The compositional dependence of the microstructure and properties of CMSX4 superalloys

Yu, Hao

Publication date
2018

Citation (APA)

Important note
To cite this publication, please use the final published version (if applicable).
Please check the document version above.
The compositional dependence of the microstructure and properties of CMSX-4 superalloys

Hao Yu*, Wei Xu* and Sybrand van der Zwaag*

*Novel Aerospace Materials group, Faculty of Aerospace Engineering, Delft University of Technology, 2629HS Delft, The Netherlands
bState Key Laboratory of Rolling and Automation, Northeastern University, 110819 Shenyang, China

E-mail: H.Yu-1@tudelft.nl

Introduction

The degradation of creep resistance in Nickel-based single crystal superalloys is essentially ascribed to their microstructure evolution. Yet there is a lack of work that manages to predict (even qualitatively) the effect of alloying element concentrations on the rate of microstructure degradation. In this research, a computational model is presented to connect the rafting kinetics of Ni superalloys to their chemical composition by combining thermodynamics calculation and a modified microstructure model. To simulate the evolution of key microstructural parameters during creep, the isotropic coarsening rate and γ/γ′ misfit stress have been defined as composition related parameters, and the effect of service temperature, time and applied stress are taken into consideration. Two commercial superalloys for which the kinetics of the rafting process are selected as the reference alloys, and the corresponding microstructural parameters are simulated and compared with experimental observations reported in the literature. The results confirm that our physical model not requiring any fitting parameters manages to predict (semi-quantitatively) the microstructure parameters for different service condition, as well as the effects of alloying element concentrations. The model can contribute to the computational design of new Ni-based superalloys.

Model construction

1. Fedelich’s phenomenological model:

\[ \lambda(t) = \lambda_0 \left( 1 + \beta t \right) \]

In which

- \( \lambda(t) \): Driven by interfacial energy
- \( \lambda_0 \): Driven by strain energy

From fitting parameters to physical parameters

\[ \alpha(t) = \text{Function(time, stress)} \]

2. Fan’s model:

\[ \lambda(t) = \frac{B_0}{RT} t \]

Composition related parameters in equation

Parameters can be obtained from ThermoCalc

- For isotropic coarsening rate: Oswald ripening
- For lattice misfit stress: $\sigma_\text{mt}$, $\sigma_\text{m}$

\[ \alpha(t) = \text{Function(time, stress, temperature, chemical composition)} \]

Model validation

Model prediction

Conclusion

- A computational model: the microstructural stability of Ni-SX superalloys as a function of temperature and applied tensile stress
- The microstructure characteristics of rafting process: γ channel widening of Ni commercial grades can be well simulated by the model
- The effects of alloying elements on the microstructures: chemical composition in Cr, Co, Ta, Mo can be improved in CMSX-4

References: