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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

Advances in Materials Technology: MONITOR

Issue Number 6 15605 April 1986

Dear Reader,

This is the sixth 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 plastic 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 that field. 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, hopefully every two years.

The first issue was devoted to steel and dealt in particular with high strength, low alloy (HSLA) steels. The second issue was devoted to new ceramics, also known as fine ceramics, high-performance ceramics and advanced ceramics. The third issue dealt with fibre optics, the fourth issue with powder metallurgy and the fifth with composites. UNIDO has received good response on the content of these issues as well as on the idea of a monitor on materials. In preparing the monitors, the Technology Programme is receiving valuable help from experts in and outside UNIDO. We hope to have their co-operation in our future issues as well.

The subject of plastics is rather wide and we have to make a rather limited selection. This issue contains one article written by two UNIDO experts and three written by outside experts as well as a current awareness section, including information on new products, new processes, applications and market trends. A list of publications and information on meetings as well as a section dealing with general information are also contained in this issue.

The UNIDO secretariat would welcome information on materials and suggestions on the format and content of the Monitor from readers.

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A. PLASTICS WITH EXTRAORDINARY PROPERTIES

Chemists can now rearrange the loops and chains of carbon, oxygen, hydrogen and nitrogen in plastics not only to make them lighter, cheaper and better protectors of perishables, but also to give them extraordinary properties. They can be made to conduct electricity, or to possess the strength of steel.

For consumers, the first rumbles of the revolution can already be heard. A plastic automotive engine has been built, giving better fuel efficiency, and on the horizon are lightweight plastic batteries, fuel cells and paper-thin arrays of solar cells that can be pulled of a roll like so much saran wrap.

Even the simple toothpaste tube is no longer so simple. Once made of lead, it is now composed of nine layers of plastic and other materials, that, among other handy qualities, refuse to break open and ooze toothpaste even after repeated folding. Further signs of the revolution are snack bags and cooking pouches that often seem impossible to puncture except for the pragmatist equipped with a sharp knife or scissors. For a variety of economic reasons, industry experts expect the pace of the shake-up to quicken. As with any revolution, there are also new risks. Researchers are constantly searching to see if the manufacture or incineration of exotic new plastics can be harmful to health. Confident of current safety, chemists say they are now confronting the knotty ecological problem of whether metal-like plastics can be developed that are easily recycled.

Emergence of super plastics

The age of super plastics has its origin in the last decade or so and is largely a result of fundamental insights into the nature of matter most especially the electronic and physical properties of monomers, small groups of molecules that can be linked into long chains known as polymers. (The word "plastic" usually refers to a mixture of one or more polymers with other materials that make the mixture soft enough to mould into useful products.) As is often the case, breakthroughs have also raised new theoretical questions.

Metals conduct electricity because they unleash and transfer their electrons - tiny sub-atomic particles that carry what had long been considered an indivisible unit of nature, the negative electric charge. But physicists believe that conductivity in plastics may well be evidence of a fractional charge. Dr. Robert Schrieffer, a Nobel laureate at the University of California at Santa Barbara, has described the work on conductive plastics as "One of the hottest areas in modern physics".

Of more than theoretical interest, conductive plastics may have wide application, according to Dr. David Mairns, a chemist at the University of Pennsylvania. He said the fabrication of light-weight fuel cells, batteries and solar cells was being vigorously pursued around the world.

Polysulfones

In addition to conductive wonders, chemical insights have given rise to a new class of supertough and heat-resistant plastics that have widely replaced glass and metal. Fifteen years ago, for instance, chemists at the Union Carbide Corp., drawing on new knowledge of how molecules interact, devised a way to hook a sulphur-based monomer into long chains. Known as polysulfones, these turned out to have a high resistance to acid bases, water and heat.

The upshot was a new family of herculean plastics. Udel the brand name of a Union Carbide super-plastic, can withstand continuous temperatures of 300°F and has a tensile strength of 10,000 lb a square inch, as against 32,000 p.s.i. for brass. It easily fills in for glass, stainless steel and nickel. Udel is widely used in medical instruments and milking machines, both of which must be sterilised before use. It can also be found in hair dryers, egg cookers, digital watch cases, camera cases, pacemakers and astronaut helmets.

Since the mid-seventies even stronger (and more expensive) metal-like plastics have emerged that can take higher temperatures and stresses. Kevlar, five times stronger than steel, is widely used to make bulletproof vests. The toughest metal-like plastic yet created was recently announced by scientists at E.I. Du Pont de Nemours. Known as Delrin ST for super tough, it will, according to Du Pont officials, find its way into everything from automotive bearings and bicycle gears to typewriter parts and ski bindings.

The power of the superplastic revolution, born of pure chemistry, has been multiplied by a bevy of new techniques for shaping plastics into useful products. Perhaps the most remarkable is a process known as "barrier coextrusion", in which different polymers, each with a unique quality, are bound together into a single sheet that performs multiple tasks such as blocking the passage of light, oxygen and flavour. An example is a potato chip bag, seemingly impervious to puncture. Its inner and outer layers block light, moisture and large chemicals while a middle layer blocks the migration of tiny molecules such as oxygen. The final two layers tie the whole thing together. High tensile strength is a by-product of the five-layer sandwich.

Just how far will the revolution go? According to chemists and industry experts, that depends to a large extent on consumers changing life patterns, as indicated by the increased use of microwave ovens, clearly require greater use of plastics in packaging. But large unknowns also lurk, such as whether their consumers will want to buy plastic cartons of unrefrigerated milk that have sat on a shelf for a year.

Economics is also a factor. Steel-like plastic is easy to make but expensive. Greater demand will drive down the price, a trend clearly at work in the automotive industry especially in fuel-conscious Europe. The amount of plastic in the typical European car has risen to almost seven per cent by weight, some models having as much as 10 per cent plastic.

A problem in all this is recycling. With cars, for example, about 70 per cent of their weight (mostly metal) can be recycled - but not plastic parts, a problem currently under attack by chemists.

The upshot is that superplastics are increasingly likely to show up in packaging, batteries, airplanes, cars, textiles, roofs, boats, paints, windows, tennis rackets, bicycle gears, solar cells, garbage bags, home insulation and a host of consumer goods. (Extracted from: Popular Plastics, Vol. XXX, No. 3, March 1985, pp. 13-15)

B. DEVELOPMENT OF MAJOR POLYMERS AND THEIR APPLICATION

During the last 25 years the rapid development of science and technology in the field of chemistry has led to the creation of hundreds of new chemicals, especially polymers possessing unique properties. Many innovations have been made in the use of new polymer substances thanks to specific properties such as thermal and electric insulation, corrosion and weather resistance, low specific gravity, water and grease resistance, facility to take permanent colours, ease of handling and cleanliness, etc.

Plastics are divided into two main groups: thermoplastic and thermosetting materials. Thermoplastics soften on heating and reharden on cooling, the process being repetitive and allowing the formation of almost any shape desired. The most important processing methods for thermoplastics are injection and blow moulding, extrusion and thermotransforming. The most widely used thermoplastics are polyvinyl chloride, resins, polyethylene (low and high density), acrylonitrile-butadiene-styrene, polypropylene, polystyrene, cellulose esters, polyamide, acetal resins, and polycarbonates.

Thermosetting resins harden when heated irreversibly. They usually have a cross-linked structure which gives them additional resistance to temperature, chemicals and creep. The following methods can be used for their processing: compression moulding, transfer moulding, casting and calendering. Among the best-known thermosetting plastics are phenol formaldehyde and melamine formaldehyde resins, polyesters, epoxy resins and polyurethane. Polyesters and epoxies are usually used as binders and adhesives, i.e. polyesters with glass fibre give fibreglass reinforced plastics (FRP or RP). By the use of different additives (diluents, extenders, fillers, reinforcing materials, plasticizers) plastics with a wide range of properties are obtained. Thanks to their variety of properties plastics are widely used in the construction industry as well as in many other sectors such as packaging, electrical equipment, transport machinery, agriculture, household goods, etc. (Extracted from a United Nations Economic and Social Council Report "The Use of Polymer Materials in the Construction Industry" [ECE/CHEM/26, 1 February 1980])

C. UNIDO NEWS

UNIDO'S TECHNICAL ASSISTANCE IN THE DEVELOPMENT OF PLASTICS FOR INDUSTRIAL APPLICATIONS

M. Youssef/V. Bysyuk*

The word "plastics" usually refers to a mixture of one or more polymers together with other materials to make it soft enough to be moulded and shaped into useful products. The plastics are divided under two distinct categories namely:

(i) Thermosetting and (ii) Thermoplastics.

There are a great many different plastics materials available with properties that can be modified in various ways: by use of additives, plasticizers, stabilizers, colourants, reinforcements; by varying molecular sizes, shapes and degrees of cross-linking; and by processing them in different ways. No other materials can be produced in such a wide variety of forms and colours, and some are even available in translucent or transparent forms.

Today more than ever there is a real revolution in plastics, and, according to chemists and entrepreneurs, the days of glass and metal are numbered for many products. Chemists can now rearrange the loops and chains of carbon, oxygen, hydrogen and nitrogen in plastics not only to make them lighter and cheaper, but to give them extraordinary properties as well. They can be made to conduct electricity or to have the strength of steel.

It is of interest to note that at present in the plastics industry the cost-property relationship is shifting in favour of more expensive (that is more technology-intensive) but less material-intensive products. For example, thinner but stronger films and sheets will be produced, plastics articles will be redesigned to have thinner walls, and elaborate means will be necessary to recover and recycle scrap and discarded products.

Conversion Industry

Plastics are processed by a range of techniques to produce components of appropriate design while taking advantage of the intrinsic properties of the material. These techniques include extrusion, injection moulding, blow moulding, frost forming as well as machining.

Plastics are used in practically all of our daily requirements as household consumer goods, toys, in construction, in packaging, in the automotive industry, in medical uses, in aerospace, in agriculture and in industry, and every day new applications are found. There are two widely used applications for plastics - industrial applications and applications in agriculture.

The industrial applications cover a very wide area of industries, of which the following are an example:

- Building and construction
- Electrical
- Electronics and telecommunications
- Engineering
- Furniture
- Medical
- Packaging
- Textiles
- Transport

while in agriculture the applications cover:

- Water conservation and management
- Growing
- Product collection and packaging
- Fertilizer and pesticides, packaging, transport and distribution
- Livestock housing
- Machinery and tools

Development of the plastics industry

The increase in the use and application of plastics and synthetic materials in industry, agriculture and building in recent years has placed polymers among the leading basic materials used for economic development in the developing countries.

Plastics are already one of the world's main groups of industrial materials. World plastics consumption is now greater than that of all non-ferrous metals in terms of weight and of steel in terms of volume. The numerous uses and applications of plastics, which are still increasing, have caused this industry generally to grow at a faster rate than most branches of the manufacturing industries and to contribute in growing proportion to the economy.

In a study carried out by UNIDO on petrochemicals, the demand for plastics for the period 1980 to 1990 in developing countries is

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estimated at 11 per cent per year. This means 6.5 million tons in 1980 rising to 22 million tons in 1990. The corresponding production in developing countries in 1980 was about 3.5 million tons and in 1990 is expected to be around 15 million tons.

The share of the production of plastics and synthetic fibres in the developing countries is expected to reach 25 per cent and 30 per cent, respectively, in the next decade, thus showing that the Lima target of 25 per cent of world production in the developing countries by the year 2000 can be obtained as far as the manufacture of plastics and synthetic fibres is concerned.

A developing country may find it convenient to start with the production of thermosetting resins e.g. phenol formaldehyde, urea formaldehyde. These products of condensation of formaldehyde with respective chemicals are polymers with a wide spectrum of end use. Though these materials were the first to be discovered as polymers at the beginning of this century, their use has continued to diversify - the phenolic foams are used in wide applications for cold storage, air conditioning, high temperature insulation, laminated switch boards, etc. The manufacture of general purpose thermoplastic resins, e.g., polyethylene, polyvinylchloride and polystyrene in units of smaller capacity and based on renewable feedstock, e.g. alcohol produced from agricultural products, has been found to be economically viable under certain conditions. Some developing countries with no access to hydrocarbon feedstocks may find it interesting to examine this option.

There are a number of options available to the developing countries to enter the era of plastics in a modest way suitable to the needs of a particular country.

In many developing countries much of the plastics processing outputs are directed to the easier household consumer market where product quality is not critical. Everything processed, whether good, bad or average, is sold without question and quality control is often unknown.

Normally in developing countries only a few companies see plastics processing as a long-term business. They are prepared to back medium- and long-term development operations in principle, but generally, for financial reasons, are unable to undertake such work themselves.

Taking the above into consideration it is highly unlikely that the economic and social advantages that could be derived in the development of a country through the applied application of plastics in both agriculture and industrial uses will materialize unless there is some Government intervention or the plastics industry is able to organize itself in such a manner as to tackle such problems.

Technical assistance through UNIDO

In order to successfully develop wider market areas it is necessary to establish a suitable institution that would be equipped and staffed with specialists capable of providing the necessary technological development and subsequent technical services to support and strengthen the plastics industry as well as providing suitable training facilities.

There has been a continued demand for UNIDO assistance in establishing such institutions. These so-called "Plastics Technology Centres" or "Plastics Development Centres" assist the plastics industry in establishing meaningful standards - an essential step in the extension and development of markets for plastics products where performance characteristics are the main criteria for the product, for example, in rural development, construction, automotive industry, medicine, packaging and other industrial applications.

Nothing can be worse for the future of this industry than to have substandard products fail in use. To help and assist the plastics processors understand the need for and to introduce quality control are areas where a PDC could be of service to the industry.

Such centres have been established and are being established by UNIDO in a number of countries such as China, Colombia, Burma, Bangladesh, India, Iran, Indonesia, Egypt, Ecuador, Mexico, Pakistan and Burkina Faso, and these centres will greatly facilitate the process of technology transfer in this field.

Usually, when such a project is initiated, UNIDO organizes what we call a "Plastics Week", in which experts from developed countries are invited to present papers on the latest technology in specific fields and conduct practical demonstrations and consultations with the local industry. The following is another practical example of initiating such a project: In co-operation with the Government of Romania through the Joint UNIDO/Romania Centre, UNIDO, in December 1975, fielded a mobile demonstration unit for the processing and use of plastics in agriculture in Mali and in Burkina Faso. The unit consisted of plastics processing equipment mounted on trucks and was accompanied by 13 experts who demonstrated techniques of plastics processing and the use of pipes, films and sheets for growing and for water conservation and irrigation, with emphasis on desert agricultural techniques. Participants from five other countries of the Sahelian region were present at some of the demonstrations. A project was initiated in Burkina Faso following these demonstrations.

When such a project is initiated the operational activities of UNIDO consist mainly in providing the following inputs:

(a) Making available its technical staff as well as internationally recruited experts who advise the PDC (Plastics Development Centre) on their specific problems;

(b) Training the technical staff and personnel either locally or abroad on individual or group basis;

(c) Supplying specialized testing equipment and quality control laboratories as well as pilot or demonstration plants for R&D and training purposes;

(d) Establishing agricultural research and demonstration stations.

Many of these institutes are encouraged to establish sister institution arrangements with similar institutes in both developed and developing countries to provide a means of continuously updating technology and to facilitate the process of technology transfer in this field.

TCDC arrangements between some of these centres such as India/Bangladesh and Egypt/Mexico have been established.

It is also worth mentioning that UNIDO, in co-operation with the Austrian Government, has been conducting annually since 1970 a training programme on plastics technology. The yearly programme is up-dated and tailored to the needs of the developing countries by UNIDO's technical staff and the staff of the institute undertaking the training programme. Furthermore, UNIDO, in co-operation with the Government of Argentina, has conducted training programmes in plastics technology in 1974 and 1975 for participants from Latin America.

Plastics in agriculture and water management

The large-scale use of plastics in agriculture is relatively new, having started to build up in volume only during the last decade.

It is only in more recent years that a number of developng countries have now started to show an active interest in this subject. The reason for this awakening interest is due to the realization that plastics, of the correct quality, can offer both technical and economic solutions to many agricultural problems. In this sense, plastics are currently being regarded as a tool to serve the needs of agriculture both by way of increasing efficiency as well as output.

Each country must carry out its own development and experimental trials under its specific conditions of usage, if plastics are to provide both the technical and economic solutions to the agricultural problem.

Development programmes for plastics in agriculture applications involve a knowledge of two technologies: plastics and agriculture, and the development work also involves outdoor trials and demonstrations at suitable agricultural experimental sites before effective solutions are obtained.

There is generally a lack of plastics technology and know-how in producing the correct quality of plastics products for agricultural use. The main uses of plastics in agriculture are in greenhouse covering, tunnels, mulches, reservoir and irrigation channel lining, fertilizer storage (silos), fertilizer and product sacks, crop and silage cover, shelters and livestock protection, tubing and pipe for water supply and irrigation, water tanks and containers, product handling, plant pots and equipment components.

Some applications of plastics in agriculture will now be mentioned but these are only a selection of a very wide range of applications which have been developed, and the development process is a continuous one.

a. Plastic covered tunnels

There are many forms of plastic covered tunnels in use, ranging from low tunnels, up to "walk-in" tunnels or greenhouses.

Whilst the original and traditional concept of a greenhouse was to provide a warm atmosphere, in which plants could be grown "indoors" in countries where the winter climate was too cold for outdoor growing, this concept has taken new meaning. By providing low-cost transparent tunnels in which the plant can be grown, it is now possible to control the total environment in which the plant grows, thus enabling optimum yields to be obtained.

Thus there are wide-ranging climatic conditions in which the utilization of plastic tunnels has found economic solutions.

b. Soil fumigation

Large sheets of PE film are spread over the ground to be sterilized and gas is introduced under the film through a flexible plastic tube.

This technique is used to eliminate harmful pests and diseases from the soil, which in turn assists also to develop strong plants and improved yields.

Crop storage

Apart from the use of woven sacks for crop storage, film-lined wire mesh silos have been constructed for the storage of grain.

Fibre reinforced plastic silos (composites) are also constructed for grain storage, which can have a capacity of several hundred tons.

Water management

Film as a waterproof membrane for lining large agricultural reservoirs is a standard practice.

Film is also used as a waterproof membrane for the lining of canals. The purpose of the lining is to prevent seepage and control weed growth.

Fibre reinforced plastic composites are also utilized to form prefabricated irrigation channels and water reservoirs.

There is an increasing trend to move to piped water supply for drinking and for irrigation. This is particularly so where "trickle irrigation" is used. The principle of trickle irrigation is to deliver to the plant roots only sufficient water for the plant's need, thus achieving a more efficient management of limited water resources.

Various trickle irrigation systems have been designed which are of two basic types. The first type is based on plastic pipes to which are fitted adjustable drip nozzles or other devices which ensure a drip outlet. The second type is based on a plastic lay-flat tubing or sheath in which the flow rate of the water is controlled by using water friction to reduce the pressure.

This is undoubtedly an area in which developing countries will find many benefits for water supply and conservation and increased crop yields in the future.

One of the simpler applications of plastics film in agriculture is its use as a "mulch". This means "a covering over of the soil". Straw, hay, dead leaves, etc. have all been used for many centuries as a natural mulch on soil to keep the soil moist. With plastic film however, there is one important difference, it is completely impermeable to water and thus by preventing the evaporation of the moisture from the soil, it plays a positive role in water conservation.

Since the use of plastics in agriculture is a relatively new technology, it became clear that there was a need to provide a suitable platform to bring together the many different parties, organizations and institutions with a common interest in agriculture. These include the plastics industry, Government departments concerned, financial institutions, research workers, farmers and growers associations, etc. This has been achieved by the formation of a National Committee for Plastics in Agriculture, which provides the necessary centralized institutional facility whereby knowledge and experience could be pooled and exchanged.

National Committees have been formed in Argentina, Bulgaria, Egypt, France, Germany, Federal Republic of, Hungary, India, Italy, Japan, Mexico, Portugal, Spain, the United Kingdom and the United States of America. They are also qualified to become members of the International Committee for Plastics in Agriculture, CIPA, operating from Paris, if they so wish. Through membership in this organization a wider range of contacts with international experts and institutions becomes possible, and they are able to participate at the International Congress on Plastics in Agriculture which is organized every three years and is only successful with UNIDO's sponsorship. Such Congresses were hosted in Argentina, Portugal and Mexico under the sponsorship of UNIDO and the next one will be held in Egypt in 1986.

Through the activities of national committees the area of priority and development needs can be identified, and suitable work programmes determined for execution by appropriate agricultural research institutions and experimental stations. UNIDO plays an active role in the establishment of such committees.

In short, the need to undertake both the plastics and the agricultural development work in developing countries should be of concern to both the plastics industry as a whole and to the Government.

For the plastics industry, the use of plastics in agriculture and industry generally represents a new market area both of large potential size and with the prospects of repeat orders. This represents a solid base for the development and expansion of a plastics processing industry.

For the Government, the advantages to be derived for the national economy through the use of plastics in agriculture are great. There are also desirable social improvements arising through increased incomes which derive from increased and/or efficient agricultural outputs. In addition the expansion of the market will also lead to additional employment opportunities.

It has also been the effort of UNIDO to promote the use of plastics in the developing countries utilizing the natural resources available in such specific areas while at the same time trying to keep the developing countries abreast of the new frontiers of technology in this field. The major contributions have been:

(a) Development of composites specific to the concerned areas e.g. jute reinforced polyester;

(b) Development of composites of plastics with natural rubber to enable natural rubber producing countries to meet the competition of synthetic rubber;

(c) Development of technology for carbon fibres in developing countries to enable developing countries to enter the area of carbon fibre composites for the specific applications in those countries.

