exceed 1 m.

The experimental arrangement is so designed that the flow of heat is only in one direction, i.e. the axial direction of the cylindrical specimen. Radial heat losses are prevented or minimized in most of the apparatus by the use of a guard heater which is so adjusted that the temperature gradient is zero in all directions except in the direction of the axial heat flow.

Provided that the above-mentioned requirements are fulfilled the thermal conductivity can be determined by the following equation:

$$K = \frac{-q \Delta x}{A \Delta T}$$

K = thermal conductivity

q = rate of heat flow

A = cross-sectional area of the specimen

ΔT = temperature difference between two points of measurement along the heat flow directions

x = distance between the points of temperature measurement

In most modern apparatus the rate of heat flow is determined by the power input to an electrical heater, but it may also be determined by a calorimeter or a heat flow meter. Temperature measurements are generally made with thermo-couples inserted in the specimen or embedded in grooves on the specimen's surface. The method is fairly successful up to about 400°C.

The guarded hot plate method is very well developed and very commonly used in research institutes as well as in industrial laboratories. Due to its wide range of applicability it is the most important method for determining almost every kind of insulating material used in technical applications and buildings.

Recent work on improving the method was mainly directed towards evaluating heat loss, which is not entirely negligible, in order to correct the obtained results and increase their accuracy.

Investigations are also being carried out while running the apparatus under different atmospheric pressures, because the kind of gas and its pressure quite remarkably influence the conductivity of porous insulating material.

<u>Comparative method</u>

This method is also based on a longitudinal steady state heat flow. The rate of heat flow is determined by the temperature drop in a reference material. The reference sample of known thermal conductivity is placed in series with the unknown specimen. Under ideal conditions, that means the same rate of heat flow through the reference sample and the specimen. The thermal conductivity can be determined by use of the following formula

$$K = K_r \frac{A_r(\Delta T/\Delta x)_r}{A(\Delta T/\Delta x)}$$

where the subscript r represents the reference sample.

Comparative methods have the advantages of simpler apparatus and easier operation and because of these they are very suited to the field of material development, since they can quickly provide thermal conductivity data on new materials. In particular the increasing number of composite materials can be easily tested by this method.

The results obtained are of lesser accuracy than those obtained via the hot plate method as a result of the uncertainty of conductivity of the reference sample, the conductivity mismatch between specimen and reference sample and the interfacial thermal contact resistance. The method is generally used in the temperature range of -50°C up to 950°C. Above 950°C it is very difficult to reduce heat loss and therefore measuring is not usually carried out.

For special purposes methods with radial steady state heatflow have also been developed. A cylindrical method is the most important of these but is only used for special applications, e.g. thermal conductivity measurements of granules or powders because of the rather complicated specimen preparation.

The conductivity is calculated from the expression:

$$K = \frac{q \ln (r_2/r_1)}{2\pi l (T_1-T_2)}$$

l = length of the central heater

T_1, T_2 = temperatures measured at radii r_1 and r_2

<u>Line heat source method</u>

This method uses a long thin heater wire as line source. The wire, usually made of platinum, is supplied with a constant power input. This hot wire - the method is often called the "hot wire method" - is embedded in a large specimen, which is initially at a uniform temperature. After the heater is turned on the temperature of the hot wire is recorded as a function of time.

The thermal conductivity is given by the expression:

$$K = \frac{q}{4\pi l} \quad \frac{\ln (t_2/t_1)}{(T_2-T_1)}$$

T_2-T_1 = temperature difference between two different times (t_2, t_1)

The main advantage of this method is its applicability at very high temperatures. The method therefore plays an important role in energy saving investigations because it is very suitable in determining thermal insulating materials for high-temperature application such as refractory stones. The large specimen volume (dimensions are: 230 mm x 114 mm x 64 mm) makes the method suitable for determining heterogeneous materials and even powder samples. Its disadvantage, however, is the very long time needed for a test and the limited conductivity range ($K < 2\ W m^{-1}K^{-1}$) - if the temperature of the hot wire itself is not measured, but rather a certain point in the sample, it is possible to increase the conductivity range up to $25\ W m^{-1}K^{-1}$.

The method is to become an international standard method for testing refractories. An FRG pre-standardization already exists (DIN 51 046) and an ISO standard is under elaboration.

<u>Flash method</u>

Thermal diffusivity is determined when this method is used. A flash of thermal energy is supplied to one of the surfaces of a disk specimen within a time interval that is short compared to the time required for the resulting transient flow of heat to be propagated through the specimen. In most modern equipment a laser supplies a flash of energy to the front face of a thin disk specimen. The dimensions of the specimen depend on the design of the equipment being used, but are in general about 10 mm in diameter and 1 to 3 mm high. The temperature time history is recorded on the rear face of the specimen. It is advantageous to measure the temperature by a contactless method, such as by pyrometry, in order to avoid problems with thermal contacts, response time and heat transport along the wires using thermocouples. The thermal diffusivity can be determined from the thickness of the specimen l and the time $t_{1/2}$ at which the backface temperature reaches half its maximum value by the expression:

$$a = 0.139\ l^2/t_{1/2}$$

The advantages of this method are the very simple specimen geometry, simple operation, quick measurements and a wide temperature and diffusivity range. Because of these advantages it is a very suitable method for generating data for a data sheet and is also a very good quality-control instrument.

Flash diffusivity measurements are therefore often used in the field of material development work, as when investigating materials for tool cutting, cemented carbides and ceramics. Another field of application is connected to safety considerations related to nuclear power stations. In this case it is important to know the temperature distribution in a reactor core after an accident involving loss of coolant. In order to calculate this distribution the thermal diffusivity of uranium dioxide at very high temperatures, and even in the molten state, have to be known.

Almost all of the materials can easily be measured by the laser flash method although care has to be taken in determining heterogeneous materials because representative sampling and the achievement of a undirectional heat flow may be difficult. Translucent materials can only be measured by this method if the faces are coated over with an opaque heat-absorbing layer. The method is standard for diffusivity determination of graphite samples up to high temperatures. In additon work is being done to establish it as an international standard (ASTM e 37.05.03) for diffusivity measurement in general. Thermal conductivity can be calculated from diffusivity, specific heat and density data as mentioned before.

C. Thermal expansion

Thermal expansion data are necessary for the calculation of thermal stresses. In addition, this property characterizes the material very well, e.g. the determination of phase transition and shrinkage during the sintering process are important applications of thermal expansion measurements.

The trend in advanced materials is to develop materials with very low thermal expansion coefficients. Such materials are very suitable for high temperature application because of the reduced thermal stresses and thermal shock sensitivity. On the other hand the development of these materials requires measuring methods which are even able to determine very low thermal expansion at very high temperatures.

The linear expansion coefficient is the fractional increase in length per degree rise in temperature at a particular temperature and therefore given by the following expression:

$$a(T) = \frac{1}{l} \frac{dl}{dT}$$

a = linear expansion coefficient

l = length

The mean expansion coefficient, which is commonly reported, is given by the equation

$$A = \frac{1}{Lo} \frac{L - Lo}{T - To}$$

i.e. fractional increase in length as a result of increase in temperature from To to T.

Tube dilatometers

These dilatometers are the ones most commonly used. With the non-differential tube type dilatometers the method is a comparison method in which the thermal expansion of the specimen is compared to the tube material. With a differential dilatometer the thermal expansion of a specimen is measured according to a reference material.

An important application for differential expansion measurements is in quality control. It is now routinely used for quality control measurements, for instance on gas turbine components and glass-ceramics. Improvements had to be made to run the dilatometers at high temperatures.
High-temperature dilatometers are nowadays made of alumina, tantalum or other refractory materials.

Interferometers

With interferometric methods the absolute value of thermal expansion can be directly measured. The number of fringes that pass a reference point is a measure of the change in length of the specimen. Using these methods it is necessary to polish parallel optical flats on two opposing faces of a rigid test block and to take measurements of displacement after several hours of temperature stabilization. The accuracy of the mean thermal expansion coefficient is limited due to uncertainties in temperature uniformity but it is within the range of 10^{-8} K^{-1} over the temperature range of 25°C to 200°C. Because of the requisites of the sample's condition, porous or thin bars cannot be measured by these techniques.

X-ray methods

The thermal expansion of crystalline materials can also be measured with X-ray cameras and diffractometers. The principle of the measurement is based on the change of distance of atomic planes with temperature. By means of X-ray diffraction the extent of this change can be measured.

When using the camera method the specimen has to be a fine-grained polycrystalline wire, a powder or a single crystal. Instead of using X-ray diffraction, neutron diffraction may be used for special measurements of thermal expansion of materials which are composed of light elements such as special plastics and other hydrocarbon-based material. The main disadvantage when compared with the X-ray method is price, because for thermal neutrons a nuclear reactor is required as their source.

D. Specific heat

Specific heat also characterizes the thermophysic-thermodynamic behaviour of the material and is necessary for calculating thermal conductivity from diffusivity measurement and vice versa. Therefore a description of some important methods is included in this report.

The prime methods for measuring the specific heat of solids which are commonly used are the mixtures or drop method, the adiabatic method, the comparative method, the pulse heating method and modifications of these.

Drop calorimetry

In drop calorimetry the heated sample is dropped into the calorimeter and the heat given off by the sample to the environment is measured. Depending on the medium to which the heat is released the calorimeter is called an ice, an isothermal water or copper block calorimeter. The amount of heat released from the specimen is measured by the temperature increase of the medium, e.g. water or copper.

Pulse heating method

For materials which are electric conductors this method may be preferable. The specimen is heated directly by its resistance. The current flowing through the specimen and the voltage fluctuations are measured simultaneously as a function of time. The specific resistance at each time interval is calculated from the cross-sectional area of the sample, voltage, current and distance between voltage probes. The specific electrical resistance is then plotted as a function of time. The specific heat can be calculated from the mass of the sample, the temperature coefficient of the resistance and the time rate of resistivity change.

Differential scanning calorimeter

This is an apparatus commonly used to determine specific heat. It is often used to generate data, particularly for conversion of thermal diffusivity in thermal conductivity data and vice versa. Small specimens - solid samples are often cylindrically shaped with a diameter of about 6 mm and a height of about 1 mm - are fastened to a heated sample holder and the heat inputs are measured to achieve a linear increase of the specimen's temperature. The calibration is checked with a reference material. Usually a sapphire is used as a standard.

III. RECOMMENDATIONS

Because of the increasing economic relationships between industrialized and developing countries the number of goods which the developing countries offer for sale will probably increase. In connection with this development there is a strong demand for quality control of products originating in developing countries and the industrialized countries wish to be sure that the quality control is performed in accordance with international standards.

The best way of fulfilling this requirement is to carry out international standard tests for quality control. To ensure a consistent quality of these tests there is a trend towards largely automatic procedures i.e. computer controlled testing. Developments in the field of mechanical testing, where the number of standard tests is very high, shows the possibilities and tasks of applied electronics and computers.

The same goal, that is a higher quality assurance, is obtained by further improvements to existing tests, whereby the properties are checked under conditions as close as possible to their intended application. In the field of mechanical properties, the examples are creep and fatigue tests, which can even now run under corrosive conditions. Apart from the field of non-destructive testing, which is not covered by this report in which tests are improved further and new ones invented, a fairly recent method in materials testing is the application of acoustic emission.

A completely different trend is observed with the thermophysical properties tests. Mechanical properties were always very important, therefore tests for these have existed for a long time and are being continuously improved and expanded. The most important of these are already internationally accepted standards. In thermophysical testing the properties become more important relative to the current energy situation and therefore thermal conductivity, specific heat, thermal expansion and so on have to be included in material characterization to a far greater extent than in the past. In accordance with this trend some new methods were developed and the accuracy of existing ones were carefully reviewed and a number of standardization procedures are presently being carried out.

In short the modern trend in quality control is to make the tests

- Quicker
- More accurate
- More reproducible
- More reliable

With respect to developing quality control in developing countries some recommendations may be made:

- In general it would be very useful to apply personal computers to the test equipment. Experience has shown that a PC placed close to the test is better than a huge central computing unit.
- Every test should be run as far as possible automatically.
- In a field where international standard tests exist these should preferably be used.
- For self-developed methods a routine procedure should be established and documented. In addition it is important to fix a quality assurance programme for the test.
- In relation to equipment, it should be pointed out that in many cases the larger the possible field of application, the more efficient is the apparatus. Examples are the comparative or laser-flash method for thermal conductivity measurements, tube dilatometers for thermal expansion and the differential scanning calorimeter for the determination of specific heat.

Standardization of testing, evaluation methods reviewed: Japanese experience

Over the next five years, the Agency of Industrial Science and Technology, part of the Ministry of International Trade and Industry, will be promoting standarization (the establishment of standards in the Japan Industrial Standards [JIS]) of testing and evaluating methods in the three fields of fine ceramics, new organic composite materials, and new metallic materials. The purpose of this project is to make possible the mutual comparison of test data. By establishing JIS standards for these fields involving revolutionary new materials, the Agency of Industrial Science and Technology aims not only to react with felixibility in quickly establishing and modifying standards while taking into account users' needs and technological developments, but also to make international standards of the ISO (International Standards Office) a reality. The agency wants to seek the future direction for JIS standardization, with the Long-term Plan for Promotion of Industrial Standardization of the Japan Industrial Standard: Research Council (an advisory body to the Minister of International Trade and Industry) as a focal point.

The field of new materials is a key technology

The requirements of new materials are increasing, exemplified by the demand for lighter, stronger, and less costly materials. Of course, the development and application of fine ceramics, organic composite materials, and new metallic materials came about in response to such requirements. In the field of fine ceramics, research and development is making rapid progress in oxide-based fine ceramics, as well as non-oxide-based fine ceramics, such as nitride-based, carbide-based, and carbon-based fine ceramics. In the area of functions, it is expected that a variety of materials will be developed having functions such as thermal and chemical stability, electrical conductivity, and ferroelectrical properties, as well as new properties which combine these functions.

In the field of new organic composite materials, the requirements are increasing in level and in variety, and developments are being made which will further increase the functional and performance levels. Highly functional polymer materials have been used in electrical materials, optical materials, photosensitive materials, separation membranes, etc., but there are many more applications to be researched and developed. Since highly functional polymer materials and high polymer composite materials have excellent thermal properties, mechanical properties, durability, and molding properties, progress is being made in applying them to many fields, including electrical and electronic parts, magnetic tapes, automobiles, and aircraft.

In the field of new metallic materials, progress is being made in the research and development of new metallic materials possessing physical functions such as shape memory, hydrogen storage, or the ability to change light or pressure into electricity, and chemical functions such as catalytic properties. These materials are called highly functioral new metallic materials. On the other hand, the development of high performance new metallic materials is also progressing, with emphasis on requirements such as super heat resistance, super plasticity, high strength, high corrosion resistance, super conductivity, and vibration resistance.

Preconditions for testing and evaluation not yet determined

The overall field of these new materials covers a wide range, from materials that have already achieved practical application to those that have yet to be researched and developed. In the future, these new materials will play an essential role in the development of advanced technologies such as electronics, mechatronics, new energy, and aerospace.

Since the prerequisites for testing and evaluation of the basic properties of these new materials have not yet been determined, there is a lack of reliability with respect to these materials, and there are obstacles to their smooth development and application. If both makers and users could test and evaluate new materials using the same methods, there would be no problem, but when users are deciding whether or not to use (purchase) new materials, they usually have their own tests. Thus, the lack of reliability resulting from differing methods of testing and evaluation hinders the development of applications of new materials.

It has therefore become essential to systematize and standardize (to establish JIS standards) testing and evaluation methods so as to permit mutual comparison of data. If such systematization and standardization becomes a reality, not only will it be possible to establish more trust between makers and users, but it will also become easy to determine the technological level of new materials, and it will become possible effectively to promote the development and application of new materials.

The Agency of Industrial Science and Technology recognizes that since new materials will be used to increase the level of advanced technological fields and to increase the level of a variety of products, the testing and evaluation of the materials will differ from that of past materials. These differences are as follows: (1) The level of the characteristics will differ; (2) The environments and conditions under which the materials will be used will be more rigorous; (3) The requirements for reliability will be high; (4) It will be necessary to evaluate quality in field conditions; (5) It will be necessary to evaluate quality from the standpoint of processing characteristics; (6) There will be a greater variety of tests and evaluations; and (7) The tests and evaluations will be more reliable. The standardization of testing and evaluation methods for new materials will be difficult if already standardized methods of testing and evaluating existing materials are used just as they are. It is thus considered necessary to develop new data bases and new testing methods for standardizations.

The difficulty of obtaining "consistency"

JIS standardization should be conceived of in such a way that the system of standards is consistent. The types of standards include "Basic Standards", "Standard Methods of Testing and Evaluation", and "Product Standards". In the case of basic standards, plastic terminology standards (JIS K 6900) were established in 1977 for new organic composite materials, and efforts are being made to make this terminology consistent with that of the ISO (International Standards Organization).

Standards have been established for metals in JIS G 0203 (Steel Terminology - products and quality), but given the present state of development and application of new materials, it is necessary to unify terminology in all fields of new materials. For example, the term "delay fracture", referring to mechanical properties of structural materials, means "The phenomenon of a sudden brittle fracture of a material which has been used over a long period of time under static stress at room temperature, due to the influence of hydrogen", in the field of metals, but in the field of ceramics, it means "creep". In order to select materials based on their properties, there should not be contradictions among the definitions of the terms in each of the three fields of new materials. In order to avoid this, it is thought that before deciding on terminology in each of the fields, priority should be given to the establishment of JIS standards, since there is a need to standardize the terminology standards as one of the basic standards.

With regard to "Standard Methods of Testing and Evaluation", common testing and evaluation items will be established for all materials, since there are many classifications in the three fields. Furthermore, individual testing and evaluation standards will be common to all three fields, as in the case of basic standards, so as to simplify decisions regarding the potential use of a sample and its reliability as a material. Also, due to the partial revision of standards for existing materials, those that can be applied to new materials will be put to practical use.

It is hoped that standardization of "Product Standards", will proceed in a timely manner, with users' needs, trends in technology development, and trends in demand taken into consideration.

In the actual process of standardization, Basic Standards and Testing and Standard Methods of Testing and Evaluation will be given priority, in accordance with the timing of the establishment of JIS standards. Furthermore, the policy for JIS standardization will be to give priority to individual materials which are strongly desired by both makers and users, and which have already appeared on the market, and in the case of testing methods, priority will be given to methods that will effectively promote the expansion of research and development of materials and the development of applications of materials. In the case of fields in which there is significant technological progress, speedy revision will be carried out so that the standard can be established and publicized in the necessary time period. Also, if necessary, schedules and proposals from stages prior to establishment of the standards will be made public as necessary to promote a progressive and flexible process of standardization.

In addition, research into foreign and domestic trends in standardization necessary to determine priorities for standardization will be improved and intensified. The aim of this research will be to organize data bases for test data and systematically to determine users' needs. Its application to internationalization is also considered important. Since it is expected that "friction" in the field of advanced technology will gradually increase in the future, the policy will be to make known both domestically and abroad the need for the establishment of JIS standards as well as their content, and to obtain an international consensus, and also to propose the use of the JIS standards as international standards.

The speedy establishment of an organization for evaluation proposed

The general direction of JIS standardization with regard to testing and evaluation methods for new materials has been indicated, but there still remains the task of organizing a system for carrying out the testing and evaluation in question. The more innovative the new material is, or the more limited its application, the more costly will be the equipment for testing it, and since the equipment will not be used so frequently, the cost of testing and evaluating new materials will be high. The use of testing and research facilities of national organizations such as the Agency of Industrial Science and Technology has of course been suggested, but the fact is that there are limits.

The importance of gathering and storing test data has been pointed out, but there is no suitable system for accumulating and making the data available.

It is clear that this is a problem that cannot be solved by a private enterprise on its own. In the field of materials, a Fine Ceramics Centre has been set up as a foundation, but since the local industries in the Chubu region of Japan are very prominent in this project, it is not exactly the type of centre that is needed. In the future, the use of public funds to establish centres such as the Fundamental Technologies Research Promotion Centre, the co-operation of national and prefectural research laboratories and nonprofit foundations, as well as links between private companies and universities, and the establishment of other comprehensive systems to promote data gathering and dissemination will be an urgent task. It is expected that the establishment of testing and evaluation functions will become even more necessary as more new technologies are developed. (Excerpts from an article written by Noboru Morishita in Japanese in Tokyo Nikko Materials, January 1986)

Time to measure quality costs: UK experience

Customers worldwide are increasingly demanding higher product quality and value for money, and overseas competitors are placing a high priority on improving their quality performance. While many people in the UK are concerned about the cost of implementing such quality control procedures, few have a clear understanding of how much poor quality is actually costing them.

The cost of quality can be divided between three main functions, namely: failure, appraisal and prevention. And one of the main reasons given for the lower quality costs of other major industrialized nations is the level of attention they give to failure prevention. This takes in the cost of all raw materials, components and finished goods which fail to comply with specification (and includes scrap, rework, design mods, formal complaints and customer returns). In other words costs incurred because the product/component was not made right in the first place.

While quality control is still directly tied up with inspection, the emphasis is now firmly on using metrology-type data to gauge and in some cases control the variability of the manufacturing process. A whole range of electronic and optical instruments are now controlled by microprocessors and many can be hooked up to data-processing units or micro-computers for data recording, statistical analysis and the supply of much valuable management information. The spread of inspection equipment which can be linked to a computer and used to offer some level of process control ranges from the humble micrometer right (albeit of the electronic variety) through in- and post-process gauging stations, right up to co-ordinate measuring machines.

The idea of establishing process variability isn't new - only the techniques of gathering and processing such information have changed.

Today's methods of process control are less mechanically orientated, centring firmly around the use of electronics and optics. And the processing power of the computer (and its ability to analyse and present these measured values in different ways) has done much to transform established statistical analysis procedures into useful and dynamic quality tools. When combined with automatic size control, such control equipment has the ability to correct dimensional drift long before an out-of-toleranced part is ever produced.

Electronic mikes

Also capable of being linked to a host computer (by way of its RS232 I/O port) is the new series of electronic internal micrometers recently introduced by Bowers Internal Gauges. Available in 14 different sizes (from 6 to 204 mm), these instruments have an overall resolution of 0.001 mm and battery life is guaranteed for 12 months continuous use. Optional extensions enable deep bores to be accurately measured, while statistical analysers and printers can be supplied as part of a complete process gauging system.

In a similar vein, electronic caliper gauges from Marposs can also be equipped with statistical analysers. Shafts and external diameters from 10 to 60 mm diameter can be checked with only one frame size and adjustment for different sizes takes only a few minutes. Two adjustable fixtures - for shafts and disc-shaped parts - can house the caliper to give simultaneous readings on key dimensions within seconds of the component being loaded. The job of collating all this measurement data is handled by a Marposs statistical analyser.

On a more general quality analysis theme, Sellars Datasystems has introduced a hand-held data collector known as Dataputer. Looking like an overgrown calculator, the unit can interface with a wide variety of electronic instruments and contains software to produce a range of statistical analysis functions. These include histograms, capability indices and sampling control charts. Dataputer can also be hooked up to most makes of micro- and mini-computer if data retention or enhanced statistical analysis is required.

Two new systems on the market look set to change this image. The first of these is the Universal Magnetic Particle Inspection System from Inspection Equipment. The Interflux IE semi-automatic system is of multi-station, rotary transfer type and uses what's known as advanced swing field technology. This links current- and flux-induced magnetism in stepped phases which are 90 degrees apart - so the magnetization of the component swings through 360 degrees. The system is said to show up all defects (no matter what their orientation) and is fast, with full magnetization achieved in one shot.

The second example relates to a new series of Tiede units for magnetic particle inspection, available from Wells Krautkramer. These bench type instruments also feature the swing field system and are micro-processor controlled to simplify and speed up test procedures. Timing for magnetizing, rinsing and demagnetizing can be accurately adjusted to suit the component under test (which can range from 50 to 300 mm diameter), while the microprocessor ensures that test settings are maintained and repeated exactly for automatic cycling.

Still on surface analysis, Rank Taylor Hobson's Form Talysurf permits the measurement of many straight or curved components whose contours were previously difficult (if not impossible) to assess by normal methods. The instrument uses a laser interferometric transducer type pick-up and will measure both form error and surface texture from a single traverse. The entire measuring cycle is controlled by a micro-computer, so speeding setting-up, calibration and actual measuring procedures. Results are displayed on a VDU and can be output to a printer if hard copy is required.

The computerized system for hardness testing can be used for testing all types of metals and hardness can be determined in Rockwell, Vickers or Brinell. When supplied in its full computerized form, the package includes a Sharp PC-1500 computer and printer, and Equomodule software. The software will print out results, allow for different impact directions, print a histogram, and calculate a statistical analysis of the results. In this form, the whole system is battery powered and comes in its own standard size attaché case.

Computerization, is at the heart of much of the development activity on the general quality front. But for production engineers engaged in automation projects, it is the auto-size control features of modern inspection set-ups which hold most appeal. For the ability to close the process control loop and offer an independent verifier is essential in any advanced manufacturing technology (AMT) project which is to run with limited manning levels or even unmanned during the 'third shift'.

There are different ways of actually measuring key features on a component before the computer side of the package handles the statistical analysis functions and signals any corrections to the tool offsets of a CNC machine tool. Most popular methods at present centre on either onmachine probing or immediate post-process electronic gauging. True-in process gauging, with adaptive control, is still very much the sole preserve of grinding.

Probing turning

One user which opted for touch-trigger probing on a new Heid H6.6CNC lathe was Holset Engineering. The Halifax-based company produces crankshaft vibration dampers (from castings ranging in size from 200 to 3000 mm diameter) and flexible drive couplings which are capable of transmitting from 0.45 to 1,000 hp/rev. But the Heid SDM532 CNC lathe is being used on a family of over 30 damper bodies with bore sizes ranging from 25 to 150 mm diameter and tolerances of H7 or even H6 on some occasions. Key production requirements on these castings were: short lead times, minimum set-up, low cycle times and reduced inventory of finished parts.

To help meet these demands, the company decided on an LP2 touch-trigger probe and the Mark IV inductive transmission system for Renishaw Metrology. While this probe has been designed to work in hostile environments, Heid decided to provide additional protection in the form of a hinged shield which covers the probe when it is stored in the turret. Jets of air are blown across the stylus tip and through the bore of the casting to ensure that accurate readings are taken. The ruby ball on the stylus tip touches the inner face of the bore immediately after the first roughing operation, with the offsets of the Siemens 3T CNC system being automatically updated for the finishing cut. If the probe readings indicate that the offset required for the final cut is over 50 per cent of the finished bore tolerance, then production will be halted immediately and the operator alerted.

Production often starts from cold and without the probe a variation of up to 53 microns has been recorded over a run of 40 components. However, two-point in-process gauging with the Renishaw system reduced this variance to only 14 microns. On-machine inspection has also cut complete production times from 27 down to 5 minutes per component and setting times are much lower. Probing has also speeded the production of one-offs with cycle times down from one hour to only 10 minutes.

Immediate post-process electronic gauging stations are favoured in some automated cells as the actual production process is not held up while multi-measurements are taken. However, most systems are not as flexible as probing and they are at least one part behind, for another component is being machined while the previous one is checked. Recent installations at R. A. Lister (where flywheels produced in an automated cell are checked on a Tesa post-process electronic gauging station) and at Rolls-Royce (where small compressor blades produced in special ECM cells are inspected by Machsize computerized gauging stations) indicate the trend toward electronic gauging stations in AMT type environments.

