Foreword

Multiscale Microstructure, Mechanics, and Prognosis of High Temperature Alloys

A number of critical applications in industry demand the use of high temperature alloys that can withstand various extreme environments under elevated temperature conditions. Reliably predicting the life of these components, which may be subjected to damage associated with creep deformation, cyclic loading, environmental degradation, and combinations thereof, is a challenging endeavor. Under these conditions, the state of the microstructure after processing and its evolution during service lead to damage mechanisms that manifest over multiple length scales, ranging from quantum and atomistic scales to the mesoscale to the macroscale. These industrial applications motivate the dissemination of both fundamental and applied research and development aimed at accelerating the implementation of technologies that can drastically influence this field.

The symposium ''Multiscale Microstructure, Mechanics and Prognosis of High Temperature Alloys'' was held during the 2015 TMS Annual Meeting from March 15–19, 2015 at the Walt Disney World Resorts in Orlando, FL. This symposium was sponsored by the TMS Materials Processing and Manufacturing Division (MPMD) and High Temperature Alloys Committee (HTAC). This symposium provided a venue for presenting recent achievements in understanding the microstructure evolution and mechanical behavior in high temperature alloys over multiple scales in order to ultimately predict the prognosis and life of components. Recent advances in experimental and computational capability have greatly improved our ability to understand and quantify deformation mechanisms in high temperature alloys. In particular, the goal of this symposium was to accelerate the development and acceptance of new methodologies for improving prognosis through understanding the fundamental relationships between material microstructure and mechanical behavior in these alloys. The subject areas of this symposium ranged from atomistic, discrete dislocation, and continuum mechanics approaches for various length scales as well as experimental mechanics results that elucidate the behavior of high temperature alloys. The organizers would like to thank the speakers and all the participants for their excellent contribution to the success of this symposium—there were over sixty talks, including twenty invited speakers and two keynote speakers. This special issue presents some of top research papers submitted to this symposium, which were subjected to a rigorous, high-quality review process in line with that set forth by the Editor (Prof. David Laughlin) and Editorial Board of Metallurgical and Materials Transaction A.

The first paper[1] titled ''Microstructure Evolution of a Platinum-Modified Nickel-Aluminide Coating During Thermal and Thermo-mechanical Fatigue'' by Sallot (Safran Tech), Maurel, Rémy, and N'Guyen (Centre des Matériaux, MINES ParisTech), and Longuet (SNECMA) relates to the microstructure evolution of a platinum-modified nickel-aluminide coating on single-crystal nickel-based superalloy. Nickel-based superalloys are relied on for increasingly more severe environments. Hence, it is important to understand how the microstructure of the coatings (phases, phase transformation kinetics) evolves under various thermal cycling and thermo-mechanical fatigue (TMF) conditions in order to better engineer these coatings. This study systematically examines different cycling and fatigue conditions for platinum-modified nickel-aluminide coating and quantifies the coating microstructure and its evolution using image segmentation and microstructure characterization. Grain boundaries within the external coating and interfaces between the thermally grown oxide, external coating, and IDZ play a commanding role in diffusion, phase transformation, and microstructure evolution of conventional platinum-modified nickel-aluminide coatings.

The second paper[2], ''Creep Mechanisms of a Ni-Co-Based-Wrought Superalloy with Low Stacking Fault Energy,'' by Tian, Xu, Cui, and Sun from the Institute of Metal Research, Chinese Academy of Sciences, relates to the influence of stress and temperature on the creep deformation mechanisms of Ni-Co-based superalloy engineering with low stacking fault energy. A wide range of creep experiments were conducted over a range of both stresses (345 to 840 MPa) and temperatures [923 to 1088 K (650 to 815 °C)]. Scanning electron microscopy and transmission electron microscopy (along with creep life results) were used to identify the change in microstructure and, subsequently, four different creep mechanisms, which were used to formulate a creep deformation mechanism map as a function of both stress and temperature for this newly developed class of superalloy.

The third paper[3] titled ''Evaluating local primary dendrite arm spacing characterization techniques using synthetic directionally solidified dendritic microstructures'' by Tschopp (Army Research Laboratory), Miller (Air Force Research Laboratory), Oppedal (Mississippi State University), and Solanki (Arizona State University) relates to the development and comparison of different techniques for charactering the local primary dendrite arm spacing in directionally solidified dendritic microstructures, such as nickel-based superalloys. In this work, controlled, synthetically generated microstructures—cubic and hexagonal microstructures with varying degrees of disorder—were used to assess the capability of several Voronoi-based techniques to capture local microstructure statistics (primary dendrite arm spacing and coordination number). The Voronoi tessellation technique with a polygon-side-length criterion best characterized the known synthetic microstructures. Systematically studying and evaluating the capability of the different techniques can be an important step for experimentally correlating with both processing and properties in single-crystal nickel-based superalloys.

The fourth paper[4] titled "Activation energy calculations for the Portevin–Le Chatelier effect in Nimonic 263 superalloy" by Han, Tian, Chu, Cui, Hu, and Sun from the Institute of Metal Research, Chinese Academy of Sciences, relates to the appearance of serrated flow (i.e., the Portevin–Le Chatelier [PLC] effect) during plastic deformation in the Nimonic 263 superalloy. Tensile tests at temperatures ranging from room temperature to 1033 K (760 °C) with strain rates from 0.1 to 4×10^{-4} s^{-1} were investigated to explore the onset of the PLC effect as well as to quantify the activation energy (and cause) for this mechanism. Three types of serrations were observed (Types A, B, and C) throughout the tested temperatures. The activation energy Q for the PLC effect was determined to be about 70 kJ/mol, in agreement with that for diffusion of substitutional solutes (e.g., Cr and Mo) in a Ni matrix by pipe diffusion. This work provides a better fundamental understanding of the dependence of this phenomenon on temperature and strain rate and how this couples with substitutional solutes in this complex superalloy system.

Last, we would like to pay our gratitude and our respects to our co-organizer and colleague, Dr. Jeffrey L. Evans. After helping to initiate and organize this symposium, Dr. Jeffrey Evans passed away in May of 2014. He was a dedicated professor in the Department of Mechanical and Aerospace Engineering at the University of Alabama in Huntsville, with a passion for research pertaining to the influence of temperature and material synthesis methodologies on the mechanical behavior (creep, fatigue) of nickel and nickel-based superalloys. He was honored with numerous awards and recognitions for both his teaching and his research, including the National Science Foundation's prestigious Faculty Early Career Development Award. Dr. Evans was just recently awarded tenure and promoted to Associate Professor at the University of Alabama in Huntsville. He certainly was in our thoughts for the TMS symposium and also in putting together this special issue.

REFERENCES

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