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PLASTICS AND RUBBER RESEARCH AT WALTHAM ABBEY

Explosives Research and Development Department

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FOR many years shrouded in secrecy, the Explosives Research and Development Establishment at Waltham Abbey opened its doors to industry this summer and showed some of the extensive work carried out on plastics and rubber materials. Much of this is aimed at service requirements, and polymeric binder for rocket fuels is a typical area of investigation. However, a great deal of activity is more general in nature and the improved end products will be equally useful to the armed forces and to industry as a whole. One topical class of materials is represented by the high strength fibre reinforced composites, and ERDE have achieved a leading position as producers of silicon carbide and silicon nitride whiskers. At the same time they have invented a process for aligning these and other fibres in resin matrices in order to achieve the maximum benefits from their strength.

Whisker and Composite Production

Considerable progress has been made in the area of fibre composites, and much of the work is complementary to that of the RAE at Farnborough, who have been so successful in developing carbon fibres. The following materials have been included among many other lines of research at ERDE :

Fibre-Filled Thermoplastics. The preferred fibre for this class is asbestos, due to its low cost and high modulus. Best performance is obtained if the fibres are graded to give a high ratio of length to diameter. Results of incorporating asbestos into thermoplastics are given in Table I. These are for fibres without special surface treatment, but research is seeking to impart even better properties by employing techniques similar to those which currently enable glass fibres to stick to thermoplastics.

Oriented Reinforced Thermosets. For this class of materials asbestos is again popular with ERDE. Some results obtained with fibres about 2 mm. long are given in Table II.

These properties are only possible when the fibres have been aligned in the matrix.

Aligning Processes. Previous methods of incorporating small fibres and whiskers into resins were crude and difficult to automate. Recently two wet processes have been brought to semi-commercial development by ERDE. Firstly, the fibres are cleaned and sieved into lengths. Then in the **Alginate Process,** (a) a viscous slurry of the asbestos in ammonium alginate solution is extruded into HCl solution. Flow action in the extruder die orients the fibres, while contact with the HCl gels the carrier to alginic acid. The cord can then be used to make oriented mats which are heated to burn off the alginic acid and are then ready for impregnation with resin. Disadvantages are:

(1) Because the alignment is 100 per cent, the mats lack mechanical strength and can only be handled with difficulty before resin impregnation.

(2) The alginate compound is a total loss.

For the **Glycerol Process,** (b) the fibres are again made into a viscous mass but this time with glycerol. The compound passes through an extruding slit which oscillates over a slowly moving endless mesh belt. The glycerol is removed by suction, and the sheet passes on to a wash and dry section, before being wound up as a roll. The whiskers are aligned by the extrusion and the motion of the bed. Advantages of this patented process are:

TABLE I

Plastic	*Specific gravity*	*Tensile strength, psi*	*Flexural modulus, 10^6 psi*	*Specific modulus, 10^6 psi*
Polypropylene ...	0·91	4,400	0·15	0·17
+40 per cent asbestos	1·29	6,800	0·77	0·60
Toughened polystyrene	1·04	3,500	0·27	0·26
+30 per cent asbestos	1·27	9,500	1·60	1·26
ABS	1·04	5,300	0·22	0·21
+30 per cent asbestos	1·27	13,900	1·13	0·89
Nylon 6	1·14	11,000	0·34	0·30
+30 per cent asbestos	1·38	19,000	1·09	0·79

TABLE II

Fibre in composite	*Fibre content vol %*	*Specific gravity*	*Flexural strength, psi*	*Tensile modulus, 10^6 psi*
Asbestos (alginate) ...	61	1·99	116,000	14·4
Asbestos (aligned sheet)	54	1·95	103,000	11·0
Chopped carbon ...	64	1·65	90,000	22·5
Silicon nitride whiskers	39	1·87	111,000	13·0
Silicon carbide whiskers	39	1·9	220,000	25

(concluded overleaf)

(1) Alignment is about 95 per cent, but the slight misalignment gives the mats sufficient strength to be handled easily.

(2) Almost all the glycerol is recovered.

The mat or sheet is then built up, resin added, and the article press moulded at about 1000 psi.

A number of composite materials have been made on these principles. Among these are the silicon carbide composites which do not yet approach their theoretical performance and should eventually prove most interesting.

Metal reinforcement can also be carried out, although with rather more difficulty than with plastics. Aluminium alloys show great promise when reinforced with silicon carbide, the material being largely isotropic, whereas plastics composites tend to be unidirectional in their strength. One such metal composite selected for further development is based on the Concorde aluminium alloy, RR58.

Materials Testing

Apart from the above investigations into new materials, much work is being carried out into the physical and chemical behaviour of polymeric materials under a variety of conditions ranging from hostile accelerated ageing under dynamic stress to long term outdoor weathering.

Engineering applications of plastics materials and composites can be more efficient if the long term properties are known accurately. The apparatus shown in Fig. 1 measures Flexural Stress Relaxation. The test beam is loaded flexurally and allowed to recover. Relaxation modulus is plotted against relaxation time. Four materials have been investigated, as indicated in Fig. 2.