The actual method of measurement favoured by most manufacturers of electronic gauges is the linear displacement voltage transducer (LDVT). However, the real power of such systems centres firmly on the ability of the software to collate multi-dimensional data and interpret this mass of information in a whole host of different ways. To get some idea of the power of such quality equipment, here is a brief run-down of the features offered in the range of automatic gauging units produced by Vernon Gauging Systems.

Typical inspection machines can perform static, dynamic or simultaneous measurements and display statistical batch information in the form of mean and range charts, and total batch histograms, as required by user. Each plot on the mean and range chart is related to time and may be 'flagged' to indicate that a tool adjustment has taken place. The histogram has the mean, plus and minus three standard deviation points indicated and additional data. Extra video display units may be used to inform the operator of current machine status and will advise of any corrective action necessary (if this is not handled automatically by way of corrective feed-back loop).

At the low-cost end of the gauging market C. E. Johansson and Syke Instrumentation have co-operated on a method of automating inspection routines. The set-up consists of the latter's Syko miniature robot which is programmed to load a component into a Johansson Combicheck gauging fixture. Such an arrangement could be used to transfer parts from a discharge chute on an NC machine to the electronic gauge. And by using Metem or Cejmatic measuring control, the system can provide automatic size control.

While co-ordinate measuring machines (CMMs) and non-contact measuring instruments can be used to close the process control loop, most do not function in this manner. However, shop-floor type measuring machines - rugged and high speed CMM-type units and measuring robots - are beginning to make their presence felt. And one of the latest in this 'new breed' is the process control robot (PCR) from Brown & Sharpe.

Basic design of the PCR centres on a five-axis horizontal robot arm with a probe and rotary table. The high-speed (500 mm/sec.) machine is designed to act as a standalone quality cell within an FMS and is linked directly to the host computer. Intended for 100 per cent inspection, it records out-of-tolerance conditions or statistical analysis of drift and feeds this data back (by way of the host computer) to the machine tool controller for automatic offset adjustment. (Extracted from Metalworking Production, January 1986, pp. 85-93)

Advanced techniques of electron microscopy for studying materials (D. J. H. Cockayne, Electron Microscope Unit, University of Sydney, N.S.W. 2006)

The past decade has seen a rapidly increasing use of the electron microscope for studying materials problems, not only as an imaging tool, but especially as an instrument that offers a wide range of analytical facilities. To make optimal use of the instrument, and to ensure correct interpretation of the data it provides, it is necessary to have an understanding of the available modes of operation and of their limitations. At the present time both the modes of operation and their limitations (accuracy, sensitivity, resolution) are changing rapidly as instrumentation is improved, electron scattering theories are developed, and new techniques are devised. Each of these three areas is a discipline in itself, but what is important to those interested in investigating microstructure is which instrument and what technique to use in a particular situation.

Electron microscopy can be carried out either in the transmission or the scanning modes (Figure 1). In the transmission mode, parameters of particular importance to a discussion of techniques are the angle between the incident beam direction and the lattice plane normal (in metallurgical studies, generally measured by the parameters $\underline{s}$ or $\underline{v}$), and the diameter of the objective aperture. If the objective aperture is only sufficiently large to permit one Bragg diffracted beam to reach the image, then the image is referred to as a bright-field image if that beam is the forward-scattered beam, and as a dark-field image if it is not. More generally, the terms 'bright-field' and 'dark-field' refer to images to which the forward-scattered beam does or does not contribute, respectively.

In the scanning mode, the collected electrons can be detected either on the same side of the specimen as the incident electrons (scanning electron microscopy - SEM) or on the opposite side (scanning transmission electron microscopy - STEM) (Figure 1). One of the principal advantages of the scanning mode is that imaging can be combined with microdiffraction and microanalysis from chosen regions of very small diameter. Moreover in dedicated scanning instruments the resolution can be at the atomic level for suitable specimens.

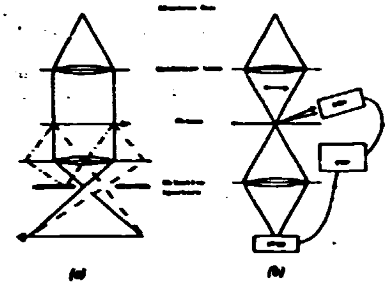


Figure 1. Basic modes of operation of the electron microscope: (a) transmission (TEM); (b) scanning (SEM) and scanning transmission (STEM).

High-resolution electron microscopy

Unlike the light microscope, the resolution of modern electron microscopes is not limited by the electron wavelength but by lens aberrations. Advances in reducing these aberrations, together with the development of accurate theories of electron scattering in crystals and computing techniques for simulating images from model structures, now make it possible to study crystalline materials at, or close to, the atomic level of resolution. Images are formed by allowing a number of Bragg-diffracted beams to pass through the objective aperture (Figure 1), which then interfere in the image plane to produce a high-resolution image. To obtain interpretable image detail at this level of resolution, a number of important experimental conditions must be satisfied both in the foil (e.g. maximum foil thickness, accurate specimen alignment) and in the electron optical parameters of the microscope (e.g. the number of diffracted beams passing through the objective aperture, the setting of the focus conditions within a narrow range). As the resolution of the interpretable image detail becomes higher, the more critical is the setting of these parameters; for the high-performance high-resolution instruments there is evidence to indicate that computer setting of some of the optical parameters is necessary.

The values of these various parameters, and the accuracy with which they must be set, have been established by studying how computed images vary with changes in the parameter settings. The information carried by the scattered electrons can be modified by the electron optics (through the 'transfer function') and, by computing images for model crystals, the relationship between details of the model and details of the image can be investigated. When this relationship is such as to allow a direct interpretation (atom group by atom group), the image is referred to as a structure image, and there is then a one-to-one correspondence between atomic structure and image contrast. In other cases the image may be referred to as a 'lattice image' or a 'lattice fringe image', and the relationship between structure and image detail may then not be direct.

In forming high-resolution images of defects, it is obviously desirable that the structure of the defect should not vary significantly through the foil in the direction of the incident beam if the image is to be interpreted without difficulty. For example, dislocations viewed along their line have been imaged in a number of studies and in recent years considerable attention has been paid to planar defects such as stacking faults and G.P. zones and to interfaces viewed edge-on.

One of the most difficult areas of high-resolution microscopy is the quantitative imaging of small particles. A great deal of both theoretical and experimental work has been pursued in an attempt to provide reliable imaging techniques for detecting and sizing small particles, and in the fields of thin films, amorphous semiconductors and catalysis the need for such techniques is growing. Atomic-level information concerning the surface of small metal particles is possible using high-resolution instruments but sizing and counting a statistically significant number of particles can give difficulties. In transmission images, and for particles <4 nm in size, the accuracy of particle detection and sizing depends critically upon the objective aperture size and the focus conditions. Detailed studies have shown that great care must be taken when interpreting fine image detail from such materials, because the transfer function can easily produce artefacts. One of the most promising techniques is hollow cone illumination in which an annular condenser aperture and a complementary objective aperture give axial dark-field imaging. The method improves particle contrast, and the range of incident beam directions included in the cone of illumination increases the proportion of particles showing strong contrast. Even so, considerable caution must be taken in interpreting the images obtained.

Other techniques suitable for imaging small particles are the Z-contrast method of Crewe and the weak-beam method. Using this latter technique, 0.5 nm platinum particles have been detected when supported on a thin Al_2O_3 film. This detection sensitivity was achieved by choosing an objective aperture of suitable size to exclude from the image the Bragg reflections of the Al_2O_3 support film - a technique that has shown considerable promise in many studies.

Diffraction contrast

Images formed by allowing only one Bragg diffracted beam to pass through the objective aperture (Figure 1) can produce diffraction contrast because of variations in diffracted intensity across the image. Diffraction contrast using strongly excited Bragg reflections (s or w small) is a powerful tool for differentiating between defect parameters (such as possible Burgers vectors), but is now such a basic tool for the materials electron microscopist that it does not come within the terms of this review. However, as a tool for detecting small differences in geometrical parameters, it is relatively insensitive. For example, using strongly excited Bragg reflections, dislocation dissociation widths and constriction geometries cannot be studied in detail below $\simeq 8$ nm and the geometries of loops smaller than 10 nm in diameter cannot be distinguished. For this reason a number of specialized diffraction contrast methods have been developed which extend the sensitivity and resolution of diffraction contrast images. Head and co-workers formulated techniques for rapid image simulation of micrographs.

By matching the experimental images with the images simulated from a range of postulated defects, defects can be analysed at a much higher level of resolution than is possible with standard contrast techniques.

A second technique for extending the sensitivity and resolution of diffraction contrast images is weak-beam imaging. This technique involves forming a dark-field image by using a Bragg reflection for which the perfect lattice is oriented far from the Bragg reflecting condition. The image of the matrix (foil) then appears (relatively) dark, but regions of the foil where the lattice strain is sufficiently high to locally reorient the lattice into the Bragg orientation (e.g. near dislocation cores) give strong Bragg scattering and consequently produce high image contrast.

Weak-beam imaging has been used in conjunction with video imaging to record the geometry of dislocations and other defects under dynamic conditions. The polar nature of this material results in there being two types of dislocation (α and β) with different core structures. Video weak-beam recordings have shown that the α and β dislocations (which can be directly distinguished in the image) have significantly different velocities under the electron beam.

Limitations on weak-beam imaging are the low image intensity (with consequent difficulties in focusing), the stability of the specimen holder and stage (which causes image drift during the recording of micrographs) and the masking of the image by diffuse scattering. Developments in modern instruments involving brighter sources, more stable specimen holders and stages, and higher accelerating voltages will increase the range of materials and defects to which the techniques can be applied.

Structure-factor contrast

Structure-factor contrast arises through a local change in the electron scattering power due to variations in the local structure factor. This may come about through, for example, atomic substitution or the agglomeration of point defects. In most cases the conditions that produce structure-factor contrast also produce lattice strain, in which case structure-factor contrast and strain contrast occur together. But by careful choice of the operating reflection, strain contrast can be minimized or even made to disappear. A particularly interesting method is that of using superlattice reflections for the imaging of disordered regions in ordered alloys. The method has been used to investigate the extent of disordered zones in displacement cascades in ordered Cu_3Au caused by heavy-ion or neutron bombardment. Image calculations have established that disordered zones of diameter $\gtrsim 2$ nm in an ordered matrix give good contrast using this technique.

Reflection electron microscopy

In contrast to transmission techniques, reflection electron microscopy (REM) involves forming images with diffracted electrons which are incident upon and leave from the same surface of the specimen.

Reflection electron microscope images can be obtained in the scanning mode (SREM) or by using a conventional transmission electron microscope. As with transmission images, the objective aperture is used to select a particular (reflected) diffracted beam; but because scattering angles for high-energy electrons are small ($\sim 10^{-2}$ radian) the image is formed with the surface being viewed at grazing incidence. Consequently the image of the surface is foreshortened by a ratio of approximately 40:1. Because of this, horizontal and lateral resolution are somewhat different, and depend very much upon the diffraction and surface geometries.

Studies of these kinds, and the sensitivity of the technique to surface irregularities, indicate that REM and SREM will be of particular interest for surface studies such as the deposition of adatoms, surface nucleation and migration, and phase transitions. The value of the technique for studies of catalysis is obvious. Clearly for such studies, methods of obtaining and retaining clean surfaces within the electron microscope are of paramount importance, and many systems are now being designed and built with this consideration in mind.

Scanning techniques

Figure 2 shows some of the variety of signals produced by fast electrons incident upon a specimen in the electron microscope. With a scanned electron beam coupled to a synchronously scanning CRT, any of these signals can be used to modulate the image brightness and hence produce an image. The feasibility of using any particular signal depends upon the signal-to-noise ratio, and upon the detector and amplifier sensitivities. Routine techniques include imaging with backscattered and secondary electrons, the use of characteristic X-ray energies to produce elemental maps, and scanning Auger and energy-loss imaging.

(a) Cathodoluminescence imaging

In materials with certain energy band-gap characteristics, defects can act as the sites for radiative recombination when fast electrons are incident upon them, resulting in the emission of light photons. By placing a photomultiplier as a detector close to such a specimen in a scanning electron microscope, the emission of the light photons can be used to form a cathodoluminescence (CL) image on the scanning microscope screen.

The technique can be used at relatively low resolution to map regions of CL activity; this can be done by imaging with particular regions of the CL spectrum (e.g. at band edges) to reveal concentrations of individual types of defect.

(b) Scanning electron acoustic microscopy

Even more esoteric techniques are being developed. By chopping an incident scanning electron beam at frequencies in the 10^5 to 10^6 Hz range, periodic thermoelastic expansions can be produced below the surface of a target specimen. The acoustic waves that result are detected by a transducer, and a (scanning electron acoustic) image is produced using a phase-locked amplifier. Resolution in the range 0.2 to 10 μm is produced by local variations in the thermal and elastic properties of the specimen.

(c) Differential phase contrast Lorentz microscopy

Electrons passing through a specimen having magnetic domains are deflected in a direction, and through an angle, dependent upon the strength and direction of the magnetic field. Lorentz microscopy, in the Fresnel mode (by defocusing the objective lens) or the Foucault mode (by displacing the objective aperture), is a well-established technique for studying the magnetic domain structure.

(d) Z-contrast

When electrons are scattered by a thin foil, the angular distributions of inelastically and elastically scattered electrons are quite different, with most inelastically scattered electrons being contained within a narrow cone in the forward-scattered direction. Consequently, if an annular (dark-field) detector is placed in the path of these electrons, it will collect (predominantly) the elastically scattered electrons, for which the scattering probability is proportional to $Z^{3/2}$ (where Z is the atomic number). If at the same time a separate (bright-field) detector is placed in the path of the forward scattered electron cone, most of the inelastically scattered electrons, with scattering probability proportional to $Z^{1/2}$, will strike this detector. With sufficiently small electron probes, the technique has allowed single heavy atoms on low-Z substrates to be imaged. This has great potential for the identification of heavy-metal stains or labels in biological tissue, but in materials science, interference from diffraction contrast effects can cause difficulties. However, the technique is finding increasing use in the study of small catalyst particles and with increasing interest in energy loss studies, is likely to find further application in specialized fields.

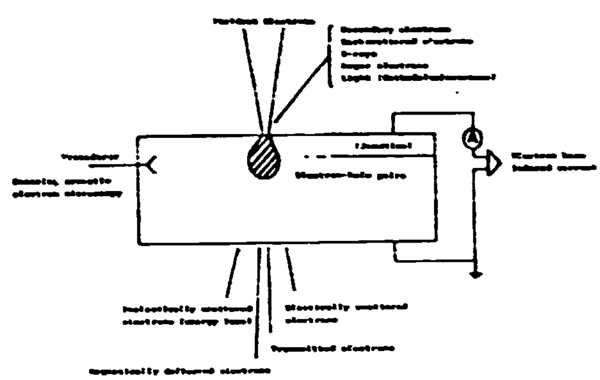


Figure 2. Some of the signals that can be produced in an electron microscope.

(Excerpted from Metals Forum, Vol. 8, Nos. 2 and 3 - 1985, pp. 67-74)

Nondestructive testing method overview

Composites, principally fibre-reinforced plastics, continue to replace metals in an increasing number of applications. Better methods of producing and testing composites enable these lightweight and chemically resistant materials to be used in more critical applications. Performance versus cost-effectiveness determines the level of sophistication applied in testing each composite part. Risk avoidance drives the need for advances in nondestructive testing (NDT). Composites defy several standard NDT methods used with steel. Radiography is unlikely to find a network of microcracks or debonds. Ultrasonics, especially the frequencies used with metals, may not get through a laminate, or may not produce a clean echo, due to the scattering of the beam by fibres. Most composites are nonconducting; therefore, eddy current and magnetic particle inspection are ineffective. Methods that are useful include low frequency ultrasonics, sonics, acoustic emission, penetrants, leak tests, thermal imaging, optical energy radiography, moduli determination, and optical methods, such as visual inspection or diffuse reflectance measurement.

Acoustic emission

Acoustic emissions (AE) are noises made by rapid stress variations within a material. Simplistically, AE is the noise something makes while breaking. Typically, AE is caused by microstructural failures such as fibre breaks, matrix debonding, or microcracking. These events usually start at loads below half of the ultimate failure load. Composites are very noisy; generally they make a lot of snapping noises before they break, much like a tree limb. Several AE tests are becoming ASTM standards. Generally, these tests require attaching sensitive transducers containing crysals similar to those in phonograph cartridges to a sample or structure. The structure is loaded and the AE events are quantified. Measurements such as the number and amplitude of emissions are typically displayed versus the load or time at which they occur. High AE rates during normal loading or continuing AE at a constant load are indications of insipient failure.

Sonics

Sonic methods determine modes of vibration or resonant frequencies of a structure. Generally, the structure is excited with a known force while displacement or acceleration is measured elsewhere. From these measurements, highly stressed areas and large defects can be identified, and elastic moduli can be determined. With considerably more analytical sophistication, stress distributions under various frequency loadings, and ultimate structural adequacy can be inferred. Defects such as plate vibration frequency, damping, and phase shift can be detected.

Ultrasonics

Ultrasonic testing generally employs a transducer emitting short, high frequency, pressure bursts. These travel through a portion of the sample and are received by another transducer. Unlike sonic signals, ultrasonic signals are localized. Composites attenuate ultrasonic energy rapidly, requiring shorter paths or lower frequencies than metals. A common frequency used is 0.5 MHz, though 25KHz to 5MHz are used regularly. The predominant mode used to test metals is the pulse echo mode. This mode uses a single transducer to send a pulse and receive the echoes. Defects such as delaminations and material differences are indicated if the echo returns before the expected back surface echo. In layered composites, each layer may return an echo, obscuring defect echoes. Alternatively, the echo amplitude off a reflecting plate behind the sample may be monitored or the signal transmitted through the sample may be monitored by a second transducer behind the sample.

Radiography

Radiography can detect material voids down to about one per cent of local minimum radiological thickness. On the average, radiological thickness varies directly with atomic number times density for typical medical X-ray energies. Since many composites have high local variations, small resin cracks are seldom found by radiography. Crack planes perpendicular to the rays are not detected. Glass distribution, large voids and cracks, cracks and delaminations filled with dense penetrants, and thickness changes can all be measured radiographically. Making exposures at many angles will indicate cracks at the angles of inspection, and allow a two dimensional internal slice to be reconstructed. A set of these would give three-dimensional density information. However, some microcracks are smaller than film or detector resolution. Radiography is relatively costly, but less sensitive than AE. In situations where it is desired to look through metal and see plastics or other materials containing hydrogen, neutron radiography can be used.

Penetrants

Penetrants, such as red or fluorescent dyes, will penetrate most cracks open at the surface. Debonds around single fibres generally will not be detectable with visual examination even if the penetrant does migrate into the debond. Very sensitive dye penetrants will diffuse into many plastic matrices and occlude small cracks or voids. Despite these limitations, penetrants will usually give a good indication of damage on laminates that have been loaded beyond the elastic limit. This method, though messy, is cheap and indicates both damage location and qualitative damage severity.

Leak testing

Leak testing is generally done by maintaining a differential pressure and using a detectable fluid. Differential pressures are limited by the system tested. Leak detection sensitivity depends on fluid and detection scheme. In approximate order of large to small leak detection, fluids and schemes used are:

Fluid	Detection method
Liquids	Level versus time or flow rate to maintain level
Compressed gases	Listen for leaks
Compression gases	Pressure or weight reduction over time
Liquids	Visual seepage detection
Compressed gases	Bubbles in water or soapy solution
Tracer gases such as fluorocarbons, ammonia, or helium	Electronic sniffers or chemical colour changes

Although hydrogen is the most sensitive fluid, helium is generally used for safety reasons. Even when helium leaks quickly, other gases or liquids may not leak. Hence, an appropriate or working fluid must be used.

Thermal imaging

Thermal imaging can be used to inspect large areas. It is especially valuable for insulated structures and heat-generating components. Relatively large temperature differences (several degrees) may be noticed using infrared cameras. Several sensitive cameras specify resolution of 0.05°C. A more sophisticated method for finding flaws in material uses radiant heating and analysis of the transient surface temperature to quantify anomalies. Voids near the surface quickly cause the surface to become hotter, while deeper voids take longer and are not as distinct. Quantitative analysis is complex. A third method uses very sensitive (0.001°C) temperature detection to measure high stresses due to the adiabatic heating and cooling under fatigue loading. The cyclic temperature variation is proportional to the sum of the principal stresses. A fourth method uses conventional infrared cameras. If a viscoelastic material is cycled quickly, then steady state hot spots will indicate high stress areas in equilibrium with paths for the heat to escape.

Moduli determination

Moduli may be determined by standard mechanical tests, sound velocity, or vibrational resonance methods. In a composite, an increase in modulus is usually associated with an increase in strength. This is particularly true for shear strength and modulus. This is in contrast to steels, whose moduli can remain constant over a wide range of strengths.

Optical methods

Optical methods are the most widely used. When a laminate is transparent or translucent, cracks and delaminations are obvious. Microscopic debonds around individual fibres, though too small for penetrant detection, can be detected in relatively clear laminates. The debond causes the laminate to look clouded, especially when viewed with soft light on a flat, dark background. ASTM standard E 97, Test Method for 45-deg, 0-deg, Directional Reflectance Factor of Opaque Specimens by Broad-Band Filtre

Reflectometry, measuring diffuse reflectance, can be used to quantify this phenomenon. (Excerpt from ASTM Standardization News, July 1986; article written by Paul McGowan, senior scientist for Owens Corning Fiberglass Corp., Granville, OH, USA)

Prototype of an in-service inspection system (ISIS) for composites

An ultrasonic technique was developed under an AFWAL/ML contract to record the flaw indication and position in composites to minimize operator dependence and increase inspection reliability. In the programme, specimens representing typical composite structures and containing implanted flaws simulating service-induced or production defects were fabricated. Improvements were made to the state-of-the-art ultrasonic inspection techniques to detect these defects. In a follow-on programme, a prototype inspection system was designed using the experience and results obtained in the mock-up laboratory system development. The system, ISIS-P, consists of five assemblies: (1) ultrasonic pulser-receiver, (2) transducer, (3) position sensing, (4) data acquisition and processing, and (5) display and recording. The ultrasonic unit in ISIS-P has the capability to determine flaw depth in composite laminates and has a variable flaw-gate width, self-adjusting to the laminate thickness. The position-sensing assembly uses two sensors and covers a minimum area of 2 by 2 ft (0.06 by 0.6 m) with an accuracy of 0.10 in. (0.25 cm). A dedicated microprocessor is used for data acquisition and processing and for control of peripherals. The data-display and recording assembly uses an electronic graphics display and hard copy unit. These assemblies are integrated into a portable, easy-to-use, one-operator inspection unit for field and depot usage.

System design and fabrication

A major design improvement of the ISIS-P was in the data-acquisition and processing and the display and recorder assemblies. A dedicated microprocessor was designed to replace the computer. In lieu of the digital plotter, an electronic graphics display was used. A cassette tape drive replaced the floppy disk unit. A waveform digitizer was designed to replace the transient recorder used in the laboratory mock-up system. Modifications to the Sonic Mark IV unit were designed to add the features of flaw depth determination and self-adjusting gate width. Details of these design changes are described in the following paragraphs.

Transducer assembly

The transducer assembly consists of an upper unit housing the stylus generating the low-frequency sound for position sensing and a lower unit containing the inspection transducer. An acrylic solid delay line can be attached to the face of the inspecting transducer. The length of the delay line is dictated by the maximum thickness of the part to be inspected. An adapter is available to accommodate different transducer diameters. A diagram of the transducer holder design is presented in Figure 1. The delay line is not necessary for the inspection of thick adhesively bonded honeycomb core structure, so a spring-loaded direct-contact transducer with an aluminium handle is used. A sketch of the direct-contact transducer holder is shown in Figure 2.

Two buttons and a light-emitting diode (LED) indicating light are provided at the upper unit of the transducer holder assembly. The buttons are provided to allow the operator to communicate with the data-acquisition and processing assembly. The LED indicating light is to signal the condition when a loss of coupling occurs. In addition to cables leading to the microprocessor from the button switches, indicating light, and the stylus generating the low-frequency sound waves, there is also a shielded radio-frequency (RF) cable connecting the inspecting transducer to the ultrasonic unit.

Position-sensing assembly

The position-sensing assembly is required to provide location data of the transducer assembly to within 0.10 in. (0.25 cm). It consists of a Graf-Pen sonic pulse generator and a pair of point microphones. The arrival time of the sonic pulse at each of the microphones can be used in a triangulation algorithm to determine the transducer position. A 9 in. (23 cm) bar houses the preamplifiers for the two sensors, which contain piezoelectric elements. The two sensors are connected to the bar by wires and are mounted on aluminium arms. The arms are connected to the bar by hinges so that they can be retracted when not in use. They can be fully extended to a length of 24 in. (61 cm). The length is used in the microprocessor's triangulation software. A Pana-Vise manually operated vacuum grip is fixed to the underside of the 9 in. (23 cm) bar so that the assembly can be attached to any part of the surface of a composite component. The range of effectiveness of the two-point sensor system is 22 by 24 in. with an accuracy of better than 0.030 in. (0.76 mm). The active inspection area must be located at least 4 in. (10 cm) from the bar housing the preamplifiers.

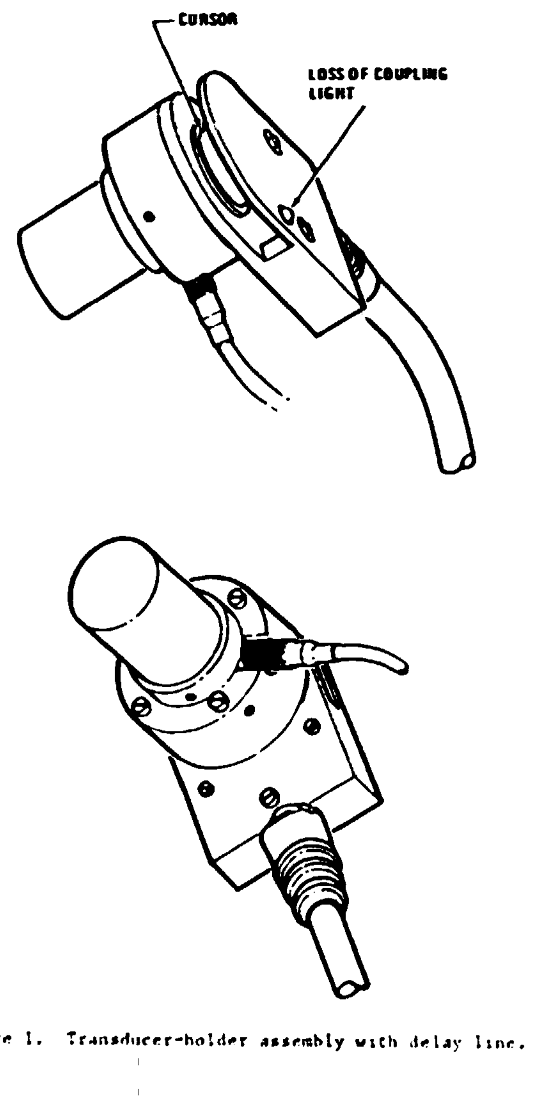


Figure 1. Transducer-holder assembly with delay line.

The control unit of the position-sensing assembly is located in a separate unit. This unit initiates the low-frequency sound waves and measures the time of flight of the sound waves from the cursor to the sonic microphones. The time measurements are converted into digital form and transferred to the microprocessor. The microprocessor converts the time measurements into distances and calculates the transducer position as the point of intersection of circles of the calculated radius, centered at the microphones. Only one of the two intersections defined by such circles will lie in the inspection zone.

