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Chapter 6

Effect of Precipitation on Cryogenic Toughness of N-Containing Austenitic Stainless Steels After Aging

Maribel L. Saucedo-Muñoz and Victor M. Lopez-Hirata

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Abstract

This chapter shows the effect of intergranular precipitation on the cryogenic toughness of N-containing austenitic stainless steels in comparison to that for 316-type austenitic stainless steels. First part of the chapter deals with the thermodynamic stability and growth kinetics of the precipitated phases in the austenite matrix based on Thermo-Calc software. To continue, the experimental evolution of precipitation for N-containing steels is compared to that of 316-type steel and the difference between them are explained based on the Thermo-Calc PRISMA-calculated results. Finally, the effect of intergranular precipitation on the cryogenic fracture toughness is also analyzed using Charpy V-Notch impact test results. The fracture mode is also related to the precipitation characteristics.

Keywords: N-containing austenitic stainless steel, precipitation, aging, toughness

1. Introduction

Austenitic stainless steels are used to construct different equipments with good corrosion resistance in most of the principal industries, for instance, the chemical, petroleum, and nuclear power industries. These structural materials are iron alloys, which contain a minimum of about 11% chromium. This content of chromium enables the formation of a passive film, which is self-protecting in different environments [1].

Nowadays, there are more than 200 different alloys, which can be recognized as belonging to the stainless steel group, and each year new ones and modifications of existing ones appear. In some stainless steels, the chromium content now approaches 30%, and many other elements are added to provide specific properties or ease of fabrication. For example, nickel,
Figure 8. CVN impact energy at −196°C for the aged (a) 316, (b) A1, and (c) A2 steels.
The variation of CVN impact test energy at −196°C with the volume fraction of intergranular precipitates is shown in Figure 10 for the aged A1 and A2 steels. These figures show clearly that the impact energy decreases with the increase in volume fraction of intergranular precipitates promoting the intergranular brittle fracture. This fact suggests that the intergranular precipitates cause the loss of cohesion of grain boundaries, as shown in Figure 11. This figure shows precipitate chains on grain boundaries for the A2 steel aged at 900°C for 10 min.

Figure 9. SEM fractographs of CVN impact specimens at −196°C for the (a, b) 316, (c, d) A1, and (e, f) A2 steels aged at 700°C for 0 and 1000 min, respectively.

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It is important to point out that the N-containing A1 and A2 steels have higher mechanical properties at cryogenic temperatures than those of the 316 steel; however, the former steels are more susceptible to the grain boundary embrittlement.

Figure 10. Plot of CVN impact test energy vs. volume fraction of precipitates for N-containing steels.

Figure 11. SEM fractograph of CVN impact test specimen of A2 steel aged at 900°C for 1000 min.
5. Summary

This chapter shows the effect of precipitation on cryogenic toughness for N-containing steels. The presence of intergranular nitride precipitates causes a severe decrease in CVN impact test energy for steels after aging at temperatures between 700 and 900°C for times as short as 10 min. This fact is attributable to its higher volume fraction of intergranular nitride precipitates due to their higher interstitial solute contents in comparison to 316-type steels. In contrast, the 316 steel shows a better resistant to the decrease in impact energy after aging in spite of the faster growth kinetics of precipitation. N-containing steels exhibit the presence of intergranular brittle fracture as a result of the grain boundary nitride precipitation. This behavior may be also present during the welding of this type of nitrogen-containing steels because of the short aging time for precipitation.

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Author details

Maribel L. Saucedo-Muñoz* and Victor M. Lopez-Hirata

*Address all correspondence to: maribelsaucedo@prodigy.net.mx

Instituto Politecnico Nacional (ESIQIE), CDMX, Mexico

References


