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CARBON FIBRES

TENSILE TESTING

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CARBON FIBRES 2

tensile testing

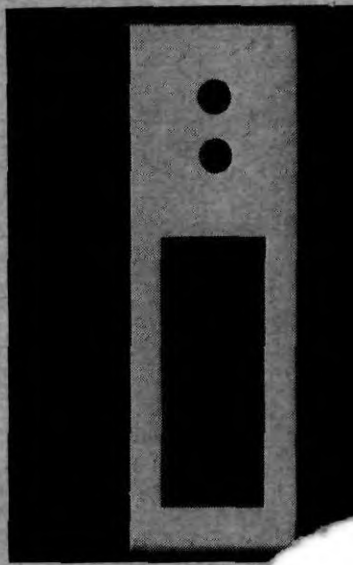


Fig. 2. For tensile test
diameter carbon fibres
attached to a card. T
across holes punched in

GLASS FIBRE reinforced composites have pushed material performance into areas not attainable with metals or alloys, particularly in terms of strength/weight ratios, corrosion resistance and adaptability to fabrication. But the merits of these materials are now being overshadowed by the outstanding stiffness displayed by composites reinforced with carbon fibres. Such filaments can display a stiffness five times that of glass fibre and a carbon fibre resin composite can have the same elastic modulus as steel but weigh only one-fifth as much as the metal.

Such outstanding properties gave Rolls-Royce a trump card in selling its RB 211 turbofan engine to American aircraft constructors, for if the fan had not been made from Rolls-Royce Hyfil carbon fibre composite the power unit would have been heavier, noiser and less efficient.

The RB 211 engine is the first item to go into production anywhere in the world incorporating carbon fibre composite and it reflects the lead that Britain holds at present in this new technology, an advantage which it is hoped to keep through the development of production processes capable of exploiting the vast commercial potential awaiting carbon fibre materials. Applications are by no means confined to aerospace but also cover fields as widely differing as pressure vessels, bearings for heavy rolling mills, all forms of plastics tooling, deep-sea submersibles, artificial limbs, unbreakable glassware, car bodies, yacht hulls and similar structures.

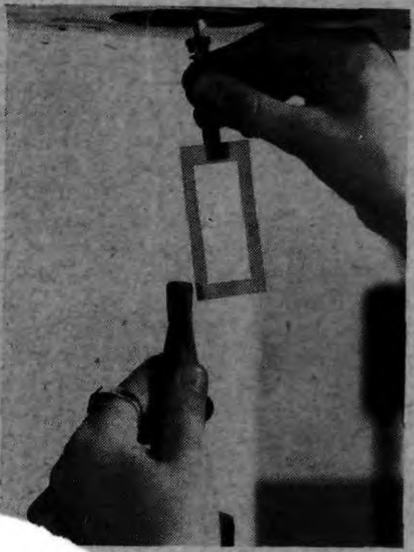
Fig. 1. Both a table and floor version of the Instron universal materials tester are used in the laboratories of Morganite Research and Development Ltd.

Apart from Rolls-Royce, production of carbon fibres and composites is being further developed by two industrial firms who have been licensed by the National Research Development Corporation to exploit the original processing studies carried out at RAE, Farnborough. One of these is Morganite Research and Development Ltd., Battersea, London (part of the Morgan Crucible organisation), who are producing carbon fibres under the name of Modmor Type 1 (high modulus) and Modmor Type 2 (high strength). Their respective minimum tensile strengths are 200 000 and 350 000 lbf/in² and when made up into epoxy resin composites they can display interlaminar shear strengths (ILSS) of at least 7 000 and 10 000 lbf/in² respectively.

Service Performance

In view of the steadily growing world interest in the use of carbon fibres it is not surprising to find a veil drawn over future production techniques being explored. This does not apply to some of the methods used for determining the service performance of carbon fibres and composites. Indeed, the techniques are those generally applicable to other materials, with the proviso that physical characteristics must be extremely accurately assessed because the properties of synthetics can be readily modified, thus making reliable quantitative measurements essential. To this end, it is necessary to obtain precise stress-strain curves produced by variations in load, temperature and other parameters over rigidly-controlled periods of time.