UNITED NATIONS AND UNIDO REPORTS COVERING PLASTIC MATERIALS

5 March 1981 (UNIDO/IO.419)
Report on the Testing of Plastics and Rubber.
Ajit Sankar Bhaduri DIO/Chem. Ind. Branch

2 October 1981 (UNIDO/IO.487)
Joint IDCAS/UNIDO Project for Development of the Plastics Processing Industries in Arab countries (UC/IDC/79/088) (Mission Report).
H. M. El Sharkawy (expert in plastics)

13 December 1982 (ID/WG.384/10)
Some Significant Advances in Materials Technology (Expert Meeting Preparatory to Int. Forum on Technological Advances and Development, Moscow, 29 November-3 December 1982).
Edward Epremian

13 December 1982 (ID/WG.384/11)
New Materials, New Technology.
N. S. Enikolopov, S. A. Volfson
(Inst. of Chem. Physics, USSR Academy of Sciences)

13 December 1982 (ID/WG.384/12)
Development and Application of New Materials: A Prospective View.
N. A. Makhutov, Mech. Eng. Res. Inst., USSR Academy of Sciences

17 March 1983 (ID/WG.384/1/Rev.1)
Implications of New Materials and Technology for Developing Countries.
UNIDO Secretariat

April 1983
Aide-mémoire: Ad-Hoc Expert Group Meeting of Internationally Renowned Polymer Scientists and Technologists (UNIDO: 2-4 November 1983)

Paper written by M. Parthasarathy (UNIDO expert) presented to Regional Symposium for Plastics in Agriculture for African Decade, 27 October-1 November 1984. "Role of plastics in water management and irrigation"

Joint AIDO/UNIDO Project for Development of the Plastics Processing Industries in Arab Countries (UC/IDC/79/088); Study on Establishment of a Regional Plastics Development Centre, by A. S. Clarke, UNIDO Consultant

1981 (UNIDO/IO.419)
Report on the Testing of Plastics and Rubber.
M. A. Youssef

UNIDO/IO/R.125
Les Plastiques dans le Développement rural (Agriculture, Gestion des Eaux, Utilisation Domestique, Emballage, Recipients et Construction). M. Youssef

UNIDO/IO/R.126
Fabrication de Produits en Plastique aux Fles du Cap-Vert. M. Youssef

19 March 1985 (CHEM/AC.15/R.2/Add.2, 3 and 4)
Additives for Thermoplastics.
United Nations Economic and Social Council.

1 February 1980 (ECE/CHEM/26)
The Use of Polymer Materials in the Construction Industry.
United Nations Economic and Social Council.

UNITED NATIONS AND UNIDO MEETINGS ON PLASTICS SINCE 1980

6-11 November 1980
8th Int. Congress on the Applications of Plastics in Agriculture.
Lisbon, Portugal.

6 October - 14 November 1980
In-Plant Group Training Programme in the Field of Plastics Technology.
Vienna, Austria.

29 September - 12 November 1981
12th In-Plant Group Training Programme in the Field of Plastics Technology.
Vienna, Austria.

17-21 May 1982
Petrochemical and Polymer Consultation Week.
Porto Alegre, Brazil.

5 October - 15 November 1982
13th In-Plant Group Training Programme in the Field of Plastics Technology.
Vienna, Austria.

11 October - 21 November 1983
14th In-Plant Group Training Programme in the Field of Plastics Technology.
Vienna, Austria.

1 October - 9 November 1984
15th In-Plant Group Training Programme in the Field of Plastics Technology.
Vienna, Austria.

30 September - 8 November 1985
16th In-Plant Group Training Programme in the Field of Plastics Technology.
Vienna, Austria.

3-6 November 1985
Expert Group Meeting on Enterprise-to-Enterprise Co-operation among Developing Countries (ETEC) with Special Emphasis on PLASTICS in the Latin American Region.
Buenos, Aires, Argentina.

8-12 December 1985
Workshop on Plastics in Agriculture.
Alexandria, Egypt.

October/November 1986
17th In-Plant Group Training Programme in the Field of Plastics Technology.
Vienna, Austria.

D. ENGINEERING PLASTICS APPLICATION

It has been about 15 years since engineering plastics first appeared on the market. The market has already reached 300,000 tons annually, and there are reportedly about 20 kinds of products. Meanwhile, although it has resulted in heating up the competition between synthetic resins, the trend toward higher properties indicates a multifaceted evolution toward a high-tech era. Demand has already risen from several thousand tons to more than 10,000 tons, and the scope has broadened to what is called a "general purpose" engineering plastics field from the standpoint of use and price, and further to a field of "super engineering plastics" or "specialty engineering plastics", opening up new areas and functions. It is a fact that engineering plastics themselves are expanding with solid progress. With specialty and discriminated general purpose resins as appropriate materials to meet the needs of the times, high expectations are held for the evolution of the new field.

Representative engineering plastics include polyamide, polycarbonate (PC), polyacetal (PA), polybuthylene terephthalate (PBT), para polyphenylene oxide (para PPO-PPE) and polyethylene terephthalate (PET). These are so-called "general purpose engineering plastics", and they are distinguished from specialty engineering plastics or super engineering plastics. Specialty engineering plastics include polyphenylene sulfide (PPS), polysulfone (PSF), polyarylate (PAR), polyether sulfone (PES), polyetherether ketone (PEEK), polyimide (PI), polyamide-imide (PAI), ekonol, polyetherimide, phenol-alalkyl and ionomer, in addition to perfluoroalkoxy (PFA) copolymer resins and fluorinated ethylene propylene (FEB) copolymer resins. About 20 kinds of specialty engineering plastics are used and produced domestically in Japan. Of course, there are monopolies and import-dependent varieties, and active research and development as well as market cultivation goes on.

The properties of engineering plastics are appropriately serving the needs of the age. Uses of these materials have been extended to the highly popular radio casettes, VTR's and office equipment, and as basic materials in the advanced industries. At the same time, new products and uses have been developed.

However, despite the fact that engineering plastics are presently in the spotlight, there is expected to be a slowdown in the appearance of new resins, or rather they can no longer be expected, and the producers are concentrating on research and development to modify existing resins. Under such circumstances, new products and uses are to be expected with the producers clearly responding to the situation. For example, regarding the modification of engineering plastics, there are expected to be: (1) inorganic fillers (glass fibre, talc, mica, titanic acid kalium) and organic fillers (carbon fibre, special synthetic fibre/rubber), (2) compound resins (polymer alloys), which are a blend of 2 or 3 kinds of resins and elastomer, and (3) IPN (interpenetrating polymer network). Among the answers from producers to the recent questionnaire, partial progress is seen regarding (1) and (2), and much further progress is demanded of them regarding their functions. There was a period when grade diversification of general purpose resins was implemented in simple form. In the case of engineering plastics also, a trend toward diversification of well-known brands is apparent. There appears to be some excessive qualities, and it is hoped that a solid position for the new materials will be established.

Listing engineering plastics in the order of large demand, there are: polyamide, polyacetal, polycarbonate, para PPO, polybuthylene terephthalate and reinforced PET. With the exception of polyacetal, the volume of every item is smaller in Japan compared to the American market. Although reinforced PET has not reached 10,000 tons annually, a growth rate of 10-15 per cent is forecast for the future. Among the producers, Teijin Ltd. was the first to establish manufacturing technology, followed several years ago by Toyobo Co. (product name: BYULOPET), Mitsubishi Rayon Co. (product name: DYANITE), Mitsubishi Chemical Industry Co. (product name: NOVODUR), Asahi Chemical Industry Co. (product name: SUNPET), Kanegafuchi Chemical Industry Co. (product name: HI-PALITE) and Unitika (product name: C-PET). There are also imports by Dupont and Akzo. In the United States, they are included in the same statistics with PBT and are not included in the five major general purpose engineering plastics.

Of course, polyamide is the largest in volume. The demand in 1984 was estimated at 105,000 tons annually, and it was used for electronic/electrical parts and auto parts. Of marked growth was polyamide 66, which is more expensive than the polyamide 6 resin. However, its properties are highly evaluated and has shown growth in industrial uses. The chief producers are: Asahi Chemical Industry, Ube Industries, Toray Textiles, Dainippon Plastics and Polyplastics Dupont-Japan. In addition, the Showa Denko Co. began in October two years ago to import and sell products for the Rhone Poulenc Co. of France (product name: TECHNYL), thus responding fully to the demand for engineering plastics. Asahi Chemical Industry, a top maker of the 66 resin (product name: LEONA) is working to develop IPN and to expand the polyamide market. This includes polymer alloys and polymer blends that use 6 and 66 as the base, and they continue to be representative of general purpose engineering plastics. Much is also expected from research and development by Ube Industries, Dainippon Plastics, Daicel Chemical and Toray Textiles.

The next largest volume of resins comes from polyacetal. It was developed by Dupont (product name: DERULYN) about 25 years ago as a "challenge against iron". Dupont began export sales to Japan, and the development of a domestic market was started. In Japan, led by Polyplastics (product name: DURACON), Asahi Chemical Industry (product name: TENAC) and Mitsubishi Gas Chemical (product name: UPITAL), producers are seeking a stable supply system for office equipment, factory equipment, electronics and autos. Foreign producers include: Dupont, Celanese, Hext, BASF and ICI. Dupont and BASF products are imported by Japan. In particular, engineering plastics are used largely for electronic and electrical components using a high proportion of polyacetal. The level of research and development at Asahi Chemical Industry, including rationalization of the manufacturing process, is very high, and the product is the only one among engineering plastics that surpasses U.S. production. The annual demand in 1984 was estimated at about 79,000 tons - a growth rate of 25.6 per cent compared to the previous year.

Others are polycarbonate, para PPO and PBT in that order. The demand for PC is about 50,000 tons annually, the production capacity for para PPO is 70,000 tons annually, and the annual demand for PBT is estimated at 25,000 to 30,000 tons. The demand for PBT alone has more than doubled during the past three years. There was a period when general purpose engineering plastics failed to show any growth. However, during the 1 and 1/2 years, from the latter part of the year before last to the early part of this year, a double-digit growth was achieved concurrent with the general business recovery of the chemical industry and of synthetic resins.

PC is a general purpose engineering plastic noted for its transparency and balanced quality. It is used widely for medical care, public safety and miscellaneous goods, centering on the broad areas of electronic/electrical parts and machine/industrial equipment parts, and has a stable demand and supply base. It is sustained in particular by the cultivation of markets and is used by such domestic producers as Teijin Chemical Industry (product name: PANLITE), Mitsubishi Gas Chemical (product name: UPICON), Mitsubishi Chemical Industry (product name: NOVARAX) and Idemitsu Petrochemical Ind[illegible] (product name: IDEMITSU POLYCARBONATE), in addi[illegible], to the Engineering Plastics Co. (EPL) that imp[illegible]s and sells products made by the General Electric Corporation (product name: LEXAN). None the less, the problem of raw materials continues to exist.

Producers of para PPO are: EPL (product name: NORYL), Asahi Chemical Industry (product name: ZYLON) and Mitsubishi Gas Chemical (product name: UPI-ACE). The annual production capacities are: 50,000 tons by EPL and 10,000 tons each by the other two companies. High production by the companies continues, and Asahi Chemical Industry plans to boost production this fall to 18,000 tons. In particular, regarding the demand for PPO, conspicuous growth is seen for such OA equipment as computers, copiers, printers and facsimiles. It has partly penetrated the markets of ABS, polycarbonate, polyetherimide and PBT, and it has reached a market scale considered second only to polyamide by fully manifesting its properties. Especially EPL and Asahi Chemical Industry are actively promoting the development of new markets and achieving concrete results. For example, they are reportedly co-ordinating production of OA equipment, such as the development of an electromagnetic shield grade for housing material as a substitute for ABS and the marketing of conductive compounds. Their future activities are the center of attention.

PBT has also shown high growth during the past year or two. PBT producers have maintained a high rate of operation, and their facilities appear to have reached their limit of capacity. Polyplastics, EPL, Teijin, Mitsubishi Chemical Industry, Mitsubishi Rayon and Dainippon Plastics are actively pioneering new uses, fully utilizing the properties of general purpose engineering plastics.

The outstanding trait of engineering plastics has been their high functions. In this article, we will consider those with an annual demand in excess of 10,000 tons as the five major engineering plastics. In comparison, resins with high properties and high prices centering on heat resistance are generally called "super engineering plastics" or "specialty engineering plastics", but the definition is ambiguous. Nevertheless, they possess properties that qualify them as basic materials from which "lightness, thinness, shortness and smallness" can be obtained. Along with new ceramics and carbon fibres, their demand scale and commercialization as advanced basic materials have been remarkable.

Amid the upgrading of synthetic resins as a whole, super engineering plastics are also facing a strong demand for higher functions. Speaking of engineering plastics, virtually all of them were thermal plastic resins, but engineering plastics consisting of thermal sclerotic (hardening) resins, such as phenolalkyl, have also appeared recently. There are also resins that are somewhere between thermal plastic and thermal sclerotic resins, and a variety of such resins are being developed. In addition, the tasks facing these high-function engineering plastics include the establishment of polymerization and application technology. Among polymer basic materials are: glass fibres, inorganic fillers and specialty carbons, and they are expected to lead to the introduction of engineering plastics with new basic materials and new properties.

For example, super high molecule polyethylene and ABS/polycarbonate alloys may be included in engineering plastics. We have examined the present situation of several kinds of main engineering plastics such as polyarylate, polyphenylene sulfide (PPS), polyoxy benzoil (ekonol), polyether-ether ketone (PEEK), polyether sulfone (PES) and polyimide.

One type of specialty engineering plastics in the spotlight is the PPS resin. Developed by Phillips Petroleum (U.S.), it is a crystalline chain high polymer with a simple structure. It has superior heat resistance in addition to low combustibility, chemical resistance and dimensional stability, and much is expected of it in the future. PPS is supplied by such polymer producers as Phillips Petroleum (annual production: 6,000 tons) and by compounders such as Dainippon Plastics, Hodogaya Chemical Industry (which has a co-operation agreement with Toyo Soda Manufacturing Co.), Asahi Glass and Shin-etsu Polymer. Also, pilot plants of Toray Industries and Phillips Petroleum have started operations in addition to multi-faceted research and development. Moreover, since the key patent for the production formula from Phillips Petroleum has expired, Kureha Chemical Industry and Toto Chemical Industry have newly entered the field on an independent basis. Naturally, Phillips is taking steps in response to this.

In other areas, polyarylate, which was developed in Japan, was marketed in 1975 by Unitika under the product name "U-Polymer." Unitika has since been working on market expansion and has reaped results. Japan has thus been creating products under independent technology in engineering plastics. In the past, it was dependent on the west European countries, following their models. The recent trend, including the research and development of modifying technology and plastic processing technology, is expected to gather momentum in the future.

On the other hand, polysulfone was developed by an American company, UCC (product name: U-DEL), and is imported and sold by Nissan Chemical Industry in the Japanese market. It is taking time to produce polysulfone domestically. Also, polyetherimide was developed by General Electric (U.S.), phenolalkyl by Albright and Wilson (Britain), ionomer by Dupont (U.S.), ekonol by Carborandum (U.S.) and polyether sulfone by ICI (Britain). They have been sold in the Japanese market and are now being produced domestically.

Ekonol is a polymer that is closer to metals from the standpoint of polymer structure. It is produced domestically (annual production capacity: 50 tons) by Sumitomo Chemical Industry, and shows solid growth centering on grinding materials. Also, PEEK is being promoted in the Japanese market by ICI Japan, Sumitomo Chemical Industry and Mitsui Toatsu Chemical Industry. The properties of these resins are being fully exploited, and are moving into separate areas from general purpose engineering plastics.

A new stage is evolving in the engineering plastics business, centering on such integrated chemical companies as Mitsubishi Chemical Industry, Sumitomo Chemical Industry, Ube Industries, Showa Denko and Mitsui Toatsu Chemical Industry. They are utilizing the various properties of these materials with an eye on the advanced industries and the 21st century, as evidenced by the evolvement of the petrochemical industry by Mitsubishi Petrochemical, Mitsui Petrochemical and Nippon Petrochemical, in addition to the evolvement by Toray Industries, Asahi Chemical Industry, Unitika, Dainippon Plastics, Denki Kagaku Kogyo and Asahi Glass. These companies are conducting research and development from such a standpoint. (Source: Kagaku Kogyo Nippo in Japanese 25 August 1985, p. 3)

E. ADVANCED FIBRE REINFORCED PLASTICS (FRP)*

In this article, the present state of progress in the development of different kinds of resins used as matrix material in the production of FRP and various other kinds of materials which are being utilized as reinforcement, and the features of those resins and reinforcement materials are being described.

Table 1 (see page 35) shows the classification of various kinds of materials used to manufacture FRP.

* This is an abbreviated version of the article "Advanced Fibre Reinforced Plastics" prepared by the Industrial Survey and Research Department of Kagaku Sangyo Kaihatsu Co. and published in Tokyo NIKKO MATERIALS.

Resin for FRP production

The resins which are utilized in the production of FRP are divided into two major categories - thermoplastic resins and thermosetting resins.

Thermoplastic resins are the kind that either melts or hardens when heat is applied. Such resins either turn into a fluid state or change their original shape as a result of the heat applied. As resins in the category of thermoplastic resins, the representative ones are vinyl chloride resin, vinyl acetate resin, acrylic resin, polyamide, polyethylene, and fluororesin.

On the other hand, thermosetting resins are the kind that hardens above certain temperatures when they are subjected to heat. These resins permanently lose some of their physical features which they had before being heated. With such resins, once they have hardened as a result of heating, they never turn into a liquid state even if they are heated again. Phenol resin (bakelite), urea resin, melamine resin, unsaturated polyester resin, and epoxy resin are the representative resins in the category of thermosetting resins.

Usually thermosetting type resins are utilized mainly for the production of FRP.

Unsaturated polyester resin

Unsaturated polyester resin contains unsaturated acid such as maleic anhydride or phthalic acid. By adding saturated polybasic acid such as phthalic anhydride and isophthalic acid, polyhydric alcohol such as propylene glycol and ethylene glycol are obtained. Unsaturated polyester resin is a resin in liquid form which can be obtained by dissolving polyhydric alcohol and unsaturated alkyd.

As a method to set unsaturated polyester resin the radical polymerization method is being utilized. In this method, the setting is carried out by bridging unsaturated polyester resin with vinyl monomer like styrene. As catalysts used to promote the setting process, either naphthenic acid cobalt, dimethylaniline, or benzoyl peroxide is utilized depending on the temperature at which the setting takes place. In order to realize proper gelation time suitable for a particular method of molding of the resin, it is important to pay due attention to the temperature of the room where the setting is carried out and to the adjustments of the catalysts and the agents to promote the setting process to ensure maximum efficiency.

In addition to the above-mentioned method for carrying out the setting of unsaturated polyester resin, there are also other methods available by which the radical polymerization is carried out. They involve the process of projecting either ultraviolet rays or radiation at the resin for setting. All of these methods have already been put into practical application.

The chemical features of unsaturated polyester resin have been found most suitable for the production of FRP. For this reason, this resin is the most popular among those being presently utilized in the production of FRP in Japan, and it is now used in about 90 per cent of the total output of FRP in the country. In 1983, the production of unsaturated polyester resin stood at 190,000 tons, of which 70 per cent was used for manufacturing FRP.

With the field of application of FRP expanding appreciably in recent years, users have increasingly been demanding a diversification in the characteristics of FRP so that they can choose the most suitable type of FRP for their application.

Making FRP fire-resistant

FRP's application fields include its usage as housing structure material, creating various housing-related equipment and facilities, and application in the field of transportation. The FRP to be utilized in these fields of application is naturally required to be fire-resistant.

Fire resistance in unsaturated polyester resin has been realized by adding or mixing with the resin substances such as halogen group elements, phosphorus compound, or inorganic fillers, including hydrate alumina. When inorganic fillers are utilized to impart fire resistance ability to unsaturated polyester resin, they are required to be added in relatively large dosages. Recently, a new method to make the resin fire-resistant has been utilized. The method calls for applying a layer of a certain kind of paint on the surface of FRP products. Such a coating produces an inert gas when it is exposed to fire, and this causes the formation of a foam layer which in turn works to protect the FRP products from fire by insulating them from the heat of fire.

Corrosion-resisting resin

In recent years, demand for FRP to use in tank in supply systems of water for drinking and other purposes, for brewing tanks, pipes, and manufacturing other kinds of goods have been on the increase in Japan. When unsaturated polyester resin is used to produce these products, the resin is required to have good corrosion-resisting ability. It is expected that demand for the FRP which has a good anti-corrosion capability and weatherability would further increase in the future.

At present, there are a number of methods available to improve corrosion-resisting ability in unsaturated polyester resin. Those methods require reducing the coupling density of the ester involved, reducing or closing the end group, introducing hydrophobic type acid or hydrophobic type glycol, and making a careful choice of monomer.

Different kinds of unsaturated polyester resins which are quite corrosion-resistant have already been put on the market by several producers. They include a product tradenamed Derakane produced by Dow Chemical, Epocry II by Shell Chemical, and the products belonging to the epoxy acrylic resin category or vinyl ester resin category which are being manufactured by domestic makers such as Hitachi Chemical and other manufacturers.

On the other hand, as a resin having weatherability, the resin which contains an ultraviolet rays absorbent such as salicylate derivative, which imparts weatherability to resins, has been available on the market.

