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IN MATERIALS TECHNOLOGY

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Materials Optimization – the key to Product Profitability

The unprecendented rise in materials costs in the past year has focussed attention on materials selection as the key to the economic design and manufacturing of engineering products. However, selecting the right material can be difficult, particularly in times of supply shortages. The optimum material for a given product at a given time is a compromise of price, performance and availability and a systematic approach is needed to identify which materials, after appropriate processing, satisfactorily achieve this compromise. This article describes a method which has recently been developed.

Specify design function

The starting point for the selection and specification of a material for a product is a definition by the designer of the functions the product must perform. The techniques for this procedure are well established and generally result in a simple statement of a basic function, plus secondary functions. If we take the example of a connecting rod between a piston and a crankshaft then the basic function is to "provide linkage" and a secondary function may be to "reduce weight". These functions which the product must fulfil have to be translated into materials properties such as strength, stiffness, corrosion and wear resistance, formability etc. To assist the selection procedure these requirements should be weighted in order of importance.

Strength, stiffness, and toughness

For most engineering components space limitations will limit section size and this in turn will determine the minimum strength which a candidate material must have. For large components, strength will generally be more important than stiffness and vice versa for small components. When selecting a material on the basis of strength, it should be remembered that all components contain flaws, and these may limit the load bearing properties of the material depending on the nature of the flaws and the toughness of the material. Where a number of materials meet the minimum requirements of strength, material choice can be assisted by comparison of cost per unit strength $\frac{\text{(cost per unit weight x density)}}{\text{tensile strength}}$

Corrosion resistance

The requirement of corrosion resistance will vary widely between different components; for example, small pits which may be unimportant in large sectioned components would be catastrophic in pressurized piping. Selection of materials for corrosion resistance depends on a knowledge of the in-service environment of the product and susceptibility of materials to different forms of corrosion and degradation. Some types of corrosion, such as crevice corrosion, are avoidable by correct design; others can be prevented by surface coatings (paints, plastics, sprayed or electrodeposited metals etc.). When a material is being used in an unfamiliar environment, a testing programme will often be necessary to ensure the suitability of that material. ▷

Wear resistance

As with corrosion, the wear resistance requirements will be very different for different components. For certain parts such as gears, piston rings and liners a small amount of running-in wear is desirable to produce an even distribution of stresses over the mating surfaces. However, the wear debris should be removed or absorbed so that local stress concentrations are not developed and the total wear should not be such as to exceed the designed dimensional tolerances. In other components longer term wear problems such as cavitation erosion in impellers and propellers, progressive pitting fatigue in rolling element bearings and gears, or erosion and abrasive wear in process plant and earth moving equipment must be delayed as long as possible, ideally to just beyond the intended service life or at least until replacement or maintenance is convenient and economic.

The selection of materials for wear resistance requires analysis of the expected tribological conditions on the product in terms of loads, relative speeds, lubrication possibilities etc. As with corrosion resistance it may be possible to obtain the necessary wear resistance by the combination of a cheap readily processable base material plus surface coating. A wide range of these coatings is available to improve running-in characteristics and longer term wear resistance.

Manufacturing route

The selection of manufacturing route will depend on such factors as component size, shape, section thickness, desired tolerances and surface finish and perhaps most important of all the number to be produced. Design and production can often impose conflicting requirements on a material and the successful reduction in the cost of such products will depend on achieving the right compromise.

Materials Costs

The total or in-position cost of a material will be the sum of several factors as is illustrated in Figure 1. An important point to be made is that cost factors are not independent. The material of a component is the common link throughout the design/manufacture/performance sequence. For example cost saved on a poorly specified, inexpensive, as-bought material may be more than lost through in-house processing difficulties and vice versa.

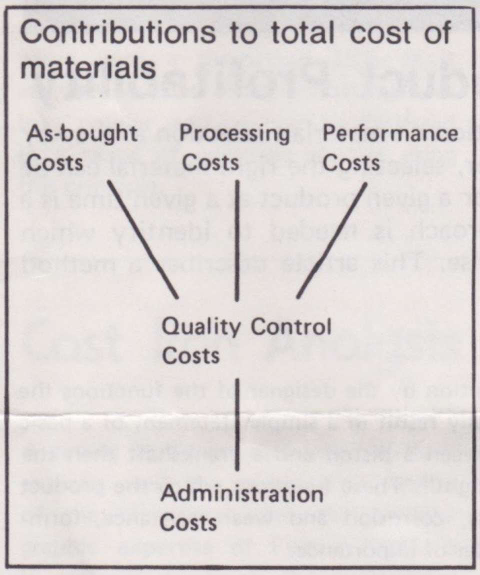


Figure 1.

In many instances, after comparing the required materials characteristics with commercially available materials and making a rough estimate of the costs, several material/manufacturing routes will be possible and more formal evaluation of each possibility is required. For each candidate material the required characteristic, strength, stiffness, corrosion and wear resistance etc. is given a relative merit rating M_i relative to the other materials (the best material is rated as 100 and the others scaled proportionally.) For strength and stiffness this is a simple matter as numerical values can be used to calculate the relative merit rating. For corrosion and wear resistance a quantitative approach will rarely be possible and relative merit rating will have to be derived from test data and any accumulated product experience. In the case of methods of manufacture, ideally the relative merit rating should be the total cost of manufacture by each route. However, at the product planning stage accurate estimates are extremely difficult and certain cost items such as the machinability of a material may at this stage be left as a required material characteristic M_i, and candidate materials rated according to machinability on the basis of published data or preferably shop floor experience. When the relative merit of each characteristic for each material and the absolute or relative cost of the manufacturing routes have been established, the candidate materials can be compared by calculating

$$\Sigma_i \frac{W_i M_i}{C}$$

for i = 1 to i = n where n is the number of required materials characteristics, M_i is the relative merit rating for the material for the ith characteristic, W_i is the relative importance of that characteristic to the product function and C is the total cost of material/manufacturing route.

The material/manufacturing route with the highest value of

$$\Sigma_i \frac{W_i M_i}{C}$$

can now be considered in more detail to decide precisely which grade of plastic or alloy type should be selected or which modifications of composition and processing are practical to maximise the value of this term.

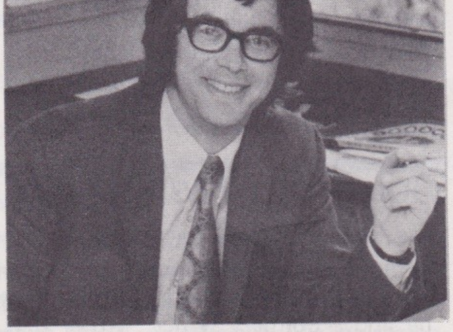
Which is the Optimum Material/Process for your Products?

To help you answer this question Fulmer has prepared a Materials Optimizer which within its four volumes contains comparative information on metals, plastics, ceramics and related component manufacturing processes.

The Fulmer Materials Optimizer is published in loose leaf form, to facilitate updating. New or replacement sheets will be sent out twice a year to subscribers. A brochure giving a complete list of the contents of the Optimizer plus specimen pages is available on request.

Prospective purchasers are welcome to visit Fulmer and examine the Optimizer. Alternatively there will be other opportunities to evaluate the information system at demonstration seminars which will be held in various locations throughout the U.K. Details of these will be announced in the press. If you would like to visit Fulmer or be included on the invitation list at the demonstration seminar in your area please contact Dr. N. A. Waterman.

Author



Dr. N.A. Waterman, Editor and Project Manager of Materials Optimizer. □

Dr. Philipp Gross

1899–1974

The death in London on May 20th of Dr. Philipp Gross brought to an end a long scientific career of great distinction. Born in Austria in 1899, Gross saw military service in Serbia in the First World War and after 1918 pursued academic studies, eventually holding professorships of physical chemistry at Vienna and Istanbul. After a visit to England in the summer of 1939 to attend a scientific conference, he remained in this country for the rest of his life. After a period at Bristol University, he became a technical adviser on problems that had arisen in a war-time magnesium plant, and so began a study of metallurgical processes that continued actively up to the time of his death. His work during the Second World War also aroused his interest in the chemistry of aluminium, and led to his invention of a new technique for producing that metal—the Gross process—with which his name will always be associated.

