Development of a Physically-Based Creep Model Incorporating Eta Phase Evolution for Nickel-Base Superalloys

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Introduction

Nickel-base superalloys used in electric power generation plants are subjected to high temperatures and high stresses for very long times.

This leads to microstructural instability in most cases.

In certain alloys strengthened by Ni_3Al γ' (gamma prime) precipitates, a common instability after long service times is the formation of Ni_3Ti η (eta) phase precipitates. This η forms at the expense of γ'.

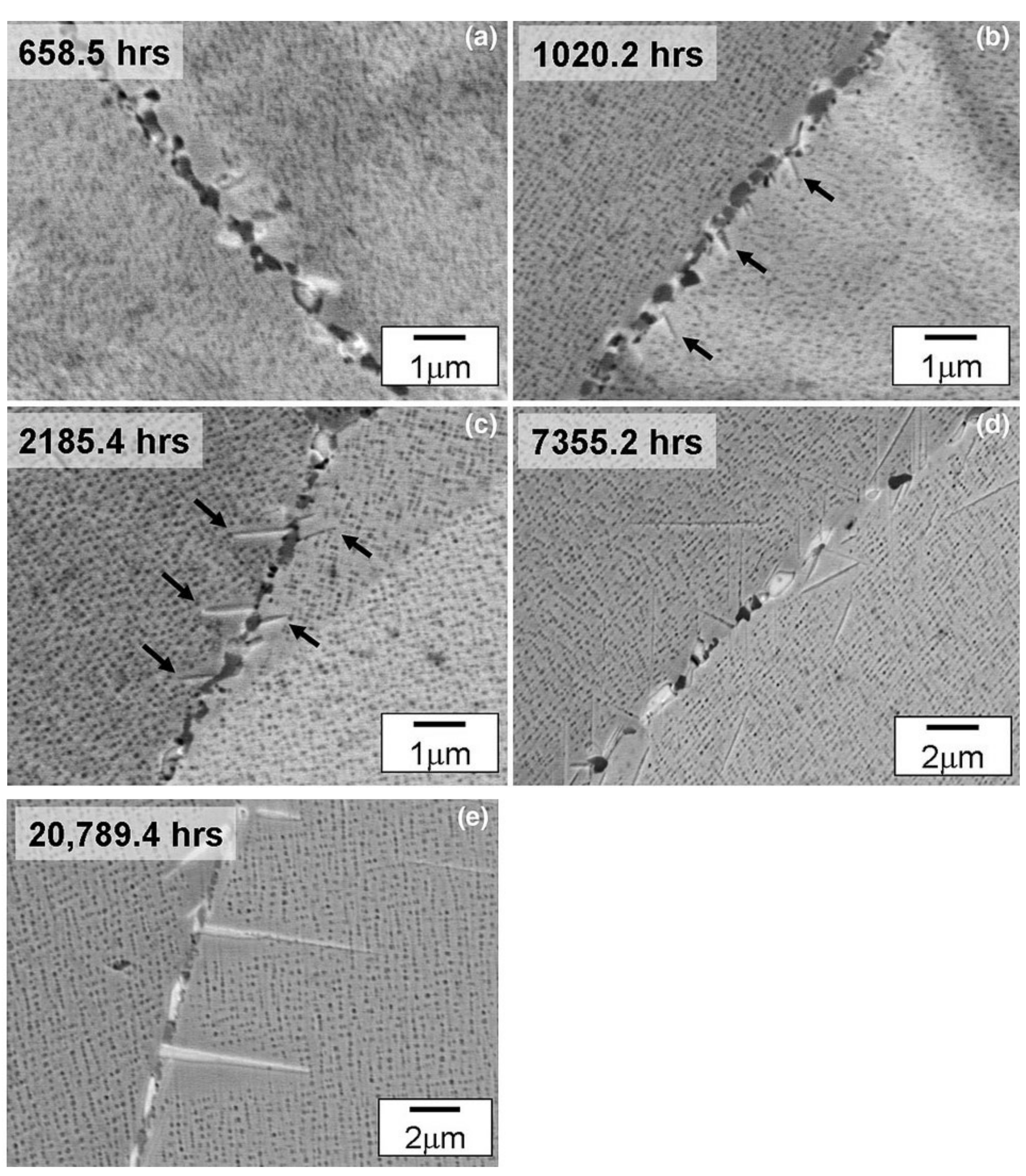

Fig. 1. Evolution of η phase precipitates (needle shape) at grain boundaries in Alloy IN740 exposed at 750°C. Shingledecker and Pharr, 2012.

It is not well understood how this instability affects creep performance, which is one of the most important variables in component durability.

The primary objective of this work is to develop a physically based creep model for Alloy Nimonic 263 that synthesizes known creep behavior based on γ' strengthening with a new understanding of the effects of η phase on creep performance at long service times in fossil energy power plants.

