

Modeling of carbides precipitation during weld solidification of solid solution strengthened Ni-Cr-Fe alloys with Hf, Mo and Nb additions

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Abstract – Ductility-Dip Cracking (DDC) is a solid state cracking phenomenon, which occurs in several FCC materials during their processing. However, the fundamental mechanism behind this failure mechanism has not been elucidated. Recently, it has been suggested that carbides precipitation could have an important role on DDC mechanism on Ni-base alloys. Therefore, is very important to understand the precipitation process of such phases in these materials. This work presents the thermodynamic and kinetic modeling of carbides precipitation during weld solidification of Ni-Cr-Fe alloys with Hf, Mo and Nb additions. Experimental validation is based on optical and electron microscopy analyses

Solid solution strengthened Ni-Cr-Fe superalloys (as Alloys 600 and 690) are an important materials family widely used in petrochemical, nuclear, and aerospace industries where a combination of high corrosion resistance and good mechanical properties during high temperatures applications are necessary. High temperature forming and welding of these materials could generate ductility-dip cracking (DDC), which is a solid state cracking phenomenon that it occurs at intermediate temperatures (between 0.6 and 0.8 homologous temperature). It has been associated to grain boundary (GB) sliding and an important reduction of ductility [1]. Recently, it has been suggested a possible role of primary and secondary precipitates, as MX and $M_{23}C_6$, on the DDC phenomenon. The primary MX (M stands for metal and X for C and N) pins GBs during their migration and promotes ondulated GB morphology [2]. The secondary $M_{23}C_6$ may be playing a role on the intergranular microvoid formation [3]. Additions of elements that could improve DDC response, as Hf, Mo, and Nb, are being studied in Ni-Cr-Fe alloys, but it is not clear yet the effects of these elements on precipitation behavior of these alloys.

Carbide precipitation on Ni-Cr-Fe alloys has been simulated thermodynamically and kinetically using Calphad-based methodology [4]. Thermo-calc® and Dictra® software, Ni-data and MobNi databases were used. As welded microstructure cooled at $100K.s^{-1}$ was simulated. The chemical composition of the studied materials is presented in Table 1. The simulation revealed that the mass fraction and transformation (*liquidus*, *solidus*, and solid state) temperatures were modified in alloys A and B when compared to alloy P (Fig. 1). In addition, the as-weld microsegregation structure (Fig. 2) changed from columnar (Alloy P) to fine columnar dendritic, which is thought to be potentially favorable to improve the DDC resistance of these alloys.

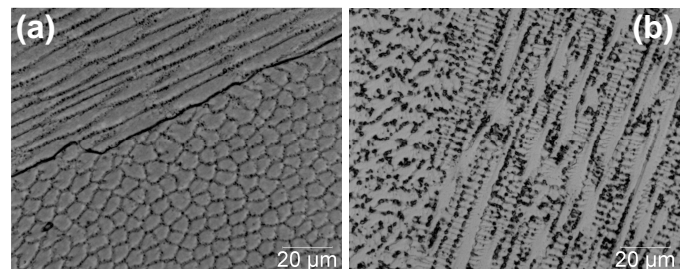
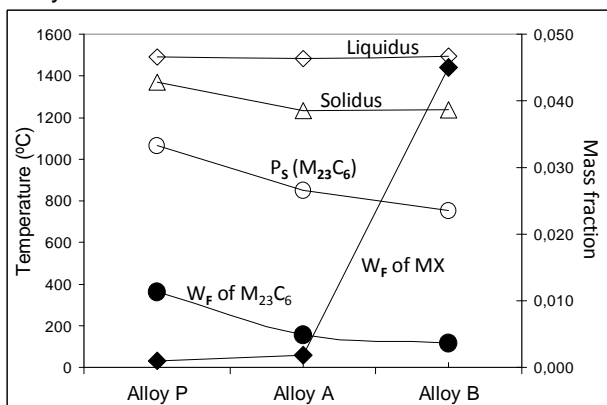


Figure 2: As-welded microstructure of. (a) Alloy P and (b) Alloy B. Optical microscopy, H_2CrO_3 electrolytic etching.

Figure 1: Curves of Temperatures and mass fraction of precipitation of alloys. P_s is temperature of start precipitation. W_f is mass fraction.

Table 1. Chemical composition of Ni-Cr-Fe alloys simulated. The compositions are in weight percent.

Material	Ni	Cr	Fe	C	Nb	Ti	Mo	Hf
Alloy P	Bal.	29	10	0.02 – 0.03	<0.01	0.5 – 0.6	---	---
Alloy A	Bal.	29	10	0.02 – 0.03	2 – 3	0.5 – 0.6	2 – 4	---
Alloy B	Bal.	29	10	0.02 – 0.03	2 – 3	0.5 – 0.6	2 – 4	0.2 – 0.5

References

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