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Mechanical response of dual phase steel at quasi-static and dynamic tensile loadings after initial fatigue loading

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ABSTRACT

This paper presents an analysis of the mechanical behavior of DP500 steel previously exposed to cyclic loadings with constant stress amplitude. Stress–strain curves were determined for a two strain rates using servo-hydraulic testing machine and tensile Hopkinson bar. Tests were accompanied by digital image correlation, which enabled us to estimate strain localization at various initial fatigue loading conditions. Independently of the pre-fatigue parameters, initial cyclic loadings induce increase of yield stress. Similar behavior is observed for the ultimate tensile strength (UTS) estimated during the Hopkinson bar test. For low strain rates, UTS remains almost constant. On the contrary, increasing the number of cycles lowers the value of elongation at fracture and decreases the strain corresponding to UTS. In every case discussed, higher initial cyclic loading stress induces stronger evolution of mechanical parameters of DP500 steel. Macroscopically estimated strain measured at quasi-static loading conditions is higher than dynamic ones. The opposite behavior was found during analysis of local strain, i.e. strain obtained during the Hopkinson bar experiment was higher than that obtained by using the servo-hydraulic testing machine.

1. Introduction

Dual phase steel (DP) microstructure incorporates hard martensitic or bainitic phase dispersed in a soft ferritic matrix. This composition results in very good strength, drawability and work hardening. Moreover, due to good strain redistribution capacity, finished parts made of dual phase steel have superior mechanical properties to those made of as-received material. Given their high energy absorption capacity and fatigue strength, cold rolled dual phase steel is particularly well suited for automotive structural and safety parts such as longitudinal beams, cross members and reinforcements. Since nowadays vehicle design is based on CAD systems, dual phase steel constitutive relations are widely used for fatigue and crash modeling (Barlat et al., 2014; Xu et al., 2014).

Constitutive behavior of DP steel may be described by using the Johnson–Cook relation (Qin et al., 2013). Both grades of tested materials, namely DP700 and DP500, show a clearly observed strain rate hardening effect. In order to investigate true stress–strain curves and elongation at fracture, a digital correlation method was applied. Optical field measurements demonstrate that strain localization is present during tensile tests of specimens made of DP steels even before peak load is attained. It was also found, after tensile tests of notched specimens, that increase of stress triaxiality value induces decrease of effective plastic strain at failure (Anderson et al., 2014). Additionally, elongation at failure increases with strain rate. Plastic deformation of DP steel, and so formability, strongly depends on strain heterogeneities at the microscale between soft ferrite and hard martensitic

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