Approach

In a previous collaboration between Michigan Tech and EPRI, alloys were developed that are very similar in composition to Nimonic 263, but which contain 100% η and no γ'.

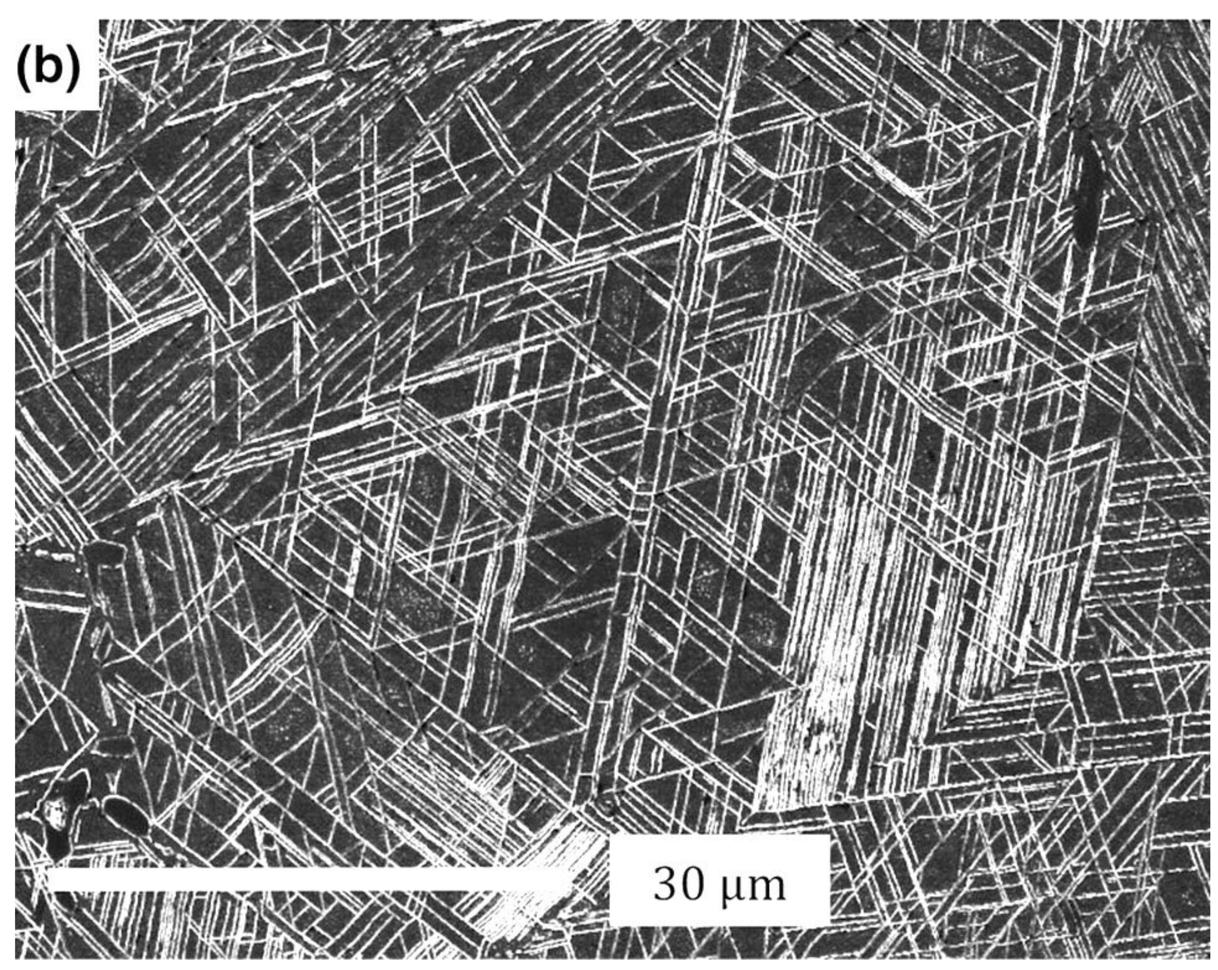

Fig. 2. SEM micrograph of an alloy based on Nimonic 263 containing only η phase in a Widmanstätten plate microstructure. Wong et al., 2015.

These experimental alloys allow us to study the creep behavior of a typical alloy over a very wide range of microstructures. Nimonic 263 can be heat treated to form both γ' and η, similar to IN740 (Fig. 1). Standard Nimonic 263 contains only γ'. So we are able to creep test alloys over the complete range:

[All γ'] → [γ' + η] → [All η]

Developing the heat treatments to form the γ' + η microstructures was one of the first tasks.

Results

Creep tests have begun on standard Nimonic 263 (where there are gaps in the data) at EPRI.

Creep tests on the η alloy are near their conclusion at EPRI.

Heat treatments are in progress at Michigan Tech to develop the γ' + η microstructures, and preliminary results are available.

Nimonic 263 samples were aged at temperatures of 750°C, 800°C, 850°C, and 900°C, for 100 hours, 500 hours, and 1,000 hours. Samples are currently still in the furnaces and will be treated for up to 5,000 hours at all four temperatures.