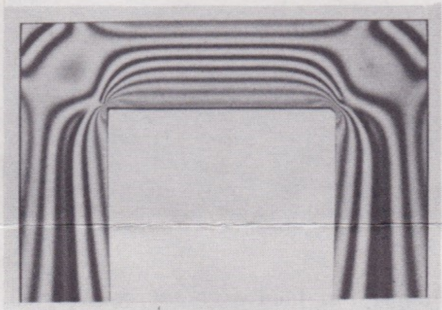
Working at the Fulmer Research Institute from 1946 onwards, he was responsible for research into many aspects of metal extraction and metallurgical thermochemistry: always characterized by boldness and originality in conception, these studies rank among the most notable contributions to chemical research made in this country since the last war. Apart from his important innovation in aluminium technology, however, his real achievement lay in having introduced into the techniques of extraction metallurgy an element of sophistication previously lacking, and the influence of which is still not spent. The University of Vienna made him an honorary professor in 1968, and recently awarded him its Gold Medal.

His many friends also knew him as a deep student of art history. He had a particular knowledge of Byzantine art, and, with his late wife Maria, had formed a discriminating collection of icons and other paintings.

The above obituary notice written by D.L. Levi, appeared in The Times on 29th May 1974. □

Photo-elastic Stress Analysis

With the complexity of design and loading conditions found in modern structures, excessive stress concentrations produced in members under operating loads can lead to catastrophic failure. Often these stresses are developed by abrupt variations in the component cross section producing stresses which are not always possible to calculate.



Mechanical systems can be usefully studied by exploiting the photo-elastic properties of plastics. Scaled transparent models are examined in polarised light and the stress distributions deduced from the optical effects observed. The photograph shows stress concentration fringes at the inside corners of a frame subjected to transverse loads on the vertical legs. Comparison of the stress patterns near to the two internal corners shows the marked effect of even slight radiusing.

Photo-elastic methods of experimental stress analysis provide an accurate and direct approach for solving many industrial design problems, particularly stress concentrations due to holes, notches and discontinuities in structural and machine elements. Other problems investigated by photo-elasticity range from the shape of dams to the profile of screwthreads. Currently at Fulmer the photo-elastic technique is being used to study stresses in new constructional materials.

For more information on this and other aspects of the Fulmer Stress Analysis Service, please contact N.A. Waterman, or L.W. Turner. □

Direct Induction – heating of powder

The features of heat penetration, speed and cleanliness associated with induction heating are beneficial in the heating of metal powder compacts, with their high surface area and poor thermal conductivity. Applications include:

- dewaxing and rapid sintering of shaped powder metallurgy components,
- rapid heating of powder preforms prior to consolidation;
- heat treatment of porous components.

Fulmer is to undertake a study of the technical and metallurgical factors which determine the success of the direct induction heating process.

These include:- generator frequency, size and shape variables, material and compact characteristics, temperature distributions and dimensional changes, progress of alloying and particle surface reactions.

For further information contact F.G. Wilson. □

Analysis keeps ahead

As a result of concern expressed in the Press recently about possible health hazards from vinyl chloride monomer, Yarsley Testing Laboratories have been dealing with enquiries to determine very small amounts of this monomer in P.V.C. compounds.

The technique now used is called 'head space' sampling and uses gas chromatography as the sensing instrument. This has been used by YTL for many years for determinations of volatile substances, such as residual solvents, in plastic films for electrical and food-packaging applications.

Previously vinyl chloride monomer was not thought to be present in P.V.C. compounds in any significant amount, probably because very searching analysis is necessary to detect and measure the parts per million amounts which are now considered to be important.

Head-space sampling is replacing solution methods of liquid injection into a gas chromatograph and, by eliminating difficulties of solvent purity and viscosity effects, higher sensitivities can be achieved.

The method has been refined particularly for P.V.C. in resin or moulded form, but other polymers and plastics may have similar traces of volatile substances and the same type of analysis can be applied.

