2002 ME Graduate Student Conference
April 13, 2002

PRECIPITATE GROWTH FEATURES IN THE DUPLEX SIZE g ¢ DISTRIBUTION IN THE SUPERALLOY IN738LC

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ABSTRACT

IN738LC is a modern, nickel-based superalloy utilized at high temperatures in aggressive environments. Durability of this superalloy is dependent on the strengthening by g ¢ precipitates. Like other superalloys, IN738LC owes this exceptional strength to its FCC Ni-rich matrix strengthened by the g ¢ Ni_3 (Al, Ti) precipitate phase with $L1_2$ superlattice structure. The volume fraction of this precipitate phase in this superalloy is about 40 to 43 %.

Microstructure control and stabilization is very necessary for the effective utilization of the superalloy IN738LC at high temperatures. Developing suitable processes to reduce the grain size of the parent phase and preventing the grain growth and precipitate growth to improve the mechanical properties of the material are important in industrial applications. The current study focuses on the stability of the duplex size g ¢ precipitate microstructure in the alloy.

A standard heat treatment that is generally applied in the industry to IN738LC is a solution treatment at 1120 °C / 2h / WQ and a subsequent aging treatment at 850 °C / 24h / FC. This treatment gives the duplex size distribution for the g ¢ precipitates in the matrix. A microstructure with fine g ¢ precipitates develops if solutionizing is carried out at 1200 °C / 2 h / AAC. Agings at lower temperatures after 1200 °C / 4 h / AAC or WQ conditions lead to precipitate growth. Aging at 1120 °C / 24 hours / WQ produces coarse size g ¢ precipitates. Further heating of the above specimens at 1140 °C / 6 hours / WQ produces a duplex microstructure1). Increasing the holding times from 1 hour to 100 hours shows joining of the fine particles to form bigger particles, leading to distinct raft patterns. Two different g ¢ precipitate growth processes were observed: merging of smaller precipitates to produce larger ones (in duplex precipitate-size microstructures) and growth through solute absorption from the matrix (Oswald Ripening)2).

The growth characteristics of the g ¢ precipitate in their duplex size distribution (fine and medium sizes) are not known. The current research takes up this issue and analyzes the simultaneous growth features of both the fine and the medium size precipitate particles in the duplex size microstructure when the alloy samples are heated for different lengths of time at temperatures in the range of 800 °C to 1100 °C.

The experimental procedure is as detailed. Small pieces of the alloy IN738LC, 4 mm thick and 6 mm edge length were wrapped in stainless steel foils and sealed in silica tubes in vacuum and solution treated at 1200 °C for 4 hours. The tubes were quenched in cold water and then reheated at 1120 °C for 24 hours resulting in a coarse precipitate microstructure. The temperature was then raised to 1140 °C and the coarse precipitates were allowed to dissolve partially into the matrix. Water quenching the capsules after 6 hours at 1140 °C yielded the starting g ¢ precipitate duplex size distribution.

These samples were later individually sealed under vacuum in silica capsules and heat treated at 800 °C, 850 °C, 900 °C, 980 °C, 1040 °C and 1100 °C for periods of 1, 3, 7, 13, 25, 50, 100 and 200 hours. Six to eight capsules, each carrying one sample, were put in the furnace at one of the chosen temperatures. The samples were individually removed, after specified time periods at the given temperature, and quenched in cold water. Cold water quenching retained the precipitate grain microstructure after the given reheating.

For precipitate microstructure studies the samples were ground using grinding paper with coarse (120) to fine (600) grit size and polished on rotating wheels with fine alumina powder of size down to 0.05 micron. After cleaning they were etched with a solution of composition 33 % HNO_3 + 33 % Acetic acid + 33 % H_2O + 1 % HF. JEOL 840A Scanning Electron Microscope equipped with an ultra-thin window EDS was used to characterize the size and morphology of the precipitates.

Microstructures were digitally recorded using a Macintosh Quadra data acquisition and control system and analyzed for precipitate grain size later. Precipitates in selected microstructures were also analyzed for composition

using Energy Dispersive Spectrometer (EDS) attached to the SEM. Magnification is maintained at 8000 X to facilitate direct comparison.

The Salient Results are as follows.

(i) Both the fine and medium size g ¢ precipitates grow with time at given temperature (e.g. 1040 °C) for which microstructural changes are illustrated with time – Fig 1.

(ii) With increasing temperature growth rate increases for constant time – Fig 2 shows micrographs at different temperatures for 25 hours of heating time.

