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On the interaction between transformation induced plasticity and the austenitic stainless steel anisotropy (AISI 304) under shear loading path

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ABSTRACT

It is well known that for the AISI 304 austenitic stainless steel some parameters such as temperature, strain rate, material anisotropy and loading path are the main factors which strongly affect the kinetic of transformation induced plasticity (TRIP) in this material. In literature, tensile and compression tests represent the commonly experimental tools studied on this material. Under such type of loading, dissymmetry plastic behavior was obtained due to the martensitic kinetic evolution.

The aim of the present work is to highlight the role of the TRIP phenomenon on the initial material anisotropy of the AISI 304 material using appropriate experimental framework. The cross-coupled effect of the phase transformation on initial anisotropy is studied through special loading test (simple shear test (SST)) conducted at various temperatures.

1. Introduction

In automotive industry, the association of the strength and the excellent formability of steels remain an increasing need for economical reasons. Combining these properties, plastic instability may not occur without large deformations. During the forming process when the austenitic stainless steel (AISI 304) is subjected to specific load conditions at low temperature a new martensitic phase is formed. It is well known that under these conditions process forming a combination of new properties lead to high ductility and good tensile strength [1–7]. This transformation induced plasticity phenomenon called TRIP effect is attributed to the progressive transformation phase from the metastable fcc austenite (γ) to the new variant bcc martensite (α'). Mangonon and Thomas [8] showed that the sequence of the martensitic transformation in the austenitic stainless steel AISI 304, is generally produced as follows: Austenite $\gamma \rightarrow$ martensite $\varepsilon \rightarrow$ martensite α'.

On the other hand, it has been established that the temperature, the strain rate, the loading path and the material anisotropy are the most current factors which strongly affect the martensitic transformation kinetics [5–7]. Many microstructure studies were carried out to elucidate the martensitic transformation mechanisms and to find the appropriate models describing the kinetics of this process. Many authors [1,2,6,9,10] have established the evolution of the martensitic volume fraction in monotonic tensile and compression test. They have showed that the amount of the martensite is more developed with decreasing of the temperature and/or increasing of plastic deformation.

Alternatively, Powell et al. [11] and Kubler et al. [12] were interested to identify the effect of the loading path on the martensitic transformation kinetics. They have showed that the martensitic volume fraction is more important in tensile load than that in compression or torsion test and the hardening rate is also modified. Stringfellow et al. [10] have generalized the Olson and Cohen model [5] by introducing the stress state effect. The effect of non-proportional loading during tensile–torsion tests on austenitic stainless has been carried out by Calloch and Marquis [13] and Calloch et al. [14]. Gallee et al. [15] have expected that the hardening levels in cyclic tensile–torsion may be twice higher than that in tensile–compression loading. Moreover, Olson and Cohen [5] have deduced that the transformation could be emphasized by strong values of the three-dimensional stress state. This fact was also observed by Jacques et al. [16] on a general TRIP steels during tensile test. Okutani et al. [17] carried out various experimental tests (uniaxial tension, compression, equibiaxial compression and deep drawing) on a 304 austenitic stainless steel at room temperature. They have reported that the martensite volume fraction increases with hydrostatic stress pressure under uniaxial tension. However, these authors have found that martensitic volume fraction is higher for compression test than that for tensile test. Lebedev and

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