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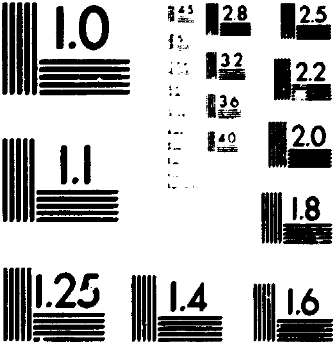

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QUALITY ASSURANCE OF FABRICATED COMPONENTS*

by

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* The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO.

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1.0 INTRODUCTION

Quality Assurance is an integrated quality system on which the final product reliability depends. It is aimed at creating built-up quality from the beginning of design, through all phases of planning, manufacture, final product acceptance and most important, to provide the customer with a product which performs as per its intended service. Checks are carried out for conformity with specifications through quality control procedures as laid out in the assurance system. Today, as much as 70% of all manufacturing is by way of fabrication in India as against only 30% about 30 years back. Even the most sophisticated equipments like pressure vessels, pipe lines, oil exploration vessels, use fabrication to a large extent.

Welding plays a significant and a very prominent role in the modern fabrication technology. It must be realised that substantial economic gains can be achieved when a rational method is established for relating the level of weld quality in a given product to the service conditions to which it is expected to work and the consequences of failure. It is very difficult to get "100% perfect welds". The aim shall be to achieve quality welded components at economic cost with adequate margin of safety under the conditions of service for which the finished product is designed. Reliable metal joining techniques shall be adopted without which joining of special materials will be only a lab curiosity. The design shall accomplish adequate margin against premature failure but not to penalise efficiency through over design. The significance of weld quality shall be well understood as demanded by the products manufactured to different applications such as structural components for heavy duty cranes, pressure vessels, boilers, aircraft components, nuclear power components, space ships, oil drilling rigs, etc. The strength of the weld shall be atleast matching to that of the parent material. A systematic and balanced approach with sound judgement on the occurance of different weld defects, their interpretation, evaluation and prevention will pave a long way in ensuring enhanced quality of a product during manufacture, erection and in service.

Over the last few years, there has been a tremendous growth in the scope and scale of non-destructive testing, and it has now achieved a recognised status in the field of engineering, but the most important criterion in the application of NDT is still the appreciation of the limitations of the various techniques, and even when a particular technique has been proved and carefully formulated it is almost always left to the individual concerned to use his experience and judgement in assessing the results of the experimentation.

A number of NDT methods are available, but welded constructions vary so much in type and design that it is only possible to give general guidance as to which method will be most suitable for any particular weldment. Before a final choice of method is made, it is necessary to know the type and orientation of any imperfection that might be anticipated in the weldment. It would, for example, be no use specifying the visual or penetrant method of examination for detection of a mid-thickness defect, that did not break the accessible surface of the component. When additional non-destructive examination is required the choice of method will obviously be governed by a number of factors such as -

a) Thickness of material to be inspected

b) Service conditions of the component

c) Availability of suitable equipment and personnel

d) Cost of inspection; and

e) Space requirements for testing

2.0 DIFFERENT NDT METHODS

There are four important methods commonly employed in the quality control of welding, viz., Radiography, Ultrasonics, Magnetic Particle and Penetrants. Each method having its own particular field of application as well as its inherent limitations.

3.0 SELECTION OF NDT METHODS

3.1 Radiography:

Radiographic inspection is the well established method for detection of internal as well as surface defects, and has been written into the inspection codes of various organisations. Radiographic techniques exist for Butt Welds and many other forms of welded joints, but all involve access to both sides of the object. Ideally, all gross defects such as porosity, slag inclusions, and incomplete penetration can then be detected provided that they have sufficient effective radiation absorption difference as measured in the direction of the radiation beam. On the other hand, cracks and planar defects which diverge considerably from the direction of the radiation beam would nearly always escape detection. Other basic limitations of the radiographic method are that it is not capable of detecting metallurgical structural changes, nor will it detect internal stresses in the specimen. Additional practical limitations concern on one hand, the availability of suitable equipment for the thickness range to be examined, and on the other hand the hazard arising from the use of ionizing radiations. In choosing a suitable radiographic technique for a particular weldment, the operator is faced with the problem of coordinating a number of variable factors not the least of which is the choice between X and Gamma radiation. The portability of Gamma equipment and the fact that electrical supplies are not required means that Gamma-radiography is the accepted method for the inspection of welds where the radio-active isotope can be used for Panoramic radiography of circumferential butt welds. Three types of radio-active isotope sources are currently available, viz., Iridium 192, Caesium 137 and Cobalt 60.

TABLE - I

Isotope	Half Life	Penetration Energy (MeV)	Thickness Range
Ir-192	74 days	0.26-0.67	20-75 mm
CS-137	33 years	0.66	10-60 mm
Co-60	5.3 years	1.17-1.33	50-200 mm

In the pressure vessel industry, it is customary to employ radiographic methods of quality control for all the main butt welds using X-ray equipment for smaller thickness upto about 40mm of steel and Ir-192 and Cobalt-60 sources of Gamma radiation, or other high energy equipment for greater thickness. However, of late, ultrasonic equipments are used to scan the weld.