(iii) From the sizes of precipitates obtained from different microstructures, the molar activation energy for the growth process for both the fine and the coarse precipitates were calculated using the formula:

$$d_t^n - d_0^n = Kt \; where \; K = K_0 \exp\left(-\frac{Q}{RT}\right)$$

(iv) Size data obtained are plotted in Fig 3 for different times at 1040 °C and in Fig 4 for the 25 hours treatment at different temperatures.

(iv) From these data, activation energies for growth of fine and coarse precipitates were obtained. Their values are: _______ and _____ respectively (from data for different temperatures for 25 hours, Fig 3) in the range _______ to ______ °C and ______ to _______ in the range _______ to _______ °C. The corresponding activation energies at 1040 °C are _______, ______, respectively for fine and coarse precipitates in the time range 13 to 50 hours.

FIGURES AND TABLES

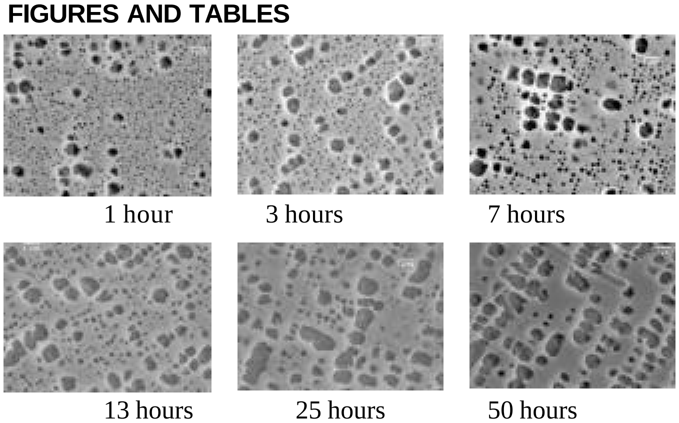

Figure 1: Microstructures of duplex IN738LC aged for different times at 1040 °C /WQ

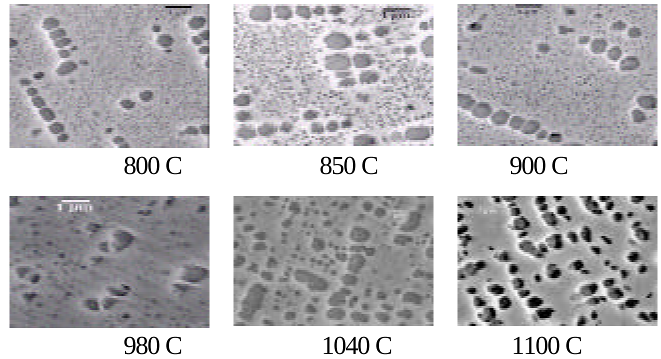

Figure 2: Microstructures of duplex IN738LC aged at different temperatures for 25 hours/ WQ

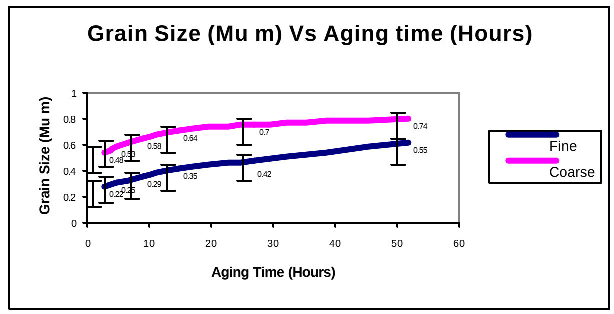

Figure 3: Plot of precipitate sizes Vs time at 1040 °C

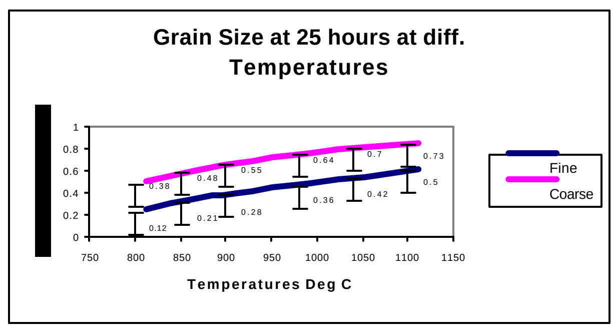

Figure 4: Plot of precipitate sizes Vs temperature for 25 hours aging treatment.

ACKNOWLEDGMENTS

Support from NASA through DGAP grant sponsored through the LA Board of Regents and LaSPACE consortium is appreciated.

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