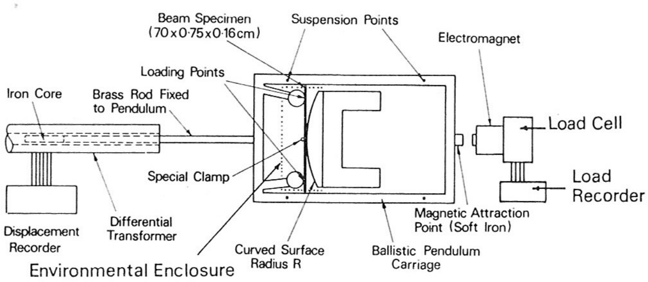

Fig. 1. Flexural stress relaxation apparatus

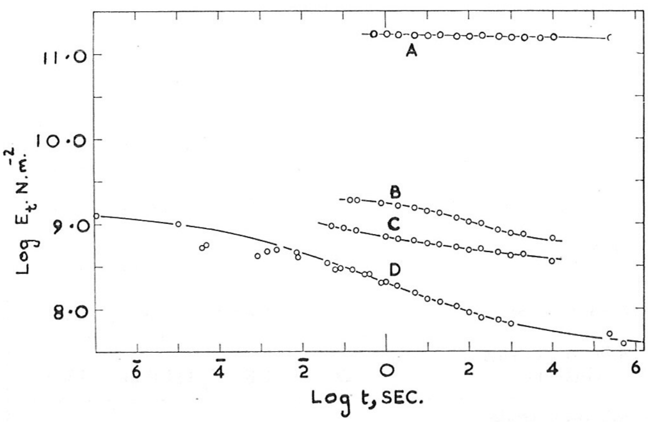

Fig. 2. Stress relaxation stiffness for beams of non-metals

A RAE Carbon Fibre Composite

B Polypropylene

C PTFE

D Low Density Polyethylene

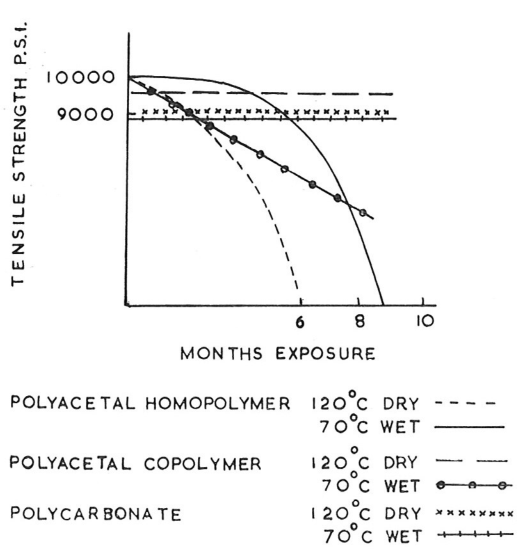

Fig. 3. Selection of materials tested for long term breakdown in polymers

A further apparatus developed by the investigators is the Sliding Pendulum device which measures the energy absorbed when a specimen is deformed, and may have application as a quality control test. A third device measures flexural creep by bending a beam.

One very useful parameter obtained from these experiments is E_∞, modulus at infinite time, which measures minimum stiffness and can be used as a design limit to give maximum mechanical life.

General Polymer Development and Applications

Work of the Polymer Development and Applications Group is divided into three main sections, rubber proofed fabrics, evaluation of new rubbers, thermoplastics and thermosets, and special investigations and trouble shooting. In the first and third groups fall the problems of strength in adhesive or stitched joints such as those on Dracone flexible barges, large pillow tanks, or Hovercraft skirts. One team has worked out in collaboration with the University of Strathclyde a method of accurately calculating the strength of an overlap joint in rubberised fabrics, and from this approach has been able to improve existing design. Trouble shooting has led to an improved conductive rubber which prevents static electricity build up on solid tyres, and work is progressing well on fibre reinforced thermoplastics with the accent on asbestos.

Associated with this group is the Polymer Chemistry Section, where long term breakdown in polymers through a variety of causes is examined. Close liaison is kept with the Joint Tropical Research Unit, Queensland, and results from the Australian sites correlated with those from the UK. Fig. 3 is taken from the very wide selection of materials tested and shows some rather surprising differences in performance. The unit has an excellently equipped laboratory with such advanced instruments as an NMR machine, automatic viscometer, osmometer, etc.

These few examples illustrate the extremely wide scope of the polymeric activities undertaken at ERDE. Since this Ministry of Technology establishment is paid for from industrial and private taxation it is obviously desirable that industry as a whole should benefit from it to the maximum extent, and the recent increase in accessibility should be welcomed. The work being done at ERDE must continue to be integrated with that of other national research establishments so that duplication is avoided. In this way the UK polymer industry and its customers will be assured of a leading position in the international scene where competition from abroad will increase in the future; one has only to look at the Rolls-Royce–Lockheed engine contract to see how this actually does happen in practice and to realise that some Government departments make good use of public money.