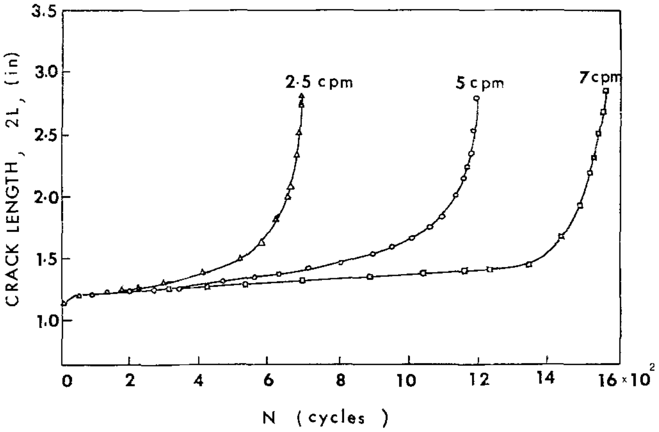

Figure 3 Effect of cycling frequency on crack growth of PMMA in 99% carbon tetrachloride.

to know the fracture toughness at which unstable cracking ensues. This value may be calculated from the load and critical length measurements. At room conditions, PMMA has a fracture toughness of about 0.56 kg cm^{-1}, whereas in the presence of these two organic solvents, a higher fracture toughness of 0.865 kg cm^{-1} was measured.

Acknowledgement

The author wishes to express his gratitude to Professor Charles Gurney for his helpful suggestions and encouragement during the course of this work which was performed at the University of Hong Kong.

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An LVDT extensometer for tensile studies of composite materials

The subject of this note is an economical, adaptable, high sensitivity extensometer system based on d.c./d.c. linear variable differential transformer (LVDT) transducers. These operate in the same way as a normal LVDT but the oscillator and detector circuits are built into the transducer body. This particular unit is designed to monitor the faces of glass-fibre-reinforced cement specimens, with nominal cross-section dimensions of 50 mm × 10 mm, in a uniaxial tensile test; it has also been used successfully for other similar materials and specimen sizes.

Lawley and Meakin [1] also employed a LVDT element in their extensometer for the study of microplasticity in metals. In a review of the alternative measuring methods for their application they rejected the use of resistance gauges, optical gauges and capacitance gauges mainly because of their limited range (maximum strain 1×10^{-2}). The capacitance gauge described by Roberts and Brown [2] Bacon and Cowling [3] and recently by Bonfield *et al.* [4] have a higher strain sensitivity (5×10^{-7}) than gauges based on LVDT elements (2×10^{-6}) but because they are concentric to the specimen, they average out any strains resulting from non-axial stresses. Non-axial stresses are introduced if the specimen is slightly curved initially or if it is anisotropic for any reason. The requirements for measuring bars and sheets of fibre reinforced cement composite are as follows: (1) a high initial sensitivity, better than a strain of 1×10^{-5}, to allow study of the elastic behaviour; (2) a range up to a strain of 1×10^{-1} to enable monitoring of the pseudo-ductile behaviour resulting initially from multiple cracking and progressing ultimately to fibre pull-out and failure; (3) ability to monitor separately the two sides of a sheet or bar so that the effects of anisotropy resulting from maldistribution of fibre or variations in matrix quality from side to side may be studied. To suit particular experimental requirements it may be of help to either average the signals from the two sides or to take the difference. The differential signal can be of particular value for detecting the onset of microcracking in composites with brittle matrices.

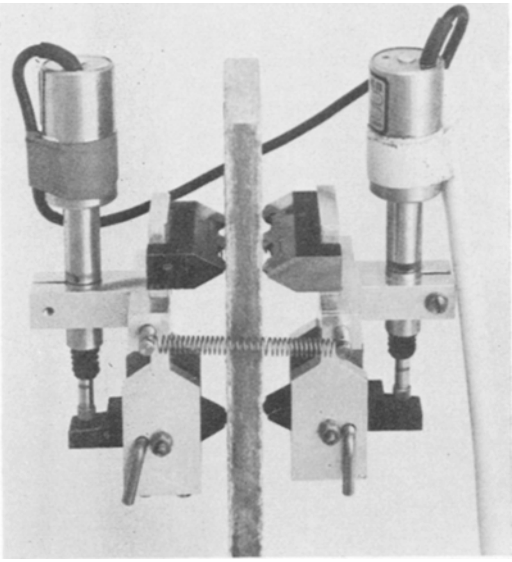

Figure 1 Extensometer mounted on a specimen.

The basic unit is made up of two identical mounting assemblies held together with springs to enable both sides of the specimen to be monitored. These assemblies were designed and built to the required specification by the design section and engineering workshop of the Building Research Establishment. Fig. 1 is a photograph of the two assemblies mounted onto a specimen with the transducers in place. The mounting assemblies consist of a pair of fixed knife edge points spaced about 30 mm apart and a single pivoted knife edge, having an anvil at the other end, on which the transducer bears. The hardened steel knife edges are held by a duralumin frame. A central fixed knife edge, set back from the other two, allows narrow specimens to be measured. Since the transducers are spring loaded to the "out" position they follow the anvil automatically. The gauge length is set, by the distance between the fixed and moving knife edges, at 50 mm when the zero-locating pin is in position. The mechanical ratio is set by the position of the pivot point at 1:1.