Heat-resisting resin

Ordinarily, heat-resisting unsaturated polyester resin is manufactured by adding isophthalic acid to the resin. When phthalic anhydride acid was utilized as an additive instead, the breaking of the principal chains of the ester involved takes place when the resin containing it is heated, causing a sublimation of the phthalic anhydride acid. But when isophthalic acid is used, no such phenomenon can be observed.

Epoxy resin

At present, epoxy is the second most popular resin in use for the production of FRP.

Table 2 (see page 35). Resins used in the production of heat-resisting fibre-reinforced thermal plastic

Epoxy resin is a compound which has at least more than two epoxy groups within a single molecule. It is divided into glycygyl (phonetic) type epoxy resin and non-glycygyl type epoxy resin.

More than 90 per cent of the epoxy resins currently being manufactured are of the bisphenol A glycygyl type. This type of epoxy resin constitutes the mainstay of the resins currently being utilized for the production of FRP.

In an effort to further improve the heat-resisting ability of FRP, research on novolak type epoxy resin for use in the production of FRP has been conducted by the industry. And the introduction of brominated epoxy resin is also under study for the production of fire-resisting FRP.

Vinyl ester resin (epoxy acrylate resin)

Vinyl ester resin which can be created by causing bisphenol A glycygyl type epoxy resin and unsaturated basic acid to react with each other, displays particularly good chemical-resisting capability. This produces vinyl ester resin which is utilized increasingly today in the production of various equipment and facilities used for the prevention of environmental pollution. The only drawback of the resin used for those applications is its high cost. Compared with unsaturated polyester, utilizing vinyl ester in the production of those equipment and facilities is much costlier. At present, the companies which are marketing vinyl ester resin include Dow Chemical, Shell Chemical, Showa Highpolymer, and Dainippon Ink and Chemicals.

Phenol resin

The FRP which is produced using phenol resin is estimated to account for between 4 and 5 per cent of the total FRP output. Phenol resin performs well in heat resisting, chemical-resisting as well as solvent-resisting. Among other advantages of this resin over other kinds of resins are its relatively low degree of degeneration in strength after the resin has been put into a boiling liquid for a certain length of time. However, phenol resin has disadvantages, too. The resin is brittle, takes longer for setting, and is not easy to colour. At present, the resin is utilized primarily in the production of fishing rods, ski sticks, and pipes, among other products.

Other kinds of resins

The several kinds of resins described so far in this article account for a majority of thermosetting resins which are used in the production of FRP. Among other kinds of thermosetting resins which have not been mentioned are polybutadiene resin and silicone resin. Polybutadiene resin excels in corrosion-resisting and has good electrical characteristics. On the other hand, silicone resin is superior in strength and has good electrical insulating capability. These features explain why both polybutadiene resin and silicone resin are utilized in special fields of application such as the electric and aircraft industries.

Resin for FRTP production

The term "Fibre Reinforced Thermal Plastics" (FRTP) has been coined for a plastic to distinguish it from FRP which utilizes thermosetting resins as material in production.

In the development of FRP, the main goal of development has been to produce a plastic with better strength. In the case of FRTP, researchers have been aiming at making an improvement not only in its strength but also its heat-resisting ability as well as stability in dimension.

Ever since glass fibre reinforced polyamide was put into practical use in the industry in 1956, various kinds of FRTP have been developed so far and some of them have already begun to be utilized in practical application.

FRTP is being utilized primarily in the production of products such as cars, electric appliances and electronic parts. In many of these products, FRTP is employed as a substitute for aluminium.

REINFORCEMENT MATERIALS

As reinforcement materials for utilization in the production of FRP, the following ones are chiefly used at present. They are glass fibre, carbon fibre, metal fibre, synthetic fibre, natural fibre, asbestos fibre, boron fibre, ceramic fibre, and whiskers.

Glass fibre

Glass fibre is one of the reinforcement materials popularly utilized in the production of FRP. With respect to tensile strength, glass fibre displays a fairly high level among long fibre materials, which is only second to that of steel and boron fibres. But in terms of elasticity rate, glass fibre displays the lowest level. This means that when a certain degree of stiffness must be attained in glass fibre, the thickness of the fibre must be increased. This is a major drawback in using glass fibre as reinforcement material.

In contrast to glass fibre, carbon fibre has a higher degree of elasticity and it is lighter. Due to these advantages, carbon fibre has begun to be utilized as a reinforcement material which is now available on the market. Though it is inferior to E type glass fibre, C-type glass fibre fares better in acid-resisting capability, and this is why it is utilized in the FRP in the production of tanks for holding various kinds of chemical fluids. S-type glass fibre is utilized in the production of the FRP which is destined for usage in the military, space, and aircraft due to its higher strength and higher elasticity.

The features of glass fibre are as follows: (1) It has a very high tensile strength value and the strength increases as it becomes finer. (2) It excels in shock-resisting capability for it exhibits high strength and has a high extension rate within the breaking elasticity limits. (3) It has a very high elasticity rate and has no yield point. (4) Glass fibre is heat- as well as fire-resistant and its strength is not affected up to a temperature of about 200°C. (5) The fibre exhibits good chemical resisting ability, except for boron and hot concentrated phosphoric acid. (6) In glass fibre production, the fibre length can be freely adjusted, and short as well as long fibres can easily be produced. (7) Glass fibre poses almost no health hazard to the human body.

When using glass fibre as reinforcement material in the production of FRP, the fibre must be treated first on the surface with the surface treatment agent in order to improve bonding between the fibres and the resins utilized for production of FRP.

Carbon fibre

Carbon fibres are divided into high-performance type centering on PAN system fibres and general-purpose type centering on pitch system fibres. The high-performance type is further divided into highly tough type and highly elastic type.

Today it is estimated that the total world production of carbon fibre stands at around 2,000 tons per year. Of this production figure, the PAN system fibres account for about 80 per cent and the balance is the pitch system fibres.

Boron fibre

The development of boron fibre started in the United States around 1960. In 1966, the fibre began to be practically utilized as structural material in aircraft production. In recent years, boron fibre has been introduced into fishing rods and golf club shafts, and the fibre is attracting increasing attention from the industry because of its promising usefulness.

The boron fibre utilized in these products is made by vapour coating 12 μm tungsten fibre with boron chloride or boron obtained by thermally decomposing organo boron, thus making the fibre vapor-coated into long fibre with a diameter of 0.1 mm. Boron fibre's strength is as high as three times that of carbon fibre. But it is heavier, hard, and snaps relatively easily. It is difficult to make a curved surface in products using boron fibre. The cost in producing boron fibres is about twice that of carbon fibre. For these reasons, it is expected that the application fields of boron fibre will be relatively limited.

Alumina fibre

Alumina fibre is produced by either treating alumina at high temperature or by applying a special treatment to turn it into polycrystalline fibre. The principal feature of alumina fibre is its very high heat-resisting capability which ranges from 1,300 to 2,000°C. In terms of strength, alumina fibre is inferior to carbon fibre, but it possesses better electric insulation capability. Due to these characteristics, it is utilized in the production of a kind of FRP which is beginning to be used in space and military applications. Research has been under way in an effort to introduce alumina fibre also into car production. Alumina fibre is regarded as one of the promising kinds of fibres as reinforcement material in the production of FRP.

Silicon carbide fibre

Silicon carbide fibre dubbed "miracle fibre" was originally developed by a professor at the State-run Tohoku University. Silicon carbide fibre can be obtained in uninterrupted form from the production system by polymerizing organic silicon compounds, melt-spinning the polymerized compounds, and then firing the spun object.

Silicon carbide fibre thus created is stronger than piano wire and has better high temperature characteristics than carbon fibre with a heat-resisting capability of up to 1,300°C. In addition to these advantages, silicon carbide fibre has good wettability with metals. Because of these features, it is utilized mainly as reinforcement material for metals. Research has been under way to make it possible to utilize silicon carbide fibre in ceramic and in resins as their reinforcement material.

Organic fibre

Alamid fibre developed by Du Pont of the United States as been gaining increasing attention within the industry in Japan as a substitute organic fibre which could be utilized to replace natural fibre and regenerated fibre like rayon.

In Japan, it is said that Teijin has embarked on a programme to use this fibre as reinforcement material in some products on a commercial basis using its own technology.

PRESENT SITUATION IN FRP DEVELOPMENT

As described in the preceding sections of this article, FRP is a composite material which is made up of the matrix resins and the reinforcement fibres. By changing the composition between the resins and reinforcement fibres, different kinds of FRP can be manufactured. However, only a few of those have been put into practical use. Among those being utilized now, only three kinds of FRP - GFRP, GFRTP, and CFRP - account for a majority of Japan's FRP market.

In the following sections, we will discuss the current situation in the development of FRP products and their application fields. At the same time, the recent situation in the development of advanced FRP products will also be discussed.

Glass fibre reinforced plastic (GFRP)

Glass Fibre Reinforced Plastic was developed first among reinforced plastic products. GFRP accounts for most fibre reinforced plastic products whose production volumes are listed in various trade papers under the product name FRP. As for the matrix resin in the production of GFRP, it is estimated that unsaturated polyester resin counts for more than 90 per cent of those resins utilized in the production of FRP. However, recently other GFRP products with epoxy resin as the matrix material have also begun to appear on the market. (See table 3, page 36.)

Regarding the production method of FRP, there are traditional methods such as the hand lay-up method which involves lamination work by hands, and the spray-up method in which blowing by a spray gun is involved. In recent years, new mechanical GFRP molding technology has been introduced and the producers are using those new molding methods by choosing the most suitable for particular GFRP products they are going to manufacture. Those molding methods are. the cold press method in which the molding is carried out using the press; the resin ink jet method in which a resin in liquid form is injected into a mold filled with reinforcement glass fibres; the matched die method in which the molding is carried out by applying heat and pressure to the GFRP production materials which are placed into a metal mold; the continuous drawing method; the continuous panel molding method for the production of corrugated as well as flat-surfaced plates; and the filament winding method. The matched die method is further divided into the MMD method, the SMC method and the BMC method.

Among the varied methods used today in the production of GFRP, the hand lay-up method is still the most popular. However, considering the fact that until 4 or 5 years ago about 60 per cent of GFRP production had been carried out using this method, today the ratio has declined appreciably. This indicates that automation and introduction of mechanical molding machines have made progress in the industry in the past several years.

Carbon fibre reinforced plastic (CFRP)

The practical application of CFRP to a number of commercial products started around 1973 when carbon fibre reinforced plastic began to be utilized for the production of sports and leisure items such as skis, tennis rackets, golf clubs, and fishing rods. The industry's efforts to develop new fields of application of CFRP stepped up since the early 1980s.

As carbon fibres utilized for the production of CFRP, the fibres belonging to PAN system are most popularly used at present. Those carbon fibres are being utilized for reinforcement after being processed as prepreg, cloth, filament winding, or spread roving.

The advantages of CFRP over other kinds of fibre reinforced plastics are its light weight, high mechanical strength, relatively strong stiffness, good wear-resistance capability, good characteristics in electric conductivity, X-ray penetrability, and good corrosion-resisting ability. The CFRP's light weight results from the relatively low density of materials composing it. The high mechanical strength means that CFRP also excels in tensile strength, and the CFRP's strong stiffness has something to do with its high elasticity rate.

Due to these merits of CFRP, it has been used in a wide range of products and the application fields are expected to expand still further in the future. Table 4 (see page 36) gives the names of products in which CFRP has already been introduced. CFRP is now one of the high-tech industrial materials which have a promising future in their prospective usefulness as new industrial material.

Fibre reinforced thermoplastic (FRTP)

FRTP first came into being after FRP belonging to the polyamide system was developed in 1956. FRP which has been produced using thermoplastic resins (TP) as matrix material is called FRTP. As reinforcement material, glass fibre is being utilized most widely at present. But carbon fibre and metal fibres are also being employed.

At present, a number of companies are engaged in the production of fibre reinforced plastics on a commercial basis with the combinations of the matrix resins and the kinds of reinforcement materials varying from producer to producer. Toray Industries is producing polyamide and imide, ICI is manufacturing PPS and PEEK, and Mitsui Petrochemical Industries is making polyamide bismarimide resin.

FRTP combines the features of thermoplastic resins and those of glass fibre or carbon fibre, depending on which of the reinforcement materials is utilized. Compared with metals, thermoplastic resins have an advantage in specific gravity, corrosion-resisting capability, and electric insulation ability. But thermoplastic resins are inferior to metals in mechanical strength, stiffness, and heat-resisting capability. Consequently, FRTP which incorporates either glass fibre or carbon fibre as reinforcement material, displays mechanical strength which matches that of metals and, at the same time, exhibits overall features which surpass those of metals.

At present, FRTP is used in the production of car transporting vehicles in parts of the vehicles such as the exterior surface, inside walls of the compartments, and the engine rooms. Reinforced plastic is also being used to produce mechanical parts and electric as well as electronic parts.

Other FRP products

As for high-tech FRP, there are hybrid FRP, metal fibre reinforced plastics (MFRP), boron fibre reinforced plastic (BFRP), and aramid fibre reinforced plastic (AFRP).

Hybrid FRP employs a combination of glass fibre and carbon fibres as reinforcement material. Depending on the way the reinforcement material is combined with matrix resins, hybrid FRP is divided into the so-called in-layer type and inter-layer type. As the matrix resin, epoxy resin is utilized the most at present. Hybrid FRP is deemed suitable for use in applications where good materials involved are required, such as in building construction, marine application, and the production of various industrial members.

MFRP is one kind of fibre reinforced plastic in which metal fibres such as stainless steel fibre or aluminium fibre is utilized as reinforcement material.

Stainless steel fibre reinforced plastic has been developed to produce car brake pads as a substitute for asbestos pads. In addition to this, other kinds of MFRP have been developed in which a combination of aluminium fibre and glass fibre is employed as reinforcement material to create an MFRP with good thermal conductivity. Aisin Seiki is producing this kind of MFRP. An MFRP which carries a metal filler is being developed, which combines the features of resins and metals, including electric conduction capability. The development of this MFRP will be further stepped up in the future.

F. CURRENT AWARENESS, TRENDS AND DEVELOPMENTS

- General

Coating plastics with metal

Development of a new process for coating plastics with metal that could cut costs by 30 per cent is the objective of a study offered by Battelle's Columbus Laboratories. During the proposed study, researchers will attempt to prove commercial feasibility of the process, further develop it for commercial applications, and transfer the technology to industry. The study is being offered on a group basis, with sponsoring companies receiving licensing rights to use the process.

The new process - called in-mould plating - could eliminate several steps presently required when coating plastics with metals. Additionally, it has the potential of expanding the types of polymers and coating materials that can be used, and it accelerates plating operations.

With the procedure, metal is deposited on the surface of a stainless steel mould typically used on a production line. The metal is applied to the mould by a fast-rate electrodeposition technique. This creates a smooth metal surface on the side touching the mould and a rough surface on the opposite side. Molten polymer then is injected into the mould, forming a bond with the rough side of the metal. At this stage, a final decorative finish can be applied, if desired.

In-mould plating is, in effect, the reverse of conventional electro-plating on plastics. With conventional processes, polymers typically are first melted and formed and the metals are then applied by various etching and plating steps.

During the study, Battelle will concentrate on developing prototype procedures for plating with an insert technique. Parts would be made in a two-step operation, first, by preparing a number of electroformed metal shells and then inserting them into the mould to complete a normal injection moulding cycle.

Subsequently, Battelle plans to develop an integrated electroplating and injection moulding system. Consideration will be given to both material and process parameters, with emphasis being placed on developing adhesion between the polymer and metal in the plated structures.

The final step in the study would be to demonstrate a pilot plant operation. The objective is to produce a representative commercial product, which would be evaluated for performance characteristics. The study also will include a preliminary economic evaluation of the process.

In small-scale laboratory studies, Battelle experts have been able to deposit from 0.5 mils of metal in 17 seconds to 4 mils of metal in two minutes, because the plating operations have been accelerated. With proper design, a continuous process might produce a completed part every 30 to 40 seconds.

The researchers said that one advantage to in-mould plating is that polymers other than acrylonitrile butadiene styrene (ABS) can be plated. Also, several metals - including copper, zinc, and nickel - appear to be candidates for plating. With conventional procedures, ABS is the major resin used with a base coat of copper.

Previous estimates indicate that the in-mould plating process could reduce the costs associated with conventional procedures. Major savings are projected because the process uses less materials and energy and because moulding and metallizing are done in one integrated operation rather than in several steps. Also, savings can be realized because the process does not produce etching wastes that need to be disposed. (Joseph Preston, Battelle's Columbus Laboratories, 505 King Avenue, Columbus, Ohio 43201, USA (telephone: 614/424-5560)) (Source: Manufacturing Technology Horizons, Vol. 2, No. 4, July/August 1983, p. 2)

New technique gives plastics a hard coating

STC Technology Ltd. has developed a novel plasma etching and coating process which can deposit hard dense coatings on suitable thermoplastics, as well as metals, by virtue of being able to keep the substrate at approaching room temperature throughout the coating process.

This compares with conventional plasma methods which restrict substrate temperatures to above 350°C and place thermoplastics substrates out of court as a result. The low substrate temperature during deposition using the STC process is made possible by providing a much higher degree of dissociation than with conventional plasma methods. A high degree of dissociation is important if a minimum of bonded hydrogen is to occur within the coating.

Preliminary results show that hard, dense, wear-resistant coatings of silicon carbide can be produced on polycarbonate sheet, to improve its wear resistance by a factor of x120, over the uncoated polymer.

Considerable further improvements can be expected by incorporating an organic transition layer so as to avoid the sharp interface. For comparison, commercial polycarbonate sheet with a siloxane coating achieves an improvement factor of only x10 to x 20. (Extracted from: Engineering, November 1985, p. 664)

Plastics flamespray system

Metallisation has introduced a new flamespray system for the application of plastics coatings. The PPl series can be used in a host of industries for the application of coatings either for corrosion protection or special purposes like non-stick linings, anti-abrasion coatings and insulation protection. (Source: Engineering, February 1986, p. 202)

Injection molding

A scientist at the Massachusetts Institute of Technology has recently patented a controllable heat transfer device for use in precision injection moulding applications. Known as a "volume-controlled variable conductance heat pipe", the device provides controlled heating and cooling of a portion of the mould cavity surface during the moulding cycle, which in turn results in less shrinkage and distortion of the moulded part.

By placing one end of the heat pipe near the surface of the mould cavity, the rate at which the part cools can be controlled during the moulding cycle. Similarly, the heat pipe can be used to heat up selected mould cavity surfaces.

This controlled cooling and heating significantly reduces built-up stresses within the moulded part resulting in less distortion and improved mechanical and optical properties. If higher moulding pressures are used at the same time, workpiece shrinkage can also be almost totally eliminated.

Although controlled heating and cooling of the mould has been attempted before, it has generally been found to increase the moulding cycle to a point where it is not economically practical. By using heat pipes, however, the inventor believes that sufficiently short cycle times can be achieved to justify the technique. (Arthur Smith, Patent, Copyright and Licensing Office, Massachusetts Institute of Technology, Room E19-722, 77 Massachusetts Avenue, Cambridge, Massachusetts 02139, USA (telephone: 617/253-6966)) (Source: Manufacturing Technology Horizons, Vol. 2, No. 5, September/October 1983, p. 1)

Plastic drum is robust

Tanks & Drums is launching its L210 L-ring plastic barrel this spring. The blow-moulding equipment has been developed and built by Krupp Kautex of the FRG.

The barrel is made in hdPE and is said to be robust with strong impact resistance. Two grades will be available: standard and heavy duty. It gives the same degree of protection for hazardous products as lacquered steel or composite drums, but is lighter and easier to clean for re-use. (Extracted from Process Engineering, April 1986, p. 89)

Soltex Polymer Corporation has introduced an intermediate-density polyethylene copolymer that is compatible with injection blow moulding tooling designed for high-density polyethylene. Containers fabricated from the resin exhibit superior surface gloss and environmental stress crack resistance, according to Soltex. (Source: Chemical Marketing Reporter, 9 December 1985, p. 55)

New thermoplastics self-reinforcing, resist heat

The first injection mouldable liquid-crystal polymer has gone into production at Dartco Manufacturing Co. (a subsidiary of Dart & Kraft Co.) and is now available in production quantities.

Tradenamed Xydar, the self-reinforcing thermoplastics (so-called because the polymer tends to form strong, fibre-like chains upon solidification) have a melting point of approximately 790°F. Nevertheless they can be processed on conventional injection moulding machines modified with suitable barrel heaters and mould oil-cooling.

The high temperature thermoplastics have excellent chemical resistance, electrical properties, and fracture toughness that are said to exceed those of other high-temperature thermoplastics. The aromatic copolyesters have a UL continuous-use temperature rating of 465°F and a heat-deflection temperature of 671°F.

Xydar is inherently flame resistant and is expected to receive a UL94 V-O rating. Its limiting oxygen index is 42. In addition, smoke generation is very low: the polymer has a smoke-density rating of 3-5 after 4 minutes in the NBS smoke chamber.

According to Dartco, the liquid crystal polymers have other processing advantages besides their good mouldability. No postcuring cycle is needed, unlike some other high-temperature thermoplastics, and the material requires no mould release. Up to 100% regrind can be used with no deleterious effect on part quality.

Two of the three commercially available grades are in the SRT series (unreinforced): SRT 300, a regular melt-flow grade, and its high-flow counterpart, SRT 500. A second series of compounds called FSR (filled, self-reinforcing) also is on the scene; FSR 315, the only grade in the series currently available, is a 50% talc-filled version of SRT 300. (Dartco Manufacturing Co., Augusta, GA, USA) (Source: Plastics World, December 1984, p. 71).

