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NEW OXIDE-FIBRE/MOLYBDENUM-MATRIX COMPOSITES

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ABSTRACT

This paper presents a new family of high temperature materials those being molybdenum matrix composites reinforced with fibres containing yttrium and ytterbium silicates. It is shown that the composites retain sufficiently high strength up to a temperature of 1400°C. An important feature of the fibrous composites developed is their sufficiently high fracture toughness at room temperature. This feature makes the composite different from molybdenum alloys filled with ceramic particles.

Keywords: fibrous composites, molybdenum matrix, yttrium silicates, ytterbium silicates.

INTRODUCTION

Development of new heat resistant materials with the use temperature higher than that of nickel superalloys is, perhaps, the most important and highly difficult problem of a chapter of materials science concerned with structural materials. This is important since an essential enhancement of operating temperature yields a great improvement in the effectiveness of many structures. In particular, in gas turbine, this either increases thermal effectiveness due to an increase in the operating temperature with the same level of cooling or decreases the fuel consumption due to decreasing the power necessary to cool hot parts. At the same time, enhancing operating temperature provides control of deleterious emissions, such as NO_x. The problem is really tough since the material should satisfy a number of mutually contradictory requirements, an example being strength and creep resistance, on one side, and fracture toughness, on the other side. This contradiction provides a serious problem in developing metal alloys hardened by ceramic particles. However, replacing particles with ceramic fibres allows developing composites characterised by simultaneous growth of strength and fracture toughness (Mileiko, 1997, 2015). Recent finding of a possibility of decreasing the oxidation rate of molybdenum, which is used as the matrix material for composites reinforced with oxide fibres containing a chemical element forming a molybdate on the composite surface (Mileiko, 2012, 2015a), stimulates a search for new fibres to reinforce molybdenum bearing in mind a possibility to exploit new ways to protect molybdenum from oxidation. Silicon-containing oxides look attractive in this respect (Zhou, 2013; Tian, 2016). Still, no attempts to obtain fibres based on the silicates are known. In the present work, for the first time, such fibres are obtained as reinforcements of molybdenum matrix and mechanical properties of the oxide/molybdenum composites are studied.

RESULTS AND CONCLUSIONS

The internal crystallization method [Mileiko, 2005] was used to produce composite specimens. The raw mixtures of oxide powders Y_2O_3 - SiO_2 for melting and crystallising them to form fibres in molybdenum matrix had molar ratios: 0.5 - 0.5 (yttrium silicate Y_2SiO_5), 0.55 - 0.45 and 0.6 - 0.4 (close to the yttria-silicate eutectic). Also were prepared a mixture of Yb_2O_3 - SiO_2 with molar ratio 0.6305:0.3695 to produce fibre close to yttrbia-silicate eutectic composition. In the full text paper the microstructures of the composites and fibres are discussed; here just some mechanical properties of the composites are presented (Figs. 1 to 3).

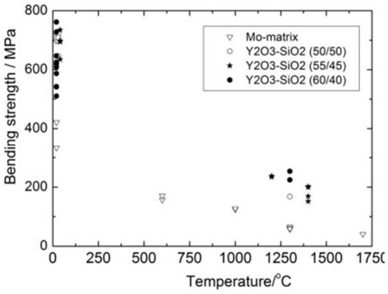

Fig. 1 - Temperature dependence of the composites containing yttrium silicate based fibres and the ureinforced matrix.

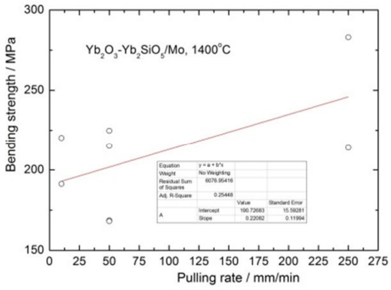

Fig. 2 - High temperature strength of the composite reinforced with Yb_2O_3 - Yb_2SiO_5 fibres versus crystallization rate of the fibres.

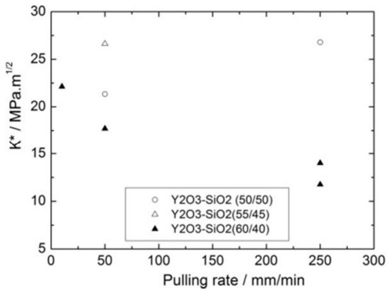

Fig. 3 - Fracture toughness of of the composite reinforced with Y_2O_3 - Y_2SiO_5 fibres versus crystallization rate of the fibres.

One can see that (i) the composites retain sufficiently high strength up to a temperature of 1400°C; (ii) mechanical properties of the composites depend on fibre crystallisation rate; (iii) fracture toughness of the composites depends on the fibre composition and crystallisation rate and the value of critical stress intensity factor can be larger than 20 MPa·$m^{1/2.}$

These properties of the composites with silicate-based fibres make them to be potential candidates for future high temperature materials.

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