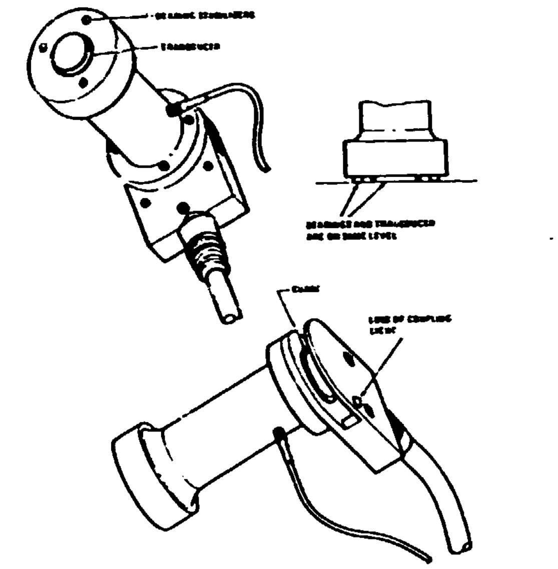


Figure 2. Direct-contact transducer-holder assembly.

Ultrasonic assembly

The Sonic Mark IV was selected as the ultrasonic unit. After comparing the resolution, bandwidth, and power of the instrument to the requirements of ISIS, certain modifications were needed to meet these requirements fully.

The signal-processing and flaw-recognition schemes require the monitoring of the signal amplitude in two flaw gates. Therefore, a separate circuit board was acquired to add another gate and a flaw-depth determination capability to the Sonic Mark IV ultrasonic unit. A 10 MHz oscillator was used to provide a clock for timing the intervals between the ultrasonic front-surface reflection signal and the flaw signal. The time intervals were then converted into flaw-depth measurements using the velocity of propagation. Using the 10 MHz oscillator, a depth resolution of ±1 ply can be achieved. The Sonic Mark IV's circuit design was modified to provide an additional capability for the flaw gate to adjust its width according to the thickness of the specimen. The specimen thickness information measured by the timing oscillator is furnished to the microprocessor. The microprocessor sets a delay of the initiation of the flaw gate corresponding to the near-surface resolution and assigns a gate width corresponding to the specimen thickness. A typical timing diagram is shown in Figure 3.

All the modifications for the Sonic Mark IV ultrasonic unit are housed in a 6 in. (15 cm) extension package that can be attached to the back of the unit in lieu of the standard back cover. Internally, a connector provides the link between the printed circuit boards and the front portion of the unit. Externally, connections to the microprocessor and other assemblies are effected by multi-pin connectors on the side of the extension. Additional adjusting knobs for the ultrasonic unit are mounted on the side of the extension.

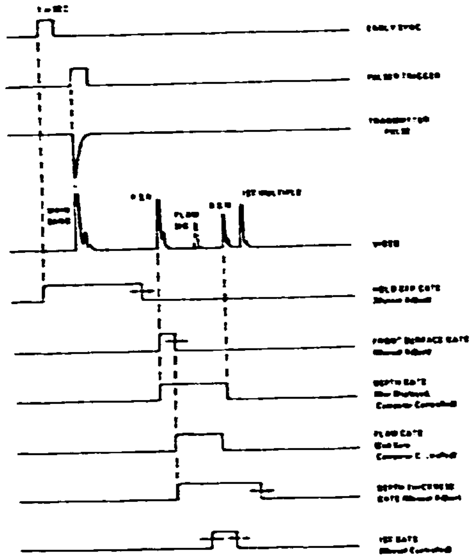


Figure 3. Typical timing diagram for ISIS.

Data-acquisition and -processing assembly

The data-acquisition and -processing assembly consists of a Motorola 6800 microprocessor system and the inputs and outputs necessary to interface with other assemblies having the storage capability and operational speed to meet the data-acquisition and signal-processing requirements. The assembly design incorporates the latest state-of-the-art computer technology to enhance the data-acquisition and -processing capabilities of ISIS. The assembly rapidly acquires, processes, and stores digitized waveforms on demand. In addition to the input functions, the system outputs a real-time C-scan display of the inspection on a graphics terminal.

The microprocessor uses 64 kilobytes of memory consisting of 48 kilobytes of random-access memory and 16 kilobytes of read-only memory (ROM). The ROM contains the system-level software developed with General Dynamic's Microprocessor Development System.

The waveform digitizer for ISIS was designed around a TRW monolithic video analog-to-digital converter (adc), circuit board Model TDC1007PCB. A block diagram of the digitizer is shown in Figure 4. Differential line drivers and line receivers are used between the digitizer and microprocessor to ensure interface signals free of part noise.

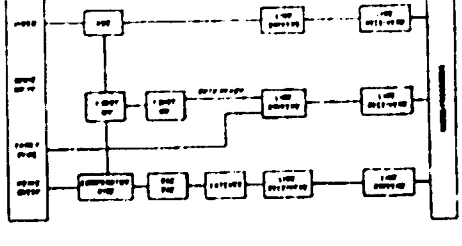


Figure 4. Waveform digitizer block diagram.

The position sensors are interfaced to the processor via a parallel interface. There are provisions for 12 bits of X-information, 12 bits of Y-information, and 16 bits of status/control information. An interrupt is generated by a push-button on the transducer assembly, requesting the processor to obtain and store the digitized presentation of the RF waveform being processed by the waveform digitizer.

The graphics terminal has an RS-232C serial interface. The display can be physically removed up to 25 ft (7.6 m) from the system. The operator can still see the display without RF interference in a high-noise environment.

The waveform digitizer is interfaced to the processor through a parallel interface. When a request is made by pushing a button on the transducer assembly, the computer obtains the digitized waveform from the waveform digitizer. This information is plotted on the graphics display and stored on the tape cartridge.

The printer/plotter provides hard copies of digitized RF waveforms, C-scan recordings, and co-ordinate/amplitude listings. In addition, the printer/plotter can function as a high-speed printer capable of producing listings from the data-acquisition and -processing assembly.

For the tape transport, an interface was designed that allows the data-acquisition and -processing unit to store data on the tape. This interface transfers 192,000 bits of information per second to the tape.

The overall interface uses differential line drivers and line receivers in each assembly to maximize noise immunity. Shielded and twisted pairs of wires are used to interconnect line drivers and line receivers, increasing the noise immunity even further. Figure 5 shows the block diagram of the data-acquisition and -processing assembly interface.

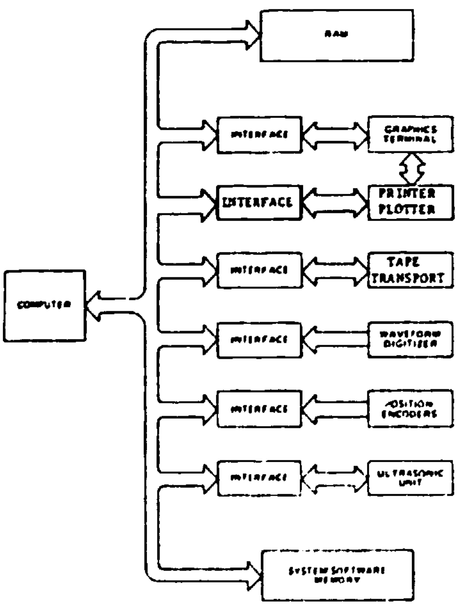


Figure 5. Block diagram of data-acquisition and -processing assembly interface.

Data display and recorder assemblies

The display and recorder assemblies consist of a graphic display unit for real-time monitoring of the inspection results, a printer/plotter for reproducing hard copies of the display, and a magnetic tape transport for permanent records. The graphic display is a Tektronix 4025 raster-scanned graphic terminal providing a 12 in. (30 cm) diagonal display on a green phosphorous screen. The keyboard in the graphic terminal is also used for communicating between the operator and the system.

Software development and inspection scheme

The software development and inspection scheme of the ISIS-P can best be illustrated by using the system to inspect a graphite-epoxy composite reference specimen containing implanted flaws simulating delaminations. The reference specimen is 3 by 18 in. (8 by 46 cm) and 80 plies thick. The implanted flaws were fabricated by inserting, in the laminate, pairs of circular patches of 0.0005 in. (0.013 mm) thick Kapton films laid one on top of the other with edges sealed. The Kapton patches were inserted at different depths of the laminate, ranging from 54 to 78 plies. These implanted flaws did not leave any visible imprints, for the flaws were extremely thin.

Inspection procedures

Before the inspector starts the inspection, he inserts a magnetic data tape cartridge in the tape unit. He then types a two-letter code to initiate the scanning software routine. The system responds by listing the settings on the ultrasonic unit he should establish corresponding to the part he is inspecting. Specific prescan gate settings and initiation procedures are then conducted by the inspector.

The location of the inspection, name of the inspector, date of inspection, and specimen identification information are entered by the inspector through the graphic display keyboard. The cell size is the distance in inches between adjacent points in the dot matrix of the area map. Other information pertinent to the instrument setting for the inspection is programmed in the software and displayed on the graphic terminal so that the inspector can duplicate these settings. Finer matrix grids provide better flaw-size and -location resolution but incur slower inspection speed.

The inspector starts the scanning routine by positioning the transducer assembly over three target points and activating a switch to record the co-ordinates of these points. The target points generally are physically identifiable points on the part so that the orientation and locations of flaws in the part may be correlated with the actual part. After the target points are recorded, the inspector locates the corner points of the area on the part to be inspected. The outline of the area to be inspected is input as the corner points of a polygon with up to 16 sides. The corner points in the polygon must be located consecutively.

After the corner points have been located, the outlined area will be filled with light dots occupying corners of the square cell with the specified cell size. As the inspector scans within the outlined area, light dots in the scanned locations will be erased on the graphic display. If a flaw is present, the light dot at that location will be transformed into a bright dot. When all the light dots have been erased within the outlined boundary, the scanning is completed. If the inspector has doubts about a certain area that he has scanned, he can activate a subroutine in the programme to outline the rescan area within the part boundary. The flaw data in the rescan area will be erased, and the area will be refilled with light dots. As the inspector rescans the area, new data will be gathered and fill the area in the memory core matrix. The system has the capability to digitize and record the RF or video waveform displayed on the CRT of the ultrasonic unit. This capability provides a permanent record of the ultrasonic waveform at any location on the part. This waveform record can serve as a reference for data interpretation in anomalous areas.

Data-processing procedures

The inspection data stored in the microprocessor memory or recorded in magnetic tape cartridges are processed by a post-inspection data-processing routine in the software package. Several forms of C-scan output can be produced by the system in data processing. A scanned area plot in hard copy is available showing a 1/4-scale reduced plot of the area that has been scanned. C-scan inspection records are available in 1/4-scale and full size. (From F.H. Chang, J.R. Bell, J.K. Brown, and R.W. Haile, 'Prototype of an In-Service Inspection System [ISIS] for Composites', Materials Evaluation, Vol. 43, No. 9, August 1985, pp. 1117-1123. Excerpt reprinted courtesy American Society for Nondestructive Testing, Inc., Columbus, OH, USA))

Lifetime prediction of ceramic materials

In ceramic materials the lifetime of components is dictated by the growth of a flaw to a critical size. At temperatures of less than half the melting point, subcritical crack growth takes place in a brittle manner under static loading conditions. The rate of growth is controlled by the stress intensity factor at the tip of the most severe flaw and by the environment. Strengths may be halved by the presence of the latter. At high temperatures creep-assisted crack growth takes place leading to more severe degradation with time.

Considerable research is currently devoted to improving the toughness of ceramics. The consequence of higher fracture toughness, as with metallic components, enables such concepts as 'leak-before-break' of pipes and pressure vessels to be invoked.

The strength of brittle materials is controlled by the size of the largest defect through the well-known Griffith equation. However, there is a statistical distribution of defect sizes in most brittle materials that have been introduced during the initial powder processing and sintering stages or upon subsequent shaping of the material. The variability in defect size and location leads to a consequent distribution in strengths which must be appreciated before component design can begin. In addition, ceramic components exhibit a time-weakening behaviour analogous to metals when stressed. This apparently 'delayed spontaneous fracture', which can occur after supporting a load for some time, is often termed 'fatigue' or 'static-fatigue'. For such spontaneous fracture to occur, the largest defect must grow in a subcritical manner to the critical size. This form of crack growth in ceramics and glasses is enhanced by the presence of moisture. It is analogous to hydrogen embrittlement and stress-corrosion cracking in metals; the latter term is often used when describing moisture-assisted slow crack growth in ceramics. The presence of moisture, and other highly polar molecules such as ammonia, hydrogen sulphide, etc., leads to a stress-assisted chemical reaction at the crack tip and bond rupture at considerably lower crack tip stress intensity factor, K, values than under vacuum or inert atmosphere.

Fatigue of metallic components is generally associated with cyclic fatigue. This topic has been well researched in metals because of its severe consequences, but until recently it has received only modest attention in the ceramic literature. The linear-elastic behaviour of ceramics and their extreme fragility has probably been responsible for such neglect. This limited research suggests that, unlike metallic components, the only factor that dictates the lifetime of ceramics under cyclic conditions is the integrated time under load rather than the number of cycles.

During the past decade there have been considerable advances in the development of high-toughness high-strength ceramics. The major toughening mechanisms for these materials include stress-initiated volume-expanding phase change as in partially-stabilized zirconia (PSZ), microcracking and fibre or whisker reinforcement. To date, little research has been done on the lifetime and fatigue properties of such materials; however, it is recognized that the increased fracture toughness is accompanied by irreversible processes about the crack tip. This fact together with the commonly observed non-linear stress-strain-to-failure curve, imply that cyclic fatigue may lead to rapid degradation if the material is loaded beyond the elastic limit.

At elevated temperatures, typically in excess of half the melting point, the lifetime of ceramics may be influenced by creep deformation in addition to moisture-assisted crack growth. The limitation of material strength and lifetime through creep has been reported for materials containing glassy grain boundary phases, such as silicon nitride and debased aluminas, and for materials that experience creep as a result of their fine grain size. The situation for this class of materials is different from that observed at low temperatures, in that cracks may be nucleated by grain-boundary cavitation and linking of favourably disposed cavities. the mechanical behaviour and dependence of lifetime on stress of such ceramics has many similaritiesd with the creep rupture of metallic components.

Crack velocity - stress intensity factor relationship (V-K curves)

The breakthrough in the understanding and rational fracture mechanics interpretation of subcritical crack growth in brittle materials was made in the late 1960s by Wiederhorn and colleagues. These workers found that a systematic relationship existed between crack velocity, V, applied stress intensity factor, K, and the moisture content of the environment. This was demonstrated for a range of glasses using the double cantilever beam (DCB) loading geometry which enabled crack velocities from 10^{-11} to 10^{-1} ms to be investigated. Since then crack propogation data have been collected for a variety of ceramic materials including porcelains, high-alumina ceramics, silicon nitrides and carbides, various piezo-electric and other oxide ceramics, etc. Crack velocity data have been obtained in various environments including numerous gases and aqueous solutions of various pH concentrations and at various temperatures.

The basic form of the relationship between crack velocity and applied stress intensity factor is shown schematically in Figure 1. It consists of three regions: the low velocity régime or region I where crack growth depends upon the environment and stress intensity factor, an intermediate régime or region II where the crack velocity is independent of K but dependent on environment, and region III where crack velocity is strongly dependent upon K and independent of environment. Region I may be displaced to the left or right depending on the concentration of moisture or reactive species in the environment. There is a displacement to the left with increasing humidity and temperature. The plateau régime, region II, of the V-K curve is a consequence of diffusion-limited access of moisture to the crack tip. With increasing humidity the plateau velocity increases. In region III the crack velocity exceeds the rate of moisture arriving at the crack tip, and the K value associated with this régime is the critical stress intensity factor, K_{Ic}, for spontaneous crack growth. Sometimes at very low crack velocities ($<10^{-9}$ ms^{-1}) a threshold K value for the onset of crack extension has been determined. The lifetime of a ceramic component is determined almost completely by region I, the region of slowest crack extension.

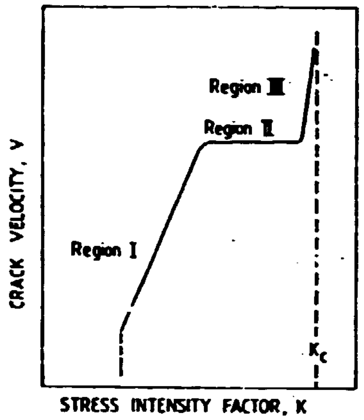


Figure 1. Schematic diagram of crack velocity versus stress intensity factor for a ceramic material in a moist environment.

Residual stress and microstructural influences

Flaws generated by contact with sharp objects leading to inelastic deformation, such as about a Vickers hardness impression, usually have a component of residual stress. This stress must be taken into account in determination of the stress intensity factor at the crack tip. The major difference between the applied and residual stress intensity factor is that the former increases with crack growth whereas the latter decreases. A secondary consideration is that the residual stress component may decrease with time through relaxation of this stress by the operation of alternate cracking systems about the contact site, such as lateral cracking. Situations where these residual stresses are significant are those where damage has been introduced into the material's surface by grinding, scratching, sharp grit contact (erosion), etc.

At this stage it is appropriate to introduce an alternative testing strategy for the evaluation of toughness that simultaneously overcomes the statistical complications introduced in the previous section. This involves the deliberate introduction of defects of known size into the material surface that are larger than the statistical distribution of flaw sizes, and then measuring both the inert strength and strain-rate dependence of strength. From the former it is possible to measure the toughness whilst, from the latter, to evaluate the fatigue-controlling parameters.

Non-linear loading behaviour

Non-linearities in stress-strain curves of ceramic materials may occur for a number of reasons. At high temperatures this may be the result of viscoelastic or creep behaviour. At room temperature this form of response may be found in materials that incorporate irreversible energy-absorbing processes at highly stressed regions such as that about the crack tip. Such processes occur in the newly developed ceramic materials that rely upon transformation toughening, microcracking or fibre-reinforced toughening. These areas are fields of active material development, and to date only qualitative indications of the lifetime are available. However, more quantitative analysis of the lifetime and determination of crack growth parameters under creep conditions have been determined recently.

Proof testing

The only technique that ensures the lifetime of a component in service for a specific period, provided no additional flaw populations are introduced during service, is proof testing.

The choice of appropriate proof-testing stress may be made on the basis of the crack propagation relationships and inert strength data. Unfortunately because of the low toughness of most ceramics and the catastrophic consequence of even small flaws of ~100 μm or less - flaws that are virtually impossible to detect by current non-destructive techniques - complete proof testing of batches is essential.

The higher the ratio of proof test to service stress the longer the ensured lifetime of a component. A typical schematic plot of service stress to lifetime is shown in Figure 2. Examples of the applications of lifetime predictions to ceramic materials are listed in Table 1.

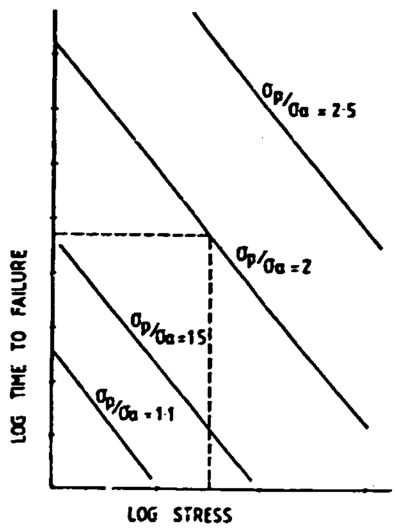


Figure 2. A schematic plot of the anticipated lifetime of a ceramic component that had been proof tested at various multiples of the in-service applied stress.

TABLE 1

Applications of lifetime predictions of ceramic materials

Application	Reference
Optical fibres	30, 31, 32
Disks (turbines and grinding wheels)	33
Ceramic nuclear reactor fuels	34
Porcelain	35
Skylab windows	36, 37
Graphite materials	38

(Extracted from Materials Forum, Vol. 9, Nos. 1&2-1986, pp. 34-44; article written by M. V. Swain, CSIRO Div. of Met. Science, Normanby Rd., Locked Bag 33, Clayton, Vic. 3168, Australia)

CURRENT AWARENESS

The scanning acoustic microscope - a new tool for the materials scientist

The technique of scanning acoustic microscopy (SAM) has recently emerged from the pure research laboratory and has begun to find its way into the industrial world. It is rapidly becoming established as a method of non-destructive evaluation particularly suited to the detection of surface or near-surface inhomogeneities and discontinuities on a microscopic scale, and is the subject of a recent Royal Microscopical Society Handbook.

The SAM differs from conventional ultrasonic equipment in two important ways: the frequencies used are much higher, and an acoustic lens is employed to give a focused beam. It differs from conventional optical and electron microscopic methods in that the images are formed by the interaction of sound waves with the sample. Therefore, contrast depends upon the elastic properties of the sample and quite different information from that given by optical or electron microscopy is obtained. Interaction of acoustic waves with the sample proceeds mainly by either direct reflection of longitudinal waves back into the coupling medium, giving contrast through variations in the reflection coefficient across the sample, or by mode conversion of the incident acoustic radiation to surface acoustic waves which propagate on the surface of the sample and scatter, giving rise to the distinctive contrast modes associated with the SAM. In addition, contributions to the image contrast are not necessarily restricted to the surface layer. Under certain conditions, information on the nature and distribution of sub-surface features may be obtained.

The range of applicability of the technique is wide. Workers in a number of laboratories are using the SAM in studies as far apart scientifically as investigations of the internal structure of living cells, and of bond failures in semiconductor integrated circuit packaging technology.

Conventional reflection scanning acoustic microscope

Although it is not possible to manufacture a satisfactory acoustic lens that will image all parts of the sample simultaneously, such as in conventional light optics, it is possible to focus an acoustic beam to a diffraction limited spot by making use of the large velocity mismatch between sound waves in materials such as sapphire and water. A SAM lens based upon this principle is shown in Figure 1. Acoustic waves produced by the zinc oxide piezoelectric transducer are refracted at the lens/coupling medium interface to form a convergent beam. Either the lens or the sample may be mechanically scanned in a raster and the image built up by detection of the echo signal for appropriate points of the scan. This echo intensity can either be used immediately to modulate the brightness of a TV monitor rastered synchronously with the lens, or digitized and read into a frame-store for subsequent display and image processing.

The excitation frequency applied to the lens is usually in the range 0.2-2 GHz, with the combination of frequency and scanning method being chosen according to the particular application. The instrument at NPL can operate in two frequency régimes. For low frequencies around 50 MHz a fixed 15 mm radius lens is used and the sample and water bath are scanned using stepper motors under computer control. In this case the scanned area may be up to 40 mm x 40 mm, with the image acquisition time a function of this area. At higher frequencies in the range 0.5-1 GHz, the lens, of internal radius 100 μm, is mounted in a miniature scanner assembly which can be attached to a conventional optical microscope turret. This allows an image of up to 400 μm square to be acquired in about 10 seconds. In either case, data are digitized and stored as 256 x 256 pixel images with 8-bit precision.

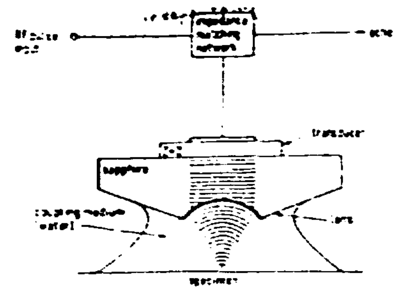


Figure 1. Principle of reflection SAM

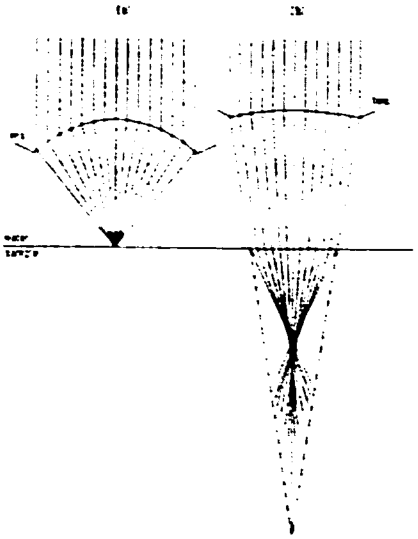
Image contrast

When the acoustic microscope lens is accurately focused on the surface of the sample, the echo intensity, and hence the brightness of the image, depends upon the acoustic reflection coefficient of the sample/coupling medium interface at that point. For a flat specimen with no topography, the surface focus image represents a 'map' of the acoustic reflection coefficient over the area scanned. The lateral resolution of this map depends upon the lens characteristics and the frequency of acoustic radiation used but is of the same order as the wavelength in the coupling medium at that frequency. Typical values are 30 μm at 50 MHz and 1.5 μm at 1 GHz. Contrast in this surface image can be related mainly to variations in density and velocity of sound across the specimen surface.

A ray diagram for an acoustic lens of 45° half-angle focused on the specimen surface is shown in Figure 2(a). Moving this lens towards the surface in an attempt to produce a subsurface focus would result in an unacceptably high level of spherical aberration from refraction at the water/specimen interface. However, if the lens opening is restricted to a narrow aperture, aberrations inside the specimen are reduced, and a good subsurface focus achieved, as shown in Figure 2(b) for a lens of 11° half-angle. This allows images of the interior of solid samples to be built up. The problem of attenuation in the sample restricts this mode of imaging to frequencies typically below 200 MHz.

V(z) effect

Of great interest is the situation in which an attempt to obtain a subsurface focus is made with a wide-angle lens at frequencies at which attenuation of longitudinal waves in the material under investigation is high. In this case, incoming waves incident on the water/sample interface at the critical angle for total internal reflection undergo mode conversion to generate surface acoustic waves (Rayleigh waves), which propagate in the surface layer of the sample. These surface acoustic waves reradiate part of their energy back into the coupling medium, again at the critical angle, as shown in Figure 3. The reradiated waves interfere with the directly reflected waves, resulting in a periodic variation of the transducer output voltage V as a function of lens displacement from the surface focus z. This periodicity, known as the V(z) effect, is an important source of contrast in the SAM.



(a) Surface focus for acoustic lens of 45° half-angle; (b) subsurface focus for acoustic lens of 11° half-angle.

Figure 2. Acoustic lens foci.

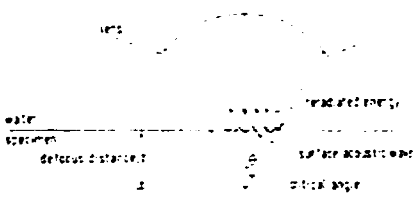


Figure 3. Generation of surface waves by wide-angle lens defocused towards sample surface.

A V(z) curve obtained from the surface of sapphire using a cylindrical acoustic lens is shown in Figure 4. The cylindrical lens gives a better response than the conventional spherical lens in the presence of elastic anisotropy. Similar curves are obtained from isotropic materials using spherical lenses. A spherical lens must, of course, be used for imaging. The periodicity in the V(z) curve is dependent upon the elastic properties of the specimen and is an important source of contrast in acoustic microscopy.

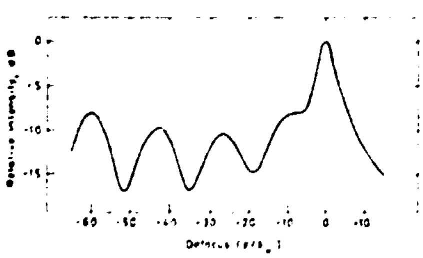


Figure 4. V(z) curve of single crystal sapphire surface (after Ref.7).

Grain contrast

An important aspect of imaging in the reflection SAM is the ability to detect contrast from the random orientation of grains in a material and thus to visualize the grain structure at a polished but unetched surface.

Response in presence of discontinuity

Figure 5 shows a ray diagram for an acoustic microscope lens defocused towards the surface of a sample containing a reflective discontinuity, for example a narrow crack, oriented parallel to the axial ray.

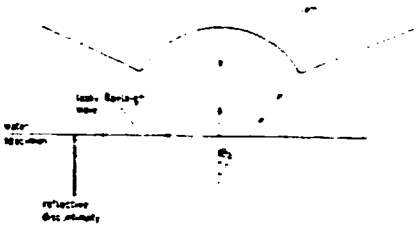


Figure 5. Ray diagram for acoustic microscope lens defocused towards surface of sample with reflective discontinuity.

Applications

The recent emergence of SAM as an imaging technique, and the unique nature of the contrast, preclude an exhaustive list of possible appliciations.

Microstructure

In materials development it is often of immense importance to be able to visualize the grain structure of the material, since this can have a dramatic effect on its performance. For conventional optical microscopy, the normal procedure is to section and polish the material and then use one of a variety of possible chemical etching processes to preferentially remove some aspects of the microstructure and hence reveal the grain structure in the topography of the resulting surface.

Diffusion bonding

Diffusion bonding is the technique of joining two pieces of material by making use of their ability to interdiffuse under controlled conditions of temperature and pressure. A very strong bond can be formed, and the method is being used increasingly as a practical production tool. It is, however, sensitive to the condition of the surfaces to be joined. The presence of contamination, or the use of incorrect pressure or temperature, can lead to failure to form a bond. Perhaps more seriously, these can also cause the formation of microscopic voids or other discontinuities at the bond which may significantly weaken it but are extremely difficult to detect non-destructively. This difficulty may be overcome by the use of the acoustic microscope. In general, the reflection acoustic microscope is suited to the sample geometries encountered in diffusion bonding, although some progress has been made with the alternative transmission technique.

Figure 6 shows the geometry that was used for imaging a diffusion bond between an alloy ring and a ceramic plate. A narrow-angle lens was used with an acoustic frequency of 50 MHz to image through the ceramic and across the bond area. The rear face of the ceramic is expected to give a strong echo and hence show up brightly in the SAM image. Regions where the bond is good will give a weak echo because of the impedance difference between the two materials, and hence will be darker in the image, whereas any void or discontinuity in the bond region will cause a strong echo and will therefore be detected.

It may happen that the interface voids in a faulty diffusion bond are too small to be detected by the SAM operating at a sufficiently low frequency to achieve penetration to the depth of the bond. In this case a generalized echo intensity may be seen over the area in question, but it is necessary to section the material to view the microstructure at the interface.

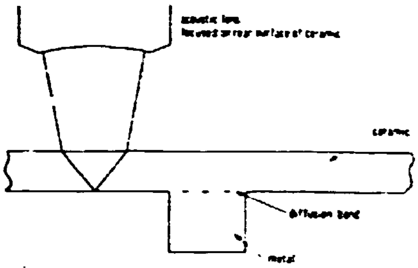


Figure 6. Geometry used to obtain diffusion bond image.

Cracking in ceramics

Engineering ceramics are brittle materials that fail from flaws without the occurrence of gross plastic flow. These flaws are the result of manufacturing defects or surface damage produced during component preparation or in service. Cracks associated with this surface damage often propagate to form defects which significantly weaken the material. The materials are partly translucent and are difficult to image in the optical microscope; they are also insulators and cause problems with charging in the electron microscope. These difficulties do not occur in the SAM, and there is the added advantage that the presence of a crack and its relationship to the material microstructure may be revealed in one image from a polished but otherwise unprepared surface.

Microelectronics

The SAM has a potentially very useful role in the important area of imaging of defects within integrated microelectronic circuits.

It will be necessary to improve the resolution of the acoustic microscope if it is to keep up with the trend towards further micro-miniaturization in modern integrated circuits. The SAM routinely operates at up to 2 GHz, which can give resolution of around 0.5 m using water as the coupling medium. To improve on this it is necessary either to increase the excitation frequency, causing severe problems with attenuation, or to change the coupling medium. A resolution of 20 nm has been demonstrated using 8 GHz acoustic radiation with liquid helium as a coupling medium, but this is unlikely to become routine laboratory practice in the near future.

Composite materials

Compared with conventional materials, the principal advantages of fibre-reinforced composites are in weight-saving and strength. The orientation of the fibres, their distribution and adhesion to the matrix in which they are embedded, are important in this respect. Acoustic microscopy may be advantageously used as an aid in the determination of these parameters. (Excerpts from Materials Science and Technology, September 1986, Vol. 2, pp. 881-887, article written by G.C. Smith)

NBS leads VAMAS programme on advanced materials test methods

The US is leading the Versailles Project on Advanced Materials and Standards (VAMAS), an international research programme to develop basic test methods for a new class of materials - advanced ceramics, polymer composites, and metal alloys. Lyle H. Schwartz, director of the National Bureau of Standards, Institute for Materials Science and Engineering, assumed leadership of the VAMAS steering committee when member countries met in West Berlin at Bundesanstalt für Materialprüfung, 10-14 May 1986. Dr. Schwartz says, "The ability to measure the performance of advanced materials with internationally accepted test methods will help US industry compete worldwide and promote an acceptance of new materials in high technology products". NBS is contributing in all areas of international "round-robins" and leads technical work in surface chemical analysis, weld characteristics, and factual materials data banks.

Other projects - in polymer composites, ceramics, wear test methods, polymer blends, hot salt corrosion resistance, bioengineering materials, superconducting and cryogenic structural materials, and high temperature creep - are directed by research groups of other participating nations. (VAMAS Secretariat, A257 Materials Bldg., National Bureau of Standards, Gaithersburg, MD 20899, USA.) (Source: Ceramic Bulletin, Vol. 65, No. 8, 1986, pp. 1103 and 1104)

Nondestructive neutron testing

Three manufacturers are associated in the development of a mobile neutron radiography instrument for nondestructive testing in industrial environments and for the study of new materials; they are Sodern, a subsidiary of the French company Philips (through TRT, Radiotechnique, and LEP), Dornier System (FRG), and Sener (Spain). It is called the DIANE [Integrated and Automatic Device for Neutronography] project.

The device will consist of a sealed-tube fast neutron generator (flux of 10^{12} neutrons per solid angle of four and per second), a thermalizer, which is a sphere about 80 centimeters in diameter filled with a fluid to slow the neutrons (to obtain "thermal" neutrons), and a collimator for a parallel beam of neutrons. The whole assembly would weigh about one ton.

Neutronography - complementary to X-ray radiography - makes it possible to discriminate between bodies of neighbouring atomic weights, and to study corrosion, adhesion, and other phenomena. This technique is already well known, but with fixed reactors (CEA at Saclay, CEN at Grenoble), which in fact was the subject of a conference, the Second World Conference on Neutron Radiography, 16-20 June 1986 in Paris (Palais des Congrès).

Sodern will be primarily responsible for the neutron generator and detector head; Dornier will cover the positioning and control robotics, and Sener safety and security problems. The programme will spread over four years. (Extracted from Sciences & Techniques, Paris, April 1986, p. 52)

X-ray spectrometry and fluorescence inspection provide quality control for industry

The US iron and steel industry is using the efficiency and quality control provided by microprocessor-based equipment to stay competitive with European companies. At the core of many iron and steel companies' quality control systems is sophisticated analytical equipment that uses X-ray fluorescence spectroscopy to ensure a quality end-product. Overall accuracy and reproducibility are tied directly to controlling the sample - its homogeneity, stability, and preparation. Additional cost benefits arise from the technology's critical precision of interpretation, speed of analysis, and the ability to store data for materials and market projections.

The bulk of the workload in iron and steel laboratories consists of analysing a wide range of materials for the composition control required to monitor furnace operations efficiently. Analysing scrap and ferro-alloys on delivery is advantageous financially to the refiner to confirm the supplier's analysis, which governs the price of the materials, and to provide the complete data required to adjust the furnace operation to what is required by the specification. Techniques for representative sampling of bulk materials such as iron ore, fluxes and slags were developed as a preliminary to an efficient analytical procedure. X-ray fluorescence spectroscopy eliminates the twin errors of mineralogical and interference effects on end-products. (Excerpt from Materials Evaluation, 44, September 1986, p. 1153)

Experiments in compound materials

The National Aerospace Laboratory of the Science and Technology Agency has decided to invest in facilities for experiments in compound materials. The facilities will be used not only for experiments with energy-efficient aircraft and a Japanese version of the space shuttle, but will also be used for projects in private industry, such as the Boeing 7J7 now under development by Japan and the United States.

The plan includes a facility for testing local strength of materials and components, one for testing partial structural strength, and one for non-destructive testing.

The materials and components testing facility will be equipped with numerous stress-testing devices and devices for simulating various environmental conditions. The goal will be to study the behaviour of various compound materials under diff ring conditions.

The facility for testing partial structural strength will test full-scale mockups of subassemblies such as the tail sections of aircraft. Differing flying conditions will be simulated in order to test the strength of the subassemblies. Tests can be carried out under temperatures of -80 to +100 degrees centigrade. The non-destructive testing facility will use X-ray, ultrasound and thermographic equipment to detect structural damage. The National Aerospace Laboratory has embarked on this project in response to the increasing use of compound materials in the aerospace field. Such research centres as the Air Force Flight Testing Laboratory in the United States and the Royal Aircraft Laboratory in Great Britain have already constructed large-scale facilities for this purpose. (Source: Nikkei Aerospace, 9 June 1986, p. 8)

Materials analysis

Materials analysis by laser-induced breakdown spectroscopy or LIBS, developed at the Los Alamos National Laboratory in the US, is to be used by West German company Metallgesellschaft to identify metals and alloys.

Intense laser light is focused on a small piece of the material to create a tiny "fireball" of hot, ionised vapour or plasma. The excited atoms in the plasma radiate light in colours that are specific to the elements in the material. Computer-aided spectrum analysis immediately measures all the wavelengths present and prints them out, revealing the exact composition of, say, a metallic alloy. (Source: Financial Times, 6 June 1986, p. 9)

Government sets up MAP and TOP Networking Centre

The Government has set aside over £1 million to help manufacturing industry link up its computer-based equipment. The money will be used at a centre where products can be tested to see if they conform to the Manufacturing Automation and Technical Office Protocols (MAP and TOP).

The Networking Centre at Hemel Hempstead will also offer consultancy, training and information services while pursuing contract development for standard and special-purpose test systems. (Source: Machinery and Production Engineering, 19 November 1986, p. 5)

A tool for materials testing

Researchers at Sandia National Laboratories Livermore (SNLL) and Lawrence Livermore National Laboratory, both at Livermore, Calif., have developed an instrument that allows the simultaneous measurement of X-ray fluorescence, X-ray absorption and electron density in a material sample. X-rays generated by the device have a minimum effective beam diameter of 15 microns, which is less than one-fourth the diameter of a human hair.

Monte C. Nichols, a researcher with SNLL's Exploratory Chemistry Div., who is credited with the conceptual design of the X-ray microanalyser, says existing X-ray fluorescence equipment cannot match the new instrument's ability to measure extremely small areas or its ability to detect low elemental concentrations. The instrument's X-ray beam can penetrate a sample, allowing nondestructive imaging of layers of structures beneath the surface. In addition, says SNLL, researchers can use the microanalyser to test for the presence of elements in biological and non-conductive materials without applying a conductive film or without examining the sample in a vacuum. (Source: Chemical Week, 17 September 1986, p. 34)

Precision and cost-efficiency in automated testing

From TMI's growing Monitor X line, the Monitor/Burst is designed for precision and cost-efficiency in automated testing. This unit may be used with any burst tester - operating within any range psig - at an accuracy of ± 0.5 per cent. It may also serve as a basic component in building an automated test station, tailored to meet changing needs and budgetary allowances. The Monitor/Burst's RS-232 output enables its connection to a computer. Other testers and Monitor X equipment may also be added to or removed from the system as desired. (Source: ASTM Standardization News, December 1986)

A new family of automated materials testing systems

A new family of automated materials testing systems, introduced by the Tinius Olsen Testing Machine Co., promises to usher in a new era of testing efficiency, speed, accuracy, and flexibility for North American manufacturers. Developed in West Germany by Roell + Korthaus GmbH, these Autotest systems fuse elements of robotics, specimen preparation, materials testing, and computer science into a testing system allowing flexible configurations designed for varying levels of automation and speed. (Source: ASTM Standardization News, December 1986)

Fully automated materials testing

Fully automated materials testing is now available from Instron. With robotic sample handling and loading, the productivity, precision, and efficiency of testing operations can be improved. Instron offers the Zymark laboratory robotics system integrated with Instron's universal testing instruments to fully automate the handling of test samples. Optional dimensional measurement, bar code reading, and data acquisition systems provide additional complementary functions for even greater test automation and higher laboratory productivity. (Source: ASTM Standardization News, December 1986)

Portable kit

Barcor's portable inspection kit is suited for quick, precise, glare-free VT of surfaces and openings as small as 2 mm. Designed to meet a wide variety of needs, the kit consists of a hand-held instrument having 32 lens configurations with 0-10x magnifications and a built-in fibre-optic lighting system; a separate, angled, general-purpose fibre-optic inspection light; a hand-held, high-powered 2.5x fixed magnification direct-viewing scope, a 110 V rechargeable handle; and a case for storage and carrying.

The kit is suited for close, precise, distortion-free VT of surface defects, weld joints, printed circuit boards, through-plated holes, and the inside of small parts, bores, cylinders, and minute or shallow openings. Engineered to reduce or eliminate shadows and glare, halogen illumination is transmitted by fibre optics in a 360 degree ring of intense yet cool light. Included is a polarizing filter to reduce glare, an ultraviolet filter, a green filter, and a special crosshair lens cover. (Barcor, Inc., Deerfield, IL, USA.) (Source: Materials Evaluation, 44, September 1986, p. 1171)

Development of wear monitoring techniques

Spire Corp., Bedford, MA, USA has received a $215,000 two-year award from the National Science Foundation to continue development of wear monitoring techniques for magnetic media using surface layer activation (SLA) techniques. The project will develop techniques suitable for commercial applications in magnetic media and other industrial areas. Spire pioneered development of nondestructive SLA methods to monitor and measure material loss from surfaces exposed to corrosion. These techniques, particularly those using radionuclide markers, have evolved into reliable diagnostic tools most commonly applied to bearings, piston rings, and valve engine part inspections and have also been used to monitor erosion and ablation in pipelines, drilling equipment, and missile nose cones. Monitoring gamma-rays escaping from a thin surface layer activated by exposure to a high-energy particle beam to measure wear, erosion, or corrosion is an established technique. Because resolution in this technique is a function of the total depth of the active layer, much finer increments of wear could be detected by using ultra shallow layers of activity. The new programme will address reproducibility and accuracy issues using shallow layer activity, test both methods to determine depth profiles of induced activities, and determine the uniformity and consistency of the profiles themselves. (Source: Materials Evaluation, 44, September 1986, p. 1168)

Digital RT

An X-ray inspection system using AS&E's Ultimate X-Ray Detector (UXD) incorporates two high-spatial-resolution subsystems: a digital radiography subsystem (Ultimate Micro-Dose) and a computed tomography subsystem (Micro-CT). Ultimate Micro-Dose and Micro-CT can be used in laboratory and production NDT applications.

The UXD combines the patented precision features of AS&E's large industrial CT machines and the versatility of modular tabletop X-ray systems. The basic UXD system configuration consists of several modules: X-ray source, UXD detector, motion and handling gantry, data acquisition, data reduction, image display, and operator interface. The modules can be configured for various NDT applications, including turbine blade orifice alignment, rock porosity studies for oil transport investigations, discrimination of density variations in ceramic components, and fibre delaminations in composites.

In the digital radiography mode, the UXD provides images of 4096 by 4096 elements. Thus, in an 8 by 8 in. (20 by 20 cm) field, spatial resolution of 0.002 in. (0.05 mm) is possible anywhere in the field.

In the CT mode, the UXD achieves the same spatial resolution of 0.002 in. (0.05 mm) with defect repeatability as small as 0.001 in. (0.03 mm). This level of spatial resolution enables the user to locate and measure cracks, delaminations, and subtle variations in material density. Micro-CT, in its standard configuration, can inspect objects up to 6 in. (15 cm) diameter and cover a wide range of densities, from plastics to metals. The technique of Micro-CT is especially suited for cases where X-ray scattering renders conventional tangential boundary images useless.

The output image is in a digital format, so that the image can be processed, manipulated, or enhanced with standard techniques. Final data, along with a complete inspection record, are stored in digital format on disk or tape for archiving. User-friendly attributes are standard. (American Science and Engineering (AS&E), Inc., Cambridge, MA, USA.) (Source: Materials Evaluation, 44, March 1986, p. 394)

X-ray imaging

Radiographic Automated Production and Testing (RADAPT) systems use solid-state discrete detectors for computerized X-ray imaging.

RADAPT systems are available in three functional configurations: line scan systems, which use a small number of discrete X-ray detectors to help determine sample characteristics, such as dimensions and density; projection scan systems that use an array of detectors to create X-ray image data for 100 per cent inspection and automatic defect recognition; and tomographic scan systems, which include high-speed processors to construct cross-sectional data.

Applications include aerospace, manufacturing, food processing, electronics, and other industries with critical materials that require nondestructive internal analysis. BIR will also evaluate current inspection problems that are beyond the capabilities of conventional techniques. (Bio-Imaging Research (BIR), Inc., Lincolnshire, IL, USA.) (Source: Materials Evaluation, 44, March 1986, p. 394)

Computer control boosts materials testing routines

The new 7158 computer-based universal materials testing machine introduced by Avery Denison provides similar facilities to the earlier 7157, but extends the capacity for maximum force from 250 to 500 kN.

The computer controls the entire cycle, and provides extensive data displays and post-test processing capability. For example, proof stress, ultimate tensile strength and percentage elongation for individual tests can be calculated, and a stress-strain curve can be presented with colour graphics.

The computer can also prepare statistical analysis for a series of tests.

During machine operation, computer control gives the important advantage of accurately maintaining a preset loading rate through a servo-hydraulic system, for one or a series of tests.

The machine has a 'soft' interface to permit operation with an IBM, Hewlett-Packard or Apricot micro which uses the same executive software. (Source: Machinery and Production Engineering, 5 November 1986, p. 87)

Exxon, NBS agree on joint materials facility

Exxon Research and Engineering Company (ER&E) and the National Bureau of Standards have entered into an agreement to develop an important materials science and engineering instrument at NBS at Gaithersburg, Md., USA. The 3-year agreement provides for the funding and expertise needed to develop a new Small Angle Neutron Scattering (SANS) instrument at the NBS reactor cold neutron source.

SANS is a method of using relatively low-energy neutrons as probes to measure the structure of materials in very great detail. It is a nondestructive technique that has a diversity of applications ranging from the study of density variations in alloys to the determination of the size and shape of large molecules such as polymer chains or proteins.

The programme is intended to cover the design, construction, and maintenance. The estimated cost is $1 million, to be shared equally by ER&E and NBS. (Source: R&DM Digest, March 1986)

Laboratory furnace

A laboratory furnace introduced by Lenton Thermal Designs Ltd., which has the capability to reach its maximum operating temperature of 1,700°C in only 15 minutes, incorporates the means of communicating with an associated computer. Designated the Ultraspeed 1700 Series, the furnace is available in three optional chamber sizes: 3.5 litres; 12.0 litres; and 28.3 litres. The chamber is constructed entirely with ceramic tiles of vacuum-formed aluminium silicate, which has extremely low mass and, therefore, ensures high operational efficiency. The heating elements are suspended within the chamber, along each side. It is the use of this chamber material, together with the heating method, which provides the furnace with its extremely high operational efficiency and characteristically high throughput: maximum operational temperatures are reached in under ten minutes, and the furnace chamber also cools at an extremely fast rate.

Programming is effected by means of an integral control module situated in the base area of the furnace. This multi-segment profile generator combined with an associated three-term controller, enables advanced process programmes to be created. Programming is extremely simple in certain instances, and the module provides a continuous display of the current state of the programme. (Source: Metals Industry News, September 1985, p. 14)

Hardness testers

EquoTip Assocs., Denver, CO, USA, make the EquoTip portable hardness tester and, for automated hardness testing, the EquoMatic E hardness tester. A briefcase carries the EquoTip portable hardness tester with the EquoInterface II, coupling paste, a test block, a choice of impact devices, and a Sharp computer with program already installed to provide a printout in three different modes of testing. The device can be used for several hours without external power and can be recharged.

The EquoMatic E automatic hardness tester is designed as a compact module that can be integrated into a specific testing location by the user. The device can be mounted in an inspection line or in a fixed measuring station. The precision feeding of the measuring head can be varied within a distance of up to 10 mm by a vertical moving unit, and a horizontal moving unit provides for three individual measurements at a point-to-point distance of 3 mm; the measured value can be evaluated as the average of the three measurements. (Source: Materials Evaluation, 44, February 1986, p. 186)

Quality control

A Vision Statistical Processor (VSP), which is used with Itran machine vision inspection equipment to perform statistical process control (SPC) for ensuring quality control during the manufacturing process has been introduced. VSP analyses measurements of parts by computing such statistics as averages and variances. Results are displayed either on a CRT in the form of charts and graphs or printed out as hard copy. Manufacturing engineers can use this information to spot gradual changes in the manufactured part as it is being produced. Knowing this, users can identify the source of part deviation and adjust the manufacturing process before bad parts are produced. (Itran Corp., 670 N. Commerical St., P.O. Box 607, Manchester, N.H. 03105, USA.) (Source: Modern Casting, October 1986, p. 56)

Computerized testing

The Model 1712A computerized ultrasonic instrument is a self-contained, automated inspection instrument offering full digital control of all inspection parameters in three modes: manual, internal computer, or remote computer.

The 1712A features a 16-bit, 8086/8087 microprocessor, a 50 MHz analog-to-digital converter, and a single-density hard-cased micro floppy diskette that can store up to 500 kilobytes of information. It can be programmed to process complete algorithms in real time and provide a display on either the internal digital graphic display or on an external remote colour or gray-scale graphic display in both C- and B-scan modes. (SRL NDE Systems Div., Dayton, OH, USA.) (Source: Materials Evaluation, 44, October 1986, p. 1294)

New composite materials demand changes in testing strategies

Today's aircraft are being designed and built with increasing amounts of composite materials, which offer a far greater strength-to-weight ratio than conventional metals. Further, composites allow designers to go to the marketplace with smaller and more manoeuverable aircraft that are easier to repair than the planes of yesteryear.

But the low density that makes composite materials ideal for manufacturing lightweight aircraft throws a glitch into some customary methods of parts testing.

Carbon epoxy and other composites now make up 25 per cent of total material.

McDonnell Aircraft's St. Louis, MO, USA, plant has turned to two methods for nondestructive testing (NDT) of the low-density composite materials: an automated ultrasonic C-scan system, which the company developed, and low kilo-voltage (kV) static and in-motion radiographs.

The two methods are complementary; each provides information the other cannot.

The ultrasonic system inspects both the composite skin and its bond to the substructure. The scanning radiographic system checks the composite honeycomb substructures and their adhesives for flaws.

A blotch in an ultrasound image means that in that local area the attenuation is a little greater than in surrounding areas. The radiographs, on the other hand, determine whether that area is unbonded or just carries some extra adhesive.

The radiographs detect anomalies in the foaming adhesive that bonds many edge-member assemblies to the honeycomb core. The foam expands as it cures under pressure and heat, and it becomes hard and porous. But because of this spongelike quality, ultrasound is ineffective, so radiographs must determine the consistency of the adhesive.

Radiographs cannot determine, however, whether there is an area between the skin and the core that has not been bounded as long as there are no voids, so ultrasonic testing comes into play.

McDonnel Aircraft designed its own automated ultrasonic scanning system (AUSS) because there was nothing available on the market in the 1970s.

The fourth generation AUSS examines large aircraft structures, including entire wing skins, for delaminations, voids, ply slippage, and foreign objects. The computer-controlled system automatically scans the part, which is vertically positioned between two water jets that contain ultrasonic transmitters and receivers at their nozzles. Because the system uses ultrasonic frequencies of up to 10 MHz, it cannot send the ultrasound through air, but relies on water as a conductive medium.

The data collected from the automated scan are displayed on a CRT and output from a plotter. The system allows for multiple plots of scans in different decibel values.

The aircraft company has been a pioneer in standardizing and automating all testing procedures by preprogramming computers to handle exposures for different views of different parts.

Its in-motion and static radiographic systems are also computer operated. For in-motion radiographs, all the programs for inspecting a part are keyed into a computer, which then controls the path and speed of the X-ray beam and the time and kV of exposure.

A component may be subjected to as many as 18 different programs, but all the computer technician has to do is position the film and key in the part number and views desired, and the computer handles all the other variables. The operator is then free to prepare film for other shots or process and examine film from previous shots.

One of the benefits of in-motion radiography is that all details can be accurately located in relation to each other for easy interpretation of results.

McDonnell aircraft shoots its radiographs on Kodak Industrex® AA film and on Industrex M film for low kV exposures, necessary to capture the low-density composite materials. But the films are also exposed at higher kV for predominantly metal parts. While normal X-ray filming for metal parts may be at 80 kV, composites require energies as low as 10 kV. (Excerpt from <u>Materials Evaluation</u>, 44, January 1986, pp. 53-54)

<u>Ultrasonic squirter scanning</u>

Large-capacity automated ultrasonic squirter-scanning systems designed specifically for testing composites are available from Custom Machine, Inc., Cleveland, OH, USA. These systems precisely locate defects - such as voids, delaminations, disbonds, and porosity - in graphite-epoxy composites used in the manufacture of panels, fusilage assemblies, and wing components in critical aerospace applications.

Each system is customized to the customer's requirements and can be equipped with a number of options, including data-acquisition systems that provide computer-controlled evaluation tailored to specific data-acquisition needs. This option and feature mapping (identifying features of the ultrasonic signal other than amplitude) digitize the features for storage and later evaluation.

Custom Machine is currently building a number of systems for the aerospace industry. The firm's first composite testing system was recently installed at LTV Aerospace and Defense Co., Dallas, TX. This system provides a 125 by 255 by 18 in. (316 by 645 by 46 cm) inspection envelope equipped with adjustable squirter assemblies that permit inspection of fillets or curves along the transverse or longitudinal axes at variable, selectable scan speeds and indexing. Computer control, including a "teach" mode, is provided for all axes, and program entry is via keyboard, floppy disk, or digital cassette. The system is controlled by a programmable controller with a membrane operator control panel and a cathode-ray tube. Providing program control of up to ten motorized axes, this configuration permits rectilinear scans with indexing of one to four additional axes. Inclined or compound-inclined rectilinear planes can also be inspected.

The firm makes NDT equipment for the ultrasonic testing of forgings, castings, plates, bars, strip steel, tubing, and pipe. With equipment ranging from single components to fully automated test lines, Custom Machine provides complete design, engineering, and production services to industry. (Source: <u>Materials Evaluation</u>, 43, April 1985)

<u>Infrared system</u>

Agema Infrared Systems (Secaucus, NJ, USA), formerly AGA Corp., a Pharos Co., makes two infrared scanning systems of potential application to the testing of composites: the Thermovision® and the Thermoprofile®.

Agema's Thermovision® 782 portable infrared (IR) system is designed for convenient operation in the field and in the laboratory. It is rugged, versatile, and easy to operate. The basic system consists of a scanner, an opto-mechanical device that converts the IR radiation from an object's surface into an electrical signal, and a display unit that presents the IR information on a TV screen. Options include a real-time system that converts black-and-white IR images into a ten-colour TV picture (with temperature range and isotherm levels) and a digital image-processing system (with hardware and software for analysis by microcomputer).

The Thermoprofile® 5 line scanner is designed for production control in the manufacturing and processing industries, monitoring the temperature of material as it is manufactured. Among its many applications are the signaling of metal deformation, the prevention of film oxidation in plastic films, the control of film thickness variation during extrusion, and adhesion control of coatings. The test object is scanned by an optomechanical mirror system at 5 Hz with a viewing angle of 90 degrees and a field of view of 2 mrad. The output can be presented as temperature profiles, thermal contours, or complete digital thermal maps of the scanned object. The output can also be used directly as an input to correct the production process. (Source: Materials Evaluation, 43, April 1985)

Analyser offers fixed and resonant modes

Du Pont's 983 four-mode dynamic analyser offers fixed and resonant frequency modes, plus stressed relaxation and creep measurement to assess structure, mechanical properties and engineering performance of sophisticated materials. Dynamic mechanical analysis can determine the overall mechanical or viscoelastic performance of materials such as polymers and composites.

The fixed-frequency mode provides quantitative viscoelastic properties, and shows how they vary with the frequency of applied stress. This mode lets an operator pick up to 57 frequencies - in a single experiment - from the 0.001-10 Hz range.

The resonant frequency mode has the higher sensitivity needed to detect subtle transitions in a material. It lets the sample oscillate at its natural (versus fixed) frequency. It is a particularly good mode for polymer blending to achieve specific properties and to observe the interaction of blended materials.

The stress relaxation mode generates data on molecular relaxations which vary with polymer and composite structure. The DMA subjects the sample to a selected deformation (strain), and monitors the stress needed to maintain the fixed deformation (versus time) at selected temperatures.

Creep measurement characterises structural materials, and defines a material's ability to support load/stress over a specified time without excessive deformation/flow that might affect structural integrity. CM also analyses the material's ability to recover its shape once the load is removed. (Source: Canadian Research, September 1986, p. 46)

Component testing

Nukem has delivered a large ultrasonic testing system to Dassault, France, for the critical inspection of composite aircraft components. The Nukem electronics feature an extremely fast analog-to-digital converter (155 MHz) for enhanced signal waveform analysis. The menu-driven outputs include colour C-scan cathode-ray tube displays and printouts, as well as histograms plotting the attenuation characteristics of the materials under test. (Nukem, Inc., White Plains, NY, USA.) (Source: Materials Evaluation, 44, October 1986, p. 1300)

Panel inspection

Custom Machine has built various ultrasonic scanning systems for composite and honeycomb panels and parts. Complete computerization is offered - sophisticated data-acquisition packages featuring high-resolution feature mapping developed jointly with Ultrasonics International, Inc. Basically, each system falls into one of three different types.

In type 1, the panel is supported in a horizontal position, and the inspection squirters are mounted above and below the panel being inspected. Such systems have been supplied with from one to six pairs of squirters operating simultaneously.

Type 2 is a gantry system in which the panel is supported vertically. The scanning bridge is mounted above the panel being inspected and runs on an overhead track system. Manipulators extend down from the scanning bridge and direct the squirters against opposite sides of the panel.

In type 3, the panel is supported vertically. The scanning bridge travels on a track assembly that is below the panel being inspected (at or near the floor). Two columns are attached to the top of the scanning bridge. The squirters travel vertically on the columns and are directed to opposite sides of the panel. These systems can be equipped with a tank for reflector-plate inspection.

Each Custom system is customized to the customer's needs and is sized to accommodate the parts to be inspected. Many options and variations are available. Squirter systems can be provided with angulation capability so that they can be controlled in any axis or plane. Options include recorders, precise readouts, input and output conveyors, multiple transducer manipulators, turntables, and bar rotators. (Custom Machine, Inc., Cleveland, OH, USA.) (Source: Materials Evaluation, 44, October 1986, p. 1294)

Bond tester

Many combinations of composites, metals, and other engineering materials appear in today's complex bonded laminate structures. The patented Bonda-Scope® 2100 was developed in response to current requirements for a reliable bond-testing instrument that is not only versatile but simple to operate and interpret. Designed by people who understand both the practical aspects of bond inspection and the fabrication of laminated materials, the instrument can inspect metallic, nonmetallic, or combined metallic-nonmetallic structures for a variety of anomalous conditions, including measurable levels of unbonds, voids, delaminations, inclusions, porosity, fibre damage, core damage, bond-line thickness variations, and certain material properties. Configurations commonly inspected include adhesively bonded laminates, advanced fibre composites, and honeycombs.

There are two different approaches for ultrasonic testing (UT) of a laminate: pulsed wave and standing wave. The pulsed wave approach relies on resolving transmitted or reflected pulses in terms of propagation times or amplitude variations. Instruments such as the NDT Instruments' Novascope® 3000 are widely used in this approach, often favoured for evaluation of composites immediately following their manufacture.

When composites are bonded to other components in secondary operations, co-bonded during primary fabrication, or suspected of in-service degradation, standing wave propagation UT tends to be favoured. With a suitable UT transducer, standing waves are generated throughout the laminate thickness. In general, access to only one side of the part is required. Different types, sizes and depths of anomalies in multiple bond lines produce changes in the phase and amplitude of standing waves, which in turn affect the acoustic or ultrasonic impedance value at the laminate surface.

The BondaScope 2100's scope display represents an impedance plane. A digitally generated "flying dot" indicates the location, in phase and amplitude, of the tip of a vector representing the UT impedance value as detected by the transducer. Bond-line anomalies of different types or depths produce characteristic "dot addresses". When appropriate calibration standards are used, the location of the test dot can easily be compared with the location of calibration data. A simple keyboard on the front panel of the BondaScope lets the operator program up to eight calibration reference dots on the instrument's memory display.

Phase rotation, meter indications, and high/low alarms combine to enhance flaw indications and suppress small, irrelevant indications. Each BondaScope probe has a built-in miniature light-emitting diode alarm light. Once the setup is made, the operator can concentrate on scanning coverage and accuracy. Because the operator does not have to watch the display all the time, scanning rates are higher and fewer flaws are missed. (NDT Instruments, Inc., Huntington Beach, CA, USA.) (Source: Materials Evaluation, 44, October 1986, p. 1294)

Ultrasonic testing

The Nanoscope 412 ultrasonic flaw detector is particularly suited for the inspection of thin composites in the 0.015-0.500 in. (0.38-12.70 mm) range because of its near-surface resolution. The instrument has a broad-band receiver that works well in the 2.5-50 MHz range. The television display can be easily read in high ambient light. The echo pattern may be timed either from the initial pulse or from the interface between the water and the test material. The 412 provides four different outputs.

If the Nanoscope 412 is coupled to Erdman Instruments' 512A B/C-scan unit, both A-scans and B-scans of the composite can be shown. The B-scans are presented on the 19 in. (48 cm) cathode-ray screen of the 512A B/C; the A-scans, on the Nanoscope. Together, they make a powerful tool for research as well as production. (Erdman Instruments, Inc., Pasadena, CA, USA.) (Source: Materials Evaluation, 44, October 1986, p. 1299)

Complex magnetic field flaw detection method

Sumitomo Metal Industries has developed a complex magnetic field flaw detection method, to meet requirements for product quality guarantee accompanying the production of higher grade steel pipes. The method can detect flaws automatically in both magnetic and non-magnetic materials by the same line, and adapts to small-lot production.

By this method, the surface of the material to be checked is magnetized by a combination of horizontal and vertical magnetic fields, making changes in the surface of electromagnetic fields caused by flaws (type and size) easily detectable by the magnetic sensor. It is possible to detect the existence and properties of all flaws, to evaluate them, and to improve the accuracy of product quality guarantee.

Sumitomo Metal Industries, which adopted this method for the inspection line in its steel pipe production plants in its Wakayama works, will employ this for inspection of round CC billets and steel bars and will develop positive marketing approaches.

This flaw detection method offers the following features:

(1) It is applicable to all types of metal materials.

(2) It can evaluate flaw properties.

(3) Visual inspection is automated by quantitative detection of pit flaws.

(4) The detection section is small and light due to the development of three magnetization methods.

(5) It is equipped with functions of autodiagnosis made possible through signal digital processing and of automation of sensitivity setting. It has high reliability, leading to a higher operation rate. (Source: Chemical Economy & Eng. Review, May 1986, Vol. 18, No. 5 (No. 198), p. 47)

New tests have been developed

New tests have been developed that allow field researchers to detect micro-organisms that cause corrosion of alloys and destroy welds in stainless steel.

The current process takes weeks in a laboratory to determine if a problem exists but two new tests developed at Rensselaer Polytechnic Institute by microbiologist Daniel Pope give results within minutes. The first test uses antibodies specific to organisms in question. Fluorescent dyes and portable microscope are used to highlight and count presence of organisms. Field researchers can test 12 to 20 samples in 1 hour. The second test, colorimetric test, produces 12 to 18 samples in 1 hour. Colour produced determines extent of how many organisms are present. Tests are inexpensive - $1 to $2 per sample. Technology is available for licensing. (Biotest, Inc., Box 295, RD 1, Petersburg, NY 12138, USA.) (Source: Inside R&D, 30 July 1986, p. 2)

New ultrasonic sensor developed

A new ultrasonic sensor for measuring the depth and properties of treated surfaces of steels and metal alloys has been developed at the US Department of Commerce's National Bureau of Standards (NBS) by two guest workers from Johns Hopkins University and an NBS scientist.

For more than a century, metal producers have been using conventional carburizing and nitriding heat treatments to improve the performance of metals. These treatments are used to harden the surfaces of steels and other alloys, giving them added surface strength and resistance to wear and corrosion. The hardened metals are used as bearings in engines and in numerous other industrial applications where performance is especially critical.

Conventional treatments for modifying metals are being joined by emerging rapid solidification technologies using electron beams and lasers to change the microstructures of surface layers on metals. The new processes give the exterior surfaces superior performance characteristics different from their metal substrates and produce materials for high technology applications.

The sensor, which uses ultrasonic waves to make very precise measurements of both the depth and mechanical properties of surface-modified layers, is made up of two ultrasonic transducers: one to launch high-frequency sound waves and another to receive them as they move across the surface of the material.

By measuring the velocity of the ultrasonic waves, it is possible to determine the thickness of the modified surface, evaluate its elastic properties, examine the homogeneity of the surface layer, and possibly detect flaws or delaminations that may exist between the modified surface layer and the substrate.

The sensor eliminates the need to destroy finished products by cross-sectioning materials to determine the effectiveness of the processes used to modify metal surfaces and the quality of the component. (Extracted from Materials Evaluation, 44, July 1986, p. 953)

Conductivity tester

K.J. Law Engineers, Inc., Farmington Hills, MI, offers the 4900C Verimet portable conductivity tester, with plus or minus 0.5 per cent accuracy for aluminium alloys. This microprocessor device permits temperature-compensated testing of the heat-treated condition of nonferrous metal, provides direct digital readout of conductivity from 12 to 110 per cent of the International Annealed Copper Standard, and shows the calibration temperature on a dial. The stable-crystal adaptive-frequency-controlled oscillator provides 0.050 in. (1.27 mm) constant depth of penetration into the part. Thinner parts are tested using the compensation control. (Source: Materials Evaluation, 43, January 1986, p. 83)

X-ray analyser for metal alloys

A new portable X-ray analyser has been developed by the Electronics Division of Outokumpu Oy of Finland. The analyser, designated X-MET 840, can be used both for identifying alloys and for element analysis. The composition of known alloys can be measured and the result stored in the analyser's memory. When an unknown alloy is analysed, its composition is compared with those alloys that are stored in the analyser. If the composition of the unknown alloy corresponds to the composition of a stored alloy, the analyser presents its name on the display.

If the correspondence is not close enough, the analyser gives the name of one or two alloys that are close to the analysed alloy. Alternatively, the analyser can tell you the element composition of the alloy - up to six elements at the same time, in percentages. The analyser has a built-in calibration programme, which eliminates the need for an external computer or manual transfer of data for calibration purposes.

Four different types of probe can be used together with the analyser's electronic unit. Different radioactive sources and detectors are used, depending on the application. All elements from aluminium to uranium can be analysed.

According to the manufacturer, Outokumpu, the X-MET 840 analyser is particularly siutable for on-site measurements. It weighs only 8.5 kg with the surface probe attached and is said to be very fast and easy to use. The primary application of the analyser is metal sorting and identification, but it also finds use within e.g. the chemical industry for raw material and product control and within the paper and plastics industries for analysis of fillers and additives as well as coatings.

The analyser can also be used for the analysis of hazardous substances in environment protection. (Clandon Scientific Ltd., Lysons Avenue, Ash Vale, Aldershot, Hampshire GU12 5QR.) (Source: Metals & Minerals International, 4/1986, p. 21)

Alloy sorting

The Indentomet G-II marketed exclusively in the UK by quality control instrument company, ATL (Applied Technology) Ltd., is claimed to enable operators to identify the precise composition of alloys in a test which takes less than a second to complete.

Using a combination of established physics principles and modern electronic technology, the Indentomet exploits the Seebeck effect to derive accurate information from what would normally be considered to be imperfect sources of data.

The instrument relies on the fact that temperature-dependent voltages are developed across junctions between dissimilar metals.

As this phenomenon derives its energy from fundamental electronic behaviour at the atomic level, the voltages are strongly dependent on precise alloy compositions and are measurably affected by the precise physical state of the metals.

The Indentomet's LCD voltmeter display, which is calibrated to provide one division per 25mV, permits the identification of such apparently identical nickel-based stainless alloys as Monel, Inconel 600 and Incalloy 800. The instrument is also able to differentiate between aged and unaged stainless steel.

The instrument can also be used to assess coatings and metals in plate, fine mesh, wire and strip form. (ATL (Applied Technology) Ltd., Heriot House, Heriot Road, London NW4 2DG.) (Source: Steel Times, August 1986, p. 450)

Non-destructive vibration testing by digital speckle interferometry

A group of applied physicists have developed a simple, sensitive and versatile laser speckle device called Digital Speckle Pattern Interferometer (DSPI) for in situ (non-destructive) testing of stability and vibration of micrometallic components. The earlier instruments incorporating TV monitoring used non-linear electronic devices to enhance speckle contrast; these were somewhat insensitive.

Basically the device uses Reticon 100 x 1000 photodiode detector array to record and multiplex the optical signals reaching it and the diode output is analysed in a digital computer; the computer results are monitored on a video screen. In operation, He-Ne laser beam is split up into two mutually perpendicular beams at a beam splitter. One of the beams is collimated towards the test object (vibrating) onto which is fixed a beam diffuser. The diffused laser speckle beam is then reflected by a mirror. The beat difference between the reference vibration and the object vibration is focused onto the photodiode array.

Now the other split beam from the beam splitter is focussed onto a single mode optical fibre the other end of which is close to the diode array. The laser beam from the fibre is then multiplexed with the diffuse beam reaching via the test object. In the absence of vibrations of the object and of the transducer-controlled mirror, the correlation signal finally appearing at the video monitor is the standard δ-function; in the presence of vibrating test object, the output pulse is no longer a simple δ-function. The computer analyses the pulse shape and depicts the harmonic frequencies and amplitudes on the resulting waveform on the monitor. (Source: Journal of Scientific and Industrial Research, June 1986, p. 322)

Metallurgical imaging

Cambridge Instruments, Inc., Monsey, NY, has made available the Quantimet 970 image analyser for metallurgical quality control. To evaluate the performance and suitability of steels and alloys, the image analyser incorporates the DEC LSI 11/73 computer for precise simulation of international standards such as ASTM E45 and SEP 1570. (Source: Materials Evaluation, 44, February 1986, p. 196)

Copper tubing tester

K.J. Law Engineers, Inc., Farmington Hills, MI, has adapted the M4900C digital eddy current conductivity tester with a V-Block to verify the phosphorous content of copper in both finished tubing as well as bar stock. Widely used in the heat exchanger and air conditioning industries, the copper alloy CDA-122 (normally 39.90 per cent copper with 0.015-0.040 per cent phosphorus by weight) requires rigid control of the phosphorous content to maintain its correct properties for silver alloy brazing and soft soldering. Brazing with incorrect alloy mixes may result in embrittlement, porosity, or leaching of tubing walls, causing premature failure of compressor systems. The phosphorus content can be quickly determined by eddy current conductivity readings by using the Verimet conductivity tester, as has been demonstrated on 0.625 in. (1.59 cm) tubing. (Source: Materials Evaluation, 44, February 1986, p. 196)

Tiny borescope

Instrument Technology, Inc., Westfield, MA, has made available the Model 124200 Micro-Micro borescope, one-half the size of the firm's previously smallest borescope. The 0.5 mm diameter instrument allows inspection into 0.020 in. (0.51 mm) holes common in printed-circuit boards, computer chips, and related components. The borescope is available with a 2 in. (5 cm) maximum probe length. Viewing direction is forward with a 50 degree field of view. Fibre-optic illumination is included within the probe diameter. Camera adapters are available for photographic and video applications. (Source: Materials Evaluation, 44, February 1986, p. 186)

Magnetoelastic testing

The Stresscan 500C from American Stress Technologies, Inc., Bethel Park, PA, is designed for fast and simple testing of residual and applied stresses in steels. The instrument consists of a programmable central unit with interfaceable keyboard, alphanumeric and light column displays, and exchangeable sensors. Three standard depths of measurement are featured, and the device can be operated either in a programmed mode for routine stress testing or in a manual mode for calibration and research. Applications include static and dynamic inspection of stresses in welded structures, bonded composite strips, steel mill rolls, gears, shafts, and bolts. (Source: Materials Evaluation, 44, February 1986, p. 195)

Microprocessor controlled tensile testing machine

J.J. Lloyd Instruments Ltd. has introduced a microprocessor controlled, 50-kN (5-t) electronic universal tensile testing machine which offers a cost-effective replacement for a mechanical testing machine.

The new model, Type T50K, has been developed from the successful T Series machines and may be used in tension and direct compression, through zero, up to its maximum force capacity. The T50K may be fitted with a range of interchangeable, pre-calibrated load cells, providing a force measurement capacity from 0.01 N to 50 kN. All the main machine functions are push-button controlled and an in-line, calibrated digital control provides continuously variable crosshead speeds from 0.2-100 mm/min. Standard features include digital display of load and extension and Peak Hold facility with metric/imperial conversion, precision recirculating ball screws, Auto Zero for load and extension, Back Off and Scale Expansion for load and extension readings.

Optional facilities include an X/Y recorder, giving a permanent record of load/extension, an Impact Printer to record the 'peak load' and 'extension' and which will also compute and record the mean and standard deviation for batches of up to 100 samples. An input is also provided to enable a non-contacting infrared extensometer to be fitted. Other optional facilities include a computer interface, cross-sectional area compensator, automatic grip controller (enabling the machine to operate in a completely automatic mode), and a wide range of grips for use in tension or compression and flexural accessories. (J.J. Lloyd Instruments Ltd., Brook Avenue, Warsash, Southampton, SO3 6HP, England.) (Source: Metals & Minerals International, 1/1985, p. 18)

Computer-aided mobile spectrometer

The Q 500 is a compact, mobile optical emission spectrometer (OES) for mix-up checks in all sectors of the metal industry.

The test is run with a sparking probe, which is held against the workpiece to be tested, thus generating an arc between the probe electrode and the workpiece. Via a fibre-optic cable up to 12 m long, the emitted light is transmitted to the measuring instrument, in whose optical system the spectral lines characteristic of each of the elements are analysed simultaneously. (Leybold-Heraeus GmbH, Postfach 1555, D-6450 Hanau, FRG.) (Source: Steel Times, August 1986, p. 450)

Fracture testing

Fracture testing of large sections of steel, using loads beyond the abilities of any conventional hydraulic tester, has been developed at the Atomic Energy Authority's laboratories at Risley, Warrington, UK.

The technique arises from the need to test the integrity of pressure vessels and other structures used in nuclear power stations and involves spinning eight tonne steel cylinders at 7,000 rpm about a central axis.

This generates large stresses in the cylinder wall, due to centrifugal forces, and the steel can be taken right up to its yield point (at which it starts to deform). The method will initiate crack growth in pre-existing flaws. The test cylinders are 1.3 metres long, with a 1.4 metres outside diameter and wall thicknesses of up to 200 mm.

It will be possible to heat the test cylinder to 400°C and then quickly cool it by an internal water system to induce severe thermal shock to test the steel's resilience. (Source: Financial Times, 6 June 1986, p. 9)

Flux leakage testing

For inspection of ferrous tubular products, Oilfield Equipment Marketing, Inc., San Antonio, TX, offers a magnetic flux leakage process using solid-state transducers. The sensors are not sensitive to speed. Defects of 45 degrees are easily found, and defects can be detected through a much thicker cross-sectional area. High sensitivity and resolution to inside and outside diameter defects, both transverse and longitudinal, are achieved. The firm designed this system so it can be retrofitted into existing pipe inspection units. Both mobile and in-plant configurations are available. (Source: Materials Evaluation, 44, October 1986, p. 1326)

Substrate continuity tester

SCT-1000 is an automatic circuit continuity tester for production testing of complex multilayer hybrid substrates. By comparing the deviation caused in the measured capacitance, opens and shorts are easily identified. High throughput is achieved by single point probing with practically no restrictions on the number or density of points that can be tested. (Teledyne TAC, Woburn, Mass., USA.) (Source: Semiconductor International, November 1986, p. 152)

Magnetic particle system

Ridge, Inc., Tucker, GA, USA, distributes the Tiede family of mobile and stationary testing instruments for surface crack detection in aircraft parts, large castings, forged components, billets, tubes, crankshafts, etc. The Isotest-Electronic 10,000 microprocessor-controlled mobile crack detector is designed to deliver test currents from 2,500 to 25,000 A. The test current is 50/60 Hz AC or fully rectified DC, and the instrument is suited for connection to a three-phase power supply.

An important technical feature of these instruments is the switched control on the secondary side of the test current by means of power thyristors, thereby ensuring short switch times and the fast-break operation. An optimal 30-step demagnetization unit can be included, and the entire test process is controlled by a microprocessor. The electrical and electronic sections of the instrument are separate from the power section and are sealed to keep out dirt. (Source: Materials Evaluation, 44, February 1986, p. 186)

On-line grain size monitor

BNF Metals Technology Centre has reached agreement with Oxford Analytical Instruments Ltd. (a member of the Oxford Instruments Group plc) to develop commercial equipment based on BNF's revolutionary ultrasonic system for on-line measurement of the grain size of annealed copper alloy strip.

The new system promises to boost high-speed production methods by making possible more frequent and more reliable monitoring of quality; reducing scrap rates; and permitting easier control of grain size for different end-use purposes.

Industrial trials carried out at John E. Mapplebeck Ltd., Birmingham, have proved the engineering feasibility of a prototype assembly. BNF is serving as consultant for the development programme, to design, construct and prove a commercial instrument.

Grain size is a critical factor in determining the mechanical properties of wrought metal and its suitability for further processing. Ultimately, grain size affects the final properties and service performance of the end product.

Traditional methods of grain size measurement are slow, labour-intensive and notoriously subjective (as demonstrated by inter-laboratory trials). They are not amenable to on-line application and, consequently, to remedial control of the production process. Furthermore, existing methods require samples to be cut from the strip, which damages saleable material.

Ultrasonic monitoring makes possible swift and reliable non-destructive testing throughout the full length of a strip, complete with a certified print-out for each batch if required.

The use of ultrasonics in non-ferrous metals research is by no means new but the high degree of signal attenuation in copper has always been regarded as a negative factor. It was a BNF researcher who suggested that the attentuation which is due to the grain structure, might be turned to advantage for the measurement of grain size.

With the increasing emphasis on grain size in both national and international standard specifications, and the move to higher speed automatic production methods, the foresightedness of BNF researchers is now paying off. Some £200,000 has been invested over the past four years in mastering the complex physics and in learning how to capture and interpret signals backscattered from moving strip to give an immediate reading to mean grain size. It has been demonstrated that the performance of the new method on brasses is at least as good as traditional visual comparison methods and incomparably faster.

Oxford Analytical Instruments is convinced that there is a large potential international market for the instrument. The use of copper alloys in the rapidly expanding electronic components market alone should ensure an important demand for the equipment.

Work has so far been concentrated on copper alloys but there is no reason why the system could not be adapted for use with a wider range of materials. The ultrasonic back-scatter technique might also be capable of providing information on aspects of metallurgical structure other than grain size. BNF will continue to explore other potential applications in its prospective research programme. (BNF Metals Technology Centre, Grove Laboratories, Denchworth Road, Wantage, Oxon OX12 9BJ.) (Source: Metals & Minerals International, 4/1986, p. 21)

Measuring borescope

Olympus Corp.'s Industrial Fibreoptics Department, Lake Success, NY, USA has made available a measuring fibre-optic borescope that permits measurements by optical means. Inspectors can measure the length and width of even a hairline crack to make more accurate and cost-effective teardown and overhaul decisions. This ability is important in critical applications, such as the inspection of turbojet engines, where costly decisions must be made every day on whether or not to pull equipment out of service for safety and maintenance.

There are two methods of measurement. Inspectors can measure a defect by comparing its dimensions with a reference distance visible through the scope eyepiece. This method is quick and reliable. Where more critical measurements are needed, video imaging or photography may be used. Using one of the firm's video or film cameras, the inspection target as seen through the Measuring Scope is viewed on a television screen monitor, photographic print, or projected slide. Measurements of the defect and reference distance are then taken easily and accurately with a ruler. The true length and width of the defect is then quickly determined by entering these figures on a handy conversion chart. (Source: Materials Evaluation, 44, February 1986, p. 186)

An ultrasonic method finds flaws in ceramic powders

A nondestructive evaluation technique that permits producers of ceramics to automate the inspection of compacted powders while the material is still in the mold has been developed at the National Bureau of Standards (Gaithersburg, Md.). The technique is said to supply producers with information on the uniformity and density of materials at almost any stage of compaction. By measuring the time beween pulses at the top and bottom of the mold, the velocity of sound in the ceramic power can be calculated. The velocity depends on the consistency of the unfired material. (Source: Chemical Week, 15 October 1986, p. 44)

Evaluation standard of advanced materials

With the expansion of uses of advanced materials, demand for establishing standards on their quality evaluation is growing. The establishment of standards will be essential for the spread of advanced materials. Evaluation organizations step up jointly by industries, universities and the Government are now about to go into operation.

Nissan Motor and NGK Spark Plug developed jointly last year a ceramic rotor for a turbocharger for the first time in the world. The ceramic rotor is mounted on a sport car "Fair Lady Z", and it will be adopted for the "Skyline". The co-operation is based on the firm belief of the two companies that the lack of common value standards between manufacturers results in hindering the spread of advanced materials.

Wacoal succeeded in using shape memory alloy for the wire of a brassiere. The company uses the shape memory alloy produced by Furukawa Electric.

The Fine Ceramics Centre (JECC) in Nagoya City was set up in May 1985 with the support of the Ministry of International Trade and Industry (MITI) and the financial circles in the Chubu area for the purpose of establishing a ceramic unified test evaluation setup and exploring uses. It is now constructing its research institute at about ¥7 billion.