All-plastic pump eliminates hazards

An all-plastic, pistonless displacement pump has been introduced by Hill (Ernest H. Hill Ltd., Beta Works, Fitzwilliam Street, Sheffield S1 3GX, UK; tel: (0742) 23019) for transfering and dispensing fluids - including oils and most corrosive chemicals - direct from standard containers 25 l to 210 l in size. (Extracted from: Manufacturing Chemist, March 1985, p. 77)

Lining technique renovates corroding process pipes

The Insituform process utilises a polyester fibre felt liner tailored to the diameter of the pipe to be rehabilitated. The liner is coated on one side with polyurethane and the felt is saturated with an epoxy (Araldite) resin. The choice of epoxy resins available allows rehabilitation of either drinking water, gas, dilute chemical or sewage lines.

The freshly impregnated liner is inserted into the pipe through a manhole or other existing access point, using a vertical insertion tube and a head of cold water. Curves, 45° angles and the bridging of canted joints and corrosion holes present no problems. Inversion results in the epoxy-impregnated felt being pressed firmly against the pipe wall.

When the liner is in place, the water in the pipe is heated to cure the resin. The result is an epoxy/felt composite forming a snug-fitting and stone-like pipe within a pipe. As the liner is relatively thin and smooth, the flow capacity of the rehabilitated pipe is usually better than new.

In Kuwait, as elsewhere in the Middle East, sewage lines have only slight gradients, carry largely undiluted sewage at 30-50°C and are hardly ever flushed by rains. These conditions form sulphuric acid, which means that fibre cement pipe that would last 40-50 years in Europe starts to deteriorate after four to six. If remedial action is not taken, the final outcome is pipe cave-in and the collapse of the sewage system. The entire system is now being rehabilitated and it has been found that the Insituform process is faster and more effective than sliplining and costs far less than pipe replacement. (Source: Materials & Design, Vol. 5, October/November 1984, p. 206)

Plastic piping is reinforced

Available for the first time in the UK, Polugap and Ekotef glassfibre-reinforced polyester pipe products are weight- and cost saving alternatives to metal. They also offer corrosion and abrasion resistance. Intended mainly for liquid and slurry handling, both ranges are internally coated for added protection. Polugap products have a polyurethane coating firmly bonded to the GRP outer pipe. Ekotef pipes are coated internally and, if required, externally with epoxy/orgoltar for chemical resistance. (Extracted from Process Engineering, April 1986, p. 89)

Nozzle for plastics

An improved type of the tried and tested hot runner nozzle suitable for special plastics processing operations was introduced by Hasco, FRG. This meets the rising market demand for gating systems.

The tube with the central material channel of the new nozzle type Z 104 (I) is made of special molybdenum alloy. This means higher wear and pressure resistance and an excellent thermal conductivity.

The maximum operating temperature goes up to 450° (at an injection pressure of 1500 bar). Therefore this nozzle is suitable for all types of engineering resins.

The sealed heater coil is embedded in copper beryllium and shielded with a circular reflector sheet. The voltage is 220 V AC. The built-in thermocouple ensures an exact temperature control. (Source: African Technical Review, January 1986, p. 84)

Plastic tubing

The US company, Griffolyn Division have produced an economical reinforced plastic tubing designed for irrigation or air distribution purposes. Available in multi material grades and colours the tubes can be made in any diameter or length needed to achieve maximum flow. These tubes will lay flat when not full to allow crossing of vehicular and pedestrian traffic without causing damage. Black/white colour available that reduces heat and moisture build-up by 85 per cent, also will resist sun breakdown from one to six years. Features available include velcro closures, grommets and custom manufacturing to exact specifications. (Source: African Technical Review, March 1985, p. 80)

Drallim offers tube fittings in plastic

Drallim's Series N tube couplings for use with plastics tubing, hitherto supplied in nylon only, are now available in both ptfe and pvdf. These materials greatly broaden the applicational field of the products, particularly with regard to acids, alcohols and hydrocarbons, claims the company. The new fittings are available as union fittings for 6, 8 and 10 mm o/d tubing, with G 1/8 to G 1/2 ISO parallel male stud ends (formerly BSPT) and corresponding American NPT types. (Drallim Fluid Components, Brett Drive, Bexhill-on-Sea TN40 2JP, UK) (Source: Manufacturing Chemist, September 1985, p. 87)

Dunlop Sports Ltd. (United Kingdom) has developed an innovative technique for moulding hollow composite or plastic parts. Similar to the recently developed "lost metal" casting process, the new Dunlop technique also uses low melting point tin/bismuth alloy cores. The plastic or composite part is injection moulded around the core, which is then removed by immersion in a hot oil bath. The new process is being used to manufacture carbon/nylon composite tennis rackets. (Source: Manufacturing Technology Horizons, September/October 1983, Vol. 2, No. 5, p. 16)

Super-strength fibre

Last month a new fibre technology was entered in the Southern Ocean Racing Conference races in St. Petersburg, Fla., USA. Produced from polyethylene by a proprietary gel-spinning technique, the new fibre was used in sails and rope, but it can also reinforce plastics, says Allied Corp., Morristown, N.J. James J. Dunbar, director-operations, says the fibre, called Spectra 900, will compete with aramids and graphite fibres - possibly reaching an annual consumption of 10 million lb. In plastic reinforcement, Spectra 900 can be advantageously combined with graphite fibres. High strength (up to 50% greater than aramids) suggests applications in reinforced structures such as radomes, ballistic protection, medical implants, and sports equipment, says Mr. Dunbar. In 5/8 in. rope, breaking strength is ten tons, versus seven tons with nylon. (Source: Industry Week, 4 March 1985, p. 120)

- Developments in the United States of America and Canada

High heat thermoplastic outperforms PPS, DAP

A new high-modulus thermoplastic resin with superior properties at elevated temperatures has been introduced by Union Carbide Corp. Mindel B-340 is a modified polyarylether resin reinforced with 40% glass fibres. It is said to compare favourably with glass- and mineral-filled diallyl phthalate (DAP) in physical and electrical properties, thermal stability, creep and humidity resistance.

The new resin is recommended as a replacement for reinforced DAP and for glass-filled PPS in connectors, sockets, relay and switch housings and terminal blocks. Mindel B-340 has lower shrinkage than crystalline resins, which until now have been the major replacements for thermosets, according to the company.

The tensile strength and elongation of the new resin at break are more than double that of DAP. Its tensile impact strength, nearly triple that of DAP. Long term aging studies give it a projected higher continuous use temperature over DAP: 320°F.

Mindel B-340's electrical properties are also said to be superior to those of DAP. It is less lossy at frequencies up to 10 MHz, offers higher dielectric strength and better insulation resistance. (Union Carbide Corp., Danbury, CT, USA) (Source: Plastics World, May 1985, p. 148)

Dow Chemical has developed reactive processing to permanently bond coextruded layers of plastic instead of "gluing" them together with adhesive tie layers. This new technology could be the next major step in multilayer processing technology. Reactive bonding chemically produces a coextrusion whose strength is limited only by the integrity of its materials. Combinations of reactive polymers with coreactive barrier materials form multilayer sheet or film that will not delaminate under extreme temperature and stress conditions. In structures such as PP/EVA/PP, the more heat-sensitive core layer will fail before the outer layers. But in most coextrusions, including barrier, 140°C+ melt points of commonly used resins ensure that a reactively bonded web will meet high temperature retorting and sterilization exposures that now can be handled only by glass and metal containers. (Source: Modern Plastics International August 1985 p. 45)

Thermoplastic resins

Georgia Gulf Corporation has introduced a new polymer blend designed to compete with polyphenylene oxide and flame retardant acrylonitrile-butadiene-styrene.

A company spokesman says the new material is designed to fill a cost/performance niche between lower priced materials like rigid vinyls and flame retardant polystyrene, and higher cost alternatives such as PPO/PS and FR-ABS.

The material could also compete with polycarbonates in applications that demand higher performance but which do not tax the full capabilities of the polycarbonates. Such overengineered applications are the key to the new material's market potential.

Georgia Gulf claims that the material exhibits, among other qualities, excellent UV stability, and faster mould cycles that PPO/PS.

Plastics analyst Richard Kossoff notes that many new alloys have been introduced recently, and numerous new price/performance options exist for the design engineer. The large number of new products of this type makes it difficult for a new material to establish itself in the marketplace.

He says that any new material will have to prove itself in specific applications, and that in order to replace another material, the new product must demonstrate equal or better properties within those applications. (Source: Chemical Marketing Reporter, 30 September 1985, p. 19)

Dicyanate semi-IPN composite matrix (Allied Corp., USA)

A composite based on graphite or Kevlar fibres and a semi-IPN matrix that combines a dicyanate thermoset (for heat- and solvent-resistance) with either polyethersulfone, polyester carbonate or polycarbonate thermoplastics (for toughness).

The dicyanate and thermoplastic are both dissolved into a methylene chloride solution, which is applied to either carbon fibre or Kevlar fibres. Curing at 220°C-300°C causes the dicyanate to crosslink around the thermoplastic. (Extracted from High-Tech Materials Alert, Vol. 2, No. 10, October 1985)

Allied-Signal Inc. says its researchers have created a polymer that conducts protons at room temperatures. The company claims the development could have a major impact on battery, fuel cell, sensor and other technologies. Batteries and fuel cells could be made smaller and far more efficient using proton-conducting materials, it is noted. The new polymer is a blend of polyvinyl alcohol and phosphoric acid. (Source: Chemical Marketing Reporter, 9 December 1985, p. 55)

A polyurethane engineering plastic

Isoplast, a new engineering plastic, based on MDI (diphenyl methane diisocyanate), is a polyurethane polymer but does not share the rubbery properties of polyurethane elastomers.

The first commercial applications for Isoplast in the USA indicate the utility of its properties combination in many fields.

In buckets for bulk conveyors, the new plastic is outlasting other plastics in demanding applications. In conveying equipment that must dig into abrasive materials such as scrap glass and it provided the ideal combination of stiffness, impact strength and abrasion resistance. In conveying detergents and bulk chemicals, its resistance to chemical attack and stress cracking also come into play.

In irrigation sprinkler heads, it can resist fertilizers and other agricultural chemicals, water, outdoor exposure and physical abuse. In rollers for overhead garage doors, oil and grease resistance is one factor in its selection. Others are low friction and adhesion to a hub made of metal or other plastics. Its good adhesion to other materials plus resistance to scratching and cutting led to its selection as the top surface of skin made by Olin. Medical catheters and connectors rely on the purity of the materials and absence of residual monomers and other extractables. These components are gamma sterilized. In the automotive industry, General Motors is evaluating its potential as a replacement for polycarbonate in valence panels, where it would provide much better resistance to damage caused by spilled fuel and oil.

Other possible applications include sleeves, bearings, connectors and adapters, and power drive parts such as gears and sprockets. Potential uses in the recreational field include ski boots, rackets, skates, helmets and toys. Automotive applications include interior and exterior panels and parts, in addition to general mechanical components. (Extracted from: Popular Plastics, June 1985, p. 45)

Du Pont has developed a new polymerization technique that could open a new era in man-made fibres, plastics, paints and adhesives. The new procedure may allow production of new types of polymers and will reduce the cost and pollution of polymer production. The process uses an initiator molecule containing an activating group. A monomer inserts between the initiator and the activitating group. Another monomer joins between the first monomer and the activator, which is thus transferred along the chain. This group transfer polymerization (GTP) process allows easy control of chain length, and functional groups can be added that would otherwise be unavailable. The chains will continue to grow as long as monomers are available. After one monomer is incorporated to the desired chain length, a different type of monomer can be added and incorporated into the polymer. GTP uses up all the monomer supplied, so there is less waste. The monomer is also added in a more concentrated solution, reducing energy needed to evaporate the solvent. The technique uses bifluoride ion as a catalyst. Research so far has been concentrated on acrylics, and a pilot plant will be built to produce automotive finishes. Methyl trimethylsilyl dimethylketene acetal is the initiator in the process. (Extracted from: Sci. News, 9 March 1983 p. 149)

Laminate resists high temps at low cost

A new series of glass reinforced thermoset polyester sheet materials has been developed as a low cost 155°C (class F) electrical insulation. Haysite H755, which also can be specified in mechanical application requiring thermal resistance to elevated temperatures, qualifies as a GPO-1 material.

H755, which is priced similar to standard low temperature GPO-1, is available in thicknesses of 1/32 to 2 in. and in sheet sizes 36 x 72, 48 x 60 and 48 x 96 in. (Haysite Reinforced Plastics, Erie, PA, USA) (Source: Plastic World, December 1984, p. 71)

TP polyesters are first in 3 classes

Four grades of Du Pont's Rynite thermoplastic (TP) polyester have received final recognition by Underwriter's Laboratories for use in Class 180 (H) systems of insulation for transformers and other coil wound products. Along with previous recognition in Class 155 (F) and Class 130 (B), the PET (Polyethylene terephthalate) polymers are the first thermoplastics to be recognized for all three UL classes.

The four resins, FR-530, 530, 935 and FR-945, can be used as the bobbin or coil form (primary insulator) with seven other materials: wire, varnish, tape, phase insulation, sleeving, tie cord and lead wire. The materials can withstand hot spot temperatures of 155°C for Class F recognition; 130°C for Class B; and 180°C for Class H.

The glass or mineral/glass reinforced resins, which provide good dimensional stability and stiffness in thin sections, compete with thermosets, thermoplastics, paper laminates and impregnated paper. (Du Pont Company, Wilmington, DE, USA) (Source: Plastics World, April 1985, p. 73)

Call for plastics outdoors

A number of developments in the electronics industry are opening up new market opportunities for moulded plastic parts. In telecommunications and television, there is an increasing need for housings that can protect electronic gear outdoors, and engineering thermoplastics are grabbing up these applications from cast- and sheet-metal parts.

With the break-up of AT & T, new telephone installations require an interface box dividing in-house wiring from the local phone company's. According to GE's John Fasy, office and institutional programs manager for Noryl, every house and building will have a minimum of one box by 1990. At least one major company, Northern Telecom, is already using plastic interface boxes manufactured by the firm's moulding division, Cook Electric, Morton Grove, IL. Molded-in threaded inserts and colour eliminate almost all secondary operations.

Cook moulds the interface boxes from Xenoy polycarbonate/PBT alloy to achieve a balance of impact resistance (provided by amorphous PC) and chemical resistance (from crystalline PBT). Other candidates for interface boxes, according to GE, include straight PC, for high impact strength, and modified PPO, for good long-term property retention at lower cost.

Cook has also been successful converting Stranterm outdoor terminals for telecommunications cables to Xenoy. Here, plastics replace 8-10 pieces of aluminium sheet, which had to be assembled with a plastic insulator block. The PC/PBT alloy withstands insecticide sprays, a requirement mandated by the end-user. (General Electric, Pittsfield, MA, USA) (Source: Plastics World, September 1985, p. 91)

Reinforced rods are stronger than steel

Reinforced plastic rods, both hollow and solid, are said to deliver greater tensile strengths than steel at one-fourth the weight. The rods are made of continuous glass fibres (80% by weight) in a thermoset polyester matrix. The Polystal materials are made by a proprietary manufacturing process that orients the fibres in the longitudinal direction. Tensile strengths of the E-glass/polyester materials range from 203,000 to 224,800 psi.

Applications range from reinforcement for fibre optic telecommunication cables to SMC. In the latter, the rods are placed in the mould with SMC and encapsulated by the part. A textured surface on the Polystal rod provides good bonding.

At present, the rods are offered in two versions: E-glass/polyester or S-glass/epoxy in continuous lengths up to 2 miles. The rods range in diameter from 0.04 to 1 in. and are available coated with a thermoplastic resin or uncoated. The E-glass/polyester version has a tensile modulus of 7,000,000 psi, while the S-2 glass/epoxy rod has about 25% higher tensile properties. (Mobay Chemical Co., Pittsburgh, PA, USA) (Source: Plastics World, October 1985, p. 71)

Thermobonding using polyester fibre will be the bonding method of the future, according to C. Barker of Eastman Chemical Products, due to its environmental, processing and product improvement advantages over latex resins. Environmental advantages involve the elimination of aqueous discharges and a substantial reduction of atmospheric emissions. Fibre lubricant from the composite blend of the matrix and binder fibres is exhausted, while a unit bonding matrix fibre sprayed or saturated with latex resin emits a substantial portion of water vapour, which may contain formaldehyde. Four processing advantages of thermobonding over latex bonding include less energy required, cleaner operation procedures, greater control over spray gun and nozzle problems, and increased production rates. The most important advantage of thermobonding over latex bonding is product improvement - latex bonding of a nonwoven material generally produces a stiff substrate with a harsh hand. A thermally bonded substrate has no surface coating, with bond sites concentrated at the fibre crossover points throughout the matrix structure, resulting in a soft and supple hand. (Daily News, 22 September 1983, p. 20)

Thermoplastic resists high temperatures

Production of polyketone polymers will begin next year at a facility now being constructed, reports Union Carbide Corp. At that time, the high-temperature engineering thermoplastics will be commercially introduced under the Kadel tradename.

The technology involved is based on Carbide's polyarylether patents. Significant product and process developments for these new materials already are covered by a range of patents and patent applications.

Polyketones have an unusually broad performance spectrum, according to the company. They provide short-term thermal resistance to over 600°F, and will withstand long-term exposure to temperatures well above 400°F. Polyketone polymers are resistant to virtually all organic and aqueous chemicals and have exceptional combustion-resistance properties. They also are described as especially tough and wear resistant. Conventional melt-processing methods are used to produce the new thermoplastics, including injection moulding, extrusion, and melt spinning.

The combination of properties, says a company spokesman, is expected to make polyketones attractive in a wide range of demanding applications, including wire and cable insulation, electrical equipment, aerospace/aircraft structural components, and antifriction devices. (Source: Machine Design, 8 August 1985, p. 8)

Canada: New plastics have been developed by bonding acrylamide resins with hardwood pulps, according to scientists at the University of Quebec's Pulp & Paper Research Centre. The new plastics, the first to be produced from hardwood instead of softwood pulps, are reportedly stronger and cheaper than conventional plastics. The new process consists of bonding the pulp and plastic via a xanthate grafting. (Paper Jour 15 October 1983, p. 22)

- Developments in Japan

Pollution-free plastic material

Chuo Kagaku has developed a new-type plastic material "CT", which has a high resistance to heat and can be produced at low cost. The material causes no environmental pollution even when it is burned. The produce will be marketed early in 1986. It has been developed by a new technique for mixing inorganic matter into resin. (Source: Chemical Economy & Engineering Review, June 1985, p. 44)

Cross-linkable polypropylene with functions of engineering plastic

Mitsubishi Petrochemical Co., Ltd., has begun marketing cross-linkable polypropylene that has the functions of engineering plastic.

The conventional cross-linking methods are limited to either chemical means or radiation for the reasons related to molecular structure.

The company developed a new cross-linking technique called the silane cross-linking method that uses water to cross-link polyolefin with an active silane radical. Compared to conventional cross-linking methods, this has the following advantages:

(1) It provides the same level of moulding processibility as polyolefin, and the product can be formed into any shape by using a general-purpose moulding machine.

(2) Being a simple method using only water, it requires no special facilities such as a cross-linking tube or radiation equipment.

Compared to non-crosslinked polypropylene, the product has the following improvements:

(1) Heat-resistance: Increased by 30 ~ 50°C.
(2) Creep-resistance: Improved by 1,000 ~ 100,000 times.
(3) Tensile strength: Rigidity and shock-resistances improved by 1.5 ~ 5 times.

Further, it is even superior to nylon which is a typical general-purpose engineering plastic in such properties as fatigue resistance, friction, and chemicals as well as sizing stability. (Source: The Japan Industrial & Technological Bulletin, July 1985, p. 20)

Mitsubishi Rayon (Japan) has developed technology to bond plastics and ceramics by bombarding them with plasma at 20,000°C. The resulting composite material has the hardness and heat resistance of ceramics and the light weight and impact resistance of plastics. Mitsubishi Rayon coats the surface of the plastic with special inorganic materials to keep it from melting or deforming. Several plastics can be bonded with ceramics, including ABS, polycarbonate, methyl methacrylate and epoxy-carbon fibre composites (Source: Japan Economy, 11 January 1986 p. 17)

Japan: Progress in development of three new types of polymers

Sophia University, Tokyo: Research on ultrafine polymers has led to experimental production of single polystyrene molecules with diameters varying from 300 to 780 angstroms.

Mitsubishi Chemical Yokohama Research Centre: Poly (oxyethylene) derivative adsorbents are put inside hollow acrylic polymer microspheres. The acrylic polymers allow water and urea to pass into microspheres, where compounds are adsorbed by the poly derivatives. Polymer shows promise for kidney dialysis.

Matsushita Research Institute: Institute has produced polymetacyclophane that consists of metacyclophane linked with 4,4' - dihydroxybiphenyl moiety. Polymer shows promise in electromagnetic shielding. (Extracted from Chemical Week, 27 November 1985, p. 93)

Data bases

The Ministry of International Trade and Industry (MITI) in Japan will carry out a comprehensive plan for the maintenance and promotion of data bases. Some of the items being considered include: devising a plan for the development of data bases in state-of-art fields such as new materials. MITI is planning to construct a data base for fine ceramics and the Polymer Material Centre in Tokyo. (Extracted from Tokyo Nihon Keizai Shimbun, 29 August 1985, p. 5)

High-performance thermoplastic elastomer

Nippon Zeon Co., Ltd., has developed and started manufacturing "ELASTAR", a high-performance thermoplastic elastomer.

Thermoplastic elastomers have the superior properties of rubber and the high processibility of plastics, and are available based on stylene, olefin, urethan and vinyl chloride. However, as the uses of these materials expand, industry is demanding improved characteristics, especially easier use and better performance while retaining their mouldability.

