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Short Communication

Hot tensile properties and microstructural evolution of as cast NiTi and NiTiCu shape memory alloys

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A B S T R A C T

Hot tensile properties of as cast NiTi and NiTiCu shape memory alloys were investigated by hot tensile test at temperature range of 700–1100 °C using the strain rate of 0.1 s^{-1}. The NiTi alloy exhibited a maximum hot ductility at temperature range of 750–1000 °C, while the NiTiCu alloy showed it at temperature range of 800–1000 °C. It was found that at temperatures less than 750 °C, diffusion-assisted deformation mechanism was inactive leading to semi-brittle type of failure and limited ductility in both alloys. Also it was found that at temperature range of 800–1000 °C, dynamic recrystallization is dominant leading to high ductility. Likewise, the fracture surface of the specimens presenting the maximum hot ductility showed an ideal type of ductile rupture in which they gradually pulled out to a fine point. On the other hand, the decline in ductility occurred at the temperatures above 1000 °C was attributed to the liquid phase formation leading to interdendritic and intergranular type of fracture.

1. Introduction

During the past decades NiTi shape memory alloys have attracted extensive interest in scientific research. It has been reported that the addition of certain alloying elements to NiTi alloys influences their shape memory effects (SME) significantly. For example, the replacement of Ni with Cu in NiTi alloys enhances the SME by decreasing the transformation hysteresis, reducing the high sensitivity of transformation temperatures to chemical composition, and increasing the fatigue life [1–5].

Hot deformation is an essential process for production of high quality semi finished products of NiTi alloys [6]. It has been exhibited that although the primary hot working processes of these products used for the breakdown of the ingot structure involve compressive states of loading, failures arise mainly from the secondary tensile stresses. For instance, cracking and cavitation are the result of surface and internal tensile stresses, respectively. Examples of failures induced by tensile stresses include free surface bulging in open die forging and edge cracking during rolling. This phenomenon becomes more severe in hot deformation of non homogenous materials, such as coarse-grained cast alloys [7]. Thus, in order to understand the hot workability of as cast NiTi alloys in primary hot working processes, it is necessary to find out their response to tensile stresses. One of the workability tests providing the reliable information about the tensile stresses is the hot tensile test, which presents the hot ductility of alloys. Hot ductility is a reliable and accurate measure of the intrinsic hot workability and is affected by dynamic structural changes and by the occurrence of cavitation and wedge cracking phenomena [8].

Hot tensile test is also employed to study the hot deformation and superplastic behavior of intermetallic compounds such as NiAl, FeAl, TiAl, and CoTi. Some interesting results disclosed by these studies show that the mechanism leading to superplastic behavior in these intermetallics is completely different from that of conventional fine grained superplastic alloys [9–13].

According to the literature, the previous hot deformation studies on NiTi shape memory alloys are virtually focused on the effect of thermomechanical treatments on phase transformation behavior of the alloys [14–16]. In a research work done by Hornbogen [14], it was shown that ausforming of NiTi alloys at temperature range of 340–900 °C leads to decrease in martensitic transformation temperatures, change in microstructure, and considerable increase in mechanical properties. Wurzel [15] has shown that marforming of Ni rich NiTi alloys leads to an increase in reverse transformation temperatures and to a decrease in martensitic retransformability. Karaman et al. [16] have proved that severe marforming of NiTi alloys can improve the strength levels without change in the shape memory properties.

Also a number of studies [17–20] have been carried out on the hot deformation of NiTi alloys using the hot compression test. In this context, Zhang et al. [17,18] have studied the flow behavior

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