To meet these requirements, Morganite use universal materials testing instruments made by Instron Ltd. of High Wycombe, Bucks, the most advanced and versatile testing system of their type in the world. The two units used in the laboratories are shown in Fig. 1, the one on the left being a bench model with a maximum load capacity of 100 kg, the other a floor type with a maximum capacity of 10 000 kg. Both are sensitive enough to record accurately loads as low as one gramme.



Part of the card with the ...es is cut off before mount- ...emaining rectangle in the ...ster.

Fig. 4. Once clamped in the tester, the vertical sides of the rectangular card are cut off leaving the fibre in a lightly tensional position.

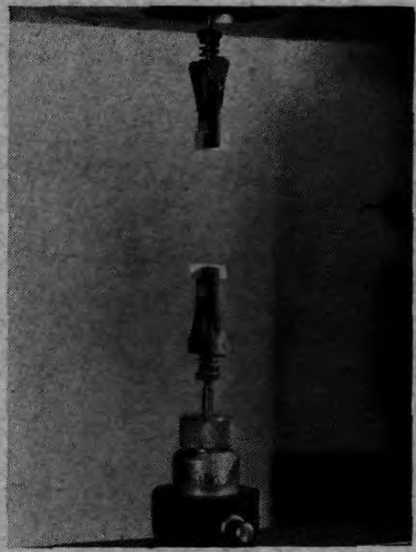


Fig. 5. Only the horizontal top and bottom portions to which the fibre is actually attached remain and are clamped in the tester.

The main components of each instrument are the test frame and the control console which between them house the inertialess electronic weighing system and associated circuits, together with a drive system which ensures a specimen is always deformed at a constant rate, regardless of the load being applied. On the table version this is achieved by a synchronous drive, while a positional servo-system is used on floor models. In all models two lead screws in the two vertical members of the test frame actuate a moving crosshead, to which a specimen is attached by a suitable jaw or fixture. With a similar clamping device, the other end of the specimen is attached either to the top fixed crosshead of the test frame (for tensile tests), or the base of the frame (for compression testing). Through suitable interchangeable load cells located in the top or base of the frame, information about load is signalled by foil strain gauges in the cell via circuits to a built-in strip chart recorder in the control console. The recorder's chart is driven synchronously with respect to the moving crosshead; chart speed can be changed in relation to that of the cross-head, so that portions of the stress-strain curve being recorded are reduced or magnified as required.

Mounting the Specimen

When it comes to tensile testing single carbon fibres it must be remembered they are only some 8 microns in diameter and this presents problems when clamping them in the test frame of the tensile tester. To solve the difficulties the clamps used are the type specially designed by Instron to ensure that specimen breakage at the jaws is minimised by carefully limiting clamping pressure. At the same time, the jaw layout permits self-alignment between a pair of clamps to compensate for any small variations there may be in specimen thickness. The second important precaution taken is to mount each specimen carbon fibre on a card as shown in Fig. 2. The fibre can be seen passing vertically across the rectangular hole in the card and the two round holes at the bottom.

To mount the fibre for testing the part of the card with the two round holes is cut off and this portion is used to establish microscopically the fibre diameter, while the rectangular frame left is positioned in the clamps of the tensile tester (Fig. 3). After ensuring that the part of the card through which the fibre passes is within the jaw area of the clamps, the vertical sides of the rectangle are cut off (Fig. 4) leaving the fibre in a lightly tensioned position and ready for test. (Fig. 5.)

The technique is used for process control purposes by batch sampling fibres taken from existing production to check their conformity to specifications. The method is also used in R and D studies for establishing Young's modulus and breaking strength values.

Testing Adhesion Strength

Another interesting use of the Instrom testers is for what might be described as short beam shear tests on carbon fibre laminated resin composites to measure adhesion strength between laminations and shear strength of laminates. Fig. 6 shows the fixtures positioned in a tester with the top half attached to the fixed top member of the test frame and the bottom half located on the moving crosshead.