ELASTAR is a result of combining the company's techniques for designing high molecular materials, including rubber and plastics, and the processing expertise of Zeon Kasei Co., Ltd.

ELASTAR has improved shape retention at high temperatures, superior resistance to oil (especially fuel oils), excellent resistance to weathering and chemicals, and can be produced with various hardnesses, in various colours and by various moulding processes.

Characteristics

(1) The materials have the good processibility of ordinary thermoplastics, allowing extrusion, injection, hollow and calendar moulding.

(2) Vulcanizing is unnecessary and this contributes to energy-saving and possible scrap recycling.

(3) Good elasticity and shape are maintained at high temperatures.

(4) Compression causes little permanent deformation.

(5) It has superior resistance to oils (fuel oil, lubricant, etc.)

(6) It is highly resistant to ozone, weathering and chemical products. (Source: The Japan Industrial & Technological Bulletin, December 1985, p. 17)

- Developments in Europe & USSR

A corrugated honeycombed polycarbonate sheet called Thermonda is the result of research by two Italian companies, the processor, Polyu and machinery manufacturer Union, and raw material supplier GE Plastics.

The sheet is said to have a K value less than half that of glass with 80 per cent transmission of light and solar energy. Light weight, self-extinguishing properties, good resistance to UV rays, temperature fluctuation and breakage are features claimed for it.

Thermonda can be extruded at the rate of 1 metre/min and the specially built line: a 100 mm single-screw extruder with a gauged flat head which provides pneumatic closing in line with a stabilisation unit; a take-up unit; a programmable shear cutting unit; and a staker for the extruded sheets. (Source: Popular Plastics, January 1985, p. 26)

The Rubber and Plastics Research Association (England) has developed a new device for blending plastics and rubber during extrusion. Known as a "Cavity Transfer Mixer" (CTM), the device is an extension to the extrusion screw and consists of a concentric rotor and stator, both of which have spherical cavities machined into their opposing surfaces. These cavities cause the plastic or rubber material to be efficiently mixed as the rotor turns. Reportedly, the CTM provides much better blending than conventional screw extruders. The CTM can also be retrofitted to existing equipment. (Source: Manufacturing Technology Horizons, September/October 1983, Vol. 2, No. 5, p. 16)

The Rubber and Plastics Research Association (RAPRA) in Britain is also conducting research into foamed nylon RIM.

The project is aimed at finding a stronger, stiffer and more fire retardant material than polyurethane RIM for use in such applications as business machines and sound reproduction equipment.

Blowing agents have been identified based on low boiling organic liquids, and RAPRA has gone as far as moulding test pieces on a modified RIM machine.

The major remaining problem is uneven expansion in the mould which has resulted in foam gradients and irregular cell structure. The next stage of the project is to tackle this problem with the identification of surfactants and nucleating agents capable of allowing better control of the in-mould foaming process. The possibility of engineering the collapse of the foam at the mould wall to give an integral skin will also be evaluated.

Despite the work still to be done, RAPRA believes that this study is further advanced than any comparable work in Europe. (Source: Popular Plastics, January 1985, p. 26)

GRP alternator frames are 40% lighter

Markon Engineering is having its revised range of 2.5 kW alternators produced with frames and terminal covers made from glass reinforced plastic (GRP). These components are being supplied under contract by the W.H. Allen Plastics Division of Bedford, NEI-APE's specialist designer and producer of reinforced composite components.

The reinforced plastics components from W.H. Allen have the same mechanical strength as the earlier aluminium alloy frames but show a weight saving of some 40% over the latter and have received full UL (USA) standards approval.

The order from Markon, which includes production by W.H. Allen of the mould and prototypes, was obtained on technical competitiveness considerations.

Markon claims to be the market leader for units of this output, and the 2.5 kW machine is believed to be the first industrial alternator in the world to have a GRP frame. Flame-retardant GRP is used because of its low density, attractive appearance and heavy-duty capabilities.

The decision to change to GRP alternator frames was taken after many thousands of hours of successful field trials with hire fleets and accelerated-life testing carried out in the laboratories of the Production Engineering Research Association at Melton Mowbray. (Source: Engineering, February 1986, p. 169)

Mainz Polymer Research Institute

A new Institute for Polymer Research at the Max-Planck Society has been in existence since the beginning of 1985 in Mainz, FRG. As a neutral research site, it is to prepare the bases for new generations of synthetics, from which industry in particular will profit. Of particular importance is the drawing up of new mechanical properties, such as matrix materials or those with a "built-in" reinforcing effect. Also important are synthetics with light-conducting properties or with usable electrical and magnetic properties. New synthetics of this type can be achieved, if more data about crystalline structures and how to control them can be gathered. In the view of polymer scientists, it is no longer enough to investigate only chemical properties and reactions to realize these goals. Only close co-operation between physicists and chemists can help. The new Institute is headed by three renowned scientists: Prof. Erhard Fischer, Prof. Gerhard Wagner and Prof. Hans W. Spiess. New construction of a separate research institute in Mainz will start this year. (Extracted from Bern Technische Rundschau No. 19, in German, 7 May 1985, p. 7)

Rhone-Poulenc concentrates its laboratories

The CLYPT is born: The research and development centre for Rhone-Poulenc's plastics research has just opened near Lyons (France), with 4,000 square metres of laboratories and workshops and 15 engineers.

The centre is equipped with the Procop system (developed by Cisigraph in collaboration with Rhone-Poulenc and other industrial partners) for the thermomechanical calculation of structures and the calculation of the flow in the moulds.

Next, the colour-formulation stage is concerned with developing the formula needed for the application on the basis of polyamide 66 (of which Rhone-Poulenc is the leading European manufacturer and second in the world after Du Pont) and other plastics of its type (thermoplastic polyesters, block-amide polymers, polyimides).

On the average, a workshop consisting of six extrusion granulation lines produces one or two formulas per day. Rhone-Poulenc lists more than 500 polyamide formulas in its catalogue. Additionally, the colour-formulation laboratory, which is equipped with the computerized Procolor system, can produce colour formulations in record time.

The transformation stage tests these new formulations, manufactures the standardized test pieces for the product evaluation laboratory and ensures the quality of the test moulds. Six injection presses of 25 to 250 tons locking force are provided. These machines are rented out to equipment manufacturers, which is a good way to dispose of the best performing models at any given moment. Some are equipped with instruments to evaluate the material's aptitude for change through specific tests (among others, a test of plastification which measures the mechanical energy absorbed by the melted material, and a test of the speed of recapturing bending rigidity which indicates the aptitude of a material to be quickly removed from a mould).

A special stage is devoted to polyimides (Kinel and Keremid), of which Rhone-Poulenc is the leading world producer. These are materials which can be found in automobile cigarette lighters, as well as in CFM-56 reactors. Polyimides also have many other applications, ranging from gears to multilayer circuits for electronics. (Extracted from Paris L'Usine Nouvelle, 2 January 1986, p. 22, article by Pierre Laperrousaz)

Polymers against frost

At a laboratory of the Institute of Physical-Technical Problems of the North, Yakutsk Branch, Siberian Department USSR Academy of Sciences, packing gaskets and rings made of polymers were introduced. What is there so new about it? "They don't fear frost," explained the Deputy Director of the Institute. The cold weather literally "devours" the lifetimes of vehicles and mechanisms. At fifty or sixty degrees below zero, their useful lifespan is reduced by two or three times and their productivity is lowered two-fold. Hydraulic, fuel and lubrication systems especially suffer greatly. With this kind of frost, rubber packing rings become brittle and crumble readily.

The new material, a new design for the parts and technology for production, is waste-free and has many advantages: lightweight, strong and unbreakable. Experimental samples of the frost-resistant polymeric insulators are being tested on operating electric power lines. Plastic channels can also carry hot water to supply industrial and residential buildings. Frost-resistant pipes will also help to prevent accidents in severe cold, reducing to a minimum the risk formerly associated with the use of metal steam lines. (Extracted from Moscow Sovetskaya Rossiya in Russian, 13 February 1984, p. 4, article by A. Orlov, Yakutsk ASSR)

- Packaging

New packaging technique - Sweden

Ideal for everyday commodities, the new technique utilizes paperboard and thin plastic sheeting but without the need for heat-sealing. Instead the film-like sheeting is stretched and glued tight to the sides of the packs. (Source: International Licensing, March 1986, p. 18)

A new nylon barrier resin for packaging

DuPont has added Selar PA, a new amorphous nylon resin, to its Selar product line for barrier packaging. The company expects Selar PA to accelerate the displacement of glass and metal and even other plastics in a wide variety of packaging applications. The resin combines glasslike clarity with strength, thermal stability and oxygen barrier characteristics. The company has high hopes for Selar PA in food packaging, particularly for products that are hot-filled. Initially, however, Selar PA will be used in nonfood packaging, including small bottles for cosmetics, as well as containers for household chemicals, industrial chemicals and automotive fluids. (Extracted from Chemical Week, 19 February 1986, p. 42)

Co-extruded plastics bottle from Plysu

Plysu Containers has introduced a multi-layer 5 l plastics bottle intended to enable the company to supply attractive, high-performance bottles for marketing and distribution of products that previously could not be packed in plastics. A version of its CS 8. bottle - a container which, to date, has been blow-moulded from high-density polyethylene - the co-extruded bottle is now being produced in sample quantities which are available to customers for testing.

The co-extruded bottles are expected to open up totally new markets for packaging of agro-chemicals, industrial chemicals, decorative and maintenance products and others which have previously been supplied in traditional materials such as glass and tinplate, says Plysu. When the bottle moves into full-scale production, it will be available moulded in the company's standard range of colours. Screen printing with customers' own brand designs in up to four colours, and pre-printed plastics sleeves and labelling will also be available. The co-extruded bottle is designed to be stacked and transported in multi-unit corrugated fibreboard transit cases. (Plysu Containers, Woburn Sands, Milton Keynes MK17 8SE, UK) (Source: Manufacturing Chemist, October 1985, p. 87)

New high-performance plastic containers

Aluminium Co. of America (ALCOA) agreed to form a 50-50 joint venture with Metal Box America to develop and produce new high-performance plastic containers for the food industry. Proposed products include Lamipac retortable containers that can be used in microwave ovens, containers made of polyethylene terephthalate, oriented polypropylene hot-fill barrier bottles and jars, and aseptic packages. (Extracted from Chemical Week, 29 January, 1986, p. 5)

Plastic and composite closures were being shown by several closure companies. Alcoa Deutschland exhibited the Talog composite closure, which consists of an aluminium roll-on top to which is attached an anti-pilfer plastic band. The same concept lies behind the Top Cap Safe shown by VAW Aluminium. It can be applied with any sealing machine on the market, no additional attachment or modification being necessary. Crown Cork & Seal showed the Obrist plastic pilferproof closure, which is being marketed through its subsidiary Crown Obrist.
Products were displayed on which Obrist closures are being used, including Coca-Cola, Pepsi-Cola, Coates Somerset Cider, beer in PET bottles and such food products as tomato sauce. (Source: Food Engineering International, September 1985, p. 27)

Retortable plastic can goes to market

Another milestone in plastics packaging was reached by American Can Co., Greenwich, CT., USA, by producing plastic cans for steam-retorted foods. The new can has a double-seamed metal, pull-tab lid that is easy to open. And because of its two-piece construction the can is easy to stack. American Can uses a proprietary multilayer co-injection blow moulding process. A five-layer parison, consisting of two polyolefin structural layers, two adhesive tie layers incorporating a desiccant, and an EVOH barrier layer, is injection moulded and then blown into a container. The desiccant in the tie layer prevents the EVOH layer from losing its oxygen barrier properties during steam retorting. This technology produces a container that preserves flavour and nutritional value throughout the shelf life of up to 2 years. (Extracted from Plastics World, August 1985, p. 8)

Alfastar (Tumba, Sweden) has developed a new technique for packaging solid and liquid foods. Roll-fed sheeting is folded into a trough-like shape for receiving preheated food. Trough edges are then sealed together under vacuum, forming a food tube that, after advancing through a tunnel-type oven, is quick heated in water to 260°F by microwaves. Next the polymer food tube is cooled by water and passed into a pouch-forming section. The pouches eliminate the need for refrigeration while retaining fresh taste and nutritional value in foods. (Machine D, 8 August 1985, p. 33)

- Building construction

Recent developments in the use of polymer concrete

Serious research on the use of polymers (or plastics) to modify the engineering characteristics of conventional concrete started in the early 1950s.

It is commonly known that Portland cement acts as a gap-filling adherent in concrete and that there is no equally economic alternative. Polymers however, used with or without cement are being developed at an increasing rate, and time has already proved that polymer concretes can be used with a tremendous advantage over conventional concretes, both economically and structurally.

The following table summarizes some of the research done on polymer concretes in recent years, and serves to illustrate the advantage of these materials.

PROPERTY	COMPARED TO CONVENTIONAL CONCRETE
Compressive strength	Increases 4 times
Tensile strength	Increases 4 times
Modulus of elasticity	Increases 2 times
Modulus of rupture	Increases 4 times
Flextural modulus of elasticity	Increases 1 1/2 times
Creep deformation	Decreases 10 times
Hardness impact values (L Hammer)	Increases more than 1.7 times
Water permeability	Becomes negligible
Water absorption	Greatly reduced
Resistance to hydrocholoric acid	Increases more than 12 times
Resistance to sodium sulphate	Increases more than 7 times

Polymer concretes:

Polymer concrete is a concrete in which the normal cementitious binder is supplemented or replaced with a polymeric emulsion (Latex) or in which after hardening of the concrete, a monomer is impregnated and subsequently polymerized. Both of these processes cause an intricate polymer chain to form which fills the voids and macro-fractures in the concrete to such an extent that it serves as a micro-reinforcing system. This greatly increases strength and durability, and signficantly reduces permeability.

Types of polymer concretes

Polymer-Impregnated-Concrete (PIC)

PIC is manufactured by impregnating hardened conventional Portland cement concrete with a liquid monomer which is then polymerized. Polymer-impregnated concrete is very much like conventional concrete in appearance. Upon close inspection, PIC may be distinguished by the presence of polymer in air voids of the concrete. PIC made from conventional concrete usually contains 6 to 7 per cent polymer by weight. Methyl methacrylate is widely used as a monomer because of its low viscosity, low cost and good properties in PIC, while a commonly used catalyst to induce polymerization is Azonitrile. The basic steps required to produce polymer-impregnated concrete are as follows:

1. Dry concrete at 150°C for 24 hours to remove free moisture.

2. Allow concrete to cool to room temperature.

3. Place concrete in impregnation vessel and apply a vacuum for 30 minutes.

4. Introduce the catalyzed monomer under a vacuum to completely submerge the specimen, then soak under a compressed air pressure at between 170-340 kPa for 2 hours.

5. Drain excess monomer and immediately backfill the vessel with warm water - this is to minimize monomer evaporation losses.

6. Apply heat (normally steam) until polymerization is completed - normally 4 hours at 70°C.

The above procedure allows for full impregnation of the concrete which is obviously an expensive process. A similar and less costly process can be used to obtain a partially-impregnated or surface-impregnated concrete. Here a vacuum and pressure soaking is not required which consequently eliminates the need for a pressure vessel as required for the fully impregnated concrete. The process consists of drying the concrete, soaking it with the monomer, and inducing polymerization by immersing the concrete in warm water or by other appropriate applications of heat. It has been reported that partially-impregnated concretes have good structural properties, excellent resistance to freeze-thaw deteriorations, water penetration, wear and abrasion, and have good skid resistance.

PIC is used in pipes, tunnel liners, beams, underwater habitats, bridge deck panels, prestressed piles, barges, and a variety of highway structures.

Polymer-Concrete (PC)

Polymer-concrete is produced by mixing a monomer with aggregates and polymerizing the material after placement. The monomer or resin therefore replaces the cementitious binder completely. In contrast to PIC, PC can be made with a wide range of monomers and the material is suitable for both precast and in situ applications. It is common knowledge that the strength of ordinary concrete depends mainly on the bond strength between the cement and the aggregate particles, and as polymers with tremendously high adhesive properties are available, it is found that cleavage and breakage of polymer concretes occur through the aggregate bodies and not in the cementitious binding planes. Because of its excellent durability and good structural properties, PCs are used effectively and economically in situations where mild chemicals, sea water, sulphate-containing soils, polluted air, corrosive effluents or sewage prevents the use of ordinary concrete.

Polymer-concrete can be produced using standard concrete mixing plants and conventional placing techniques, and is therefore readily adaptable to existing concrete production technology. The preparation of most PCs are done with liquid monomer in the proportion of 10:1 to 1:1 aggregate/resin mixes. The monomer is premixed with a catalyst and added to the dry mix. The setting time can be regulated by the added amount of catalyst or by temperature. Full strength is obtained when polymerization is completed.

Polymer impregnated concretes - applications

Pipes

Recent tests on PIC pipes placed in areas containing sulphates at concentrations up to 7-5 per cent in the soil and 5-9 per cent in the water, as well as tests on PIC sewer pipes, where the hydrogen sulphide concentration was about 10 parts per litre in the winter, and several hundred parts per litre during the summer have shown no evidence of any deterioration.

Compression reinforcement

With the advent of polymer impregnation techniques for concrete, it is now feasible to make high compressive strength concrete with excellent corrosion resistance. This fact led to some research done by Gunasekaran of the Westinghouse Research Laboratories in the USA on the use of PIC for concrete rods which can be used instead of steel reinforcement. In addition to possessing excellent corrosion resistance, the rods were found to have a weight advantage over steel reinforcement since the density of the concrete is only about one-third that of the steel reinforcement. Applications for these rods are found in numerous structural members such as columns, doubly reinforced beams, in which, due to size limitations, it is necessary to design the steel reinforcement to carry compression in bridge piers where corrosion might be a serious problem, etc.

Applications of PC include road and bridge overlays, pothole repairs in roads and runways, concrete pipes, tunnel support liners, panels, kerbstones, and a variety of specialty products like floor and roofing tiles, window sills and inflation formed dome structures.

Polymer-Cement-Concrete (PCC)

The process technology of PCC is very similar to that of conventional Portland cement concrete, and it consists basically of adding either a monomer (with subsequent post-mixing polymerization) or a polymer to the standard concrete mix. Because most polymers and their monomers are incompatible with a mixture of Portland cement, water, and aggregate, most research on PCCs have concentrated on overcoming these basic incompatibilities. Because of this problem the properties of PCC are generally only moderately improved. The main benefits of these materials are good bonding properties with Portland cement concretes, good durability, and a high degree of abrasion resistance. Strength improvements are relatively minor. PCC is also called latex modified concrete (LMC) with the three most common commercial LMC products being styrene butadiene, acrylic and epoxy emulsions. Normally the concrete mixes are designed with over 277 kg/m^3 Portland cement per m^3 of concrete, as the latexes are more effective in the richer mixes.

The main applications of polymer cement concretes are overlays for concrete bridge decks, parking garages, industrial floors and as patching compounds.

Recent developments in the use of polymer concretes

Polymer technology is undergoing rapid advancement, and new and more exotic uses are being discovered or developed almost daily.

Tunnel linings

Three full-scale tests were conducted by Carpenter, Cowan and Spencer on PIC tunnel lining and support segments erected to form a 2.4 m diametre by 2.4 m long tunnel. The load-carrying capabilities, deflections, modes of failure, and effects of backfill material were determined. The test results indicated:

1. The PIC system is viable and, compared with a conventional concrete system, can provide increased load capacity or an equal capacity with a thinner section.

2. With concrete backfill the PIC system carried 1.6 times greater load than the conventional concrete system of equal segment thickness.

3. PIC provides for superior joint strength.

4. Economic advantages of a PIC system can only be determined from a special application; however, a preliminary analysis showed advantages for PIC in long tunnels, 6.1 m or larger in diametre.

PIC bridge deck system

Research is presently being undertaken by the Federal Highway Administration (FHWA), Bureau of Reclamation, and the Prestressed Concrete Institute (PCI) in the United States on the use of prestressed PIC bridge deck systems. This system is designed to utilize the structural properties of the prestressed panels, the potential of a precast system for rapid construction, and the protection of reinforcing from de-icing salts provided by the polymer. The concept envisages precasting of deck-width sized panels, rapid erection and placement of panels at the site, and connecting of panels by post tensioning.

Seafloor structures

Because of its strength, durability and low permeability, PIC is being evaluated for undersea applications. Test results show that PIC spheres respond elastically to hydrostatic loading, and that the implosion pressures are 40 per cent greater than those of conventional concrete. The maximum operating depth of buoyant spherical PIC hulls in the ocean has been estimated at 1,220 m.

PIC plumbing fixtures

A South African firm has built a pilot plant for production of concrete wash basins, sinks and bathtubs, which are subsequently impregnated with styrene and polymerized. The final product has a very smooth, glossy surface and is called "mirror concrete".

Miscellaneous applications

In Japan, pump beds made of PIC have been in service for 2 years without corroding, in contrast to a maximum service life of one year for coated stainless steel. Ocean-going barges constructed of PIC prestressed concrete have been built with the purpose of transporting liquid natural gas. Cylinder piles used as foundation structures for major over-water bridges have been made out of PIC. Because of its higher strength and durability the wall thickness can be reduced with the effect of decreasing weight and thus reducing handling problems. The higher modulus also facilitates better driving. The use of fender piling made of PIC has considerable potential for wharves and jetties against which ships must dock. The higher energy absorption and abrasion resistance, coupled with its higher strength, makes PIC an excellent material for this use if costs can be kept within 170 per cent of the conventional prestressed concrete piling.

