**EXPERIMENTAL CHARACTERIZATION OF THE TORSIONAL BEHAVIOUR OF TIMMC TUBES**

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**Summary.** The use of Titanium Metal Matrix Composites (TiMMCs) for aerospace applications has been gaining momentum in the past three decades. The advantages of TiMMC include superior stiffness-to-weight and strength-to-weight ratios compared to conventional steels or nickel-based alloys. Potentially, the use of TiMMC can improve the torque density capacity for shafts. However, little research has been carried out on the torsional behaviour of TiMMC shafts. This paper describes a study of the stiffness characterization of Ti-6-4 shafts reinforced with SCS-6 silicon carbide fibres (SiC) at room and at elevated temperature (350°C), using lab-scale tubes with uni-ply and cross-ply fibre orientations. The effects of fibre orientation on the effective torsional stiffness and on the shear strength are described. Depending on the particular shaft application, high torsional stiffness or ultimate strength can be achieved by suitable choice of the fibre orientations.

1 **INTRODUCTION**

TiMMCs are lightweight and some of their important materials properties are better than those of monolithic titanium. For example, they remain strong at elevated temperatures, up to 350°C, which is an essential feature resulting in them being considered as candidates for advanced aero-engine shafts, with increased levels of performance. To improve the efficiency of gas turbine engines for aerospace applications, there is a requirement to transmit higher torques via a given diameter of shaft. Other potential applications of this material, include parts in aeroengine low pressure compressors, eg, blings, blades, vanes and casings. Military as well as commercial aeroengines may benefit from the superior properties of this material compared to conventional steels [1, 2].

A metal matrix composite (MMC) is a composite that contains a metallic matrix reinforced with ceramic fibres. Different combinations of matrix and fibre materials can be use, depending on the particular application. Some matrix materials are capable of operation at
higher temperatures and some have higher strengths. Different fibres also have their own particular architectures and these can be varied according to the physical conditions to which the constituent materials are to be subjected to. Particular combinations of matrix and reinforcement can be in order produce superior materials properties, tailored to a particular application. Fibre volume fractions and fibre orientations can also be altered to suit the particular applications.

In this paper, an investigation of the torsional behaviour of titanium (Ti-6-4) matrix, reinforced with SiC monofilaments (SCS-6), is described for lab-scaled specimens. The fibre orientations tested are uni-ply 0°, +30°, -30°, +45° and -45°, cross-ply fibre orientations included ±30° and ±45°. The specimens were tested at room and elevated temperatures using a shaft torsion test rig; where pure torsion was applied incrementally, with the load being removed during each increment. The effective torsional stiffness, ultimate shear strength and the ductility of the MMC were determined, taking into account the titanium effect at the inner and outer diameters of the tube specimens.

2 CONCLUSION

In general, the effective shear modulus of the MMC under different load ranges, prior to matrix yielding remains the same, as expected. For pure torque applications, the +45° fibre orientation gave the highest torsional strength, and good shear modulus and ductility at both room temperature and 350°C. However, if the torque is reversed, ie the +45° specimen is now essentially a -45° specimen, the strength and ductility are found to drop greatly. Hence, for reversed torque applications, a ±45° fibre orientation is more suitable. A 0° fibre orientation should be avoided for pure torque applications as it gives poor strength and ductility since the fibres are on a plane of maximum shear stress. Although the 0° specimen gave good ductility, the shear modulus and strength were reduced greatly. The shear modulus for either cross-ply or uni-ply for a given fibre orientation are similar. However, the strengths of the -30° and -45° specimens were greatly reduced in comparison with the corresponding +30° and +45° cases. In contrast, the strength reductions for the corresponding cross-ply cases were small.

For specimens tested at room temperature, 0° fibre orientation has the lowest effective shear modulus. The shear modulus decreased by 23% when tested at 350°C. It is found that, the temperature effect on the shear modulus for 0° specimen is significant. Specimens with 45° fibre orientation tested at 350°C for both the cross-ply or uni-ply cases had, effective MMC shear moduli similar to those obtained from tests at room temperature. Clearly for temperatures up to 350°C there is no significant effect on the effective MMC shear modulus. This because the behaviour of 45° specimens is dominated by the fibres, whereas that of the 0° specimen is dominated by the matrix material.

REFERENCES