The largest problem in evaluating ceramics is the measurement of their strength at high temperatures over 2,000°C. Measurement techniques for room temperature have been more-or-less established. JFCC, hoping to establish high-temperature measurement technology within two years, intends to set the JIS standard on the basis of JFCC standard. The establishment of standards will be useful for cost reduction. (Source: Chem. Economy & Eng. Review, July/August 1986)

Thermal conductivity testing

The Edward Orton Jr. Ceramic Foundation offers a thermal conductivity testing service applicable to ceramics and other materials with thermal conductivities of ≤ 0.21 J/cm^2.s.°C. A computerized radial heat flow method is used. Thermal diffusivity is determined by this method from which thermal conductivity is calculated using known values of specific heat and density. The results are presented in both graphical and tabular forms covering the temperature range 100°-1140°C evaluated at 20°C intervals. (Source: Ceramic Bulletin, Vol. 65, No. 9, 1986)

Device tests strength of ceramics

A device that can test the strength of advanced ceramics has been licensed for commercial application to Instron Corp., Canton, Mass. The device was developed at Oak Ridge National Laboratory, Department of Energy. Little or no accurate data exist on the tensile fatigue properties of advanced structural ceramics, as exist for metal alloys. Conventional custom-made testing devices are expensive, difficult to operate, require special specimen preparation, and frequently bend and damage specimens during testing. The ORNL self-aligning grip assembly, called "Supergrip" by Instron, provides extremely accurate specimen alignment, with no special specimen preparation required. Eight interconnected hydraulic pistons uniformly distribute a tensile load through the centre of a test sample. The device can be water-cooled easily to make it compatible with induction heating or small furnaces. (Source: C&EN, 1 December 1986, p. 21)

Plastics

Film hole detection

Hyde Park Electronics, Dayton, OH, has made available the MA-27 clear film hole detector for the detection of small holes in clear, thin, plastic film. A Microsonic® sensor array using high-frequency sound can test any material, even clear film, without being affected by contaminants such as film dust, ambient noise, and light. A modular design permits varying coverage of up to 100 per cent and flexibility for various widths of materials. The film is inspected in real time and can operate at film speeds greater than 2,000 ft/min (36 km/h). (Source: Materials Evaluation, 44, February 1986, p. 195)

Low-force tester checks many properties

The Model 858 dynamic tester has a broad range of testing capabilities in the force range from 1,000 to 5,500 psi, making it suitable for both R&D and production applications.

The unit, which has a load frame with a moveable crosshead, is available in table sizes of 27.5 x 8, 30 x 30, and 20 x 54 inches. Options include a 20-inch stroke actuator, and axial or axial-torsional testing capabilities. Electronic controls and data acquisition packages, ranging from a table-top microprocessor system to an advanced automated system are available. (MTS Systems Corp., Minneapolis, Minn., USA.) (Source: Plastics World, September 1986, from a special report "Quality - How do custom processors measure up?")

Tester reveals impact qualities faster

The ICI instrumented impact tester performs all standard tests, including Charpy, Izod, Falling Weight, and Dart-drop. Its statistical "package" enables it to test and compare up to 100 samples simultaneously. Impact properties of plastic materials and finished products can be assessed more rapidly than with conventional test systems. Faster testing enhances control of impact quality in processing operations. The tester incorporates a microprocessor control with software that guides the operator through the test procedures and eliminates subjective assessment of results.
(Carl G. Brimmekamp & Co., Inc., San Rafael, Calif.)
(Source: Plastics World, September 1986, from a special report "Quality - How do custom processors measure up?")

TMI/Dewes Gumbs high carbon steel test dies

TMI/Dewes Gumbs high carbon steel test dies are designed for use on such materials as paper, rubber, plastic, and fabric. Specially hardened for durability, cutting edges are manufactured to undergo repeated leveling and sharpening without altering the cutting area size. More than 300 types and sizes of economically priced dies are offered for specimen preparation for a wide variety of tests. (Source: ASTM Standardization News, December 1986)

Oscillating disc curemeter

Zwick of America introduces the Model 4308, the floor-mounted, oscillating disc curemeter designed to determine the vulcanization characteristics of rubber compounds, such as thermoplasticity, processing safety, cure rate, cure time and ultimate state of cure. The basic test instrument consists of a 19 in. freestanding console containing a control processor, electronic units for torque, temperature, and time measurement, and an external 12 in. CRT visual display with alpha-numeric keyboard. (Source: ASTM Standardization News, December 1986)

Method for testing plastics for light stability

Brief description is provided for testing light sensitivity of plastics, consisting essentially of exposure to a controlled light source and subsequent determinations of hydrophobicity for comparison with the values for unexposed samples. For studies on the effects of UV light, the samples were encased in a quartz capsule filled with argon under a pressure of 0.133 Pa. Following exposure to light from DRT-220 and carbon-arc lamps, the wetting angle of the plastic samples changed by as much as 60 per cent. The use of optimal doses of protective additives favoured the retention of hydrophobicity. (Article by N.M. Savvo, A. B. Kamenetskiy, R.G. Chebotkevich, M.S. Gubanova and G.N. Krasnova.) (Abstract from Moscow Plasticheskiye Massy in Russian, No. 7, July 1986, p. 40)

MARKETING

Quality control appears on the bottom line

Quality management systems cost money but have the potential to cut costs too. Increasingly they are becoming mandatory, and there is a growing interest in this field among plastics processors.

Tougher and more demanding markets plus the 1980s push to reduce costs have converged in a move towards quality assurance and quality management programmes.

The Sectoral Consultative Committee's report on the plastics industry pointed out that quality costs are intrinsically more variable and controllable than others. The price of material is outside a manager's control, and the scope for controlling other economic factors is limited. But there is no inescapable reason that 5 per cent to 20 per cent of the products made must be defective, requiring expensive scrap or rework; or that 10 per cent to 20 per cent of the manpower within the manufacturing area must be engaged on inspecting and testing this defective product.

Manufacturers in high technology areas do not tolerate lax quality levels from suppliers. Quality is not merely a pious statement - it means money. One computer multinational is DEC. It has quantified the financial penalties that a manufacturer which buys from slipshod vendors may face. A supplier may sell items at what appears to be a low price. But defective product will require some form of remedial action, increasing the real cost of the consignment to the customer. According to DEC:

- A 1 per cent defect level in components supplied increases the real, manufacturing cost of these items by 3 per cent.
- A 2 per cent defect rate increases the cost by 4 per cent, while a 3 per cent defect rate pushes it up by 7 per cent.
- With a 4 per cent defect rate, a supplier's products are costing the customer 13 per cent more than the list price.
- A defect rate of 5 per cent to 8 per cent increases the real cost by a massive 22 per cent.

These factors can be taken into account when tenders are awarded, and the quotes may be adjusted accordingly. It is one way of counting the costs of poor quality.

The consequential cost to the end user of equipment failing in the field is often such that it is well worth paying a price differential at an early stage and passing the cost of the quality effort on.

The first Irish standard for quality systems, issued last year, became a bestseller and there is a move towards an initiative specifically for the plastics industry. These are welcome developments in the light of a 1984 survey of 90 companies (carried out for the SCC report).

The increasing awareness of quality management was evident; 87 per cent of companies polled said that they could benefit from improvement to quality.

The survey looked at quality planning and procedures. Of the Irish companies, 76 per cent had a quality plan, and some 71 per cent of the foreign firms had one. An interesting conclusion, since foreign-owned firms are usually perceived to be in advance of indigenous companies. However, the level of activity and follow-through in the area of quality management was far greater in foreign-owned firms, which also made more use of international and national standards.

The survey noted "a significant absence of formal procedures for quality assurance ranging from 30 per cent to 14 per cent in the areas of raw material, process and product for all companies".

It looked at the competitive aspect of quality. Some firms were facing tough competition from imports. The problems came almost equally from low price/inferior quality items, and competitively priced/superior quality, g ods. Companies facing difficulty with the cheap, inferior imports wanted official standards, and to a lesser degree a certification scheme.

Also highlighted was the need for training in quality training: 30 per cent of indigenous companies provided such training, compared with 75 per cent of foreign firms.

A quarter of the Irish firms recorded the costs of their quality management and assurance programmes, compared with three quarters of the foreign-owned companies.

The survey concluded that while many firms considered they had a quality plan, the level of activity in this sphere (for example, training, procedures, costing and so on) "would indicate that this, in fact, is not the practice".

The report concluded that there was a need for quality training and more national standards. There is no doubt that where possible a certification scheme and attendant certification mark guaranteeing third party assurance must be introduced. The simple claim to meet a standard by marking as such and the presence of an official certification mark must be highlighted as two very different indicators of quality assurance.

As far back as 1982, proposals for an entirely new type of standard emerged. Most standards focus on specific products. consultative committee representing industry and user interests meets over a period to consider the proposed specs and requirements. Standards are generally finalized by a process of consensus; they get their sanction from the demands of the marketplace, and agreed industry practice.

Most if not all standards are issued as a response to technological and industrial developments.

One exception was the work of the British Standards Institute in the 1970s on standards dedicated not to a product or group of products but to a system of management. This led to a standard, BS 5750, which specifies a quality management system - its components, objectives and requirements.

In Ireland, IIRS had been following this pioneering work; now there are moves to establish European standards in this field. In 1982, IIRS took the initial steps to devise an Irish system, incorporating modifications and revisions which had been learned from the BSI's experience, and geared to Irish needs. A consultative committee met, discussed and circulated the proposed standard.

The result of this work is an extensive body of documentation published early in 1985, a 10-part series of quality specifications.

The core of the series is a specification termed IS 300, which outlines in a number of parts the principles of quality systems management, the necessary design, production and installation capabilities, and final test and inspection capabilities. This is supplemented by documents which advise on sampling procedures, quality manuals, quality audits and a quality glossary. A further document sets out procedures for service industry. (Extracted from Technology Ireland, April 1986, pp. 46-49).

The following two newsclips appeared in ASTM Standardization News, November 1986.

Digital durometers for testing elastomers and plastics

Zwick of America introduces a new series of digital durometers for testing elastomers and plastics to ASTM D 2240. The digital durometers are available in two models, Zwick 3123 for elastomers and the 3124 for plastics. Both durometers are equipped with an optical encoder that can determine the Type A or Type D hardness of the material under test to a resolution of 0.1 units.

TMI's Digital Polyken® Probe Tack Tester lets operators regulate test variables in accordance with specific test requirements. The instrument accurately determines tack by measuring the force required to separate an adhesive surface from a probe tip. A variety of available probes, including a temperature controlled probe to measure heat activated adhesives, test various pressure sensitive materials.

UN/UNIDO ACTIVITIES

UNIDO reports on material testing since 1970

Report of the UNIDO/Austria second training programme in plastics technology for developing countries.

Handbook on testing and standardization of plastics.

Index of national and international standards tests. (Testing for plastics).

The past, present and future of plastics in building applications. (Expert report on the use of plastics as building materials; testing facilities).

Report on technical assistance to the plastics fabrication industry in Nicaragua and proposals for the establishment of the plastics technology centre. (Expert report on assistance to the plastics ind., quality control, testing, etc.).

Recent developments of wire enamel for magnet wires in electronic and motor applications (use of plastics; testing requirements, etc.).

Laboratorium für Kunststofftechnik, a possible model for institutes of training, testing and research of plastics. (Research and testing centre on plastics).

Research and production of ceramic materials for electronics industry, Romania. (Expert report on research and development of ceramics for the electronics industry; present status with respect to laboratory and testing facilities).

Clay refining and glazed tiles manufacture, Malta. Project findings and recommendations. (Expert report on assistance in establishment of ceramics industry in Malta; preparation of testing programme, etc.).

Consultant on electro-porcelain-manufacture in the ceramics corporation in Sri Lanka. Project findings and recommendations. (Expert report report on manufacture of ceramics; required testing; etc.).

Etude préparatoire à l'implantation d'une briqueterie dans la région du fleuve, Senegal. (A study on setting up bricks production in Senegal; ceramics, testing, etc.).

Viet Nam. Air conditioning services and facilities for the metrology and testing centre at Bien Hoa. (Report on assistance to a laboratory; testing rooms for paper, leather, plastics, chemicals, etc.).

Viet Nam. Institute for Standardization and Quality Control.

Report on mission to Cipet, Madras (injection moulding technology). (Expert report on assistance to a training centre for plastics moulding technology in India, testing section, design centre, etc.).

Tanzania. Report on development of TIRDO activity in engineering services. (Expert report on assistance to a research centre (TIRDO), testing, quality control, ext.).

Technological tests for raw materials for brick plant near Khartoum-Sudan. (Report on technological tests; laboratory testing and grading of materials).

Energy conservation in non-metallics. (Expert report on potential use of a mobile diagnostic unit from Czechoslovakia for improvement of energy saving in processing of non-metallic minerals and ceramics, laboratory studies and testing results, etc.).

Mission to India. Resins as matrix for composites. (Testing experts and research programmes).

Egypt. Plastics development centre. Assistance in training for procedure and specifications of testing. Technical report.

Greece: consultation in certification and quality control laboratories for PVC pipes. (Report on assistance to quality control laboratories for polyvinyl chloride pipes in Greece, covers laboratory's testing of plastics, etc.).

Report on the testing of plastics and rubber.

Bangladesh, ceramics industry development. (Procurement of chemicals and of testing and quality control equipment).

China, mechanical properties of plastics. Report about lectures and working groups related to the testing of plastics.

Carbon fibre-reinforced plastics testing and properties optimization. (International conference on carbon fibre applications, Brazil, 1983).

India, setting up weathering and testing facilities at Cipet, Madras. (Expert report regarding assistance to plastics testing in India).

Jamaica. assistance in the development of ceramic industry.

India, assistance to Cipet/Madras in the field of rheology of polymer melts. (Expert report on assistance to a plastics research centre in India; definition and significance of rheological research and testing).

Seychelles, technological tests of ceramic raw materials. (Report on tests of local clay for potential use in ceramics industry, testing methods).

Optical fibre production. (Testing and quality control).

Testing institute and plant laboratories for testing non-metallic raw materials and products. (Report on laboratories for testing).

Sri Lanka, establishment of a ceramic research and development laboratory.

India, plastics materials and product testing programme. One year mission report. (Expert report on assistance to a laboratory for testing of plastics and plastics products in India).

Jamaica, technical report. Laboratory testing of packaging and plastic materials and plastic products.

UNDP and UNIDO visiting China

UNDP and UNIDO (as the executing agency) had organized a visit to China for US experts from the National Bureau of Standards and Chemical Research Division of the American Cyanamid Corp., in the years 1984-1985, to visit and give lectures in the Service Centre of Testing Technology in Shanghai.

The development objective of the project was to improve the research and development of industrial testing technology to disseminate and popularize the new testing technology, and to develop and distribute standard reference materials (SRMs), by gradually establishing a centre responsible for testing and analytical services, training testing technicians and studying testing methods in East China.

The Shanghai Municipal Commission of Science and Technology in 1977 acquired a collection of precision analytical instruments to augment the Shanghai Institute of Testing Technology (SITT) in order to provide a systematic testing service. The gradual shaping of the Shanghai Testing Technological Service Centre facilitates Shanghai's industries to supply a large number of technological data.

The Institute has a staff of over 600, including [illegible] engineers, 120 assistant engineers, 138 technicians and 195 mechanical and electric engineering workers. Under it there are five laboratories for material testing, chemical analysis, optics, radio-time-frequency and sensors, and a workshop. There are twenty sets of imported precision analytical instruments, including transmission electronic microscope, scanning electron spectrometer for chemical analysis. Spark source mass spectrometer, inductively coupled argon plasma spectrometer etc. They are able to provide services in testing and analysing purity, structure, opographic feature and surface of metal (and its compounds), silicate, semiconductor and organic materials.

At present, the tasks of the SITT are as follows:

(i) To test and evaluate the quality of industrial products, e.g. life, resistivity, content of oxygen and carbon and micro-faults in monocrystal; quality of various coating layers on bicycle rims and wrist watches; micro-impurities in tungsten filaments and aluminium lead wires of semi-conductor etc.

(ii) To assist factories in developing new materials, the Institute supplies the analytical data, e.g. the mechanism of anti-corrosion stainless steel, attenuation of optical fibre, the efficiency of tellurium-cadmium-mercury IR detector, the components of new enamel, the structure of crystallite glass, the quality of solder and nodular cast iron etc.

(iii) To develop standard reference materials (SRMs), and use them as a means to calibrate the analytical instruments. Now the Institute can supply several SRMs, such as NO_2, SO_2, Si.

(iv) To play an arbitration role by supplying the analytical data in case the two parties in trade do not agree with each other in quality of products.

(v) To research new testing methods and offer consultation services to the industries.

Every year, approximately 10,000 samples are tested. But compared with the rapid development in the technology of industrial production of recent years, the testing means now available in the Institute are not capable to satisfy factories and enterprises in testing and analysing their products.

GUIDE TO TRAINING OPPORTUNITIES OFFERED BY UNIDO IN 1987

Field of study	General description	Venue and host institution	Duration	Language	Qualifications
Iron and steel industry technology	Theory in technological process of equipment, economic planning, management, maintenance. In-plant training in foundry, blast furnace, sintering plant, open hearth plant, rolling mills, refractory maintenance.	Zaporoz Steel Zaporozhe Ukrainian Soviet Socialist Republic	09/02-23/05	Interregional programme English	Metallurgical, chemical, electrical or mechanical engineering degree and directly engaged in one of the production activities. Technical fields of iron and steel industry. Practical experience should not exceed three years.
Metalworking industry	Planning, executing and supervizing of the manufacturing processes of machine parts; design of jigs and mixtures, design and use of cutting tools; operation and maintenance, quality control and economics of metalworking operations, etc. Practical studies in laboratories and in-plant training in metalworking. (13 to 15 big machine-producing factories.)	Lumumba University Moscow Union of Soviet Socialist Republics	16/02-12/06	Interregional programme English	A degree in mechanical engineering (or equivalent) with at least three years of practical experience in a supervisory or managerial capacity in metalworking, particularly machine tool operations, planning, manufacture and maintenance and repair.
Engineering and industrial design	Theoretical introduction on product design, tool design, production engineering and manufacturing of prototype products and tools. Practical study assignments in design offices and laboratories for metallurgical testing and/or workshops.	Engineering and Industrial Design Development Centre Cairo Egypt	February/March	Interregional programme English	Degree in mechanical engineering or engineering degree with at least three years of experience.
Technology and equipment in electric welding	Technology and equipment for electric fusion, resistance, welding processes, modern welding, arc power resources, welding material and structures, constructive technological designing of welded material etc. In-plant training in plants manufacturing electric welding equipment, metalworking industry as well as laboratories.	E.O. Paton Electric Welding Institute Kiev Ukrainian Soviet Socialist Republic	19/03-03/07	Interregional programme English	A university degree (or equivalent) in electrical or mechanical engineering with at least three years of practical experience related to electric welding.
Cement industry technology	The programme concentrates on technical aspects of cement industry and includes technical subjects such as feasibility studies, raw materials, production management technologies, quality control, maintenance, energy conservation, pollution and pollution control.	Cement Research and Development Centre Ankara Turkey	April/May	Interregional programme English	Degree in chemical, mechanical, electrical or relevant branch of engineering; one to five years of practical experience and employed with cement industry.
Modern foundry technology	The training programme will cover the following topics: the design of modern foundry processes (including economic and technical aspects); foundry materials, melting and casting technologies, pattern-making practice, moulding materials and moulding technology, mechanization and automation of foundry processes, quality control and repair of castings, environmental protection including noise control and other safety and pollution problems.	Foundry Research Institute Kraków Poland	May/June	Interregional programme English	Degree in foundry or metallurgy (or equivalent) with at least two years practical experience (preferably in a supervisory position) in at least one of the following fields: moulding sands, moulding technologies, melting technologies, pattern-making practice, casting technologies, mechanization and automatization of foundry processes, quality control.
Iron and steel industry technology	Theory in technological process of equipment, economic planning, management, maintenance. In-plant training in foundry, sintering plant, open hearth plant, rolling mills, refractory maintenance.	Zaporozh-Steel Zaporozhe Ukrainian Soviet Socialist Republic	10/09-21/12	Interregional programme English	Metallurgical, chemical, mechanical engineering degree and directly engaged in one of the production activities. Technical fields of iron and steel industry. Practical experience minimum three years.

GUIDE TO TRAINING OPPORTUNITIES OFFERED BY UNIDO IN 1987 (continued)

Field of study	General description	Venue and host institution	Duration	Language	Qualifications
Measurements and tests in civil engineering	Participants will be able to apply various measurement methods and instruments in testing and quality control in civil engineering; in lectures, case studies, and workshops the following main topics will be dealt with: objectives of routine testing and measurement in civil engineering research; measurement methods and techniques; selected applications; organization of laboratories, training of staff.	Institute for Developing Countries Zagreb, Yugoslavia in co-operation with the International Measurement Confederation	Sept. 1 week	Interregional seminar English	Managers and/or civil engineers with a university degree in mechanical, electrical or other branch of engineering, or in physics; practical experience and responsibility in the civil engineering sector.
Iron and steel industry	The analysis and selection of raw materials, appropriate processes and technologies for iron and steel production; hot and cold rolling mill operations; quality control and testing; organization and management of steel plant maintenances.	Eregli Iron and Steel Plant Eregli Turkey	September/ November	Interregional programme English	University degree in chemistry, metallurgy, mechanical or electrical engineering (or equivalent) with one to five years practical experience and holding supervisory function.

TRAINING OPPORTUNITIES OFFERED BY INSTITUTIONS OTHER THAN UNIDO IN 1987

Course or seminar	General description	Organizer; Venue	Commencing date; Duration	Qualifications; Language requirements	Last date for receipt of applications	Fee
Análisis de fallas de materiales	Introducción al análisis de fallas de materiales metálicos. Estudio del origen de fallas y clasificación de las mismas. Estudio de casos prácticos con el empleo de equipos científicos modernos.	Dirección General de Asesoramiento Técnico Salta 2752 - 2000 Rosario - Argentina	Mayo o junio 2 semanas	Profesionales jóvenes o técnicos con experiencia Español	-	$US 200
Quality control	Classroom work, discussions, group work and visits to firms, to give participants an insight into the commonest methods for process and sampling control. Further it will be possible to see the methods used in production firms.	The Jutland Technological Institute Quality Control Section Teknologiparken 8000 Aarhus C Denmark	June 1987 3 weeks	Engineers and managerial staff of developing countries who supervise quality control, production control or factory management English	3 months prior to start of course	To be arranged
Qualité et fiabilité	Donner une solide formation à la "qualité" à des ingénieurs pour les spécialiser, grâce aux techniques informatiques les plus récentes.	Institut national des sciences appliquées de Lyon Formation continue Bât.: 601 20, avenue Albert Einstein 69621 Villeurbanne Cedex France	15.02.88 au 14.05.88	Ingénieur et technicien super. Français	2 mois avant début du stage	FF 20,475
Total quality control	The concept and principles of TQC: functions, organization and systems of TQC activities, quality policy planning and management, manpower development, education in awareness, information analysis and data collection, product design and development; QCC activities, characteristic features, rules and pitfalls, TQC activities in different industries.	Asian Productivity Organization 4-14 Akasaka 8-chome Minato-ku Tokyo Japan 107 Venue: Japan	To be decided 4 weeks	Quality control managers/engineers in industry and technical consultants of national productivity organizations, etc. of APO member countries English	3 months before commencement	$US 100 per participant from profit-making organizations
Statistical quality control, a computer-oriented approach	The emphasis is devoted to the development and applications of various statistical tools underlying the modern methods of controlling the quality of goods and services at an early stage of the production cycle and showing how the calculations can be made by computer. Topics covered in the course include: the nature and impact of the computer, flow diagrams for statistical analysis, probability and probability distributions, sampling theory and techniques, tests of significance, control charts, experimental design and regression and correlation analysis.	International Centre for Quality and Management Sciences P.O. Box 2082 3000 CB Rotterdam Netherlands	12 January 24 August 1987 and 11 January 22 August 1988 2 months	Bachelor degree or equivalent and experience in quality control or a related discipline English	3 months before commencing date	f.7,000

TRAINING OPPORTUNITIES OFFERED BY INSTITUTIONS OTHER THAN UNIDO IN 1987 (continued)

Course or seminar	General description	Organizer; Venue	Commencing date; Duration	Qualifications; Language requirements	Last date for receipt of applications	Fee
Total quality control	The course is divided into three parts: 1. Theoretical; dealing with the basic concepts, quality specifications, organization, policy, planning and motivation, economics of quality, customer service, inspection and sampling, process capability, auditing, reliability and quality improvement. Statistical tools in quality control and standardization are given special attention. 2. Practical; conducted in factories, offices or institutes concerned with quality control. 3. General; spent on transmission of knowledge, studying topics of special interest and visits to industrial plants.	International Centre for Quality and Management Sciences P.O. Box 2082 3000 CB Rotterdam Netherlands	12 January and 24 August 1987 and 11 January and 22 August 1988 4 months	Bachelor degree or equivalent and experience in quality control or a related discipline English	-	£.13,000
Quality systems installation, auditing and improvement	Various types of control systems are discussed including the organization schemes and cost-reporting methods that go with each type. For existing quality control systems, the seminar shows systematic methods of auditing and improving the system to make it work more efficiently, hence economically. Topics dealt with include: quality control functions, types of quality control systems, organization for quality assurance, introducing a quality control system, setting-up for inspection, sampling plans and their use, analysing a quality system, quality systems auditing, quality motivation and improvement programmes and quality requirements for export to industrial countries.	International Centre for Quality and Management Sciences P.O. Box 2082 3000 CB Rotterdam Netherlands	12 January 24 August 1987 and 11 January 22 August 1988 6 weeks	Bachelor degree or equivalent and experience in quality control or a related discipline. English	3 months before commencing date	£.5,500
Applied practical quality control inspection and metrology for mechanical engineering	Theoretical and practical areas of quality control, inspection and dimensional metrology.	SWEDEC International AB Riddargatan 37 S-114 57 Stockholm Sweden (can also be conducted on customers' premises)	19 October 1987 6 weeks	Professional qualifications English	15 March 1987	$US 4,200 (May 1986 exchange rate)
Metallurgical quality control	Concepts of specifications standards and quality, purchasing orders and their preparation, determination of tolerances, raw material specifications, ladle metallurgy, defects of mould ingots and their causes, defects of concast slab and their causes, determination of hot and cold rolling mill quality control conditions, sample preparation, X-ray examination and photography, evaluation of customer complaints, stock yard quality control.	Ercoli Iron and Steel Plant Ercoli Turkey	September 1987 September 1988 12 weeks	English	-	-
Pipemill inspection	Studies in specifications, codes and standards; visual and dimensional inspection; welding technology; basic metallurgy; heat treatment; welding codes; weld defects; destructive and nondestructive testing; quality assurance and evaluation; quality control.	Inspectorate - Unit inspection Sketty Hall Sketty Park Road Swansea SA2 8QE United Kingdom Inspectorate - Unit Inspection, P.O. Box 45 Portrack Lane Stockton-on-Tees Cleveland TS18 2PP United Kingdom	March and November 6 months or by arrangement	Equivalent of GCE "O" level in Mathematics, and Physics/ General Science	1 month before start of course	£160 per man/week
Nondestructive testing	Theoretical and practical training in ultrasonic, radiographic, penetrant and magnetic particle testing methods and welding inspection. (All subjects or any individual subjects may be taken.)	Inspectorate - Unit Inspection Sketty Hall Sketty Park Road Swansea SA2 8QE United Kingdom Inspectorate - Unit Inspection, P.O. Box 45 Portrack Lane, Stockton-on-Tees Cleveland TS18 2PP, United Kingdom	January, July and September or by arrangement 2-12 months	Equivalent of GCE "O" level in Mathematics, and Physics/ General Science	1 month before start of course	£160 per man/week
Quality control procedures	Theoretical and practical training in quality assurance, quality evaluation and control, statutory inspection, nondestructive testing and welding inspection.	Inspectorate - Unit Inspection Sketty Hall Sketty Park Road Swansea SA2 8QE United Kingdom Inspectorate - Unit Inspection, P.O. Box 45 Portrack Lane Stockton-on-Tees Cleveland TS18 2PP United Kingdom	March and September or by arrangement 2-12 months	Equivalent of GCE "O" level in Mathematics, and Physics/ General Science	1 month before start of course	£160 per man/week