Surface-impregnated concrete

A great deal of interest has been directed towards surface-impregnated concretes. The development of a field surface-impregnation process led to field trials and demonstrations on 20 bridges in the USA. The technique has also been used on hydraulic structures to protect the concrete against cavitation, abrasion and freeze-thaw damage. Examples of such structures are spillways, floors for stilling basins, and outlet walls.

A rather interesting use of surface impregnation was successfully used for geotechnical investigations of the foundation of the Auburn Dam in California. The process was applied to consolidate soft material in a fault zone and to allow for the taking of undisturbed samples for analyses.

Polymer concrete - applications

In FRG alone, seven factories are mass producing polymer concrete units. Local authorities in this country are specifying polymer concrete for all new water and sewage treatment plants. In a geothermal power installation in Texas where PC units are used under operating conditions of 200°C, to military applications in the Soviet Union where temperatures drop to minus 18°C, PC has proved its ability to resist variations in temperatures under highly corrosive conditions.

A recent development is a "sandwich" concrete pipe with a resin-concrete lining reinforced with glass fibres. In another research project done by Brockenburgh and Patterson, steel and glass fibres were used to strengthen Methacrylate PC. The steel fibres resulted in significant improvement of all test results while the glass fibres decreased the compressive strength but increased the tensile and flexural strengths.

PC used in superconducting turbogenerators

A polymer concrete made with epoxide resin as the sole binder with a compressive strength of 150 MPa, and a stiffness of 40 GPa at 70°C has been used to fabricate the stater structure of superconduction turbogenerators. The manufacturing technique involved vacuum impregnation of a prepacked mould filled with aggregates of a maximum size of 5 mm. This process was developed by the Civil Engineering Department at Brighton Polytechnic in response to a challenge from the designers of the superconducting turbogenerators. Further research is being conducted to use these concretes for pipes, pump and valve casings subject to corrosive conditions.

Polymer concretes are now fully competitive with conventional materials in Europe. As compared to normal Portland cement concrete, it allows (in addition to its superior physical properties) weight-savings of at least 50 per cent. This factor is of major significance as transport costs for concrete products continue to rise. In addition to the above applications, PC products are also proving to be of tremendous value in slaughter houses, restaurants, food preparation plants, and service stations where oil and grease separation is essential.

Polymer-cement-concretes - applications

A major application for PCC is found in the architectural field. PCC is used to prefabricate relatively large (3 m x 4 1/2 m) panels of masonry curtainwall which are then erected on the job site. Such an approach permits the incorporation of unusual architectural features, the guarantee of year-round delivery, high quality control and reduced construction time. PCC is also used to provide tough durable floors for various applications.

Polymer-modified shotcrete

Conventional mass concrete has been found to be unsuitable to support excavations in hard rock at depth while pneumatically sprayed concrete lacks flexibility and ductility. Polymer-modified shotcrete was developed as an alternative to the above, and it was found by Ortlepp and Wood of Rand Mines in South Africa that with a polymer content of 3 per cent (dry weight), significant changes in the properties of shotcrete can be achieved. Used together with suitable steel mesh, such shotcrete can form a tough, compliant layer which would provide very effective support for tunnel walls even after appreciable distortion.

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(Extracted from Materials and Society, Vol. 9, No. 3, pp. 371-380 (1985). Written by Deon Kruger, Rand Afrikaans University, Johannesburg, Africa.)

The following two articles were obtained from Asia-Pacific Tech Monitor:

- In 1985 an Austrian firm set up four plastic window factories in China and trained its Chinese partner's personnel in various aspects of plastic production;

- Strong light EPS

Insulfoam, a new expanded polystyrene (EPS) material is manufactured by Insulpack Industries Pte. Ltd. of Singapore, a member of the Jebson and Jebson Group of Companies, South East Asia.

The main application of insulfoam is in the construction industry but it is also popularly used in many other areas. Manufacturers use it for packaging. Exporters use it for its strength and lightness. Cold-room experts use its high-insulating properties. Art buffs use it all the time to achieve artistic finesse.

One of the main characteristics of insulfoam is its high insulating capability. Thus it is also used in roofing insulation.

Insulfoam is extensively used in void forming. Whenever a void in construction is necessary, insulfoam is cut to the exact shape of the desired void. The cut insulfoam is placed at the required position. Cement is then poured over the insulfoam. When the cement has hardened, the insulfoam is removed, if necessary. Pre-moulded insulfoam in various sizes are also readily available which can be used for creating voids for sewerage, water and gas piping.

Plastic decorative surfaces

A small firm from FRG which has carried out considerable research work in developing glass fibre reinforced plastic sheet materials for decorative purposes for floors, walls, etc., is prepared to grant a licence to an Irish company to handle English speaking markets. The package of technology includes special press tools for producing special surface finishes which simulate copper, stone, etc. (Source: Technology Ireland, November 1985, p. 12)

Glazing sheet

A double-walled, impact-resistant plastic sheet offers up to 40 per cent energy savings in primary glazing over single-pane glass or monolithic plastic sheet. Made from polycarbonate, it is suitable for retrofitting original glazing in industrial buildings. Light transmission and insulating capabilities are better than glass, or acrylic. Can be used as skylight roofing on factories. (General Electric, Plastics Group, One Plastics Ave., Pittsfield, Massachusetts 01201 USA) (Source: Industrial World, August 1985, p. 26)

Higher thermal and noise insulation and greater mechanical strength are claimed for a new PVC door and window frame system compared with existing hollow section PVC profiles.

The Thermassiv system, developed in FRG, has a solid core of polyester rods, measuring typically 1/4 in diametre and each consisting of bundles of fibres. The rods are spaced through the profiles in a matrix of hollow glass spheres in an undisclosed thermosetting plastic.

Thermal expansion of the solid core material is said to be only 25 per cent of that of hollow section PVC. In addition the extra strength enables windows to be designed with slimmer profiles. The outer skin is protected with acrylic. (Source: Popular Plastics, January 1935, p. 28)

Maintenance work on concrete often grinds to a halt in cold weather. Integrated Polymer Industries (IPI) of Santa Ana, Calif., USA, aims to change that with its Arctic Barrier coating for concrete. The product can cure within one hour at temperatures below freezing. In warm weather the coating cures within 15 minutes so one can do immediate repairs. (Extracted from Chemical Week, 12 March 1986, p. 18)

- Chemical-resistant polymer concrete

Corrosion spares few industries

Polymer concretes are a new generation of corrosion resistant materials using the latest technology of such resin systems as furan, acrylic, epoxy, polyester, and vinyl ester. These systems offer resistance to many acids, alkalies, salts, and solvents in a multitude of process industries.

Polymer concretes are a recent development emerging from the technology of mortars and monolithics. The mixing of polymer concretes uses conventional Portland cement concrete equipment. The placing and finishing uses tools common to the industry for compacting, vibrating, screeding, and finishing. Polymer concrete is equally appropriate for pouring into forms as screeding on floor areas. Advantages of high early strength, low absorption, good impact resistance, high flexural properties, and excellent chemical resistance are some attributes of polymer concrete. (Atlas Minerals and Chemicals, Inc., Farmington Road, Mertztown, PA 19539) (Extracted from ASTM Standardization News, February 1985, p. 20)

- Medical

Thermoplastics used in plastic surgery

Chlorinated polyethylene thermoplastic may be useful as an artificial material to replace damaged portions of the face and jaw. Lawrence Gettleman, a dental scientist at Gulf South Research Institute, New Orleans, USA, described the advantages of this thermoplastic to colleagues at an International Association for Dental Research meeting in Las Vegas. When mixed with softeners and coloring agents, the material can be coloured permanently to match a person's facial complexion. It is also stabler and more durable than other substances currently in use, such as silicone rubber, which can fray and tear at the edges. Studies with patients are under way to test the comfort, effectiveness, and durability of facial replacements made of the material, Gettleman says. (Reprinted with permission from Chemical and Engineering News, (c) 1985, American Chemical Society)

ICL Scientific (US) has introduced new plastic laboratory urinalysis slides, branded as the Glastic Slide, which will be added to the Kova system product line, the US largest selling disposable urinalysis system. The new slide has 10 chambers, single focal plane readability and superior optics, vs conventional slides. ICL Scientific is a 100% subsidiary of Hybridoma Sciences (US). (Clinica, 10 January 1986, p. 22)

Mitsubishi develops poreless polymer

Artificial skin and blood vessels are among the proposed applications for a new copolymer of polyamino acid and urethane. The new polymer allows moisture to pass through even though it has no pores. Instead, the acid and polyurethanes hydrophilic radicals facilitate the passage of water.

More importantly, the polymer prevents bacteria and viruses from permeating the membrane. In addition, the polyamino acid radicals mimic human cells thus allowing the polymer to be compatible with human organs. (Extracted from European Chemical News, 25 November 1985, p. 16)

Asahi Glass (Japan) has developed a fluoroplastic that eliminates the need for anticoagulants in medical applications such as artificial hearts and blood vessels. The product is a fluorine-containing segmented polyurethane. Its fluorine-containing part is hydrophobic, while the polyether section is hydrophilic. The prepolymer was developed by reacting diisocyanate (containing fluorine) with polytetramethylene glycol, then treating the product with diamine. The plastic material's strength is rated at 630 kg/cm^2, or 1.5-2X higher than that of silicone-based products. In tests with dogs and goats it prevented blood from coagulating for 30-90 min. (Japanese Economic Journal, 22 November 1983, p. 16)

Concept Polymer Technologies has developed a thermoplastic elastomer with excellent light transmission, identical appearance and lower price thermosetting silicones. Clear C-FLEX styrene-ethylene/butylene-styrene (SS) modified polymers are intended primarily for medical applications such as intravenous and chemotherapy catheters, and blood and solution bags that would best capitalize on their biocompatibility, and sterilizability. The C-FLEX elastomers have typical properties of 50 Shore A hardness, 1,340 psi tensile strength, 800% elongation at break and 300 lb/in. unnotched tear strength. (Material Engineering, October 1985, p. 15)

Premature infants may benefit from being wrapped up in a plastic bag to simulate the womb, according to B. Chandler of Plantation General Hospital (Fort Lauderdale, FL, USA). A girl born at 21 weeks gestation weighing 510 g was kept on a sheepskin-covered waterbed under radiant heaters, all within a plastic container made from a blood gas kit. The infant was surrounded except where the endotracheal tube entered. IVs were used instead of placental feeding. The child was discharged from the hospital at 38 weeks gestational age in 'perfect physical condition', and is apparently the youngest premature infant to survive. (Medical World, 11 November 1985, p. 119)

- Plastics in the automobile industry

Plastics in autos use seen growing

The market for plastics in all types of interior, exterior and functional car parts is due for renewed growth, according to a study by Business Communications Company, Stamford, Conn.

The study, by BCC's plastics division, concludes that the role of plastics and plastic car part supplies will change dramatically over the next five to ten years.

In the mid-1970s, the usage of plastics in North American cars had been predicted to increase to 250-300 pounds or more per vehicle by 1985. BCC estimates that actual 1985 usage will be closer to 186 pounds per vehicle. What happened to the earlier heavy predictions of almost all industry observers? According to BCC, three key factors led to less-than-expected growth in plastics usage.

. The real price of gasoline has declined sharply since 1980 reducing the urgency behind car weight reduction.

. The ability of the US car companies to compete against foreign companies in the small car market has always been weak. These small cars have gained an increased share of overall car sales and also embody a disproportionately high percentage of plastics parts for weight-saving and sticker price reduction. Hence, lower US production of plastics for the domestic car industry.

. The plastics industry has been unable to provide cost-effective plastic parts that could meet the increasingly stringent performance standards established by the car companies and regulatory agencies.

According to the new study, the materials preferences of automotive engineers are changing as resin and processing options have improved and that is affecting the demand for plastic parts. Automotive design engineers are interested in materials that are lightweight for good fuel economy, yet can provide maintenance-free performance. Engineers are also looking for parts that are reproducible in high volume and can meet exacting functional and aesthetic standards for improved aerodynamics. In addition, the new plastics applications will be especially useful in the cost competition with foreign car suppliers such as Japan.

The report indicates that the average volume of production of individual US car models is coming down to the point where both large and small plastic parts are cost-effective alternatives to parts conventionally made of steel, aluminium and other non-plastic materials.

Further, the report indicates that the resin manufacturers, in close co-operation with the US car companies, have been spending heavily on R&D into new plastic materials and processes since 1979. These outlays are just beginning to bear fruit. Plastic equipment manufacturers and processors have now developed techniques for using existing and new plastic materials in ways that save on total part costs, in terms of reduced cycle time, reduced labour costs in fabricating delivering and installing parts, reduced waste, and enhanced scope for parts consolidation.

Also, plastic part suppliers are gradually adopting "just-in-time" delivery systems that reduce the inventory costs borne by the car companies.

The study predicts that by 1990 the average amount of plastics in a North American manufactured car will attain and possibly exceed the 300-pound-per-car level that most industry observers had thought would be reached by 1985 - despite the continued low real price of gasoline and despite the continued downsizing of cars sold in this country.

The study notes, however, that while plastics usage per car will grow by over 50 per cent from less than 200 pounds per vehicle in 1985 to 300 pounds per vehicle in 1990, the total amount of plastics consumed by US car companies will grow by less than 30 per cent to 2.1 billion lbs. by 1990 - due to further penetration by car and car part imports.

The other potential source of growth for North American automotive plastics consumption is the growing car manufacturing operations in this country and in Canada on a wholly foreign-owned or joint venture foreign-domestic basis. In this market segment, the US plastic automotive part suppliers will have to compete with foreign-owned part suppliers operating either from their home base or from plants in this country. (Source: Chemical Marketing Reporter, 6 January 1986, p. 4)

General Motors' Buick-Oldsmobile-Cadillac Group is considering a line of high volume plastic-bodied cars for introduction in the early 1990s. Around 1 mil cars/yr would be involved in the plastic car project. The GM Buick-Oldsmobile-Cadillac Group is looking at improved sheet molding compounds, conventional injection molded urethane materials, reaction injection molded materials and some new polyurea, nylon and other polymer-blend materials with high heat-resistance features and fast molding times as potential body materials for the J-N cars. (Am Mtl Mkt, 4 November 1985, pp. 1, 37)

Polyurea RIM seen wave of the future for the auto industry

Automotive engineers may find that the answer to making large plastic body panels a cost-effective reality lies in polyurea-based reaction injection molding.

At least that is what Dow Chemical Company is hoping. The company introduced its "fourth generation" RIM technology polyurea-based reaction injection moldable polymers at a press conference during a technical conference of the polyurethane division of society of the Plastics Industry in Reno, Nev., in October 1985.

Dow believes that the developmental polymer systems can help bring about mass production of plastic door, fender, hood and trunk panels.

Currently, automotive designers and engineers are evaluating the replacement of major steel body panels with various plastics. While there have been some successes - notably the Pontiac Fiero - most industry sources project that large-scale uses of plastic in automotive body panels are at least five years away.

Current problems: Most currently available RIM urethane and engineering thermoplastics cannot withstand the 365° Fahrenheit primer oven cycle or 325° top coat bake required for on-line painting. Also, large panels of these materials typically are produced with a two-minute cycle time - yielding low productivity and poor mass production economics.

But Dow spokesmen claim the new "Spectrum" HT polyurea-based prototype products will overcome those problems, giving RIM the opportunity to challenge current RIM urethane ureas and engineering thermoplastics as candidates for future large auto body panels.

One of the new polymers, reinforced with 20 per cent glass flake, exhibits physical properties comparable to high performance engineered thermoplastic alloys and blends, Dow says, adding that high temperature stability of parts produced from the polymer is outstanding. (Source: Chemical Marketing Reporter, 28 October 1985, p. 4)

Toyota Motor (Japan) has jointly developed a combination steel sheet and plastic for use in building automobiles with Nippon Steel and Ube Industries (both Japan). The new material, which will reduce car weights by 5%, was developed by putting polypropylene or nylon between two high-tensile steel sheets. It can be used in auto body panels, roofs and many other interior and exterior parts. (Auto News, 2 September 1985, p. 14)

Mitsubishi Gas Chemical (Tokyo, Japan) has developed a stronger elastic plastic that can substitute for metal in auto parts production. Reny features high mechanical strength and modulus in a wide temperature range, high heat distortion temperature, nearly as low thermal expansion rate as metal alloys, low water absorption rate and high dimensional and mechanical stability, and the capability of precision molding and baking finish. Applications include electric and electronic appliances, nails and other building materials. (Auto News, 2 September 1985, p. 17)

Nissan Motor will introduce a car with an all-plastic body in spring 1986, for domestic and export sales. The body is reportedly 10-20% lighter than conventional steel sheet auto bodies. Nissan will use plastics from several major producers, including Toray Industries (Japan) and DuPont (US). (Jpn Econ J, 7 September 1985, p. 12)

Passenger car use of bulk molding compound (BMC) wilkl average 41 lb/car in 1995, with exterior body parts accounting for 73%, vs 15 lb/car with 31% for exterior parts in 1985, according to Market Search. The GM-80, slated for 1990 introduction, is an all-plastic-body car that could use 50 mil lb/yr of sheet molding compound (SMC), mainly for hoods and rear-end panels. By 1990, SMC may reach the production trial phase for floor pans, although Market Search expects only 1.6% SMC penetration of the floor pan market for a 3.6 mil lb market. Bayer (FRG) has introduced plastic hubcaps on some European models, and Mobay is working to introduce them in the US. J. C. Gruet of Salomon Bros. is concerned that consumers may perceive the shift from steel and iron to plastics as reducing product quality, although a recent GM market survey found that the words 'nylon' and 'fibre glass' received favourable responses. (Chem. Week, 23 October 1985, pp. 6-8)

Monsanto has developed thermoplastic elastomers that act like nitrile rubber. The new materials have oil resistance equivalent to most nitrile rubbers, with a slightly higher dry heat service temperature. The material is ideal for applications requiring profiles and shapes, such as seals, gaskets, control cables, hoses, tubes, fuel lines and diaphragms. The material will reduce per-part cost up to 30%, as well as provide close tolerances and flash-free parts. (Matrl Eng, September 1985, p. 13)

Composite drive shaft

Ford Motor Co. (USA) will soon be installing graphite and glass fibre-reinforced plastic drive shafts in its standard-size Econoline vans - under 8,500 pounds. The reinforcing fibres are arranged in layers around the shaft. The main advantages of the composite over steel are improved stiffness and an improvement in noise, vibration and harshness. There is also a sizable weight savings of 9.5 lb over conventional two-piece steel shafts. (Extracted from High-Tech Materials Alert, May 1984, p. 8)

Nylon composite snubs wear

Harris High Technology Polymers, Savannah, GA, USA, has developed a nylon 6/6-polyimide fibre-PTFE composite chain snubber for front wheel drive transmissions that prevents the drive chain from hitting the transmission housing, wearing both parts and possibly causing catastrophic damage. The composite withstands constant contact with the chain, which moves at an average 3,500 ft./min. Six month tests showed no significant wear.

The nylon compound retains its toughness in -30°F weather and 300°F operating temperatures. (Extracted from Plastics World, May 1985, p. 203)

The US automobile industry is increasing its use of plastic body panels. General Motors will use plastic body panels on its MY89 fwd Camaro/Firebird, its MY89 front-drive minivan and certain MY87 Buicks. Ford's Aerostar minivan has a plastic hood and liftgate and the curvaceous nose pieces of the new Sable and Taurus are plastic. Plastics offer lightweight, corrosion-resistance and low tooling costs for relatively low-volume production. It is also less expensive to change the shape of a plastic body panel from year to year. However, it takes longer to mold plastic than to stamp steel, which is important in the manufacturing process. And some plastics require further preparation before they can be placed on a car after the molding process. (Auto News, 30 December 1985, p. 14)

General Motors, extending the use of plastics and plastic composites in passenger cars, is now looking at underbody and chassis areas. Some believe the materials ultimately will be used in floorpans, wheelhousings, side rails, rear rails, the wheels themselves and perhaps even axles of GM's cars. (Extracted from Am Mtl Mkt, 2 December 1985, p. 24)

UK: The Atomic Energy Authority has developed a fiber-reinforced plastic engine block. The original patent was amended, saying that the plastic engine block must have a cylinder liner of sufficient strength to resist bursting. This indicates that the first prototype plastic engine blew up. (New Scientist, 28 March 1985, p. 28)

PEEK grade launched for bearings

ICI has launched a new grade of its high performance polymer Victrex PEEK specially designed for bearing applications. It has been specially formulated to optimise the essential mechanical properties, particularly friction and wear, together with ease of processing. Designed for use in bushes, bearing cages, cams and rings, PEEK KX3 is also being evaluated for under bonnet applications, such as piston scraper rings and skirts.

All bearing materials must have a suitable combination of properties relating to friction, wear and limiting PV (applied pressure x surface velocity). A low coefficient of friction is required, which varies with applied load, velocity and temperature. PEEK KX3 has a lower coefficient of friction than porous bronze with graphite, resin-impregnated carbon and polyimide with graphite.

In plastic bearings, the primary wear mechanism is adhesive wear, characterised by fine particles of polymer being removed from the surface. PEEK KX3 has an extremely low wear factor and extremely high values of limiting PV. (Source: Materials & Design, Vol. 5, Oct./Nov. 1984, p. 202)

Plastic stator for automatic transmission

Nippon Oil Seal Industry Co., Ltd., has succeeded in fabricating a stator, a core component of the automatic transmission, composed of plastic.

The stator, a runner installed between the pump and heater of an automatic transmission, reverses the oil flow from the turbine to the pump to increase torque. It normally turns at 3,000 rpm during operation.

