FATIGUE LIFE TESTS ON COMPOSITE CERAMIC

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INTRODUCTION

The stress-strain behaviour of the composite ceramics shows different characteristics compared to those of conventional bulk ceramics. This means that the usual strength criteria and design methods cannot be applied to this material. However these behavioural features, such as nonlinear stress-strain dependence and high ductility, offer great potential, and therefore test method development is necessary to allow the properties to be accurately measured and the objective use of this potential for component design.

EXPERIMENTAL PROCEDURE AND RESULTS

The objective of this investigation was the development of testing methods and evaluation of material characteristics determining the nonlinear stress-strain and strength behaviour under cyclic load, and the modelling this behaviour for use in component design. For these purposes cyclic push-pull tests on SiC/SiC fibre reinforced ceramic specimens were performed. The test loads were strain controlled with corresponding strain limits for equal stress amplitude in tension and compression during the first cycle of the test. Due to the well known difficulties of the executing tensile tests on ceramic specimens, it was decided to carry out the first test series at room temperature.

The results show a significant difference in the specimen stiffness for tension and compression (see Fig. 1). At the same time the tensile half of the load cycle causes a progressive softening with saturation at increased number of cycles. The stress-life dependence is linear in log-log system (Fig. 2). By analysis of structure under fracture conditions (Fig. 3) it is evident that the damage development within the composite structure is very slow and the uniformly distributed matrix cracks are retarded. It is interesting that under "yield" conditions, when matrix cracks develop, the life of a specimen can be very high, reaching values of a few hundred thousand cycles.

A typical fracture surface micrograph is shown in Fig. 4 and indicates that considerable fibre pull-out occurs.

SUMMARY AND CONCLUSIONS

A test method for the investigation of mechanical behaviour of fibre reinforced ceramics has been developed. The method is used to test a ceramic composite based on SiC-Fibre and SiC-Matrix. The strain controlled cyclic push-pull tests on plane specimens and the

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subsequent fractographic investigations have lead to the following important results:

1. From strain controlled fatigue tests (similar to the tests for metallic materials) the life curve can be determined which allows component design.
2. The significant improvements in fatigue behaviour expected of fibre reinforced ceramics compared conventional bulk ceramics was fully demonstrated. Consequently this material represents, through combination of high ductility and good fatigue properties, a valuable alternative for use in high temperature design.
3. Compared with monolithic ceramics the investigated material shows very low scatter of strength properties. The stress-strain curves based on the first cycle showed good reproductivity and the life curve, with a typical exponential form, demonstrated a sound interrelationship.
4. The behaviour under cyclic load conditions shows some typical features. For the beneficial properties such as high strain capacity and fatigue, the slip movements, which are possible thanks to a purely frictional bonding at the fibre-matrix interface, play a deciding role. The slip movements were demonstrated through the macroscopic stress-strain behaviour and fractographic investigations.
5. The cyclic life of this material, including that for cyclic loads above the "yield" point and which are accompanied by matrix crack development, can be very high. Consequently a large proportion of the material's capacity, up to the failure strain of this material, is available for the application in the component design.

It is clear that additional tests, especially under service temperatures and multiaxial conditions, are necessary for proper assessment of component behaviour and further validation of the above results.

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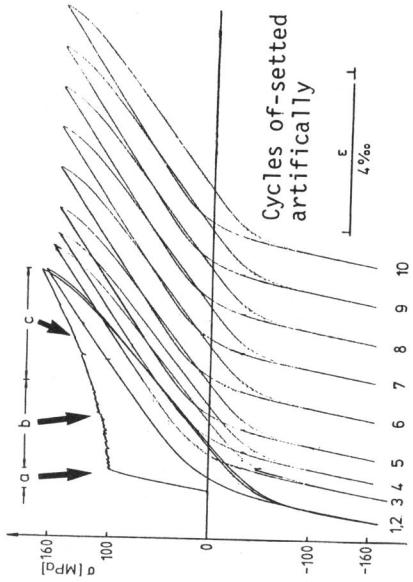

Figure 1 Cyclic test on SiC/SiC

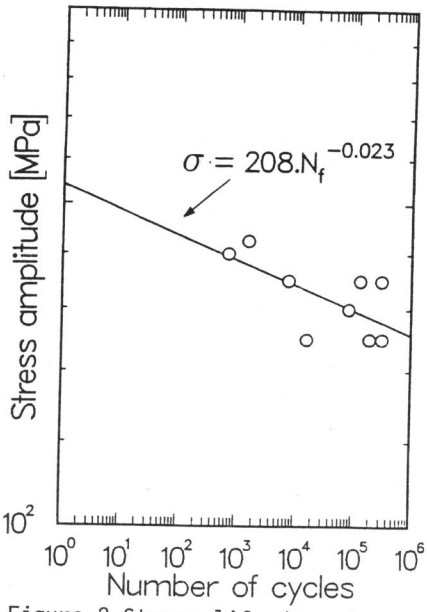

Figure 2 Stress-life dependence

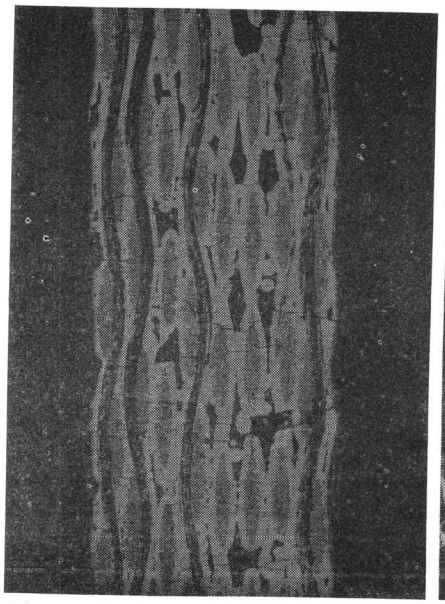

Figure 3 Matrix cracks

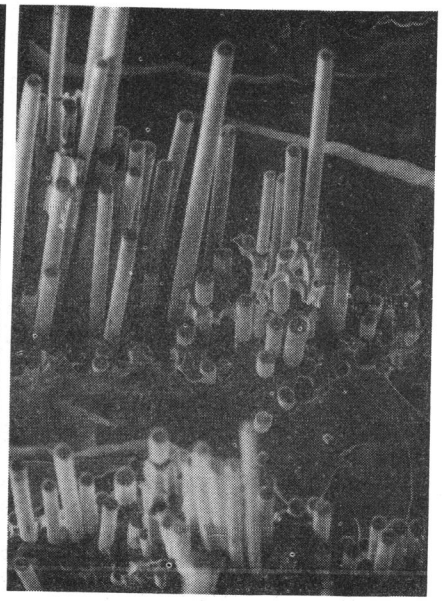

Figure 4 Fracture surface