news and views

How to have your fibrous cake and eat it

FIBRE reinforced plastic composites combine the high strength and modulus of strong fibres with a high work of fracture (toughness). Two letters in this issue describe methods of improving the work of fracture without significantly reducing the strength.

A high work of fracture allows one to use a material secure in the knowledge that in a structure it will show signs of failure long before it actually breaks. It might be thought that the combination of brittle fibres with a brittle resin would produce a brittle composite. The toughness of these materials is the result of energy-absorbing processes at the weak fibre–resin interface during fracture. The most important of these processes is probably the work of pulling out broken fibres after the crack tip has passed, leaving a whiskery fracture surface. This work decreases as the interfacial bond strength is increased because the crack then cuts more cleanly through the fibres leaving shorter pull-outs. On the other hand, to weaken the bond strength also weakens the composite.

A new approach demonstrated by Atkins (page 116) is to produce alternating strong and weak bonded regions on the fibres. The strong zones maintain the composite strength, the weak regions allow lengths of fibres to debond, break and pull out so toughening the material. He uses boron fibre–epoxy resin composites with bands of silicone grease or polyurethane varnish on the fibres to produce weak bonding while, he claims, the uncoated regions will be strongly bonded. The varnish-coated composite shows a remarkable increase in toughness at coating levels above 50% and the strength is maintained up to 90% coating. For the silicone grease the toughness increase is much more modest. The results all fit Atkins's analyses for strength and toughness. The increase in toughness with varnish coating is from 50 kJ m^{-2} with no coating to 200 kJ m^{-2} at 90% coating with no strength loss. Conventional surface treatments would only be expected to produce variations of a few per cent about the lower value without also changing the strength.

What is not clear yet is whether the varnish and grease both do act as weak coatings relative to uncoated fibres. The difference in the results for the two coatings suggests that the full explanation is more complicated. The system is obviously of commercial interest but also could be scientifically productive since our knowledge of this interface (like that of most interfaces between different phases or materials) is very limited. Carbon fibre reinforced plastics may be expected to show similar improvements but it is interesting to note that the silane treatments used on glass fibres are known often to form beads on the glass surface rather than smooth coatings.

A second approach to toughening is described by Gordon and Jeronimidis (page 116), who have considered the arrangement of cellulose fibrillae in the cell walls of timber. Gordon has remarked before that trees seem to have opted for a high work of fracture rather than maximum strength or modulus. Reasoning that this might be associated with the helical arrangement of the fibrils around the cell wall, Gordon and Jeronimidis now show that under stress the helical tube collapses and the structure undergoes extensive deformation before breaking. They report that model composites constructed on the same basis show very high work of fracture values (400 kJ m^{-2}). They report no strength or modulus measurements but theoretically the decrease in modulus should be small and presumably strength will behave similarly.

Many other approaches to improving the low toughness of boron and carbon fibre reinforced composites are also being studied. But there is a long way to go before materials of the complexity of bone, ligament or timber are developed and before the material is designed concurrently with the structure in which it will be used.

P. D. CALVERT

Micrometeoroid density from lunar craters

THE Solar System not only contains planets, moons, asteroids, comets, meteorites and meteorids but also a plethora of smaller particles known as micrometeoroids. These are so small that they do not burn out when they enter the Earth's atmosphere but are gently retarded by momentum transfer to the air molecules and slowly float to the ground. All particles with masses less than 10^{-6}g fall into this category, the Earth's surface collecting 3,000 tonnes of this material each year, enough to form a layer of dust 1 cm deep during the Earth's lifetime. The physical properties of these particles can only be measured indirectly. Experiments flown on satellites and space probes measure mass, velocity and sometimes orbit. Rockets can be used to collect the particles in the atmosphere but only pick up the micrometeoroids after they have been retarded by the atmosphere and contaminated by meteoric dust ablated from larger meteoroids. Studies of zodiacal light lead to values for the particles' dielectric constant and shape.

A new and exciting way of studying the properties of micrometeoroids is by investigating the surfaces of the small glassy spherules found in the samples of lunar soil returned to Earth by the Apollo and Luna space programmes. These spherules are formed like raindrops during the solidification of the molten ejecta blown out from the lunar surface during impact cratering and volcanic events. They then lie on the surface, exposed to space and to the micrometeoroid influx. As the Moon has no retarding atmosphere the micrometeoroids strike the spherules at velocities between 5 and 20 km s^{-1} and produce small craters.

Spherules have around 5,000 microcraters (diameters a few μm) per square centimetre of their exposed surface, the numbers of craters increasing with decreasing crater diameter. A typical microcrater is shown in Fig. 1.

Smith, Adams and Khan have concluded—in a communication on page 101 of this issue of *Nature*—that by comparing the ratio of crater depth to diameter in microcraters on the surface of lunar spherules with this ratio for laboratory-produced impact craters in glasses they can estimate the densities of micrometeoroids, the percent-