The turning point in development was the use of water-resistant phenolic engineering plastic instead of aluminium on conventional runners, to achieve higher performance.

The phenolic engineering plastic employed in the new runner shows an impact resistance 20 to 30% higher than ordinary phenolic resins and heat resistance up to 380°C.

The practical advantages of the plastic stator include its lightweight property (much lighter than aluminium) and superior formability to metal, which allows the stator to be fabricated into the integral construction. This, in turn, leads to a fewer number of components.

Since plastic offers higher molding accuracy, the weight of the circumferential portion is appreciably uniform in comparison to its aluminium counterparts. The last and the most attractive advantage is the stable price of plastic. (Source: The Japan Industrial & Technological Bulletin, April 1985, p. 30)

C. MARKET TRENDS

World plastics consumption rose in 1984

Consumption of plastics is on the rise in most of the industrialized nations, according to a recent report from the International Plastics Association Directors (IPAD). The figures, covering 1984, showed the largest consumption increases in Canada (16.5 per cent), Japan (14.2 per cent) and the US (11.7 per cent).

With the exception of France and Spain, consumption was up in all European countries. The largest gain was in Denmark, where consumption rose by 7.5 per cent. Federal Republic of Germany consumption was 6.54 million tons for the year, placing it second in world tonnage after the US (17.8 million tons).

The Federal Republic of Germany also led the Europeans in production, with 7.41 million tons and imports of 2.39 million tons. The highest European percentage increase in imports was reported in Italy, 19.6 per cent. This, however, was far below the US increase of 55.1 per cent.

Exports were up for all European countries except Denmark, with Spain showing a 26.4 per cent increase and Italy achieving a 22.2 per cent rise.

All European countries, except France and the Netherlands, report production increases. The highest were in the Federal Republic of Germany (5.3 per cent), Norway (6.8 per cent) and the UK (4.5 per cent). (Source: Modern Plastics Int., December 1985, p. 7)

The Reinforced Plastics/Composites Institute of the Society of the Plastics Industry presented an estimate at its annual meeting and trade show in Atlanta, Ga. in January 1986. In the estimate it is stated that producers of reinforced plastics have another record year in the making, with 1986 shipments expected to rise at about the same rate as they did last year, slightly more than 3 per cent, to about 2.29 billion lb. (Extracted from Chemical Week, 12 February 1986, pp. 17 and 20)

Asia

Asahi Chemical Industry Co. has developed a speciality material designed to replace aluminium in chassis in office automation products. The new material, a composite plastic of denatured polyphenylene ether (PPE), glass fibres and carbon fibres, will cut chassis weight by 70 per cent compared to conventional aluminium chassis, and reduce producton costs by 20 per cent. The new material uses Asahi's styrene-grafted PPE as the base resin. The resin was blended with between 10 and 30 per cent other materials. The composite plastic produced has rigidity comparable to that of metals - at least 60,000 kilograms per square centimeter. It can also withstand heat of up to 80°C. (Extracted from Tokyo Japan Economic Journal, 12 October 1985, p.21)

Chinese polyester plant

Zimmer AG, Federal Republic of Germany, has commissioned part of what is described as the world's largest polyester polymer plant, near Nanjing, People's Republic of China. When the entire facility is completed, it will have a daily capacity of 1,600 metric tons. (Excerpt from Chemical Marketing Reporter, 13 January 1986, p. 3)

The Indonesian synthetic fibre producer PT Susilia Indah Synthetic Fibres Industries (Djakarta) has agreed with Zimmer AG, Federal Republic of Germany, to build a polyester plant in the neighbourhood of Djakarta.

The plant is planned to come into operation in mid-1987.

There will be three parts to the new plant: a continuous polycondensation plant, a staple fibre plant (direct spinning method) and a rapid spinning plant. (Extracted from Textile Horizons, March 1986, p. 6)

A new absorbend blend from Sumitomo

Japan's Sumitomo Chemical expects to produce and market 100 metric tons during the next 12 months of a $10/kg blend of polyvinyl chloride and the company's highly water-absorbent resin. The new blend is molded by extrusion, injection or compression methods - like conventional PVC. Its applications include sealing for architecture and packaging as well as films for agricultural use. The company envisages 1,000 mt/year production at its Osaka works in three years. (Extracted from Chemical Week, 26 June 1985, p. 81)

Indonesian project for plastics to begin with Japanese firm

A $1.6 billion project to produce olefin, rescheduled two years ago for financial reasons, will continue this year through a joint venture with a Japanese company.

The Minister of Industry, Hartarto, said after a meeting with President Suharto that the Asahi Glass Group will join the project to produce the basic materials for plastic-making.

He said the project in Merak, West Java, the second phase of the project begun in Aceh, North Sumatra, is expected to produce 105,000 tons of chlor alkali, 150,000 tons of vinyl chloride monomer and 70,000 tons of poly vinyl chloride annually. Olefin, produced from natural gas, is the raw material used to make the three products. (Source: Chem. Economy & Eng. Review, October 1985, Volume 17, No. 10 (No. 192), p. 39)

USA

Performance plastics demand seen growing at a rapid pace

Demand for performance plastics will grow at an average annual rate of 14.3 per cent through the end of the decade, compared to a 6.6 per cent growth rate for the plastics market as a whole, according to Margolis Marketing & Research Company. Performance plastics will account for 2.7 per cent of total US plastics sales in 1985, and will comprise 3.5 per cent of the market by 1990. These materials are "shaping the future of the plastics industry," Margolis adds.

Sales outlook bright

Examining the sales outlook for individual end uses provides additional evidence of growth potential for performance plastics. Margolis anticipates a rise in US poundage for packaging uses from the 1985 level of 660 million pounds to 1.150 billion pounds per year by the end of the decade.

Automotive uses should consume 750 million pounds by 1990, a 300 million pound rise over the anticipated 1985 total of 450 million pounds. Electronics uses should increase consumption from a predicted 1985 total of 135 million pounds to 250 million pounds by the end of the decade. Consumption for medical uses, described as a small but highly active market, should increase by 15 million pounds from 35 million to 50 million pounds annually during the same period. (Extracted from Chemical Marketing Reporter, 9 September 1985, p. 5)

Organic fibres open up new composites market

New organic fibre reinforcements are expected to expand the markets for both thermoplastic and thermoset composites. Higher impact and tensile strengths are two reasons why.

New types of thermoplastic fibres are joining the ranks of composite reinforcements, providing more options than ever for composite materials.

Allied Corp., Morristown, NJ, USA, has become a supplier of two families of reinforcing fibres, with more in the works. Its first fibre, Compet PET (polyethylene terephthalate) introduced several years ago, is finding use as an impact improver to replace glass in thermoset systems.

Compet PET is claimed to have higher impact strength and produce better surfaces than glass.

In one interesting program, the fibre is being used as a reinforcement in injection molded TMC grill opening panels. Damage and impact resistance are prime incentives to reduce breakage during shipping and installation. More recently, Allied introduced Spectra 1000, a line of ultra-high-strength HDPE fibres.

Spectra 1000 has a 60 per cent higher tensile modulus and a 20 per cent higher tensile strength than Spectra 900, which is listed at 17 million psi tensile modulus and 375,000 psi tensile strength.

Spectra can be used to reinforce practically any resin processed under 250°F; its melting point is 303°F. Typical matrices include epoxy, polyester, vinyl ester, and even polyethylene and polypropylene. Structures have been made using filament winding, pultrusion, wet lay up, and compression molding with autoclave curing. Special laminates made of 100 per cent PE have also been fabricated by compressing fibre, film, or resin together.

Because both materials have temperature limits, Allied is developing other fibres with higher temperature capabilities.

These future fibres include ultra-high molecular weight and ultra-oriented polymers based on polyethylene, polypropylene and PVA (polyvinyl alcohol), as well as rigid rod and flexible coil polymers. Liquid crystal polymers will also eventually be available in fibre form.

PBT: the ultimate fibre?

Being developed as part of the Air Force Ordered Polymers Research Program, "PBT" (poly-paraphenylene benzobisthiazole, not polybutylene terephthalate) fibres possess extreme environmental stability and resistance to high temperatures and oxidation. They also have stiffness comparable to high modulus graphite fibres and strength and tensile properties similar to aramids. On a specific modulus and specific strength basis, PBT has the best combination of properties of any organic fibre.

The polymer does not melt, but will decompose in nitrogen or a nonoxidative environment at temperatures above 1100°F. Consequently, the fibres are suitable for continuous use at temperatures of at least 650°F and in high temperature thermoplastic matrix materials.

PBT fibres have tensile strengths of 600,000 psi and tensile moduli of 45 to 50 million psi. One limitation, however, is its compressive strength: it's about the same as aramid's and 50-75 per cent less than that of graphite. (Extracted from Plastics World, October 1985, pp. 60-62. Article written by Bob Wehrenberg)

Polymer blends

The Society of Plastics Engineers (SPE) and the National Bureau of Standards (NBS) have agreed to develop a data program on polymer blends for the plastics industry.

Under a three-year agreement, the two organizations will develop phase diagrams and important information for controlling blending processes and selecting materials for new products. NBS will be responsible for overall technical guidance, assuring the reliability of data collection, and co-ordinating with other data centres. Information on polymer blends will be published and disseminated through the National Standard Reference Data System and by SPE. National Bureau of Standards, Materials Building, Room B308, Washington, DC 20234, USA. (Extracted from Manufacturing Technology Horizons, Vol. 2, No. 4, July/August 1985)

Plastics data bank

General Electric Plastics has introduced a new data bank system on engineering plastics. ERIS (for Engineering Resins Information System) will provide designers and engineers with up-to-date comparative information on resins produced by General Electric and other manufacturers, which will facilitate application development and material selection for data bank users. The system can also perform cost analysis and economic feasibility studies. (Source: Chemical Week, 30 May 1985, p. 17)

Borg-Warner (USA) builds plastics compounding unit

A leading producer of acrylonitrile-butadiene-styrene (ABS) terpolymer resins plans to build a new thermoplastics compounding facility. Products will be used in telephones, computer and business machine housings, kitchen appliances, refrigerator, auto parts, telecommunications equipment, lawn and garden products and piping. (Extracted from Chemical Week, 23 October 1985, p. 5)

Polaroid (Rosemont, IL, USA), has introduced a new flexible plastic LCD material that is 1/10 the weight and 1/10 the thickness of equivalent glass displays. The lightweight 0.015-thick material can be custom-produced up to 16-in wide and in virtually unlimited lengths for computer displays, readout panels, and other electronic equipment. The material is also shatter-resistant. Thin and flexible, the material can be bent to a 2-in radius without affecting operating characteristics for curved displays in specialized applications. Lower power requirements - about equal to that of glass LCDs - make the new plastic LCDs suitable for battery-powered equipment. (Design News, 11 April 1985, p. 39)

Sales of polymer alloys and blends to double

Sales of specialty polymer blends and alloys will double reaching around $900 million by 1988. The reason is the increasing realization that new polymer alloys for high performance uses are cheaper to develop than new resins. New alloys such as polycarbonate/polybutylene terephthalates and polyethylene/nylons are expected to pick up about 17 per cent of the market share now held by the four major blends - polyphenylene oxide/polystyrene; polypropylene/ethylene-propylene-diene terpolymer; acrylonitrile-butadiene-styrene/polyvinyl chloride; and modified nylons. These account for about 84 per cent of present market tonnage. (C. H. Kline & Co., Inc., 330 Passaic Avenue, Fairfield, NJ 07006, USA) (Extracted from High-Tech Materials Alert, June 1984, p. 7)

GE forecasts engineering plastics growth

Engineer resins demand will rise to 2.5 billion lb in 1990 from 1.5 billion lb in 1984 (8-10 per cent year), according to GE's Plastics Group. Automotive uses will lead the way, growing 10-12 per cent/year, followed by computers and business equipment (9 per cent) and electrical/ electronic (8-10 per cent). New processing methods will spawn new products, such as large, multi-layer coextruded drums, barrels and containers; and blow molded furniture, business equipment housings and automotive parts. (General Electric Co., Plastics Group, Inquiry Handling Service, PR No.154-85, One Plastics Avenue, Pittsfield, MA 01201, USA) (Extracted from High-Tech Materials Alert, October 1985, p. 9)

US materials economy changing

"Whereas metals accounted for almost 50 per cent of the US materials industry 15 years ago, by the turn of the century they may account for less than 40 per cent. Polymers, on the other hand, likely will jump from 15 per cent in 1970 to more than 25 per cent by the year 2000," says Donald C. Slivka, a researcher at Battelle's Columbus Div. Among the new materials with the laragest potential markets that have been studied by Battelle were sialons, liquid crystal polymers and amorphous metals. According to Battelle, Japan now leads the world in commercial advanced ceramics and more efficiently targets their limited R&D funds in two areas of development: advanced materials, such as structural ceramics and optical fibres, and fifth generation computers. (Source: Modern Casting, October 1985, p. 10)

Europe

Metal Box invests

Metal Box is to invest some £2.5 million in a new factory to make plastics packaging at Southport, Merseyside. The factory will be run by its Venesta subsidiary, which is already established in plastic tubes.

To be opened by the end of 1986, the company says the Venesta plant will have the most up-to-date equipment and conditions to satisfy the quality standards demanded by the toiletries, pharmaceuticals and cosmetics markets. The product range of the plant will include decorated mono- and multi-layer plastics tubes; laminate tubes; and injection moulded components, such as closures and syringes. (Source: Manufacturing Chemist, January 1986, p. 7)

Gasket material resists corrosion and cracking

Norton Performance Plastics of Newcastle, Staffordshire, UK, has developed a new thermoplastic plastomer sheet material for gaskets and lining applications, that combines physical properties and chemical resistance not normally found in a single gasketting material. Called Norprene, it shows no sign of weakening or cracking after the equivalent years of exposure to heat and ozone in aging tests and holds to tight dimensional tolerances. These depend on the thickness and range from ±50 um on 0.8 mm material up to ±200 um on 6.4 mm thick sheet. Two Shore A hardness grades are made: 61 and 73.

Other advantages claimed for it include:

- Punchability for fast easy gasket fabrication;
- Cleanliness - no talc needed;
- Ozone resistance for longer life in electrical environments; and,
- A service temperature range from -50° to 134°C.

It is heat sealable and heat bondable for quick gasket repairs, large gasket fabrication, and tank and vessel linings. Thicknesses vary from 1 to 6 mm (1/32 to 1/4 in.). (This article was first published in Engineering Magazine, London)

The French Plastic Omnium group is to build its fourth plastics conversion plant - at Bruay-en-Artois in the North of France. The plant will supply products such as car bumpers, dashboards, typewriter parts etc. (Source: Manufacturing Chemist, January 1986, p. 13)

Polymer coating binder

Vinavil, Italy, and Borregaard, Norway, have jointly developed a new polymer emulsion for use in paper and cardboard coating. The product, called Borvicote ETC 94, has shown promising results in pilot-scale and full-scale trials and is now being introduced commercially. (Source: Pulp and Paper Int., February 1986, p. 59)

The Netherlands' DSM has started production of its new speciality polymer, nylon-4/6, in a 150-metric tons/year pilot plant. The material, called STANYL, has a high melting point and high crystallinity, factors that contribute to its durability and resistance to heat and chemicals. DSM has set its sights on applications in industrial yarn and engineering plastics. In 1975, DSM came up with the process in which the nylon-4/6 is prepared by polymerizing tetramethylenediamine and adipic acid. (Extracted from Chemical Week, 19 February 1986, p. 34)

Africa

Plastics technology

Incorporated in 1979, Kaeler (West Africa) Limited is a privately owned company providing engineering services to plastics companies in English-speaking West African countries. The parent company, Kaeler, is an international organization with the African headquarters in Nairobi, Kenya while Kaeler Engineering and Projects Limited (incorporated in 1982) in Lagos, Nigeria, serves the Economic Community of West African States (ECOWAS) member countries.

The Nigerian company is the only truly indigenous plastics, machinery services company in Nigeria and today holds service contracts and agreements with many companies, mainly Austrian and German. These services include equipping brand new factories with machinery; supplying and installing new machinery; servicing of machinery and rectification of breakdowns; stocking of spare parts for sales and services/repairs. (Extracted from African Technical Review, January 1986, p. 57)

H. PUBLICATIONS

Modern Plastics Encyclopedia 1985-86. In one single volume there are 850 pages of useful information, arranged in four easy-reference sections:

- Textbook with hundreds of articles, tables, charts and schematic drawings - your how-to-do-it of plastics.
- Design guide that helps you obtain optimum results through practical design techniques.
- Engineering data bank to guide your selection of materials and equipment.
- Directory of US suppliers of products and services.

(Modern Plastics International, 14, Avenue D'Ouchy, 1006 Lausanne, Switzerland)

Encyclopedia of Polymer Science and Engineering. Vol. 3, 2nd edition. Herman F. Mark et al. xxiv + 820 pages. John Wiley & Sons Inc., 605 Third Avenue, New York, NY 10016, USA. 1985.

The Plastics World Plastics Directory 1985 published by Plastics World Plastics Directory, Jack Hauck, Editor, 275 Washington Street, Newton, MA 02158, USA.

The American National Standards Institute, New York, NY, has published a two-volume, indexed handbook of all the plastics standards of the International Organization for Standardization (ISO). Covering terminology, sampling, and the determination of properties, the first volume contains some 60 ISO standards. The terminology section lists the principal terms used in the plastics industry in French, English, and Russian and defines them in French and English. The second volume covers standards on plastics materials, including methods of analysis and testing.

Boyden, J., 1976. A study of the innovation process in the plastics additives industry. Unpublished, SM. Thesis, Sloan School of Management, MIT, Cambridge, MA, USA.

Applied Polymer Science. 2nd edition. ACS Symposium Series 285. Roy W. Tess, Gary W. Poehlein, editors. x + 1341 pages. American Chemical Society, 1155-16th St., N.W., Washington, D.C. 20036, USA. 1985.

Polymer Stabilization and Degradation. ACS Symposium Series 280. Peter P. Klemchuk, editor. xi + 446 pages. American Chemical Society, 1155-16th St., N.W., Washington, D.C. 20036, USA. 1985.

Crompton, Thomas Roy. The analysis of plastics. NY: Pergamon, 1984. 445 p. (Pergamon Series in Analytical Chemistry; Volume 8) 84-1060. ISBN 0-08-026251-1. (Provides excellent coverage of the analysis of plastics using chemical and physical methods of analysis)

Technomic Publishing Co., Lancaster, PA, USA, has published a book that provides the full texts of 63 technical reports presented at the Society of Plastics Engineers' National Technical Conference, September 1983, in Detroit, MI. The book, called NATEC '83, supplements the reports with tables, graphs, flow-charts, diagrams, and photographs. The book covers many recent advances in plastics technology, including materials characterization and testing.

Joint Italian-Polish Seminar on Multicomponent Polymeric Systems (1982: Lodz, Poland). Polymer blends: processing, morphology, and properties. Volume 2. Edited by Marian Kryszewski, Andrzej Galeski and Ezio Martuscelli. NY: Plenum, 1984. 287 p. ISBN 0-306-41802-9 (v.2).

A Plastics Additives Handbook by Gächter and Müller includes sections on stabilisers, processing aids, plasticisers, fillers, reinforcements, and colourants for thermoplastics. It has been published by Carl Hanser Verlag, PO Box 86 04 20, D-8000 Munich, Federal Republic of Germany. 1986.

Polymers: The Origins and Growth of a Science by Herbert Morawetz, Wiley. 1985. pp 306.

Mechanical testing of plastics, second edition by S. Turner (Plastics and Rubber Institute, 11 Hobart Place, London SW1 W0HL, England), 1984, pp 240.

This is a completely revised second edition. It includes much new material to meet the demands resulting from the inevitable developments in plastics technology during the interviewing years since the first edition was published in 1973. New chapters cover: anisotropy; fracture toughness, and effects of sample state and "flow geometry".

Plastics controls. Digest Catalog 19 describes plastic products for controlling corrosive or high purity liquids. The four page catalog illustrates, describes and cites available sizes on check valves, foot valves, vacuum breakers and pressure relief valves. Other products included are pressure regulators, gauge guards, flow and level indicators, basket strainers, metering pumps, air and solenoid shut-off valves, diverter valves, flow control valves and ball valves. Plast-O-Matic Valves Inc., Totowa, NJ, USA.

Polyester processing. Bulletin J1A examines properties and processing of PBT thermoplastic polyesters. The 62-pg manual using charts and diagrams advises on material selection, troubleshooting, part and mold design, assembly and finishing, and injection molding and furnishes short- and long-term properties, ratings and agency appprovals. Celanese Engineering Resins, Chatham, NJ, USA.

A brochure (8 pp, color) from the United States Testing Co., Inc., Hoboken, NJ., describes the firm's diversified services and products for testing, inspection, research, engineering, and product development. The firm, now celebrating its 104th anniversary, is active in industries that include power generation, construction, consumer products, food, health care, housing, metal, paper, plastics, chemicals, textiles, and transportation. A second brochure (4 pp, color) focusses on the firm's metallurgical services, which include NDE (RT, UT, MT, and PT).

Rubber and polymer. Six-pg quarterly newsletter titled "Polymer Profiles" supplies polymer and rubber professionals with information about materials testing, evaluation, and characteristics. The application oriented newsletter is available free of charge. Haake Buchler Instruments, Inc., Saddle Brook, NJ. USA.

Replacement of Metals with Plastics is based on data compiled by the Production Engineering Research Association (PERA). In its investigation, the association examined 85 examples of plastics components formerly made in metal. Detailed information on 14 of these, from a wide range of industries has been included in the report. Copies of the report Replacement of Metals with Plastics are available from: NEDO Books, Millbank Tower, Millbank, London, SW1P 4QX, United Kingdom.

Plastic forming. Arrow Plastics' recent introduction of a giant vacuum-forming machine will enable designers to create large one piece components in plastic using sheets up to 10 x 6 1/2 ft. The machine, commissioned from Harwood-Moore Engineering, is capable of forming sheets in all materials including polycarbonate. For a brochure "vacuum-forming, extrusion and pressure forming" contact Arrow Plastics in Kingston-upon-Thames, United Kingdom.

Plastic honeycomb truck bodies. Data bulletin describes the use of Norcore plastic honeycomb, a lightweight core material used in manufacturing door panels for truck bodies. Properties such as resistance to warping and atmospheric changes as well as dimensions and weight are provided. Norfield Corp., Danbury, CT, USA.

High temperature thermoplastics data. High temperature thermoplastics are increasingly used in demanding engineering application for which designers require detailed knowledge of performance over extended periods. Useful data of this type may be found in a new RAPRA (the Rubber and Plastics Research Association, UK) publication - The Durability of High Temperature Thermoplastics.

The report contains the results of a three-year study, which comprised three elements: the determination of long-term durability at elevated temperatures, the examination of mechanical properties and the observation of responses to creep and fatigue loading.

Properties of polysulfone. Twelve-page product data sheet F-42072J describes Udel polysulfone thermoplastic resins. Advantages and characteristics are listed and discussed briefly. Tables of properties are accompanied by charts showing performance characteristics. Forming processes are described, and representative parts are illustrated. Engineering Polymers, Union Carbide Corp., Old Ridgebury Road, Danbury, CT 06817, USA.

Engineering resins. Literature packet familiarizes users with this company's line of engineering plastics. Fold-out provides application suggestions and physical properties of Ertalyte thermoplastic polyester. Fact sheet reviews cast nylon with internal lubricants. Booklet presents basic nylon, polyester, polyacetal and polyethylene shapes offered for machining. Technical manual gives in-depth coverage on the applications of the above resins. Erta Inc., Malvern, PA, USA.

Engineering thermoplastics. Six-pg brochure describes the products, services and facilities of the company's thermoplastics operations. The company produces filled and reinforced compounds, color and additive concentrates, and elastomers. It also furnishes compounding, polymer synthesis and formulation services. Ferro Corp., Cleveland, OH, USA.

Thermoplastic rubber. Materials and design handbook surveys the physical properties of Santoprene rubber under various test conditions and provides results in tabular and graphic format. The compound was developed to serve as an alternative to most conventional thermoset elastomers used in mechanical, automotive, and electrical product applications. Monsanto Polymer Products Co., St. Louis, MO, USA.

MacDermott, Charles P. Selecting thermoplastics for engineering applications. New York: Marcel Dekker, 1984. 171 p. 84-7048. ISBN 0-8247-7099-4. Provides a procedure for selecting the proper engineering plastic for a given application but it is not written for the plastic engineer expert in design, but for anyone with an appreciation for simple technical and mechanical considerations. Of particular interest is the chapter on the ranking of resins, with 14 ranking categories provided (viz, tensile strength, flexural strength, arc resistance, and the like). Author: with McDermott Engineering Plastics Company, Wilmington DE, USA.

Lincoln, Brayton, Kenneth J. Gomes and James F. Braden. Mechanical fastening of plastics; an engineering handbook. NY: Marcel Dekker, 1984. 217 p. (Mechanical Engineering; 26) 83-19013. ISBN 0-8247-7078-1. This much-needed tool provides the background on current developments in plastic-to-plastic, non-permanent assemblies and how fastening methods will be affected by switches to automatic assembly. Excellent illustrative matter.

Included is a useful tradenames and manufacturers appendix as well as one on fastener recommendations. For reference collections used by product designers, manufacturing engineers, and buyers of fastening products. First author is a marketing consultant, and the other two are with Continental/Midland, Park Forest, Illinois, USA.

Waddell, Joseph J. Construction materials ready-reference manual. NY: McGraw-Hill, 1984 (c 1985). 395 p. ISBN 0-07-067649-6. This is a handy field manual providing basic information on the principal materials of construction. Each of the chapters covers one major building material (e.g., concrete; plastics).

PVC plasticol coatings. Description of Arbosol, a plastic protective coating, introduces a 16-page, pocket-size booklet on the material. The brochure consists mainly of tables indicating resistance of the coating to various chemicals. Application areas are discussed briefly. Arbonite Corp., Box 888, Doylestown, PA 18901, USA.

Plastic tubing. Literature package covers plastic tubing for a wide variety of applications. Among products covered are: Flexibraid, a clear reinforced PVC tubing for air tools; Flexithane, a high-pressure polyurethane tubing for fuel and chemical transfer; and Flexitube, a transparent PVC tubing for gasoline and solvents. Plastic hoses for food and beverage handling, ventilation, and other special purposes are also covered. Pressure and temperature ratings, application information, and prices are provided. 20 pages. Flexitube International Corp., Box 292, Willow Grove, PA 19090, USA.

Plastic molding. Twelve-page brochure describes the company's plastic molding operation including mold design and fabrication, production engineering, molding operations, and quality control. Also covered are such secondary operations as conductive and decorative ink transfer printing, hot stamping, decals, ultrasonic welding, drilling, and tapping. Photos illustrate typical molded products as well as production equipment. Texas Instruments, PO Box 10508, M/S 5834, Lubbock, TX 79408, USA.

Dip-molded plastic parts. Six-page fold-out brochure describes and illustrates polyvinyl-chloride parts made by the dip-molding process. Bellows, end caps, sleeves, and flexible ducting members are shown. Details are given on the process, prototype planning, tooling, material properties and characteristics, and design recommendations. Plastic Dip Moldings, a division of Arbonite Corp., Box 949, Doylestown, PA 18901, USA.

Thermoplastic polyester elastomer. Four-page Bulletin 2308-054 presents data on Gaflex, a thermoplastic polyester elastomer that offers the advantages both of a high-quality elastomer and the processibility of a conventional thermoplastic material. Benefits of the material are listed, and a comparison of its characteristics with those of competing materials is provided. A full-page table lists properties. GAF Corp., 140 W.51st St., New York, NY 10020, USA.

Laminated-plastic tubes, rods. Discussions of typical shapes, sizes, lengths, and finishes are included in an 8-page booklet on laminated-plastic rods and tubes. Production of the shapes is illustrated, and tables list material properties and characteristics. Performance characteristics, such as collapsing pressure and burst strength, are given. Synthane-Taylor Corp., an Alco Standard Co., Box 0, Oaks, PA 19456, USA.

Thermoplastic polyesters. Three brochures describe thermoplastic polyester molding compounds. Six-page Bulletin 2308-001R5 covers Gafite compounds. Properties of nine standard grades are tabulated, and typical applications are listed. Bulletin 2308-033, 4 pages, provides similar information on four grades of Gaftuf high-impact PBT compounds. Bulletin 2308-018R4, 6 pages, covers Gafite LW (low-warp) PBT compounds. Chemical Group, Engineering Plastics, GAF Corp., 140 W.51st St., New York, NY 10020, USA.

Thermoplastics for wiring board. Brochure describes thermoplastics for injection molded printed wiring boards. The brochure has information on mold design, chemical resistance, plasticity measurements and a comparison of the properties of injection molded polyethersulfone (PES) and polyetherimide (PEI) and epoxy laminate materials for printed wiring boards. RTP, Winona, MN, USA.

Thermoplastics selector. Two-page selector chart lists mechanical, physical, thermal, and electrical properties of 21 reinforced and unreinforced thermoplastic molding resins and compounds. Also included are general data on resistance to acids and alkalis, optical characteristics, mold-shrinkage values, and tradenames of the materials. UFE Inc., Box 7, Stillwater, MN 55082, USA.

Reinforced thermoplastics. Engineering manual supplies technical data on company's line of reinforced thermoplastics. The 54-pg compilation reports on resin characteristics and lists technical and property data, injection molding recommendations, and design and surface finish considerations. Thermofil Inc., Brighton, MI, USA.

Thermoplastic extrusion. 8-page capabilities brochure describes molding facilities including extrusion activities. Small parts with complex configurations are photographed. Moldex Inc., Putnam, CT, USA.

All-plastic blowers. Corrosion resistant, all-plastic blowers in various wheel/housing combinations are featured in this 12-page pocket brochure. Discussion covers performance advantages, minimal maintenance, blower types and operation, specifications, choice of sizes, materials selection, and more. Nalge Div., Sybron Corp., Box 365, Rochester, NY 14602, USA.

Thermoplastic extrusions. Color brochure explains thermoplastic extrusion capabilities of company's extrusion division, a producer of close-tolerance sheet, strip and profiles. Thermoplastic products include nylon, acetal, ABS, acrylic, polycarbonate, polyethylene, and polyester. Moldex Inc., Park Street, Putnam, CT 06260, USA.

Custom rubber/plastic products. A 16-page brochure describes economical benefits of custom plastic injection, blow molding, and extrusion, and details rubber molding/extrusion, including rubber-to-metal bonding. Quality production and cost-saving steps are discussed, such as design assistance for increased performance, prototyping design ideas, and secondary/finishing operations. Carlisle Geauga Co., 401 South St., Chardon, OH 44024, USA.

Thermoplastic "album". "Commercial Plastics & Supply Corp.'s Greatest Hits" is a circular slide chart for the selection of 21 thermoplastic and eight thermoset plastics, in an LP album format. The "album" provides data on mechanical, thermal, electrical, and physical properties. It also lists trade names and generic categories. Album cover details company's sales and warehouse locations. Commercial Plastics & Supply Corp., 1620 Woodhaven Drive, Cornwells Heights, PA 19020, USA.

Thermoplastic elastomer. Geolast brochure explains how this thermoplastic elastomer resists oil for part-to-part consistency and fast processing in new application areas such as automotive, industrial, and oilfield operations. Pre-compounded makeup, control of dimensional tolerances, choice of process, and cost savings are emphasized. Properties and performance comparisons are illustrated. Monsanto Polymer Products Co., 260 Springside Dr., Akron, OH 44313, USA.

Plastics for Electronics. Martin T. Goosey, editor. ix + 380 pages. Elsevier Science Publishing Co., 52 Vanderbilt Ave., New York, NY 10017, USA. 1985.

Conductive thermoplastics. 20-pg booklet profiles line of electrically conductive thermoplastics. They offer varying degrees of conductivity and solve problems of electrostatic discharge and electromagnetic and radio frequency interference. Wilson-Fiberfil International, Evansville, IN, USA.

Ring-Opening Polymerization - Kinetics, Mechanisms, and Synthesis. James E. McGrath, Editor, Virginia Polytechnic Institute and State University. Examines the industrial use of polymers obtained by ring-opening polymerization. Explores applications ranging from water-soluble materials to high-performance elastomers. Includes discussions of catalysis via not only the traditional anionic, cationic, and co-ordinator methods, but also related UV initiated reactions and novel free radical mechanisms. ACS Symposium Series No. 286. 386 pages. 1985. Clothbound. LC 85-13552. ISBN 0-8412-0926. (American Chemical Society, Distribution Dept. 84, 1155 Sixteenth Street, NW, Washington, DC 20036, USA)

High-temperature composites. Brochure on high-temperature reinforced thermoplastic materials discusses materials in five resin families: polysulfone, polyphenylene sulfide, polyethersulfone, polyetherimide, and polyetheretherketone. Charts and graphs compare the differences in amorphous and crystalline materials and provide complete data on physical properties of these materials. 6 pages. RTP Co., Box 439, Winona, MN, USA.

Thermoplastic polyesters. Booklet compares physical, thermal, and flammability characteristics of competitive thermoplastic polyesters from various suppliers. Resin types include unreinforced, general-purpose, high-impact, glass-reinforced, flame-retardant, and mineral filled. Volumetric cost-analysis on a year-to-year basis from 1977 completes the package. Mobay Chemical Corp., Pittsburgh, PA, USA.

Prevex structural foam. Four-color brochure discusses structural foam grades of Prevex polymers and their properties. Includes text and color photos and a chart listing thickness, tensile strength, tensile modulus, flexural yield strength, flexural modulus, dynatup impact, flame class rating, and mold shrinkage. Borg-Warner Chemicals Inc., Parkersburg, WV, USA.

Fire Safety Through Use of Flame Retarded Polymers. Technomic Publishing Co., Inc., 851 New Holland Ave., Box 3535, Lancaster, PA 17604, USA. 717-291-5609. 1985. 200 pp. Publication consists of 13 reports originally presented at a March 1985 conference on fire-resistant polymeric materials.

Plastics finishing. Brochure entitled "Mass Finishing of Plastics" explains dry-process mass finishing technology. The technology allows large lots of parts made from a wide variety of plastics materials to be finished economically and uniformly with various surface effects. Pegco Process Laboratories, Bartlett, NH, USA.

I. FUTURE MEETINGS - PAST EVENTS

The University of Technology, Loughborough, U.K. organized in 1985 an Education Service of the Plastics Industry (ESPI) for the benefit of people who are interested in a career in plastics.

The State of Ohio, USA, in 1985, provided money to establish six Advanced Technology Application Centres. Two of the centres will be concerned with materials technology, particularly a polymer and welding institute.

Meetings on plastics in 1986 and 1987

January

8-9 "Diffusion in Polymers: Mechanisms and Applications" (City Conference Centre, London)

13-16 "Conference on viscoelasticity of polymeric liquids" (Institut de Mécanique de Grenoble, France)

22-23 "Polymer Characterization by Thermal Analysis" (Seminar and workshop, Brunel University, Uxbridge, Middlesex, U.K.)

26-30 "Plastics & Plastics Machinery Exhibition" (Jeddah, Saudi Arabia)

27-31 "World of Composites" (41st Annual Reinforced Plastics/Composites Conference, Atlanta Hilton, Atlanta, GA, USA)

28-30 "Mixing in the Manufacture and Processing of Plastics" (Kongresshaus, Baden-Baden, FRG)

February

18-20 "FoodPlas Conference" (Orlando, Florida, USA)

26-28 "Advanced Materials - New Opportunities for Chemicals" (Pittsburg, PA, USA) - Advanced composites, speciality metal alloys, high-performance polymers and ceramics were discussed

March

5-9 "Plastics, Printing and Packaging Exhibition" (Bangkok, Thailand)

12-15 "Rubberplas '86" (World Trade Centre, Singapore)

17-21 "Plastex" (International Plastics and Rubber Fair, Zagreb, Yugoslavia)

20-21 "The Plastics Industry - Positioning for Growth" (New York, USA)

20-21 "Joint Conference of the Fire Retardant Chemicals Association and the Society of the Plastics Industry" (Washington, D.C., USA)

Kuala Lumpur, Malaysia held in March an "International Exhibition of Chemical and Plastics Technology.

April

1-4 "Annual Meeting of the Polymer Processing Society" (Montreal, Canada)

5-8 "Workshop on Flow-Deformation and Molecular Reorganization in Polymers with Crystalline and Liquid Crystalline" (Montreal, Canada)

8-10 "International Conference on Fibre Reinforced Composites" (Liverpool, U.K.)

21-26 "Europlastique '86" (Paris, France)

May

12-13 "Coatings for Plastics" (Paint Research Association, Harrogate, Yorkshire, U.K.)

13-15 "Prochem '86" (Trade and Conference Fair, Rotterdam, Netherlands)

June

17-19 "Plas-Tec '86" (Exhibition and Conference dedicated to high-technology applications in the plastic industry. Atlantic City Convention Centre, Atlantic City, N.J., USA)

July

7-11 "Polymer supported reaction in organic chemistry" (Jerusalem, Israel)

21-23 "Conference on Biological Engineered Polymers" (Churchill College, Cambridge, U.K.)

21-25 "2nd International Symposium on Acoustic Emission from Reinforced Composites" - Montreal (Society of the Plastics Industry, New York, N.Y., USA)

August

18-21 "2nd SPSJ International Polymer Conference" (Tokyo, Japan)

September

23-25 "Analytical Methods in Quality Control of Plastics Materials and Moulded Parts" (Seminar, Wuerzburg, FRG)

24-25 "The Mould - Central Part of the Polymer Processing System" (Zagreb, Yugoslavia)

October

27-29 "6th International Conference on Instrumentation & Automation in the Paper, Rubber, Plastics & Polymerization Industries" (Akron, Ohio, USA)

November

4-5 "Modern Plastics International Magazine, Lausanne, Switzerland, presents a unique K'86 Pre-Show Conference, in Duesseldorf, FRG, which is followed by

6-13 "10th International Plastics and Rubber Trade Fair" (Duesseldorf, FRG)

13-15 "LidPE, vidPE and Polar Polyethylene Markets and Economics" (Zurich, Switzerland)

21-26 "Japanplas '86" (11th Plastics and Rubber Fair, Tokyo, Japan)

23-26 "13th Biennial Polymer Symposium" (Florida, USA)

26-27 "Heat Transference in Plastic Compounding" (Baden-Baden, FRG)

So far we are aware of 3 meetings on plastics to be held in 1987:

January: "Reinforced Plastics/Composites, 41st Annual Conference", Atlanta, Ga., USA

March: "Gulf Plastics '87" (Dubai International Trade Centre)

September: The Institute of Physics, London, U.K. is planning a conference and exhibition on NEW MATERIALS AND APPLICATIONS.

Meetings on plastics held in 1984 and 1985

June 1984: "Electrical Conduction in Polymers" (London, U.K.)

September 1984: The Plastics and Rubber Institute, U.K. sponsored the International Adhesion Conference at the University of Nottingham.

September 1985: "Saudi Basi Industries Corp. made its formal European debut at the International Plastics and Rubber Exhibition in Birmingham, U.K."

and

"Conference on Manufacturing Technology for Designing Plastic Parts" (Michigan, USA)

October 1985: "Polymer Symposium" (Penn State, University Park, PA, USA)

"Joint Japan/US Polymer Symposium"

"First Brazilian International Plastics Show" in Rio de Janeiro, Brazil

"New Materials Exhibition '85" (Sunshine City, Ikebukuro, Tokyo, Japan)

November 1985: "Speciality Plastics Conference" (Zurich, Switzerland)

"2nd Arab Gulf Petrochemicals, Chemicals, Plastics and Processing Industries Expo and Convention" (Al-Khobar, Saudi Arabia)

"Nouveaux polymeres, nouvelles combinaisons, nouvelles proprietes" (Societe Francaise des Ingenieurs Plasticiens, Paris, France)

"3rd Medical Plastics Conference" (Illinois, USA)

"International Plastics Conference and Exhibition" (Colombia, Sri Lanka)

Table 1: Classification of the materials constituting fibre reinforced plastic

Materials constituting the plastic	Kind of material	Materials utilized
Matrix resins	Thermosetting resin	Unsaturated polyester resin, epoxy resin, phenol resin, vinyl ester resin, etc.
	Thermoplastic resins	Polyamide (nylon), polycarbonate, ABS resin
Reinforcing materials	Inorganic fibre	Glass fibre (GF), carbon fibre (CF), asbestos fibre
	Organic fibre	Vinylon fibre, acrylic fibre, polyamide
	Other kinds of reinforcing materials	Metal fibre, whiskers, composite fibre
Other kinds of materials	Filler, setting agent, promotional agent, parting agent	

Table 2: Resins used in the production of heat-resisting fibre-reinforced thermal plastic

Material Character-istics / Resin Names	Tensile strength (kgf/cm^2)	Elongation rate before tensile break (%)	Temperature of heat transformation (°C)
Polyamide-imide	2000	5.4	271
Polyether ether ketone	2150	3	300
Polyamide/bis-marimide resins	1000		320

Table 3: Kinds of glass fibre reinforced plastic

Materials	Form of glass as a reinforcing material	Resins	Contents of glass (weight per cent)
Hand lay-up mold	chopped mat, cloth	polyester polyester	30-40 45-55
Spray up molding	roving	polyester	30-40
Perform, mat, matched die molding	roving, chopped mat	polyester	30-50
Premix molding, including BMC	roving, chopped strand	polyester epoxy, melamine, phenol, silicone	10-45
Prepreg molding	cloth		50-65
SMC molding	roving, chopped mat	polyester	29-?6
Drawing molding	roving	polyester epoxy	50-80
Filament winding molding	roving	polyester epoxy	60-90

("Technology for Molding and Processing of Fibre Reinforced Plastic" by Hiroshi Murayama, Kogyo Chosa Kai, p. 106)

Table 4: Application fields of carbon fibre reinforced plastic (CFRP) composite material

Features	Application fields
Light weight High elasticity rate High mechanical strength	Space and aircraft, automobiles, textile industry machinery, fly-wheels, centrifugal separators, sports and leisure articles (golf clubs, angling rods, tennis rackets), tools and equipment
Dimension stability	Space industry application (transponder antenna, etc.), micrometer, timing belt, ruler
Vibration absorber	Audio equipment, musical instruments, driving shafts in automobiles, leaf springs, leisure equipment and facilities
Electrical characteristics (heat generation, prevention of static electricity)	Brewing tank, plastic molding facility, static electricity prevention material, motor brush, electrode
Corrosion resisting capability	Chemical plant: collector electrode
Wear-resisting ability	Bearing, brush material
X-ray penetrability	X-ray photographic plate cassette, medical X-ray bed
Heat-resisting capability	Rocket parts, turbine engine parts, brake disc for aircraft

("Material Technology-17, Composite Materials" by Masao Doyama, The University of Tokyo Publishing House)

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.

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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 6. 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.