The d.c./d.c. LVDT transducer produces an infinitely variable d.c. output signal of one polarity for an extension and of the opposite polarity for a contraction from a central null position. Using the type specified* at a supply voltage of 15 V d.c. the sensitivity is of the order of 1 V mm^{-1} which is equivalent to 50 μV per microstrain for a 50 mm gauge length. Typical multirange chart recorders have a 10 mV full scale deflection range enabling strains of the order of 2 microstrain to be detected at a fsd of 200 microstrain; in practice the resolution is limited only by the stability of the power supply and the thermal drift of the units.

Fig. 2 shows a power supply, passive network calibration and zero offset circuit developed for

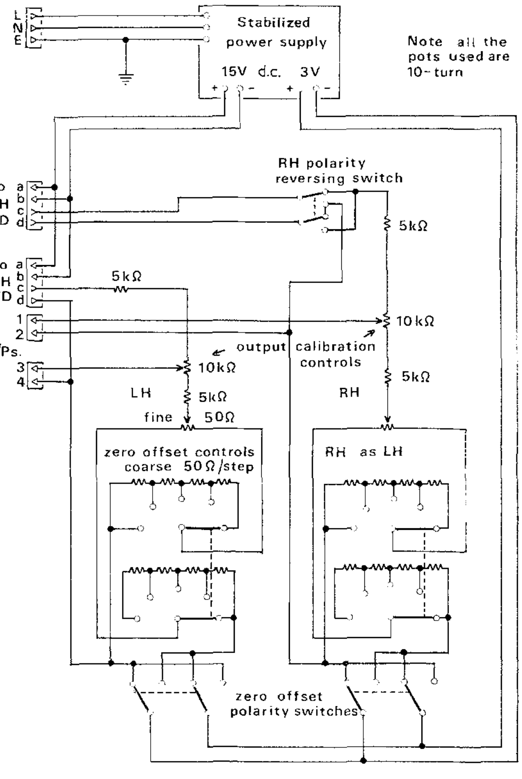

Figure 2 Power supply and calibration circuit.

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*Sangamo-Weston controls type ER 0.10 in.

this application*. This circuit offers the following features:

1. Regulated power supply to drive the transducers (from points a and b) and the zero offset circuit†.
2. A passive voltage divider network across the input, points c and d, with an input impedance of 20 kΩ and a "gain" variable between 0.25 and 0.75.
3. A zero offset facility which allows the zero to be set electrically and which can be adjusted so that the output is positive going (or vice versa) for the whole range of the transducer.
4. In the switch positions shown in Fig. 2, two independent outputs, RH and LH, are available at the output sockets 1, 2 and 3, 4 respectively for monitoring the two sides of a specimen independently.
5. Alternatively a differential signal may be obtained by using sockets 1 and 3.
6. A sum signal may be obtained by reversing the RH with respect to the LH channel and again using sockets 1 and 3. The mean is obviously obtained by halving this signal.
7. The output may be fed directly to most standard, high input-impedance, multirange millivolt recorders giving effectively an instrument with a full scale of between 200 and 10^5 microstrain. Alternatively the signals may be fed to an analogue to digital logging system whereupon the digital record on paper or magnetic tape can be analysed directly by a computer.

In conclusion, the system has been found to meet all the performance criteria set out in the first two paragraphs of this letter for static testing of composite materials. For dynamic testing, the inertia of the moving parts would restrict it to frequencies of less than 5 Hz. The system is cheaper by a factor of about three and more versatile than a commercially available extensometer‡ of similar range and sensitivity provided appropriate recording equipment is already available.

Acknowledgement

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*Alternative units are available from Sangamo-Weston Controls Ltd.

‡Coutant type KD 100/18/6.

†Supplied by Instron Ltd.

Extended basal plane shear in pyrolytic graphite at 3035 K

Pyrolytic graphite in the as-deposited state has a structure of basal plane layers which are parallel to but randomly rotated from neighbouring layers [1], a structure called "turbostratic." When heated above 2800 K, or heated and deformed parallel to the deposition plane (roughly parallel to the basal planes), this structure "graphitizes," i.e. crystal perfection within crystallites increases and unit cell height decreases; simultaneously, misorientations between crystallites decrease and preferred orientation increases. The combined processes have been likened to straightening a stack of wrinkled sheets [2].

For deformation at temperatures near 3000 K, the dewrinkling process occupies about the first 10% strain [3, 4], and has been called "first stage" deformation [3-6]. When 10% strain is reached, then, the basal planes are relatively well aligned with the tensile axis and further deformation occurs by different mechanisms [3, 4, 6, 7]. It would be of interest, however, to examine the process of shear on the basal planes after dewrinkling is complete. This communication