The Effect of Thermal Processing on Microstructure and Mechanical Properties in A Nickel-Iron Alloy

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ABSTRACT

The correlation between processing conditions, resulted microstructure and mechanical properties is of interest in the field of metallurgy for centuries. In this work, we investigated the effect of thermal processing parameters on microstructure, and key mechanical properties to turbine rotor design: tensile yield strength and crack growth resistance, for a nickel-iron based superalloy Inconel 706.

The first step of the designing of experiments is to find parameter ranges for thermal processing. Physical metallurgy on superalloys was combined with finite element analysis to estimate variations in thermal histories for a large Alloy 706 forging, and the results were adopted for designing of experiments.

Through the systematic study, correlation was found between the processing parameters and the microstructure. Five different types of grain boundaries were identified by optical metallography, fractography, and transmission electron microscopy, and they were found to be associated with η precipitation at the grain boundaries. Proportions of types of boundaries, η size, spacing and angle respect to the grain boundary were found to be dependent on processing parameters. Differences in grain interior precipitates were also identified, and correlated with processing conditions.

Further, a strong correlation between microstructure and mechanical properties was identified. The grain boundary precipitates affect the time dependent crack propagation resistance, and different types of boundaries have different levels of resistance. Grain interior precipitates were correlated with tensile yield strength.

It was also found that there is a strong environmental effect on time dependent crack propagation resistance, and the sensitivity to environmental damage is microstructure dependent. The microstructure with η decorated on grain boundaries by controlled processing parameters is more resistant to environmental damage through oxygen embrittlement than material without η phase on grain boundaries.

Effort was made to explore the mechanisms of improving the time dependent crack propagation resistance through thermal processing, several mechanisms were identified in both environment dependent and environment independent category, and they were ranked based on their contributions in affecting crack propagation.