TITLE: PROCESSING, MICROSTRUCTURE AND CREEP BEHAVIOR OF Mo-Si-B-BASED INTERMETALLIC ALLOYS FOR VERY HIGH TEMPERATURE STRUCTURAL APPLICATIONS

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1. ABSTRACT

Program Introduction: Rationale and Objectives

This research project combines a novel processing, experimental and modeling approach, with detailed quantitative analysis of the influences of microstructure, in a basic study of the creep behavior of the next generation of refractory alloys based on the Mo-Si-B system. Through these studies, we will gain insight into the high-temperature creep behavior of these materials, including the effects of microstructure and the associated deformation, damage and failure features. A model Mo-rich Mo-Si-B alloy has been chosen for study, since it is representative of the new class of ductile-brittle systems, which, owing to their promising properties, are receiving evaluation for very high temperature structural applications. Further development of these multiphase materials hinges on having a solid understanding of composition-processing-microstructure-mechanical property relations, including creep, to which the present effort is directed. This project, which is closely coupled with ongoing activities at the Air Force Research Laboratory (AFRL) and Oak Ridge National Laboratory (ORNL) on these materials, focuses on three key areas to address issues related to the creep behavior: 1) basic materials processing and microstructural studies; 2) evaluation of the creep phenomenology and establishment of the constitutive behavior of the three-phase alloy and the individual phases within the alloy, including the effects of microstructure; and 3) theoretical modeling of the creep behavior based on analysis of associated creep data, creep mechanisms, damage processes and microstructural parameters. An important component of this research is to perform a detailed analysis of microstructures utilizing modern electron optical techniques, to provide quantitative information on aspects such as volume fraction, length scales, morphology and distribution of the second-phase intermetallics, the nature of their interfaces with the matrix, and the deformation, damage and failure processes during creep. This information, together with those of the creep properties and phenomenology will be utilized to rationalize and theoretically model the observed creep behavior.

Accomplishments During the Current Period Of Performance

The basic strategy being utilized is to first establish the creep phenomenology and constitutive behavior under compression of a selected three-phase α-Mo + T2 +Mo_3Si material and of each of the three constituent pure phase materials. (Data for single-phase T2 is available in the literature, whereas those for the α-Mo and Mo_3Si have to be generated experimentally). The second step is to arrive at suitable methods for representing microstructure of these materials in three-dimensions. The third step is to model compressive creep by time-dependent finite element modeling (FEM) from constituent phase properties and appropriate representation of microstructure as a mesh. The fourth step will be to determine the creep behavior under tensile conditions and evaluate the damage processes. Tensile creep testing of these materials is a non-trivial problem because of the high strengths of these materials and high temperatures (1000-1400°C) involved, and will require special test sample designs. Lastly, another three-phase alloy composition will be evaluated to study volume fraction/microstructure effects. The aim of the modeling effort is to predict material behavior and that of the experiment to validate the predictions.

During this period of performance, we have begun studies on samples of a three-phase α-Mo + T2 +Mo_3Si Mo-3 wt.% Si-1 wt.% B alloy that was supplied by UES/AFRL. This material was processed into bulk form by Plansee (Germany) using a powder metallurgy route. Thermal influences on microstructure evolution have been studied and conditions have been established to obtain a well-defined three-phase microstructure. A set of three-point bend test samples were prepared by EDM and the bend strengths determined at ambient, 1000°C, 1200°C and 1400°C. Considerable effort has been directed toward getting the creep testing equipment and associated hardware/software at AFRL operational. We have succeeded in this effort and the first compressive creep test on a three-phase sample has been performed at 1200°C under a stress of 250MPa. Data on creep strain and creep rate with time under these conditions has been obtained.

Plans for the Next Year/Period of Performance

- Continue compressive creep testing of the Mo-3Si-1B three phase material over a range of temperatures and stresses and analysis of microstructure and damage processes
- Prepare pure phase α-Mo and Mo_3Si materials and conduct compressive creep testing of these at selected temperatures and stresses matching those used for the three-phase alloy.
- Establish sample designs for tensile creep testing. Machine samples and begin tensile creep testing at selected temperatures and stresses.
- Commence work on microstructure representation and time-dependent FEM of creep in these materials.

2. LIST OF PUBLISHED JOURNAL ARTICLES, COMPLETED PRESENTATIONS AND STUDENTS RECEIVING SUPPORT FROM THE GRANT

Publications and Presentations

None during this period of performance

Students Supported Under this Grant

Brian Riestenberg, Ph.D. student in the Department of Chemical and Materials Engineering, University of Cincinnati.