The edge of an 0·1 in thick specimen composite can be seen located in the top half where it forms a platform between two fixed metal pins on which it rests. The two halves of the fixture have then been aligned so that another pin, midway between the lower pins, can be located over the top surfaces of the specimen. This pin is held firmly in the bottom half of the fixture, but passes freely through the top half so that any effort to pull the two halves apart is impeded by the specimen. As the centres between all three pins are so closely spaced, tensile loading of the fixture creates a shearing force on the specimen and since the specimen edges are not clamped, adhesion failure can also occur. The point at which it commences will be recorded on the strip chart in terms of load and extension and a failure of this type has arisen on the specimen pictured, as can be seen by the opening of the laminations at the edge.

Accessories

Electronic testing systems of this type are playing an important role in both research and development of technologies for producing fibres and composites, not just because of their high accuracy, but also through the ability to extend the versatility of the basic instrument by adding a wide variety of accessories. A typical one is an automatic chart control system by which an operator can programme the motion of the chart with respect to crosshead motion in several ways. The strip chart can, for instance, be made to reverse in step with crosshead reversal so that a cyclic stress-strain curve is plotted by the recorder. The chart can also be switched to stop at the same time as the crosshead, or to move forward at a selected speed, thus

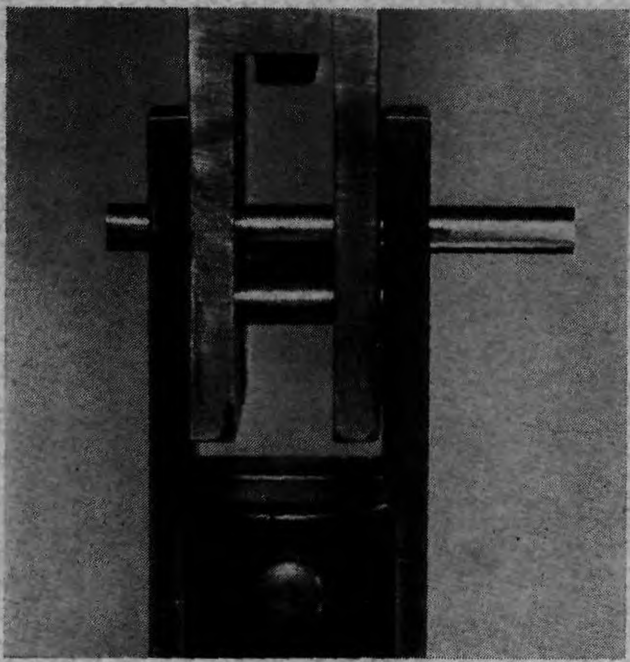


Fig. 6. This fixture is used for adhesion and shear testing laminated composites of carbon fibres. As the two halves of the fixture move apart, the top pin is forced against the specimen resting on the two lower pins, shearing the specimen.

creating a time base for relaxation curves. By recording sev tests starting from the same point on a chart they bec superimposed for immediate comparison as a family of cur

The need for repetitive testing for quality control of pro tion is also catered for by the availability of a special con which can be linked to the tester to provide a simple nume display of significant load and extension values. The versat of the QC console can be extended by facilities permit semi-automatic test sequences, and the linking of an autom programmed print-out unit through which a comme electric printing machine can sequence-record repetitive results.

As a means of curtailing the considerable amount of t that can be consumed in processing data obtained in manner, particularly if many repetitive tests are invol Instron have developed an incremental data system. sophisticated refinement releases skilled investigators for o work by automatically characterising in digital form the l strain data obtained and recording it for immediate comp processing, record storage or conversion to other data form

From the foregoing it will be seen that electronic ma testing systems of this type can not only produce phys from which such characteristics as mouldability, mac and formability of a synthetic product can be deter they can also be tailored into an automated system f control of production quality.