OXIDE/OXIDE COMPOSITES WITH SINGLE CRYSTALLINE AND EUTECTIC FIBRES

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1. Introduction

Oxide/oxide composites are attractive future materials for very high-temperature applications. Their stability in oxidising atmosphere is certainly higher than that of other candidates. There are known three types of such composites: directionally solidified oxide eutectics (DSOE), composites with poly-crystalline (CPCF) and single-crystalline fibres (CSF). DSOE, which have been known for decades, can hardly provide a necessary damage tolerance to structural elements [1], CPCFs are characterised by rather low use temperature because of inherent properties of polycrystals. Hence, CSCFs remain to be the only promising choice in the oxide/oxide family for very high temperature use. In the present paper, a brief description of a comparatively new method of making single crystalline fibres and a way to produce oxide/oxide composite specimens is presented. Mechanical properties of the fibres and composites are discussed in details focusing on creep properties and damage tolerance of the composites

2 Fibres

2.1 Fabrication

Single-crystalline oxide fibres are normally produced by using technological schemes with extremely low productivity rate and, hence, too expensive to be used in structural materials. An internal crystallisation method (ICM) developed some years ago [2], which is basically crystallisation of the melt in continuous channels of a molybdenum block, allows obtaining single-crystalline and eutectic fibres in bundles containing thousands of the fibres with a characteristic cross-sectional size of 30 to 300 μm. The productivity rate is very high and the cost can be sufficiently low for ICM-fibres to use them in structural materials.

2.2 Mechanical properties

Creep characteristics are most important properties of fibres as reinforcements for high temperatures composites. ICM-fibres are tested in mother-matrix being recrystallised molybdenum. Oxide/molybdenum composite specimens are tested in bending under step-wise changing load, which immediately gives a value of the exponent in a creep power low. Then an elementary solution of the problem of a creeping beam under bending yields value of tensile creep resistance of a specimen (a stress to cause a prescribed creep strain for a definite time; in what follows that creep strain is taken 1%, the time is 100 h). Creep resistance of the fibre is calculated in a simple manner. Some experimental results are shown in Fig. 1. It can be seen that single crystalline fibres of yttrium-aluminium garnet (YAG) and mullite have very high creep resistance at temperatures up to about 1600°C.

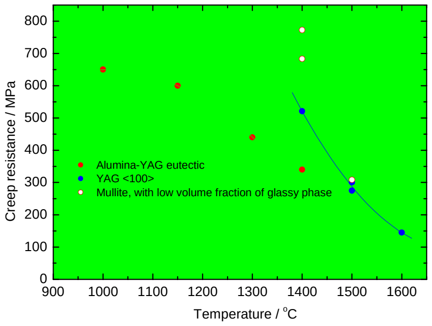

Fig. 1. Temperature dependence of creep resistance of some ICM-fibres.

3 Composites

3.1. Fabrication

To avoid problems connected to shrinkage of the matrix during pressureless sintering, a hot pressing technique was used to produce composite specimens.

3.2. Creep resistance of composites

We consider a composite with creeping matrix and initially continuous fibres. There can be observed the following four creep regimes of such composite [3]:

1. **E**: Fibres are elastic and non-breaking.
2. **Br-NCr**: Fibres are elastic and brittle.
3. **Cr**: Fibres are creeping and non-breaking.
4. **Br-Cr**: Fibres are creeping and brittle.

For each regime, a micromechanical model has been built up and dependencies of creep rate for a steady state have been written down. A schematic presentation of a map of the regimes is shown in Fig. 2. Experimental data for YAG/YAG composites with low fibre volume fraction are also shown. Using these experimental points and the micromechanical model yields the whole picture of the creep behaviour of such kind of the composites, which is also illustrated by experimental results to be presented in the full text paper.

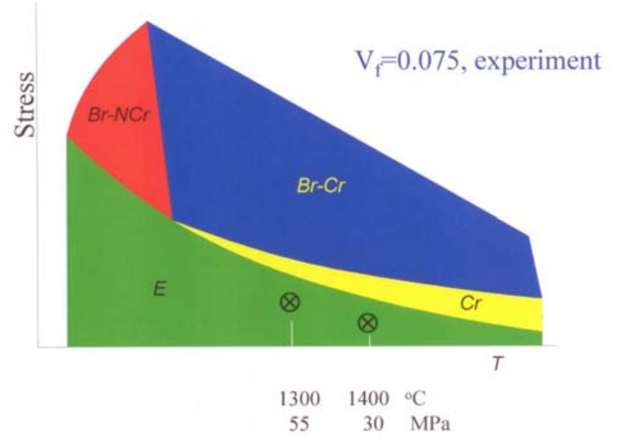

Fig. 2. A map of the creep regimes. Experimental data are shown for YAG/YAG composites.

3.3. Room temperature properties of composites

The most important property of brittle-fibre/brittle-matrix composites at room temperature is damage tolerance, which is normally estimated by a shape of the load/displacement curve registered in a bending experiment. There have been known two main methods to provide non-brittle behaviour to oxide/oxide composites: introducing a weak interface between the fibre and matrix (a well known idea) and providing a porous microstructure to the matrix [4]. Both methods have limitations by stability of the microstructure at very high temperatures. Hence, despite the first method was tested in frameworks of the present study, the authors were focusing on a new method, now to be patented, which yields the load/displacement curve illustrated in Fig. 3.

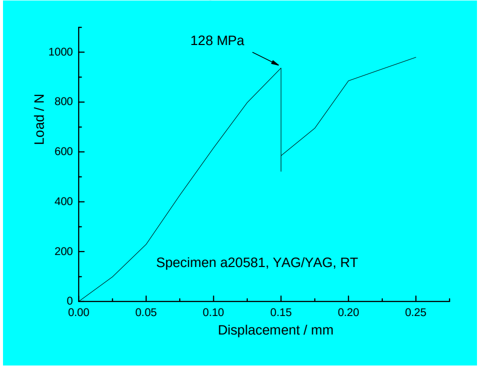

Fig. 3. A load/displacement curve obtained in 3-point bending of a YAG/YAG specimen with a new non-brittle microstructure.

4. Conclusions

It is shown that single crystalline fibres obtained by using the internal crystallisation method can be an effective reinforcement for non-brittle oxide/oxide composites with the use temperature up to at least 1400^{o}C.

References

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