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Short Communication

Hot ductility of a Fe–Ni–Co alloy in cast and wrought conditions

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ABSTRACT

The hot ductility of Fe–29Ni–17Co alloy was studied in both cast and wrought conditions by hot tensile tests over temperature range of 900 °C–1250 °C and at strain rates of 0.001–1 s^{-1}. Over the studied temperature range, the wrought alloy represented higher elongation and reduction in area as compared to the cast alloy. Dynamic recrystallization was found responsible for the higher hot ductility of the wrought alloy and the improvement of hot ductility of the cast alloy at high temperatures. At temperature range of 1000 °C–1150 °C the wrought alloy exhibited a hot ductility drop while a similar trough was not observed in case of the cast alloy. It was also found that at temperatures of 1150–1250 °C the best hot ductility is achieved in both cases of cast and wrought alloy. The experimental data of flow stress were constitutively analyzed and the apparent activation energy of deformation was estimated to be 344 kJ/mol.

1. Introduction

High temperature deformation is an essential step in the processing sequence of many industrial alloys. In this regard, the mechanical and microstructural understanding of hot deformation at different processing conditions is substantial to the evaluation of the hot ductility of metals and alloys. The hot ductility of an alloy is normally limited by a number of reasons including the generation of various deformation defects such as shear bands and wedge cracking or by some metallurgical problems. The most serious metallurgical problems limiting the hot ductility are the segregation of detrimental elements such as sulfur, phosphorous or even tin to grain boundaries and the formation of deleterious easy-melting compounds [1]. Harmful grain boundary precipitates or impurities are known as the major reasons for the significant decline of hot ductility in high nickel steels which are traditionally considered as workable materials at both low and high temperatures [2]. The drastic decrease in the hot ductility of materials termed as “hot ductility trough” has been observed in different steel grades [3,4]. Although some alloying elements such as boron have been proved to alleviate “hot ductility trough” [5], but a good hot ductility is often achieved when the dynamic restoration processes, i.e. dynamic recovery (DRV) and dynamic recrystallization (DRX) are dominant during the high temperature deformation. In fact, the restoration processes unleash the stored energy of deformation and therefore inhibit the localization of strain and the initiation or propagation of microcracks and discontinuities [6]. In order to determine the safe and risky domains of hot working respectively associated with dynamic softening mechanisms and hot ductility drop, taking the advantage of hot tensile test is very common. Hot tensile test is a well known hot workability testing technique which has been used for the consideration of hot ductility in the numerous kinds of ferrous and non-ferrous alloys [7–10].

Fe–29Ni–17Co is a low expansion alloy widely used for glass-to-metal sealing purposes [11–13]. This is because the thermal expansion coefficient of this alloy is comparable to that of glass and therefore the stress originated from the differences in the expansion coefficients at the interface is minimized. For the purpose of forming to final desired shapes, different techniques of hot and cold working may be used. As cold working process is often omitted for certain vacuum applications, hot working is more widely utilized for shaping of the alloy. However, the hot deformation regime affects the alloy structure and characteristics such as thermal expansion coefficient. Theoretical explanations and experimental investigations have suggested that the thermal expansion characteristics of a Fe–Ni–Co alloy may be affected by the microstructural conditions including residual strain, grain size and the precipitation of intermetallic phases [14]. In this regard, the hot ductility results can be practically used to determine the best regime for hot deformation and to ensure a single phase fine-grained structure.

Although the effects of hot working condition on the microstructure and thermal expansion characteristics are essential, the hot workability of the alloy has been little documented. Thus, current research deals with the hot workability of Fe–29Ni–17Co and the determination of the best condition for hot deformation.

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