Journal of Metallurgical and Materials Engineering, Vol.30, No.1, 2019.

Rapid Heating Effects on Microstructure of a Ni_3Al Base Alloy Containing Cr, Mo, Zr and B

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1- Introduction

Ni_3Al base intermetallic alloys such as IC221M have received considerable attention in recent years due to good combination of physical and mechanical properties at high temperatures. IC221M has been used for industrial applications such as transfer rolls in steel heat treatment furnaces. These rolls work at temperatures around 900°C and were replaced with H series cast austenitic steels which leads to a better resistance of the rolls in distortion and blistering pick-up. Temperature has significant effects on the microstructure, oxidation behavior and mechanical properties of this alloy. Despite the good effects of the zirconium rich phase, as a non equilibrium structure in IC221M, it is detrimental for performance in casting behavior of this alloy. Solution treatment before application can improve its oxidation behavior by reducing the volume fraction of this phase. One of the suitable methods for decreasing the elimination time of zirconium rich phase is applying rapid induction heating. This type of heat treatment increases the diffusion coefficient by inducing stress on the specimen and therefore, can affect all diffusion controlled processes.

2- Experimental

The chemical composition of the alloy used in this study is Ni-7.9Al-7.7Cr-1.4Mo-1.7Zr-0.008B (wt. %). The alloy was produced with VAR technique. Effect of rapid induction heating on the microstructure of the alloy was investigated. The annealing temperature was 1100°C, the frequency of heating cycles was fixed at 8500 Hz and the heating rate was about $21^oC.sec^{-1}$. The specimens were heated for 15 and 30 minutes at 1100°C. After annealing, all specimens were etched and examined with SEM. Mean radius of the γ' precipitates was determined using SEM micrographs. The volume fraction of γ' precipitates and high zirconium phase was determined. The microstructural changes which occurred during rapid induction heating were compared with the microstructure of specimens annealed for up to 43 hours at 1100°C with $0.167^oC.sec^{-1}$ heating rate.

3- Results and Discussion

Microstructural changes in the dendritic and inter-dendritic region during normal and rapid heating process are clarified using scanning electron microscopy and image analyzing technique and are presented in Fig. 1. Based on image analyzing technique, the as-cast microstructure consists of about 63-66 volume percent of γ' phase. Results showed that rapid heating can accelerate the elimination speed of high zirconium phase as shown in Fig. 2 and also the growth kinetics of γ' precipitates shown in Fig. 3, but has no significant effect on the growth mechanism.

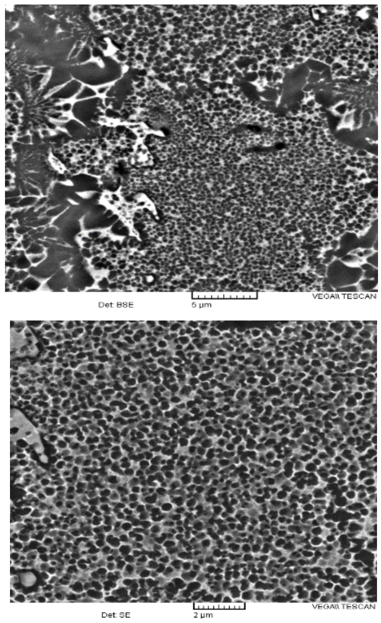

Fig. 1 SEM micrograph showing microstructural changes in the dendritic and inter-dendritic regions under rapid heating

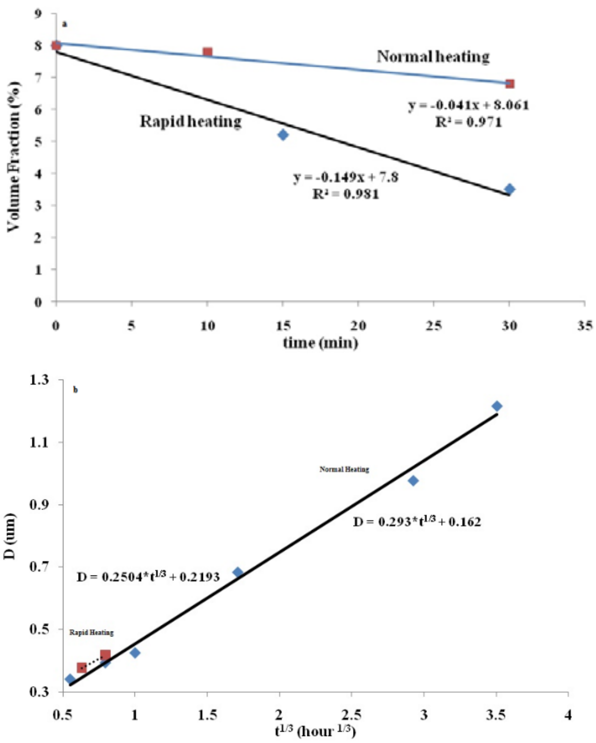

Fig. 2 Change in high zirconium volume fraction (a) and γ' growth kinetics (b) during normal and rapid heating

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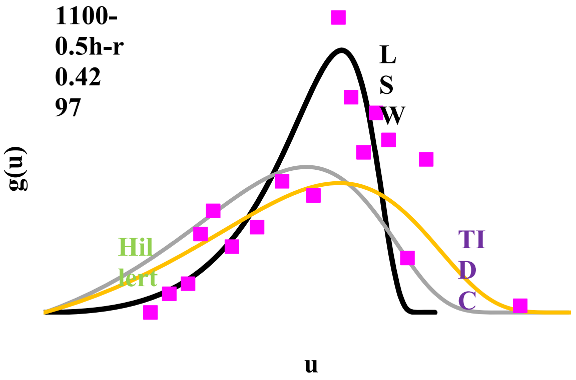

Fig. 3 Particle size distribution of annealed specimen under rapid heating (30 min, 1100 ºC)

4- Conclusions

- Due to the effect of rapid induction heating process on diffusion coefficient of solute elements i.e. zirconium and aluminum, this treatment increases the dissolution kinetics of high zirconium and also γ-γ' eutectic structures.
- Rapid induction heating accelerates the growth rate of γ' precipitates in the dendritic regions of the alloy at the beginning of the process but after a while its effect diminishes. This process has no significant effect on growth mechanism. Particle size distribution of the precipitates obeys the PSD based on LSW theory, especially in precipitates with smaller radius, although high γ' volume fraction cause coalescence of the particles and this to some extent reduce the agreement between the PSD of the particles and LSW theory.