TRAINING OPPORTUNITIES OFFERED BY INSTITUTIONS OTHER THAN UNIDO IN 1987 (continued)

Course or seminar	General description	Organizer; Venue	Commencing date; Duration	Qualifications; Language requirements	Last date for receipt of applications	Fee
Quality assurance	Quality survey and related training activities desgined to meet British Standard B.S.5750.	Metcon Training 14 Pall Mall London United Kingdom	Throughout the year	English	-	-
Quality control	Advanced materials: investigative methods for surface analysis, I.R. spectroscopy, electrical and electronic properties, tensile and dynamic mechanical testing, fluid rheology, polymers, composites and metallic materials.	Dept. of Pure and Applied Chemistry University of Strathclyde Glasgow G1 1XL United Kingdom	To be arranged Normally 3 months to one year	Professional qualifications or degree	To be arranged	To be arranged
Control de calidad I	Tecnología del control estadístico de la calidad.	Instituto Uruguayo de Normas Técnicas San José 1029 P.7 Montevideo Uruguay	2 de junio 3 de septiembre 4 semanas	Graduados en ingeniería o técnicos con experiencia Español	24 de mayo 29 de agosto	$US 90 $US 90
Control de calidad II y métodos estadísticos	Herramientas estadísticas, complementarias a las del Curso I.	Instituto Uruguayo de Normas Técnicas San José 1029 P.7 Montevideo Uruguay	5 de noviembre 4 semanas	Graduados en ingeniería o técnicos con experiencia Español	30 de octubre	$US 110

OTHER TRAINING OPPORTUNITIES AND SHORT COURSES

Course or seminar	General description	Organizer; Venue	Commencing date; Duration	Qualifications; Language requirements	Last date for receipt of applications	Fee
Iron and steel industry	Short courses on: technology of iron and steelmaking (levels I, II and III); production and maintenance in steelmaking shops, including continuous casting; maintenance management; quality control in steelmaking and rolling; material management; electro-mechanical maintenance in rolling mills; computer applications; financial management; energy conservation concepts.	Voest-Alpine Industrial Services Corp. Ltd. Kremplstr. 5 P.O. Box 2 A-4020 Linz Austria	Throughout year 1 week	Professional qualifications. English	To be arranged	AS 23,630-25,250 including lunch and in-plant transport
Industrías mecánicas	Cursos en: ensayos no destructivos, inspección y control de calidad de soldadura, metrología industrial.	CESMEC Ltda. Av. Marathon 2595 Santiago, Chile	A definir 2 semanas	Educación secundaria	-	$US 500
Contrôle industriel et qualité, normalisation et analyse de la valeur	Cours sur : initiation à l'analyse de la valeur; la normalisation d'entreprise; comment améliorer l'efficacité de la maintenance; la gestion des rechanges; la conduite des projets informatiques; le contrat de maintenance; concepts de qualité; la qualité à la production; la qualité aux études et au marketing; formation à l'audit qualité; la micro-informatique au service du contrôle qualité; les services qualité des entreprises et les logiciels; analyse de la valeur; motivation à la qualité; qualité aux approvisionnements; comprendre la normalisation OSI; comment optimiser la codification dans l'entreprise; méthodes pour établir la documentation technique d'exploitation et de maintenance; comment maîtriser la disponibilité des équipements dès la conception; la conception pour un coût objectif - CCO; apprendre à maîtriser les coûts de la qualité; auto contrôle; manuel qualité et procédures.	AFNOR (Association française de normalisation) Tour Europe Cedex 7 F-92080 Paris La Défense France en collaboration avec AFCIQ, ACANOR et AFAU	Toute l'année 2 jours - 1 semaine	Qualifications professionnelles. Français	-	A fixer
Production engineering	Courses on: foundry technology; industrial metallurgy; materials selection for design engineers; analytical procedures for testing laboratories; investigation of the failure of metallic components and structures; design, construction and maintenance of precision engineering equipment; product design for injection moulded plastic parts; basic drawing techniques; testing of plastics and other polymers; analytical procedures for testing laboratories - plastics; specialized product design; injection mould design; operation of injection moulds for plastics.	Fulmer Research Institute Ltd. Stoke Poges Slough SL2 4QD United Kingdom	To be arranged 1-6 months	Professional qualifications. English	-	£2,000-3,000 per month

OTHER TRAINING OPPORTUNITIES AND SHORT COURSES (continued)

Course or seminar	General description	Organizer; Venue	Commencing date; Duration	Qualifications; Language requirements	Last date for receipt of applications	Fee
Quality assurance and related subjects	Regular and comprehensive programme of short courses on all subjects relating to quality assurance. They include statistical quality control, metrology, quality costing, reliability engineering, quality in design, the quality of software, test and inspection, QA and process control in the process industries, system management of specification writing, prevention of human error, and overall quality management.	The Institute of Quality Assurance 54 Princes Gate Exhibition Road London SW7 2PG United Kingdom	Throughout year 1-5 days	Professional qualifications English	-	To be arranged
Construction	The seminar will cover all types of structural assessment from testing models at large scale and monitoring behaviour of full scale structures: large scale testing; prototype and proof testing; structural performance of redundant structures during demolition, dismantling and decommissioning; criteria for assessment of physical data and interpretation of testing data for the designer including liability and accuracy measurements.	Institution of Structural Engineers Informal Study Group Building Research Establishment Garston Watford WD2 7JR United Kingdom	6-8 April 1987	English	6 March 1987	£175 + VAT
Automation	Short courses on: microcomputer system design; computer aided engineering; computer aided design and draughting; introduction to microprocessors; advanced 16 bit microprocessors; digital signal processing; fibre optics; test equipment in electronic and microelectronic servicing; microcomputer interfacing; programmable logic controller projects.	New Technologies Section Faculty of Technology Nene College St. Georges Avenue Northampton United Kingdom	Throughout year 15 hours	-	-	£20
Maintenance and repair, quality control	Short courses on: industrial maintenance; quality control, quality assurance.	PERA Training Melton Mowbray Leicestershire LE13 0PB United Kingdom	Throughout year 3-5 days	Professional experience or qualifications English	-	To be arranged
Quality assurance	This short course is designed to provide engineers, technologists and management with an up-to-date appraisal of quality assurance and covers: economic, communication and planning elements of QA; statistical concepts, quality control charts, QA and the consumer. QA test procedures prior to, during and after manufacture; specification interpretation; training and certification of QA personnel; reliability case studies; the QA manual production liability.	Scottish School of Non-Destructive Testing Paisley College High Street Paisley PA1 2BE Scotland United Kingdom	6 modules and 2 symposia between September 1986 and June 1988 1 day each	Professional qualifications English	-	£50 per module £75 per symposium
Quality engineering	The primary purpose of this course is to equip the student for a career in quality engineering and to consider the technical and management factors involved in prescribing realistic quality programmes, quality systems and quality levels and the assurance of product quality; the principles and practice of non-destructive testing methods; those aspects of electronics and instrumentation that are relevant to quality engineering with NDT.	Scottish School of Non-Destructive Testing Paisley College High Street Paisley PA1 2BE Scotland United Kingdom	23 September 1987 6 months	Degree science or engineering English	1 September 1987	£1,100
Quality practice	The management of quality with the utilization of information technology; the interpretation and use of international standards and the criteria for acceptance levels ranging from general to high quality requirements.	Scottish School of Non-Destructive Testing Paisley College High Street Paisley PA1 2BE United Kingdom	May 1987 and 1988	Professional qualifications English	5 May 1987 5 May 1988	£500
Practical electronics	Practical work building and testing analog and digital electronic circuits including amplifiers for various transducers, signal processing circuits and some binary and control techniques. Participants work individually.	Department of Pure and Applied Physics UMIST Manchester M60 1QD United Kingdom	-	Knowledge of Ohms law English or French	-	Approx. £250
Control de calidad	Círculos de la calidad.	Instituto Uruguayo de Normas Técnicas San José 1029 P.7 Montevideo Uruguay	28 de octubre 6 días	Gerentes y Técnicos Español	21 de octubre	$US 110

This following article was prepared by UNIDO's Institutional Infrastructure Branch:

UNIDO's technical assistance in the field of quality control, standardization and metrology programme

Objectives, main characteristics and approach

Since its creation, UNIDO has considered the establishment, development and strengthening of quality control, standardization and metrology activities in developing countries at the industrial plant, at the national, regional and international levels, as a basic requirement and vital factor for their industrial development.

On the basis of UNIDO's experience and the ever-increasing emphasis being placed on greater quality, reliability, safety and performance of goods, products and services locally produced, imported or exported, it appears evident that the major objective is the development and management of quality, the ultimate aim being to further and continuously raise and improve the quality of life, at all levels of development.

Quality control can be most effective in:

(a) Improving the quality of products, including product life, reliability and safety;

(b) Raising the productivity of manufacturing processes;

(c) Reducing manufacturing and other costs;

(d) Achieving timely deliveries and thereby greater marketability of products and services;

(e) Facilitating exchange of goods and exports of goods and services from the developing countries;

(f) Improving health and living conditions and standards.

Another important factor which is giving this necessity an even greater importance, in the field of international trade, is the entry into force, in January 1984 of the GATT 'Agreement on Technical Barriers to Trade' also called 'Standards Code' which imposes on countries which sign and ratify this Agreement, a number of obligations in terms of quality control, certification marking and standards.

The development - and improvement - of quality through quality control, quality assurance, certification marking, laboratory accreditation, measurement and testing, cannot be fulfilled properly without at least two elements:

(a) Standardization, the availability of adequate standards and specification on one hand and

(b) Metrology, the availability of precise and continuously checked, repaired, maintained and calibrated measuring instruments and equipment.

In certain cases a third element is needed, namely industrial research and development when aimed at improving the quality of goods and products. In line with the generally accepted and UNIDO-promoted integrated approach to quality control, standardization and metrology, UNIDO tries to ensure that in the elaboration, formulation and execution of technical co-operation projects the above three components together with industrial research and development, wherever necessary, are fully integrated or at least fully co-ordinated. When projects cover one of these elements, the other two are taken into full consideration to the greatest possible extent.

The contribution of standardization to industrial development is highly significant especially in developing countries. Standards give the seal of general acceptance of goods in addition to ensuring optimum quality and facilitation technology transfer, standardization activities contribute to the overall economy of a country through cost reduction by mass production, interchangeability and rationalization and effective utilization of resources brought about by import substitution, utilization of indigenous resources, conservation of essential and scarce materials and reduction of waste materials. It is therefore evident that the role of standardization in the overall development of a country is so important that there is a great need for the establishment of national standards bodies (NSB) in all developing countries to effect its benefits. These national standards bodies can play an important role in setting national standards and by ensuring that these standards are implemented in order to assure the production of quality goods for local and export markets. Through co-operation and collaboration with standards bodies in other developing or developed countries, these national standards bodies could promote participation in international standardization activities.

Metrology covers the whole field of measurement, measuring instruments and equipment, their control, repair, maintenance and calibration, including the upkeep of high-precision reference standards (national and international) of the various units of measurement (length, mass, volume, time, temperature, electrical, etc.). Its role in industrial development is well recognized by the developing world. No scientific, technical and technological advances which affect industry and trade could be achieved without a suitable system of measurement traceable in terms of precision levels to the internationally recognized primary reference standards. The quality of industrial production depends on the better definition and accuracy of measurements.

A well-organized national metrology system providing the necessary accuracy of measuring instruments and measurement systems is also necessary in the following fields: planning of the national economy, account of material wealth, mutual trade balancing, estimation of quality production, adjustment and maintenance of technological processes, scientific researches, product interchangeability, safety and hygiene of labour, disease diagnostics, preparation of medicines and medical treatment, etc.

The existence of an infrastructure of applied, industrial metrology together with full provision for legal metrology (weights and measures as utilized mainly in trade and commerce) is a basic requirement for the development of quality and standardization, for without it the preparation and application of appropriate standards leading to a better quality, reliability and safety of industrial goods and products would not be possible.

Operational activities

The programme in quality control, standardization and metrology covers the establishment, organization, operation and development of the required institutional, legal, technical, management and administrative infrastructure required for quality control, quality assurance, standardization, certification marking, testing laboratories, laboratory accreditation, and metrology.

Some projects cover the establishment, organization and operation of a National Standards Body (NSB), for instance, by providing additional testing laboratories and facilities. Others concern the establishment and operation of quality certification marking schemes, which are often mandatory, e.g. when covering goods and products intended for export. Projects this category usually include the establishment of new specialized testing laboratories, or the organization of a network linking existing laboratories.

UNIDO projects may also cover assistance in the preparation of national standards through the establishment of specialized technical committees in industrial sectors according to particular priorities of the country covered.

In some countries, particularly where a variety of institutions, organizations and laboratories already exist, the project's objectives will be to link the activities of such institutions in a network or national system aimed at the development and implementation of national policies in standardization, quality control, certification marking, and metrology. Such systems or network aproach also ensures a better and more rational utilization of national financial, technological and human resources and capabilities.

Projects concerned with metrology involve the establishment of national metrology services including the necessary laboratories providing the national primary, secondary and working-level reference standards. The national metrology system and the laboratories should also cover the needs of industrial plants in reference standards, instrument repair and maintenance as well as calibration services. The simplest example in the field of metrology is the establishment of central and regional offices of weights and measures, which every country, even those in the early stages of industrial development, must have. Technical co-operation projects in metrology may also assist in the conversion of a country's measurement system to the metric system.

There are also projects aimed at the establishment and operation of a regional standardization organization as well as at organizing and developing the participation of developing countries in regional, interregional and international activities in quality control, certification marking, standardization and metrology. In a few cases UNIDO provides advice and assistance to enable developing countries to adhere and sign the GATT Agreement on Technical Barriers to Trade (by fulfilling its requirements). In effect these contribute toward improving the country's international trade balance.

The majority of the technical co-operation projects executed by UNIDO in the fields of quality control, standardization and metrology are large-scale projects with durations from two to five years or even longer, when follow-up phases are required. Among the biggest and most characteristic ones, the following projects can be listed:

Project number	Project title	Country
DP/BRA/82/020	Metrology, standardization and industrial quality	Brazil
DP/CPR/85/010	Assistance in development and application of precise DC and AC electric quantity measurement techniques	People's Republic of China
DP/CPR/85/025	Centre for the technique development of dimensional measuring instruments and machines	People's Republic of China
DP/ETH/84/006	National Metrology centre	Ethiopia
DP/SAU/80/008	Technical advisory service to the Saudi Arabian Standards Organization (SASO)	Saudi Arabia
DP/VIE/83/00[illegible]	National Centre of Metrology	Viet Nam

Following is a list of centres doing materials testing or research on quality control.

AUSTRALIA

DEPARTMENT OF DEFENCE, JOINT TROPICAL TRIALS AND RESEARCH ESTABLISHMENT
G.P.O. Box 638, Innisfail, Queensland

This establishment carries out studies into the various tropical environments and their influence on the performance of materials and equipment. Current research activities include: the evaluation, under various tropical environments, of new developments in a wide variety of materials including polymers, adhesives, composites, rubbers and alloys; the study of tropical environments and specific environmental parameters responsible for degradation of specific materials.

MATERIALS TESTING LABORATORY
51 Bouke Road, Alexandria, New South Wales

The laboratory provides a consultant and investigatory service in areas of non-destructive inspection, physical metallurgy, corrosion and mechanical testing.

MATERIALS ENGINEERING DEPARTMENT
Wellington Road, Clayton, Victoria 3168

Research into mechanical, manufacturing, electrical and magnetic properties of metals (notably aluminium alloys and steels), polymers, ceramics, and fibre-strengthened composites, corrosion and materials protection.

CHINA, PEOPLE'S REPUBLIC OF

INSTITUTE OF METALS RESEARCH
2-6 Wenhua Road, Shenyang, Liaoning Province

Research on steels and ferrous metals; metals science and testing; non-ferrous metals; materials for aerospace and nuclear reactor engineering.

JAPAN

MATERIALS BEHAVIOUR LABORATORY
Ehime University (Ehime Daigaku),
Shigenobu-cho, Onsen-gun Ehime 791

Current research includes: strength of metals in high temperature vacuum; simple methods of estimating stress and strain at notch root; deformational strength of welded metals; strength of structures made of paper.

MATERIALS SCIENCE AND ENGINEERING LABORATORY
Ethime University (Ethime Daigaku),
Shigenobu-cho, Onsen-gun Ehime 791

Current research includes: microscopic aspects of fracture in engineering materials; fatigue mechanisms of metallic materials; fatigue behaviour of engineering plastics.

METALS AND ALLOYS LABORATORY
Ethime University (Ethime Daigaku),
Shigenobu-cho, Onsen-gun Ehime 791

STRENGTH OF MATERIALS LABORATORY
Ethime University (Ethime Daigaku),
Shigenobu-cho, Onsen-gun Ehime 791

Singular stresses around cracks in composite materials; mechanical properties at high rates of strain.

ELECTROTECHNICAL LABORATORY
1-4, Umesono 1-chome, Sakura-Mura,
Nühari-gun 305, Ibaraki-ken

Research in the following areas: industrial standardization and related testing technology; i.e. new materials, electronics, space development technology, etc.

FURUKAWA ELECTRIC COMPANY LIMITED, CENTRAL RESEARCH LABORATORY
9-15, Futaba 2-chome, Shinagawa, Tokyo 142

Research in optical fibres, semiconductors, metals and alloys, plastic fabrication, etc., and materials testing.

INSTITUTE OF SCIENTIFIC AND INDUSTRIAL RESEARCH
Suita Campus, Mihogaoka Ibaraki-shi, Osaka University, Osaka

Materials analysis centre.

KYOTO PREFECTURAL UNIVERSITY
1 Hangi-cho, Shimogama, Sakyo-ku, Kyoto
DEPARTMENT OF ENGINEERING SCIENCE

Department conducts research in mechanical behaviour of materials and materials science.

INDONESIA

LEMBAGA FISIKA NASIONAL, NATIONAL INSTITUTE FOR PHYSICS LFN-LIPI
Jl. Cisitu, Bandung, Jawa Barat

Research and development and the provision of scientific and technical services in the field of material science and material applications in technology.

THE PHILIPPINES

MATERIALS SCIENCE RESEARCH INSTITUTE
General Santos Avenue, Bicutan, Taguig,
Metro Manila

Research on materials know-how in the field of metals, ceramics and plastics.

TAIWAN, REPUBLIC OF CHINA

MATERIALS RESEARCH LABORATORIES
195-5 Chung Hsing Road, Section 4, Chutung Chen,
Hsingchu Hsien

Research in metals, polymers, ceramics, corrosion and materials characterization, high-strength alloy steels, carbon fibre, composite materials, non-destructive testing.

THAILAND

KING MONGKUT'S INSTITUTE OF TECHNOLOGY, THONBURI
FACULTY OF ENGINEERING
Suksawat 48 Road, Bangmod Rasburana,
Bangkok 10140

Testing and certification, design, research and development and general services in the field of chemical engineering; testing for physical properties and chemical composition of metals, iron, steel, etc.

(Source: Pacific Research Centres, published by Longman Group Ltd. UK, 6th floor, Westgate House, The High, Harlow, Essex, CM20 1NE, UK. ISBN 0-582-90028-X, 1986)

List of more centres dealing specifically with materials testing: (Source: International Research Center's Directory 1986-1987, ISBN 0-8103-0470-8)

ARGENTINA

INTI CENTRE FOR MATERIALS RESEARCH
(Centre de Investigación de Materiales - CIM)
Faculty of Engineering
Ciudad Universitaria, Casillo de Correo 884
5000 Cordoba

Centre conducts applied research and provides technical assistance to industry in the field of materials science. Activities include: technical analysis, mechanical, metallographic, and non-destructive testing.

VAN WYK CENTRE FOR RESEARCH AND DEVELOPMENT
Berutti y Rio Bamba, 2000 Rosario

Centre conducts a research and development programme in material technology and structural analysis. Fields of research interest include metallurgy and material testing.

AUSTRIA

INSTITUTE OF MATERIALS AND MATERIAL TESTING
Karlsplatz 13, A-1040 Vienna

Institute's activities include research and teaching in the areas of materials science.

LABORATORY FOR PLASTICS TECHNOLOGY
Wexstrasse 19-23, A-1200 Vienna

Laboratory is a research, development and training centre. Research is concerned with the processing, testing, and application of plastics.

OEFZS DEPARTMENT OF MATERIALS TECHNOLOGY
Austrian Research Centre Seibersdorf,
A-2444 Seibersdorf

Principal fields of interest include technology development, materials research, materials testing.

BAHRAIN

MATERIALS TESTING AND RESEARCH SECTION
P.O. Box 5, Manama

Section's primary function is quality control of civil and building works. Activities also include research into materials performance.

GERMANY, FEDERAL REPUBLIC OF

FEDERAL INSTITUTE FOR MATERIALS TESTING
Unter den Eichen 87, D-1000 Berlin 45

Institute's research programme is concerned with material and construction, materials analysis and testing.

FRAUNHOFER INSTITUTE FOR NON-DESTRUCTIVE TESTING METHODS
Universität Building 37, D-6600 Saarbrücken 11

Institute conducts industrial and government-sponsored research and development projects on non-destructive testing methods for materials.

FRAUNHOFER INSTITUTE FOR SILICATE RESEARCH
Neunerplatz 2, D-8700 Wurzburg

Institute is concerned with: research, development, and improvement of non-metallic inorganic materials (glass, ceramic, cement, etc.) and their technologies; behaviour of the materials during production and application.

INSTITUTE FOR PLASTIC PROCESSING IN INDUSTRY AND CRAFT
Pontstrasse 49, D-5100 Aachen

Institute is concerned with: improving equipment technology of the testirg and production processes.

SWEDEN

NATIONAL SWEDISH AUTHORITY FOR TESTING, INSPECTION AND METROLOGY
Brinellgatan 4, P.O. Box 857501, 15 Boras 1

Authority is the central organization for official testing and inspection, including general and legal metrology. Activities include the testing of materials and construction. Authority comprises research departments for building technology and mechanics, chemistry, a centre for testing.

SWITZERLAND

SWISS FEDERAL LABORATORIES FOR MATERIALS TESTING AND RESEARCH
Ueberlandstrasse 129, CH-8600 Dübendorf

Research, development and testing of materials.

UNITED KINGDOM

NPL DIVISION OF MATERIALS APPLICATIONS
c/o National Physical Laboratory, Teddington, Middlesex TW11 OLW

Materials-processing technology, engineering ceramics, materials testing and quality of polymeric and composite materials.

FULMER RESEARCH INSTITUTE, LTD.
Hollybush Hill, Stoke Poges, Slough, Berkshire
SL2 4QD

Institute's facilities and expertise cover all aspects of research, development, design, testing and evaluation of metals and advanced engineering materials.

and FULMER TECHNICAL SERVICES
(address as above)
(Division of Fulmer Research Institute)

Provides testing and consultation services to industry and commerce on uses of engineering materials, particularly metals and advanced composites. Its activities include: mechanical testing, analysis of materials, surface analysis, corrosion testing.

Standardization

BANGLADESH

BCSIR LABORATORIES, DACCA
Mirpur Road, Dhanmondi, Dacca 5

Principal areas of research interest include fibre and polymer, glass and ceramics and engineering and process development.

CENTRAL TESTING LABORATORY
116-A, Tejgaon Industrial Area, Dacca 8

Laboratories provide quality control and standardization for government, autonomous organizations and private agencies in Bangladesh. Activities include: testing, analysing and evaluation; testing materials for the Bangladesh Standards Institution.

EGYPT

NATIONAL INSTITUTE FOR STANDARDS
El Tahrir St., Dokki, Cairo

Institute is responsible for research and development of standards; it also does materials testing.

INDIA

INDIAN STANDARDS INSTITUTION
Manak Bhavan, 9 Bahadur Shah Zafar Marg,
New Delhi 110 002

Institute conducts research related to standardization, quality control and certification.

ISRAEL

PARTICULATE SYSTEMS LABORATORY
c/o Chemical Engineering Research Centre,
Technion - Israel Institute of Technology,
Technion City, Haifa 32000

Activities focus on research and testing in the technology of particulate materials.

STANDARDS INSTITUTION OF ISRAEL
42 University St., Tel Aviv

Activities include preparation of product and national standards, testing, product quality supervision, and applied research and development. Institution maintains laboratories for testing building materials, electrical materials, etc.

MALAYSIA

STANDARDS AND INDUSTRIAL RESEARCH INSTITUTE OF MALAYSIA
P.O. Box 35, Sha Alam, Selangor

Activities include research and development for industrial applications, engineering testing, scientific testing and quality control.

PHILIPPINES

NIST NATIONAL STANDARDS AND TESTING LABORATORY
Pedro Gil St. and Taft Ave., Ermita, Manila

Laboratory tests materials.

PUBLICATIONS

European sources of scientific and technical information. 6th ed. Edited by Anthony P. Harvey, Detroit: Gale Research, 1984. 368 p. ISBN 0-582-90152-9.

Contents, abridged: Scientific and technical information centres, Patent offices. Earth sciences. Energy sciences. Materials testing. Mathematics and physics. Textiles, weaving and clothing. Timber and furniture industry. Transportation.

Note: Continues a series begun in 1957 and now in its 6th edition. As with the previous edition, coverage includes countries of eastern Europe and covers all of science and technology. The aim of the directory is to provide a contact point within each European country (30, plus an "international" category with six entries) for each subject area (25 involved). Altogether there are 1,363 entries. It is interesting to note upon inspection of the subject index that library and information science and services have the most extensive coverage followed rather closely by the term "research." However there is hardly any term indicating great specificity which has been omitted, even if some of the more common terms have a surprisingly low location count, viz: ammonia, asphalts, chromium, destructive testing, explosions, glassfibers, and hydrogen, (among many): each has only one location entry. Despite the great value of this work it is ironic that (based on a quick survey of many of the full organizational entries) access to library facilities and related services are not usually available to inquirers. Nevertheless, this tool is for virtually all science and technology collections which may have need to make European contacts, however infrequent.

TEQC83: proceedings of the International Conference on Testing, Evaluation and Quality Control of Composites: 13-14 Sept., 1983. Edited by T. Feest, Woburn, MA: Butterworths, 1983. 342 p. paper. ISBN 0-408-22162-3

Contents, abridged: Mechanical testing. Materials' characterization. Quality assurance and structural analysis. Author index.

Note: Focuses attention both on current research techniques and industrial applications as concerned with the confidence of engineers in the ability of the materials (whatever they may be) to perform as required and expected. For collections on quality control in engineering libraries.

Polymer wear and its control. Edited by Lieng-Huang Lee. Washington: American Chemical Society, 1985. 421 p. (American Chemical Society Symposium Series; 287) 85-15755. ISBN 0-8412-0932-4.

