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Dynamic tensile behavior of multi phase high yield strength steel

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ABSTRACT

Results of uni-axial tensile testing of multi phase 800 High Yield strength steel (MP800HY) at different strain rates (0.001–750 s^{-1}) are reported here. Flat specimens having gauge length 10 mm, width 4 mm and thickness 2 mm were tested to determine the mechanical properties of MP800HY under tensile loads. The quasi-static tests (0.001 s^{-1}) were performed on electromechanical universal testing machine, whereas, hydro-pneumatic machine and modified Hopkinson bar apparatus were used for testing at intermediate (5 s^{-1}, 25 s^{-1}) and high strain rates (250 s^{-1}, 500 s^{-1}, 750 s^{-1}) respectively. Based on the experimental results, the material parameters of existing Cowper–Symonds and Johnson–Cook models are determined. These models fit the experimental data well in the plastic zone. The fracture surfaces of the broken specimens are studied from their fractographs taken by scanning electron microscope (SEM).

1. Introduction

High strength steels are extensively used in the transportation industry to improve crashworthiness, increase safety and reduce weight of the automobiles [1–5]. Various types of advanced high strength steels (AHSS) for example, Transformation Induced Plasticity (TRIP) steels, TWinning Induced Plasticity (TWIP) steels, Dual Phase (DP) steels, Complex Phase (CP) steels and Multi Phase (MP) steels have been developed with a purpose of increasing strength and capability to dissipate crash energy. The knowledge of the strain rate sensitivity and crashworthiness parameters of such advanced high strength steels is necessary for the effective design of automobile components.

Huh et al. [6] compared the dynamic tensile characteristics of TRIP600, TRIP800, DP600 and DP800 steels at the intermediate strain rates ranging from 0.003 to 200 s^{-1}. It was observed that, the flow stress increases with the increase of strain rate for both TRIP and DP steels. However, the fracture elongation and the formability of TRIP-type steel sheets were found to be better than those of DP-type steel sheets at the intermediate strain rates. Yu et al. [7] studied the rate dependent behavior of DP600 steel in the strain rate range from 10^{-4} to 10^3 s^{-1}. It was noticed that DP600 is strain rate sensitive *i.e.,* on increasing the strain rate, the yield strength and the ultimate tensile strength increase. The experimental curves of these steels reveal obvious upper and lower yield points at high strain rates, whereas, such behavior is not seen at low strain rates. Curtze et al. [8] reported an experimental study on the tensile behavior of DP600 and TRIP700 steels over a range of temperature (−100 to 235 °C) and strain rate (10^{-3}–1250 s^{-1}). The tensile strength of the TRIP steel was observed to be much less sensitive to strain rate than that of the DP steel. Abedrabbo et al. [9] studied the crash response of DP600 and DP780 advanced high strength steel tubes experimentally and found that DP600 is slightly more sensitive than DP780. Geiger et al. [10] investigated the mechanical behavior of advanced high strength dual phase and complex phase steels; DP600, DP800 and CP800 under uniaxial tensile tests, layer compression tests and bulge tests. The results of the mechanical properties and flow curves show that the loading condition significantly influences the plastic response of the material in terms of strain hardening rate and stress level. Cadoni et al. [11] presented the experimental results for DP600, DP800 and DP1000 in four different strain rate regimes; high, medium–high, medium and low strain rates under tensile loads. It was found that DP1000 is less strain rate sensitive whereas DP600 is more strain rate sensitive. Boyce and Dilmore [12] examined the strain rate sensitivity of four different high strength, high toughness steels (AerMet 100, modified 4340, modified HP9-4-20 and ES-1c) at strain rates ranging from 0.0002 to 200 s^{-1}. Each of these alloys exhibits modest strain rate sensitivity. The first three alloys show their ductility decrease with the increasing strain rate, while ES-1c alloy shows increase in the ductility with increasing strain rate. Xie and Nakamachi [13] and Nakamachi et al. [14] carried out finite element analysis to study the formability and drawability of CP800 steel. It is observed from the above studies [6–14] that, the strain rate sensitivity of advanced high strength steels are less

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