Substantial amounts of η phase were produced by aging for 1,000 hours at 800°C and 850°C, as shown in Fig. 3. The η phase precipitates are the angular, needle-shaped phases present near the grain boundaries. There did not appear to be a significant loss of γ' at these temperatures, though there was some coarsening.

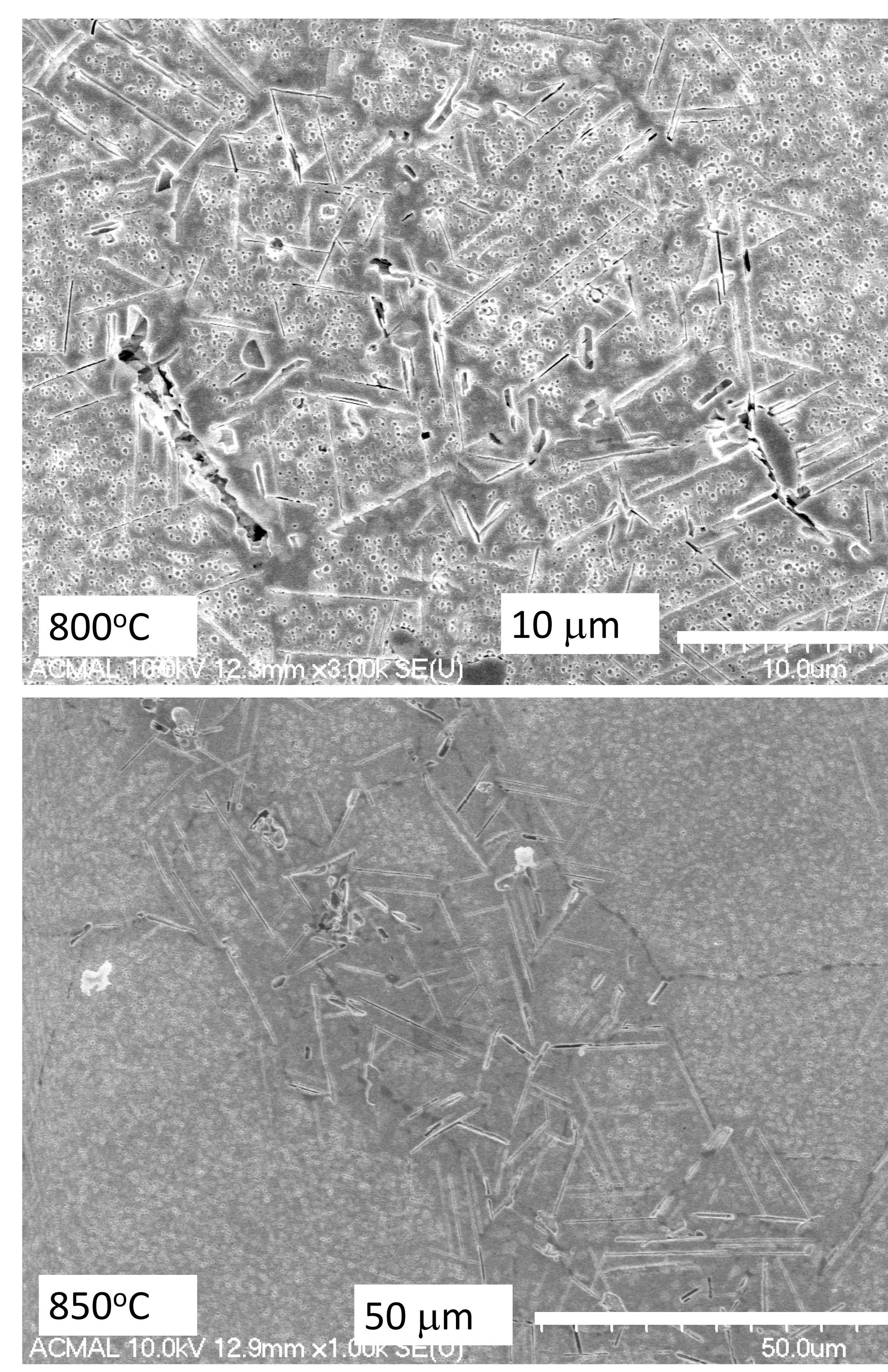

Fig. 3. η phase (needles) formed in Nimonic 263 after 1,000 hours at 800°C and 850°C.

Current research seeks to quantify the η and γ' structures as a function of aging time and temperature, and to develop optimum microstructures for the creep studies and modeling.

References: *Shingledecker, J. P., & Pharr, G. M. (2012). Metallurgical and Materials Transactions A, vol. 43A, 1902-1910.*
Wong, M. J., Sanders, P. G., Shingledecker, J. P., & White, C. L. (2015). Metallurgical and Materials Transactions A, vol. 46A, 2947-2955.

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