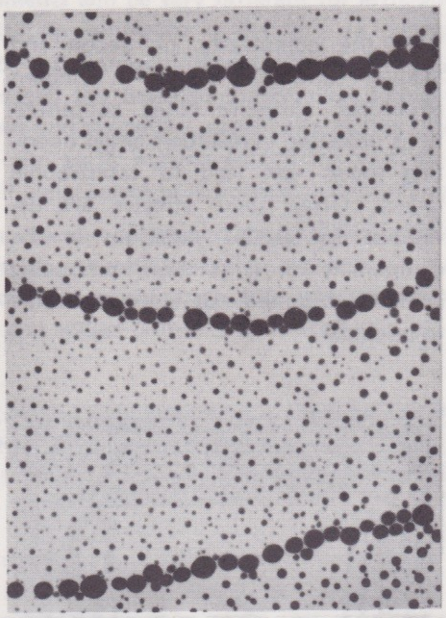
Enquiries are invited to H. Westaway at our Ashtead Laboratories. □

A New Process for Metal Filled Plastics

The precipitation of metal from a polymeric metallo-organic compound is the basis of a new project which Fulmer is launching as a multi-client study. The programme is expected to lead to a new class of materials having novel mechanical, optical, electrical and magnetic properties.

Currently, metal filled plastics are made by the direct mixing together of the constituent materials. Restriction on the lower limit of metal particle size is governed by the commercially available powders which commonly range between 1 – 100μm.

The photo-micrograph shows a precipitate of lead particles of sub-micron sizes within a matrix of a common plastic prepared by the new process. Initially the metal was attached at regular and frequent intervals to the polymer chain, but a method has been found to detach individual lead ions from the molecule to form an aggregation of lead particles well below 1μm and typically 10nm (100A). Furthermore the metal is uniformly dispersed, consistent with virtually complete precipitation, about 9 volume % as compared with a theoretical 10%. It is anticipated that other metals such as iron, copper, and gold can be dispersed in a range of common plastics using this principle.



x50K

Fulmer has filed a patent covering all aspects of the method and is negotiating a multi-client project with several industrial firms. The programme will include an in-depth evaluation of the production and properties of this class of material.

A preliminary meeting has been held with some industrial organisations and proposals prepared. At the end of September, a further meeting will be held to finalise the Project details. Organisations interested in knowing more of the proposed project are invited to contact Dr. V.G. Rivlin. □

Cast Iron Analysis

A recent study on cast iron mill rolls exploits well the quantitative facility of the Quantimet and the metallographic expertise of Fulmer Staff. It is essential to know the proportions of graphite, primary carbide and retained austenite in the production of sound rolls. Reliable determination of the phases present enables assessment of the heat treatment variables such as tempering, furnace temperature and solution treatment to be established.

Cast iron samples are first polished to reveal the graphite particles which are then automatically counted and sized by the Quantimet. The proportion of carbide present is obtained by etching the sample to darken the matrix, and revealing the carbide as a white unetched phase. When both retained austenite and carbide are present the sample is first etched to darken the matrix and the total austenite and carbide determined. By a further etch treatment the carbide is also darkened, leaving the austenite as a light phase.

Further information about the Quantimet Service from D. Bagley. □

Scandinavian Office

In order to strengthen further our contacts in Scandinavia and to develop new business, Fulmer has now opened an office in Stockholm. The address is P.O. Box 75, S-18211 Danderyd, Sweden Tel. 08-7557773. Companies and organisations in Denmark, Sweden, Finland, and Norway are invited to contact this office for further information about Fulmer. □

Appointment

Mr. John A. Howie B.Sc., F.P.I., F. Inst.R., F.I.W.M., has been appointed a Market Development Consultant to assist in the activities of Fulmer in the engineering industry. He has an unusually wide knowledge of industry ranging from cables and electronics, to industrial refrigeration and plastics pipework, both in the U.K. and abroad.

Currently he is a member of the NEDO Plastics Steering Committee and, until recently, served on the Councils of both RAPRA and PERA. □

Fulmer Seminars

SEM, EDAX, XRF, LEED, XPS, AES, ISS and Ion Probe.

These instruments will form the basis of a 3-day Seminar on Surface Analysis on 11th, 12th, and 13th December. Contact D. Nicholas for more information.

RPD Teaching Seminars

PROJECT PLANNING AND CONTROL FOR RESEARCH MANAGERS

Two day Residential Courses E.1055/12 17th and 18th October. E.1055/13 14th and 15th November.

Further information from D.G.S. Davies.

CPAC Seminars

1. Protection of Aluminium and its alloys against corrosion. 24th September.
2. Paint v Powder Coating Systems. 22nd October.
3. Corrosion Prevention in Process Plant – 19th November.

Further information from H. Silman.

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