4.0 <u>ULTRASONIC EXAMINATIONS</u>

The ultrasonic method is particularly sensitive for the detection of those defects which are not easily found by radiography; viz., fine cracks and laminar type defects. Therefore, ultrasonics is sometimes employed in addition to radiography when very critical examination of a weld is required. Available standards deal with the methods for ultrasonic examination of welds, and contain reasonably concise details. All these standards recognise the fact that any ultrasonic technique of weld examination requires experienced and conscientious operators of high integrity and sophisticated ultrasonic flaw detectors with accessories.

It is for this reason and mainly because no permanent record of result is available that the various inspecting authorities accept ultrasonic examination only under prescribed conditions such as demonstration with mock up blocks. It has already been mentioned that the ultrasonics is particularly suitable for the detection of certain types of defects in butt welds, fillet welds and critical nozzle welds.

4.1 Properties of Ultrasonics:

a) Travel in straight line
b) Suffer little absorption in homogeneous bodies
c) Can penetrate even 10M of steel thickness
d) High sensitivity to inhomogeneties, detection of even small hair line cracks is possible

4.2 Advantages:

a) The method is rapid
b) Adaptable to 100% automated inspection
c) Provides immediately and easily readable signals
d) Indicates the presence and location of defects
e) Portable - battery operation possible
f) One surface accessibility is enough
g) Its cost is moderate compared to its counterpart X-rays
h) No radiation hazard

4.3 Applications:

a) Plates	-	for boilers, pressure vessels and structurals for lamination
b) Billets	-	for voids, seggregations and piping
c) Forging	-	piping, cracks, overlaps
d) Seamless tubes	-	seams, laps, laminar flaws, etc.
e) Castings	-	cavities, shrinkages, cracks, etc.
f) Weld seam	-	Butt welds, fillet welds, nozzle welds, corner welds in pressure vessels, boilers
g) Measuring wall thickness	-	extent of corrosion or erosion in power plants, refineries, fertilizer plants, etc., pipe bend in manufacture.

h) Testing bimetallic bonds

i) Verifying certain material properties - Modulus of elasticity, grain size, tensile strength in grey cast iron etc.

4.4 Limitations:

a) Real nature of defects - difficult
b) Size of defects - not revealed directly
c) No documentary record
d) Operator dependent - Oscillogram interpretation
e) Training of personnel - for skilfull operation and application of technique
f) Sophisticated equipment
g) Reference blocks, calibration blocks and mock up blocks
h) Knowledge of metallurgy, welding, foundry technique, heat treatment
i) Surface finish - upto 250 CLA 6.3 micron
j) Unfavourable geometry - misinterpretation possible
k) Mode conversion - can cause false echoes
l) Distance amplitudes correction - defect at the farthest end will give smaller amplitude
m) Curved surface - will give rise to rocking
n) Welds with backing rings are difficult to test by ultrasonic testing
o) Defect orientation - knowledge on type of defects, their expected position on the job under test
p) Defect classification - plannar or voluminar difficult
q) Like penetrameter or IQI, on radiographs there is nothing except F.B.H.
r) Internal structure, eg. coarse grain can cause scattering

s) Use of low frequency in coarse grained material - poor resolution - high beam spread (poor defect size determination)

t) High frequency - high resolution - poor penetration - not possible to test thick objects

u) Dead zone - defects in this zone not detected - both sides accessibility or use of focussed probes

v) Testing jobs at high temperature - above 50°C - special methods necessary

w) Thin materials - special methods, eg. immersion testing

5.0 VISUAL INSPECTION

It is a simple and cheap method but often neglected method of inspection. Surface flaws can be easily marked before carrying out any NDT tests. This test requires simple instruments such as a boroscope or a magnifying glass.

6.0 MAGNETIC PARTICLE TESTS

Magnetic Particle methods can only be employed for tests on magnetizable material and in general these are only capable of revealing cracks or fissures open to the surface or maximum 6mm below surface. Neverthless, there are many applications where a magnetic particle method is particularly suitable. It is used in the inprocess testing of welds, weld edge preparation, castings and forgings. Certain codes demand magnetic particle tests after stress relief in critical weldments. There are equipments available with AC and DC currents in portable and mobile form ranging from 100 to 4000 Amps. Magnetic particle testing is done in two directions to detect flaws in different orientations.

7.0 PENETRANT METHODS

Similarly, penetrant methods are only applicable for detecting discontinuities open to surface but of course they can be applied to almost any type of material whether it be magnetizable or not. Penetrant inspection is extensively employed in pressure vessel manufacturing industries for inspection of welds.