Contents: Mechanisms of polymer wear. Controls of polymer wear. Tribological behaviour of polymers. Wear of biomaterials and polymer composites. Characterization and measurements of polymer wear. Degradation and wear of polymeric films and filaments. Indexes.

Note: This symposium volume consists of 26 chapters divided into 6 sections. Its goals are to seek a better understanding of wear mechanisms of polymers and to provide information that will lead to the development of new wear-resistant materials. Temperature effects on friction and wear, and the role of fillers in friction and wear behaviour of polyethylene are among the subjects considered. Includes literature references, an author index, and a subject index. For collections in polymer science at the research level.

Polymer NDE. Proceedings of the European Workshop on Nondestructive Evaluation of Polymers and Polymer Matrix Composites, Hotel Golf Mar, Termar do Vimeiro, Portugal, September 4-5, 1984. Edited by K. H. G. Ashbee. Lancaster, PA: Technomic Publishing Co., 1985 (c 1986). 332 p. 85-51976. ISBN 87-762-446-1.

Contents, abridged: Microstructure at the molecular level. NDE of laminates. Acoustic emission. Control of fibre orientation in short fibre composites. Vibrations, elasticity and anisotrophy under stress.

Note: This proceedings volume covers new information on non-destructive testing and quality control of polymers and composite materials. Subjects discussed include fracture mechanics as a method for quality control. Literature references, discussions of each section and a subject index are included. For research level collections in engineering and materials science.

Enrick, Norbert Lloyd. Quality, reliability, and process improvement. 8th ed. NY: Industrial Press, 1985 (c 1984). 401 p. 85-17. ISBN 0-8311-1125-9.

Contents, abridged: Inspection and testing for quality control. Process inspection with control charts. Control of variability. Further control charts. Analysis of variance. Multiple tolerance chains. Reliability design. Quality and reliability experiments, additional applications. Index.

Note: This is a revision of the 7th edition, 1977, with a slight title change from Quality Control and Reliability. There is no clue as to what has been revised and there are no literature references except about 20 in connection with figures taken from another work and footnotes. Only three are dated later than 1977 and two are undated. However, the principle emphasis is on "simplified but gap-free presentation of the important statistical methods" that form the heart of a successful program of quality control. The author is with Kent State University.

STP 889 - Microindentation Techniques in Materials Science and Engineering, concisely appraises the current status and progress in the understanding and application of microindentation techniques for materials research, mechanical surface property testing, and quality control in metals, ceramics, and polymer processing. The volume is divided into three sections on fundamentals of indentation testing, techniques and measurement, and engineering applications. The reader will learn current applications of hardness testing as both a scientific and practical tool. STP 889 can aid in interpretation of hardness testing data and help ensure high accuracy in testing procedures. The book should be of interest to materials researchers and engineers, quality control personnel, and technicians. (PCN: 04-889000-28, list price $46.00, member price $36.80)

STP 893 - Composite Materials Testing and Design: Seventh Conference, emphasizes toughness as related to damage tolerance of advanced composites. Also emphasized are the problems researchers face with characterizing and analyzing the complex failure mechanisms associated with stress concentrations and delaminations. The papers are divided into five areas: structures, failure mechanisms, strength, delamination, and analysis and characterization. Researchers and designers in the fields of composite materials and aerospace, automobile manufacturers, appliance makers, and users of lightweight, high strength materials will find the book useful. (PCN: 04-893000-33, list price $59.00, member price $47.20)

STP 896 - Elastic-Plastic Fracture Mechanics Technology, is the result of an experimental and predictive round-robin group. Over the past two decades, many elastic-plastic fracture mechanics methods have been developed to assess the toughness of metallic materials and to predict failure of cracked structural components. In the book are evaluations of the current methodologies on materials that exhibit large amounts of plasticity and stable crack growth prior to failure. Information on improved methods and guidelines for characterizing fracture of metallic materials and for designing structural components against fracture is given. The contents are divided into two sections: experimental and predictive round-robin and elastic-plastic fracture mechanics methodology. STP 896 will be of particular interest to structural designers and engineers in the aircraft, nuclear, naval, and piping industries, as well as material engineers and researchers in the manufacture of steel, aluminium, and titanium alloys. (PCN: 04-896000-30, list price $30.00, member price $24.00) Copies may be ordered from ASTM (American Society for Testing and Materials), 1916 Race St., Philadelphia, PA 19103, USA.

A guidebook on methods for nondestructive evaluation (NDE) of ceramics is to be produced by Battelle Columbus Div. during a proposed multiclient program. The guidebook will aid ceramic manufacturers in fabricating more reliable products, reducing manufacturing reject rates. Users of ceramic products will have a basis for establishing and performing their own independent quality assurance for products they purchase.

During the program, Battelle experts will survey the NDE of ceramics through a literature review and interviews with other experts. Selected NDE methods will be critiqued: acoustic emission testing, ultrasonics, radiography, microwave testing, optical/visual imaging, mechanical vibration analysis, photoacoustics, and thermal-wave, acoustic, and x-ray microscopy.

The Battelle team will organize the data into a manual that will describe each applicable method. For each method, the manual will cover such manufacturing parameters as underlying physical principles, relative merits of the method, estimated performance characteristics, estimated cost, and throughput rate.

The potential performance of each method will be compared by using a specific set of criteria on type, size, and location of defects. The improvements needed by each method will also be discussed. Firms wishing to participate in the nine-month program can obtain further information from M. Jack Snyder, Battelle, 505 King Ave., Columbus, OH 43201-2683, USA.

Methods for Analysis and Testing, Vols. 12 and 2, Institute of Petroleum, London, xix + 903; xviii + 894 pages, respectively. John Wiley & Sons Inc., 605 Third Ave., New York, N.Y. 10016, 1986.

Zwick announces the first issue of Materials Testing News, which is to be published semiannually. This new, full colour, 12 page newsletter is designed and written to appeal to all those interested or involved in automating their materials testing laboratory. The premier issue covers such diverse areas as: automated materials testing, electronic testing of yarns, torsion/tensile testing on a steering column, storing more data, and vulcanization measurement using microelectronics. (Published by: Zwick Sales Department, D7900, Ulm Einsingen, P.O. Box 9350, FRG)

Precision Scientific announces the availability of a catalog covering its full line of clamps and fixtures for Scott tensile testers, the 12 page catalog includes flat grip, cord, high elongation, and metal clamps as well as special purpose fixtures. A listing of the materials for which each type is most effective is provided.

Page-Wilson Corp. has published an illustrated booklet covering the company's various models of floor and bench-mounted Wilson Brinell hardness testers. Also included are production Brinell testers for high volume applications and a new, 22 lb, portable Brinell tester, as well as options and accessories for the various models.

The National Bureau of Standards (NBS) has published the NBS Calibration Services Users' Guide, listing the bureau's measurement assurance programs (quality control programs for calibrating entire measurement systems) and special test and calibration services that check, adjust, or characterize instruments, devices, and sets of standards. The physical measurement services of NBS are designed to help makers and users of precision instruments achieve the highest possible levels of measurement quality and productivity. The hundreds of individual services described in the guide directly link a customers' precision equipment or transfer standards to national measurement standards. The following measurement calibration areas are listed in the new guide: dimensional, mechanical (including flow, acoustic, and ultrasonic), thermodynamic, optical radiation, ionizing radiation, and electromagnetic radiation (including direct current, alternating current, radio frequency, and microwave). The guide explains fees, types of services, measurement criteria, reports of test results, references to NBS in advertisements, traceability of calibrations, and shipment of equipment. Copies of the guide (SP 250) are available from the Office of Physical Measurement Services, B362 Physics Bldg., NBS, Gaithersburg, MD 20899, USA.

An important field is nondestructive materials testing which is important not only in the manufacture of materials but also in monitoring the finished products for their functional capability and safety. The brochure "Materials Research" not only provides information concerning a new funding programme but it provides - at least in key words - an overview concerning the extraordinary multiplicity of tasks which materials scientists attack today. "Materials Research" is obtainable from the Federal Ministry for Research and Technology (BMFT), Post Office Box 200706, D-53 Bonn 2.

Toyo Seiki announces seven new catalogues: Gel Time Tester, Automatic Densimeter, Strograph "R" Series, Thermally Stimulated Current Measuring Apparatus, Rheolograph-Sol, Heat Gradient Tester, and Automatic Rubber Hardness Tester.

A flexible universal testing system designed to provide rapid, highly accurate tests of a wide range of materials is detailed in a new, 16 page brochure from Tinius Olsen Testing Machine Co. Bulletin 125 illustrates key features of the Tinius Olsen Lo-Cap UTM. American Society for Quality Control, Quality Congress Transactions, 40th, Anaheim, California, 19-21 May 1986. "The Fundamentals and Future of Quality" (Milwaukee, Wis. 1986)

Processes for fatigue enhancement of metal structures and materials testing capabilities are described in a new, 12 page brochure published by Fatigue Technology Inc. (FTI). FTI manufactures process tooling to improve fatigue life of metal structures for aircraft and other critical applications. The company also specializes in commercial materials testing of composites and metallics.

Techniques for high temperature fatigue testing edited by G. Sumner and V. B. Livesey, Elsevier Applied Science Publishers, 1985.

A major problem in the design and operation of high-temperature engineering plants is that of ensuring that critical components have acceptable design lives. Two types of power plant are the topic of this book, gas turbine engines and nuclear power stations, and life prediction for both has traditionally been based on empirical rules derived from operating experience rather than on an understanding of the physical processes. Design rules are now becoming increasingly based on laboratory testing, and this book represents a timely review of developments in high-temperature fatigue testing methods.

The book highlights the complex nature of high-temperature fatigue processes, encompassing time-dependent effects of creep, environment and gradual changes in metallurgical structure. The techniques selected for any one test will depend on the purpose of the test. For example, the type of test to be used to generate basic design data will differ from the type of test designed to elucidate the basic nature of a fatigue process or a test designed to develop a predictive model which may be used to extrapolate the data obtained from short-term laboratory tests to a long-life limit, up to 30 years for a nuclear power plant.

The book is based on papers presented at a two-day symposium, sponsored by the Springfields Laboratory of the Northern Division of the UK Atomic Energy Authority, in September 1983. The purpose of these papers was to present the experiences of different laboratories in order to develop a basis from which to evolve a comprehensive standard for high-temperature fatigue testing. The contents of the book fall naturally into three sections which may be summarized as follows:

(a) Uniaxial testing (Chapters 1-5)

It is apparent that each test method represents a compromise, and different materials and circumstances will dictate different solutions. In each case the purpose of the test needs to be defined, and the interaction between the specimen and the testing system needs to be understood.

(b) Specialized aspects of testing (Chapters 6-8)

These chapters review the requirements for testing in reverse bending, the difficulties of testing in environments other than laboratory air, and methods for defining the onset of failure in a high-temperature fatigue test.

(c) Computer applications (Chapters 9 and 10)

The applications considered here are for the collection and analysis of data, not for control of the fatigue test.

The book represents an excellent review of state-of-the-art techniques in high-temperature testing, and it would be invaluable for anyone involved in general mechanical testing. It illustrates the widely different approaches adopted by various laboratories for specimen and grip design, extensometry, and heating methods. It seem likely, based on a reading of this book, that progress towards accepted standards for high-temperature fatigue testing will be slow and that compatibility of different test techniques and comparability of test results will continue to be a subject of contention for some time.

Creep of Metals and Alloys by R. W. Evans and B. Wilshire. Published by The Institute of Metals, London, 1985.

This book is an important new addition to the literature on creep by two leading specialists from The University College, Swansea. The text covers both the theoretical and experimental aspects of creep and is written at a level suitable for advanced undergraduates or postgraduates whose interests lie in the high-temperature materials field. The chapter headings are: Uniaxial Creep Testing; Primary and Secondary Creep Behaviour; Dislocation Creep Processes; Tertiary Creep and Fracture; and The Theta Projection Concept. Four appendices are also included: Finite Element Analaysis for Creeping Structures; Constant Stress Lever Calculations; Creep Curve Parameter Estimation; and Grain Boundary Phenomena in Polycrystals.

Defect Properties and Processing of High-Technology Non-metallic Materials
Edited by J. H. Crawford Jr., Y. Chen and W. A. Sibley. Elsevier Science Publishing Co. Inc. 1984, 482 + pages.

The Materials Research Society (MRS) Symposia Proceedings have been published since 1981. This book consists of the proceedings from a symposium held in Boston during November 1983, which was subsequently published as Vol. 24 of the series. The overall aim of the symposium was to describe how the defect structures of non-metallic materials are influenced by their processing conditions and end-use.

"High-technology" materials are thought to be the building blocks of the future. The keynote address by H. K. Bowen classifies the performance prerequisite of these materials in terms of electric, magnetic, optical, chemical, thermal, mechanical, biological and nuclear functions. Naturally the driving force for these developments is based on the large market for improved products. For example, just for high-technology ceramics, there is expected to be a five-fold increase in expenditure by 1995.

The scientific contributions are broadly classified into three sections. The major section (60 per cent of the papers) concentrates on the "Properties and Structure of Defects". It immediately becomes apparent that the term "defect" encompasses a wide range of structural phenomena, among which are dislocations, stoichiometric deviations, micro-cracks and point defects - to name just a few. The focus of Part II is on "Processing Methods and Variables" and represents about 25 per cent of the book's contents. The remaining 15 per cent of the book is devoted to "Application" and is limited to topics such as laser materials, light guide technology and structural ceramics for advanced heat engines.

The 1986-87 edition of Directory of Federal Laboratory and Technology Resources describes more than 900 government laboratories, services, and facilities which have the equipment or resources to directly assist the academic and business communities in their research and engineering efforts. (Department of Commerce's National Technical Information Service (NTIS). NTIS, 5285 Port Royal Rd., Springfield, Va. 22161; reference order number PB86-100013/KCS.)

Microindentation Techniques in Materials Science and Engineering, edited by Peter J. Blau and Brian R. Lawn, ASTM, 1916 Race St., Philadelphia, Pa. 19103, 215-299-5585, 1986, 300 pp.

Publication reviews the last decade of research and application of microindentation techniques. It evaluates the current status and progress in the understanding and application of microindentation techniques for materials research, mechanical surface property testing, and quality control in metals, ceramics, and polymers processing.

Seventeen peer-reviewed papers cover the fundamentals, testing techniques, and engineering uses of microindentation-based methods. Specific subjects deal with the use of indentation methods in the study of intrinsic deformation properties, residual stress states, thin-film adhesion, and fracture properties in a variety of materials.

In addition, the publication examines current applications of hardness testing as both a scientific and practical tool. It also aids in the interpretation of hardness testing data and helps assure high accuracy in testing procedures.

FUTURE MEETINGS - PAST EVENTS RELATING TO MATERIALS 1987

5 Jan. - 27 Feb. Santa Barbara, California	1987 GORDON RESEARCH WINTER CONFERENCES 5-9 January : POLYMERS 12-16 January: COMPOSITES 26-30 January: METALS IN BIOLOGY (Gordon Research Center, University of Rhode Island, Kingston, R.I. 02881, USA)
18-21 Jan. Cocoa Beach, Florida	11th ANNUAL CONFERENCE ON COMPOSITES AND ADVANCED CERAMICS (Engineering Ceramics Div. Meeting)
19-22 Jan. Tampa, Florida	AMERICAN SOCIETY FOR TESTING AND MATERIALS INT. SYMPOSIUM (ASTM, 1916 Race St., Philadelphia, PA 19103, USA)
21-23 Jan. Cocoa Beach Florida	CONFERENCE ON COMPOSITE MATERIALS (Advanced Comp. Working Group)
28-30 Jan. Columbus, Ohio	JOINING OF CERAMICS (Ohio State University, 225 Mount Hall, 1050 Carmack Road, Columbus, OH 43210, USA)
2-6 Feb. Cincinnati, Ohio	42nd ANNUAL CONFERENCE OF THE REINFORCED PLASTICS AND COMPOSITES INSTITUTE (Cincinnati Convention and Exhibition Center, Cincinnati, OH, USA: organized by Society of the Plastics Industry)
3-5 Feb. San Francisco California	GOLDEN GATE MATERIALS TECHNOLOGY CONFERENCE (SRI International - AA-269, Ravenswood Ave., Menlo Park, CA, USA)
5 Feb. London	NDT FOR PRODUCT RELIABILITY (Plastics and Rubber Institute, 11 Hobart Pl., London, SW1W 0HL)
17-19 Feb. Cincinnati, Ohio	ADVANCED CERAMICS '87 CONFERENCE
25-27 Feb. Golden, Colorado	UNIVERSITY-INDUSTRY ADVANCED MATERIALS CONFERENCE (Colorado School of Mines)
26-27 Feb. Berlin, Fed. Rep. of Germany	STATISTICAL METHODS IN MATERIAL TESTING AND QUALITY CONTROL, SEMINAR (Deutsche Gesellschaft für Metallkunde eV, Adenaueralle 21, D-6370 Oberursel, Fed. Rep. of Germany)
9-13 March San Francisco, California	CORROSION/87 and 1987 MATERIALS PERFORMANCE AND CORROSION SHOW (National Ass. of Corrosion Eng., PO Box 218340, Houston, Texas, 77218, USA)
6-9 April Anaheim, California	ADVANCED MATERIALS TECHNOLOGY '87
13-15 May London	MATERIALS '87 - PROCESSING AND PROPERTY CONTROL (Institute of Metals, 1 Carlton House Terrace, London SW1Y 5DB
1-6 June Beijing, China	NEW MATERIALS '87
9-11 June Santa Clara, California and on 23-25 June	FIRST ANNUAL ELECTRONICS MATERIALS AND PROCESSES CONFERENCE OF THE SOCIETY FOR THE ADVANCEMENT OF MATERIAL AND PROCESS ENGINEERING (SAMPE, P.O. Box 2459, Covina, Calif. 91722, USA)
5-9 Oct. Atlanta, Georgia	ASNT 1987 FALL CONFERENCE Suggested areas include NDT research, development, and application in the transportation industry, as well as papers with specific applications to new materials, e.g., composites. (Technical Program Chairman, Lone Star Steel Corp., Lone Star, Texas 75668, USA)

Nov. 1987

Composite Materials

A call for papers is issued for a symposium on Advances in Thermoplastic Matrix Composite Materials, sponsored by Committee D-30 on High Modulus Fibers and Their Composites.

The Symposium, scheduled for November 1987, will examine various aspects of recent advances in continuous and discontinuous fiber-reinforced thermoplastic matrix composites, with major emphasis on continuous fiber-reinforced structural composites. Thermoplastic composites are receiving considerable attention for a number of impressive properties, such as impact toughness, delamination fracture energy, and solvent resistance. Also thermoplastic composite materials offer processing flexibility. As applications for thermoplastic composites increase, a forum to discuss their advantages and disadvantages in the context of processing, material response, and design and analysis is essential to advance the technology. The scope of the symposium is to discuss and share the various technical aspects of recent advances in thermoplastic matrix composites.

The topics of interest to this symposium include:

- Process modeling,
- Effect of processing on mechanical properties,
- Short-term properties,
- Fiber-matrix interface issues,
- Failure mechanics,
- Damage mechanics,
- Testing,
- Fatigue behavior,
- Environmental effects,
- Fracture toughness,
- Nonlinear behavior,
- Time-dependent response,
- Delamination behavior,
- Impact behavior,
- Damage tolerance,
- Damage repair,
- Design and analysis, and
- Other related topics.

The symposium chairman is: Golam M. Newaz, Battelle, Columbus Div., 505 King Ave., Columbus, OH 43201, USA. (Source: ASTM Standardization News, November 1986)

World Materials Congress, 1988

World Materials Congress co-sponsors

Scores of societies, associations, institutes, councils, federations, and other organizations from all over the world have already signified their intention to co-sponsor and participate in ASM's World Materials Congress to be held in 1988.

The World Materials Congress, first ever to be held, will be held in Chicago, Illinois 24-30 September 1988, and will be the featured event during ASM's observance of the 75th anniversary of its founding.

Many of the co-sponsoring organizations will program technical sessions of the Congress in their areas of expertise.

"The response to our announcement of plans for the Congress and the invitation to participate has been excellent", said Allan Ray Putnam, Secretary General for the World Materials Congress. "We have already received positive responses from 35 North American organizations and 27 international organizations from some 15 nations, and many other organizations are expected to join in the event. It will truly be a 'world' materials event."

The following is the list of current sponsors.

North America

Aluminium Association, Inc.
American Institute of Chemical Engineers
American Iron and Steel Institute
American Nuclear Society
American Physical Society
American Society of Mechanical Engineers
American Society of Agricultural Engineers
ASTM
American Welding Institute
American Welding Society
Canadian Institute of Mining and Metallurgy
Center for Metals Fabrication (Battelle Columbus)
The Electrochemical Society
Engineering Society of Detroit
Electric Power Research Institute
Federation of Materials Societies
Forging Industry Association
Institute of Advanced Manufacturing Sciences
Institute of Scrap Iron and Steel, Inc.
International Copper Research Association
International Lead Zinc Research Organization
International Magnesium Association
International Precious Metals Institute
The Iron and Steel Society
JCPDS - International Centre for Diffraction Data
The Materials Properties Council, Inc.
The Metallurgical Society
Metal Powder Industries Federation
Metal Treating Institute
National Association of Corrosion Engineers
Society of Mining Engineers
Society of Plastics Engineers
Steel Founders' Society of America
Welding Institute of Canada
Welding Research Council

International

Associacao Brasileira de Metals
Association Technique de la Siderurgie Francaise
Associazione Italiana di Metallurgia
Australasian Institute of Mining and Metallurgy
BCIRA International Centre for Cast Metals Technology
Centre de Recherches Metallurgiques (C.R.M.) (Belgium)
Czechoslovak Society for Metals Science
Centro Nacional de Investigaciones Metallurgicas (CENIM)
Deutsche Gesellschaft für Metallkunde eV
The Indian Institute of Metals
The Institute of Metals
Institute of Metals and Materials Australia
International Federation for the Heat Treatment of Materials
International Iron and Steel Institute
Iron and Steel Institute of Japan
IRSID (France)
The Israeli Metallurgical Society
The Japan Institute of Metals
Japan Light Metal Association
Jernkontoret (Sweden)
The Korean Institute of Metals
The Netherlands Society for Materials Science
The Nonferrous Metals Society of China
Powder Metallurgy Association of India
Societe Francaise de Metallurgie
Verein Deutscher Eisenhuttenleute
The Welding Institute

1986

17-20 March Birmingham UK	MATERIALS TESTING EXHIBITION (British Inst. of NDT, Institute of Metals)
19-20 March Bad Nauheim, Fed. Rep. of Germany	ACOUSTIC EMISSION IN THE STUDY, TESTING AND CONTROL OF MATERIALS AND PLANT INSTALLATION
7-9 April Charleston, South Carolina	ASTM COMMITTEE MEETING FOR E-28 ON MECHANICAL TESTING (ASTM, 1916 Race St., Philadelphia, PA 19103, USA)
8-10 April Liverpool UK	INTERNATIONAL CONFERENCE ON FIBRE-REINFORCED COMPOSITES (Plastic and Rubbber Inst., London)
8-10 April Las Vegas, Nevada	MA[illegible]G SCIENCES FOR THE FUTURE ([illegible] for the Advancement of Ma[illegible]and Process Eng. (SAMPE), P.O[illegible] Covina, Ca. 91722)

14-15 April Chicago, Ill.	SYMPOSIUM ON TESTING OF METALLIC AND INORGANIC COATINGS (American Society for Testing and Materials, Philadelphia)
15-18 April Palo Alto, California	SPRING MEETING OF THE MATERIALS RESEARCH SOCIETY, MATERIALS CHARACTERIZATION BY ION BEAMS, ELECTRON BEAMS AND PHOTON BEAMS (California Inst. of Technology, Pasadena, Calif.) -
28-30 April Charleston, South Carolina	ASTM COMMITTEE MEETINGS FOR E-9 ON FATIGUE AND E-24 ON FRACTURE TESTING (ASTM, 1916 Race St., Philadelphia, PA 19103, USA)
29 April - 1 May Charleston, South Carolina	COMPOSITE MATERIALS TESTING AND DESIGN: EIGHTH SYMPOSIUM (American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103, USA)
10 June Sligo, Eire	COMPUTERS IN QUALITY CONTROL COURSE (Sligo Regional Technical College, Sligo, Eire)
16-19 June Stockholm, Sweden	QUALITY CONTROL IN INDUSTRY - INTERNATIONAL CONGRESS (Swedish Ass. for Quality)
16-18 Sept. Guildford, UK	IPC SECOND INT. CONF. ON TESTING, EVALUATION AND QUALITY CONTROL OF COMPOSITES (IPC Science and Technical Press, P.O. Box 63, Westbury House, Bury St., Guildford, Surrey, UK.
21-24 Sept. Atlanta, Georgia	QUALITY EVALUATION '86 - TECHNOLOGY FOR TOMORROW (Techn. Section, CPPA, Montreal, Canada)
3 Sept. - 2 Oct. Paris, France	INT. EXHIBITION AND CONFERENCE ON AUTOMATIC TESTING AND TEST INSTRUMENTATION (Network Events, Printers News, Buckingham, UK)
4-9 Oct. Orlando, Florida	MATERIALS WEEK (American Soc. of Metals, Metals Park, OH, USA)
16-19 Oct. Osaka, Japan	FIRST INT. NEW MATERIALS CONF. AND EXHIBITION (InterGroup Corp., Osaka)
20-24 Oct. Los Angeles, California	TWELFTH INT. SYMPOSIUM FOR TESTING AND FAILURE ANALYSIS (ISTFA Registrar, American Society for Metals, Metals Park, OH, USA)
21-22 Oct. Corning, N.Y.	PROCESSING FOR RELIABILITY OF ADVANCED CERAMICS (Industrial Research Inst., Corning, NY., USA)
27-30 Oct. Santa Clara, California	Automatic test equipment in the areas of artificial intelligence, surface mount technology and automated visual testing techniques
18-20 Nov. Dearbon, MI USA	ADVANCED COMPOSITES CONFERENCE (American Society for Metals, Metals Park, OH, USA)
25-27 Nov. London	MATERIALS ENGINEERING '86 (Plastic and Rubber Inst., London)

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300,
A-1400 Vienna, Austria

Advances in Materials Technology: Monitor
Reader Survey

The Advances in Materials Technology: Monitor has now been published since 1983. Although its mailing list is continuously updated as new requests for inclusion are received and changes of address are made as soon as notifications of such changes are received, I would be grateful if readers could reconfirm their interest in receiving this newsletter. Kindly, therefore, answer the questions below and mail this form to: The Editor, Advances in Materials Technology: Monitor, UNIDO Technology Programme at the above address.

Computer access number of mailing list (see address label):

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Do you wish to continue receiving issues of the Advances in Materials Technology: Monitor?

Is the present address as indicated on the address label correct?

How many issues of this newsletter have you read?

Optional

Which section in the Monitor is of particular interest to you?

Which additional subjects would you suggest be included?

Would you like to see any sections deleted?

Have you access to some/most of the journals from which the information contained in the Monitor is drawn?

Is your copy of the Monitor passed on to friends/colleagues etc.?

Please make any other comments or suggestions for improving the quality and usefulness of this newsletter.

For new subscribers:

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Readers' comments

We should appreciate it if readers could take the time to tell us in this space what they think of the 8. issue of Advances in Materials Technology: Monitor. Comments on the usefulness of the information and the way it has been organized will help us in preparing future issues of the Monitor. We thank you for your co-operation and look forward to hearing from you.