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Enhancement of the fatigue life of PMMA through prior crazing

In a previous paper [1], it was demonstrated that the low-stress-level fatigue life of polycarbonate could be increased several fold by prior tensile deformation. In that case, the material was loaded to 90 to 95% of its macroscopic yield stress prior to fatigue in equal tension/compression, constant load amplitude testing. The fatigue life at low cyclic stress levels was increased by nearly an order of magnitude, relative to virgin material. The life enhancement was attributed to the relative "softness" [2, 3], at low stress levels, of large crazes. At high cyclic stress levels, where the crazed material is highly extended, the fatigue life was decreased by tensile treatment. The present communication extends these observations to another glassy polymer, PMMA.

The material used was Plexiglas® "G" sheet. The specimen shape is as described in [1]. Specimen blanks 0.63 cm × 2.5 cm × 20.3 cm were milled to produce a non-uniform gauge section bounded by 7.6 cm circular arcs. The minimum width was 0.63 cm. In order to standardize the material, all specimens were air-annealed at 120° C before testing. Pre-crazed specimens were prepared by drawing to 335 kg, 95% of the macroscopic yield load (352 kg), after annealing and prior to cyclic testing.

The fatigue frequency used was the highest that could be used without significantly heating the specimen. Fig. 1 shows the surface temperature (determined using a thermocouple attached with epoxy glue to the specimen surface) against cycling time at seven different frequencies. A frequency of 10 Hz causes thermal failure (see, for example, [4]), whereas 5 Hz causes only an asymptotic 10° C

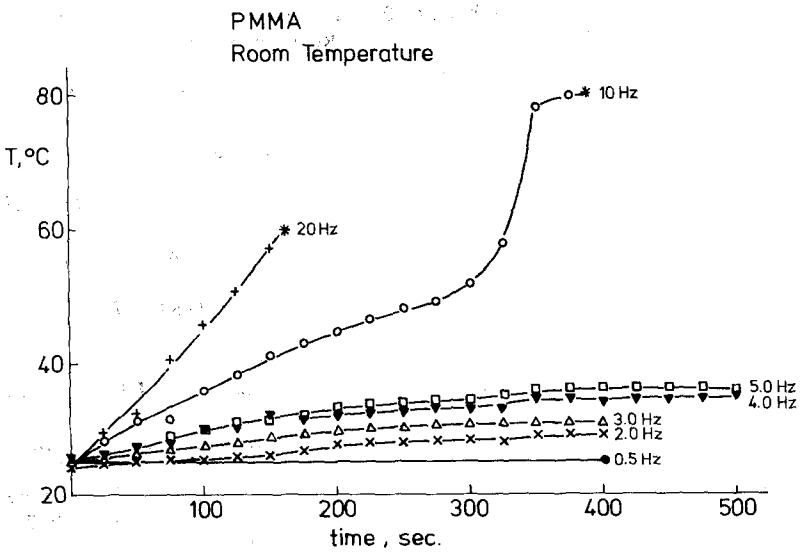

Figure 1 Temperature versus cycling time during equal tension/compression amplitude loading at ± 24.8 × 10^5 kg m^{-2}.

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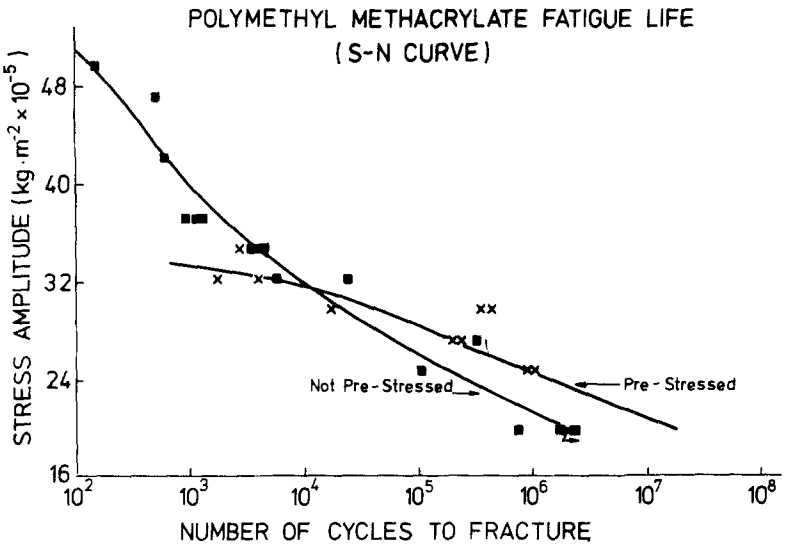

Figure 2 S–N curves for "virgin" (■) and pre-stressed (×) PMMA.

temperature rise. A frequency of 4.5 Hz was used for all specimens in this communication.

Fig. 2 shows S–N curves for "virgin" and pre-stressed PMMA. These results are qualitatively similar to those obtained for polycarbonate. As the stress level is decreased, the fatigue life of the pre-stressed material becomes progressively larger than that of the virgin PMMA. At the lowest stress used, 19.85 kg m^{-2}, the pre-stressed specimen showed no sign of damage at 1 922 600 cycles and was removed from the tester. At high stress levels, pre-stressed specimens failed earlier than the virgin material, a behaviour again that was observed for polycarbonate. The similarity of the results for these two polymers indicates that the effect of pre-stressing on the fatigue life depends on the nature of the induced crazes and not directly on the properties of the matrix polymer.

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