8.0 ACOUSTIC EMISSION

The latest trend is to monitor the health of equipments, machinery and parts when they are under actual service conditions. Most materials cry when over-stressed. These materials emit sound waves from the location where the failure is initiating. These signals are picked up and correlated with the loading conditions.

9.0 TYPICAL DEFECTS FOUND IN VARIOUS TYPES OF WELDS

To classify accurately any imperfections detected in a weld by a non-destructive testing technique, it is necessary to have a reasonably precise knowledge of the welding process involved. Certain types of imperfections are peculiar to or more prevalent with a particular welding process.

Electroslag welding, for example, is probably the most likely to contain longitudinal centre line shrinkage and side wall lack of fusion. Boundary edge porosity is another defect that is peculiar to these types of welds, and it is usually due to phosphorous seggregation in the parent plate material. When detected by radiography it presents a confusing image since at first sight, it appears to be well clear of the weld metal until one realises that there is appreciable penetration into the parent plate at mid thickness. Generally speaking, electroslag welding is of very good quality but when defects such as piping do occur they tend to be quite gross.

Welding of stainless steel material is commonly undertaken by the TIG process and in consequence such weldments may contain Tungsten inclusions, these being one of the characteristics of this welding. Oxidised roots can also be encountered in this type of welding process when the inert-gas purge is inadequate and can be readily detected by radiography. Radiography of stainless steel may show diffraction mottle patterns which can sometimes be very misleading for the inexperienced since they can easily be confused with intercrystalline cracking.

The tens of thousands of small bore tube butt welds, for example, used in a power station boiler, also have typical imperfections such as root shallowness and bore misalignment, as well as all the normal welding defects, viz., porosity, slag inclusions, piping and occasionally cracks and crack like defects.

10.0 EVALUATION, GRADING AND REMOVAL OF DEFECTS

Before attempting any remedial action, particularly with thick welds, it is essential that the depth of any imperfection be determined so as to assess its importance and to assist in its removal. Depth location may be carried out by the use of Ultrasonic techniques. Even when the depth has been determined and all other factors assessed as far as practicable the evaluation of a defect becomes extremely difficult.

It is well-known fact that most acceptance standards are empirical and as such are very limited and certainly not universally applicable. Some applications standards do list acceptance levels. With changing emphasis in NDT methods and preference given in many instances to ultrasonics rather than radiography, the whole subject becomes even more confused, because it is extremely difficult to relate radiographic images to ultrasonic indications as ultrasonic flaw detection by echo method works on the principle of reflection and radiographic inspection is based on the principle of differential absorption. Lamination is best detected by ultrasonic testing method and least detected by radiographic testing method. To evaluate the results of an NDT technique, the person responsible for the test may have to consider a number of parameters such as the -

a) Shape
b) Size
c) Position of the imperfection
d) Type of the material

e) Probable behaviour in the presence of a given imperfection
f) Service conditions of the component and stress factors

The Quality Control specialist shall be able to make decisions which imperfections may be tolerated and which should be treated as defects that are detrimental to the service life or function of the component. He must have knowledge of welding fabrication, metallurgy, etc., of the parts under test.

Rectification of faulty welds is another aspect where the Application Standard can and should provide appropriate recommendations. The specialist must take into consideration the service conditions which exist, those component working under corrosive atmosphere or stressed with cyclic loading require that the weld root should be fault-free. In certain times, it is preferable to allow certain border line defects forcing the product to be rejected at a final stage.

The effects of weld faults on the service performance of a joint are influenced by their location and disposition. In general, those located in the body of the weld being less serious than those in the root.

Any one of the following imperfections as revealed by non-destructive testing shall be sufficient cause of rejection for critical weldments -

1) Any type of crack or crack-line defect to any extent;
2) Lack of root or side wall fusion or incomplete root penetration to any extent

Planar defects are more dangerous than voluminar defects due to stress concentration being more on plannar defects. Porosity and slag inclusions are allowed to certain extent in heavy duty structural weldments, if they do not impair the design thickness. Undercuts which form sharp notches are not tolerated and are all to be smoothened out.

11.0 NEED FOR TRAINING AND QUALIFICATION OF PERSONNEL

It is pertinent for the operator to know his job and be qualified to carryout the tests as per given procedures. Non-destructive evaluation being mostly operator dependent requires that the personnel should be certified. In addition, the integrity and conscientiousness of the operator becomes vital when decision to accept or reject a job are based on results furnished by him. To cater to the needs of Indian Industries for trained manpower in this field, Welding Research Institute, Tiruchirapalli imparts training in Non-destructive testing and allied inspection techniques at different levels. The training programme lays emphasis on step by step approach to skill improvement through elaborate practical exercises, theoretical inputs and guided reading in the areas of specific interests. During the programme periodical tests are conducted for qualification and proficiency.

12.0 CONCLUSION

Usually, it has to be borne in mind by the Quality Control Engineer that quality shall be maintained at economic cost by carrying out inspection at suitable stages. Unless quality is built-in, the product reliability cannot be assured.

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