

The effect of dynamic strain aging on room temperature mechanical properties of high martensite dual phase (HMDP) steel

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ABSTRACT

AISI 4340 steel bars were heated at 900 °C for one hour, annealed at 738 °C for different durations and oil-quenched in order to obtain dual phase steels with different ferrite volume fractions. A 3% prestrain at the temperature range of 150–450 °C was then imposed to the samples, and room temperature tensile tests were carried out, afterwards. Results indicate that the maximum values for both yield and ultimate tensile strength would exist for the samples pre-strained at the temperature range of 250–300 °C. Also, a sudden drop of the ductility was observed at the mentioned temperature range. The observed behavior might be attributed to the occurrence of dynamic strain aging taken place at this temperature range. It was also shown that the ferrite volume fraction has not had any remarkable influence on the strength behavior of the samples, yet its increase was shown to have affected the work hardening behavior of the samples. Fractography analyses were also performed, showing the featureless fracture surface of the samples prestrain at the range of 250–300 °C, confirming the occurrence of dynamic strain aging at this condition.

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1. Introduction

Dual phase (DP) steels are developed from conventional low alloy steels [1] constituting a soft matrix, e.g. ferrite, and a stronger second phase such as martensite or bainite [2]. Dual phase steels have proper mechanical properties such as high workability, as well as interesting characteristics like continuous yielding and low yield to tensile strength ratio which make this class of steels to have high potential for practical use, especially in automotive industries [2,3].

Dual phase steels are commonly produced in two manners; the first is the heat treatment of low alloy steels at the intercritical temperature region, i.e. ($\alpha + \gamma$) region, followed by quenching to room temperature. The other includes rolling in autenitic region, followed by cooling to ($\alpha + \gamma$) temperature zone and quenching [2,4]. So far, numerous research works have been conducted on dual phase steels. Among those, investigations on mechanical and impact properties of dual-phase AISI 4340 steels with various microstructures [5–8], influence of high temperature deformation on mechanical response [9–11], and some studies on triple phase steels [12] are of great interest.

A remarkable metallurgical phenomenon influencing the mechanical behavior of steels is dynamic strain aging (DSA) [13]. This phenomenon is related to the interactions between

dislocations and solute interstitial atoms of C and N [14] or other substitutional atoms such as Cr in the metal matrix [13,15]. The mentioned interaction leads to successive locking and unlocking of dislocations to the so-called atomic atmosphere, resulting in jerky or serrated flow also known as Portevin-Le Chatelier effect. It should be mentioned that DSA is accompanied with inhomogeneity of deformation [16], as well as it may significantly influence the mechanical properties, for instance, resulting in an increase in the yield and UTS of the material [17]. Effects of this metallurgical phenomenon on DP steels have been examined in some works. For instance, it has been shown that similar to low carbon steels, dynamic strain aging can occur for dual phase steels at the temperature range of 150–450 °C, as well [9,18–20]. It has also been demonstrated that a 3% prestrain in the mentioned temperature range can be considered to be an optimum value, resulting in the best room temperature mechanical properties of these steels [14,20]. An optimum value of flow stress with a minimum elongation value have been reported to exist in certain temperatures in the temperature range of DSA, in dual phase steels [21]. Calculation of activation energy for the onset and termination of DSA for the dual phase steels reveal that the carbon atoms diffusion in ferrite matrix is responsible for the occurrence of this phenomenon in dual phase steels, while no significant effect is due to the existence of martensite network in the material [21].

Due to the lack of literature concerned with the mechanical behavior of high martensite dual phase steels, accompanied by aging treatment at intermediate temperatures, this paper was

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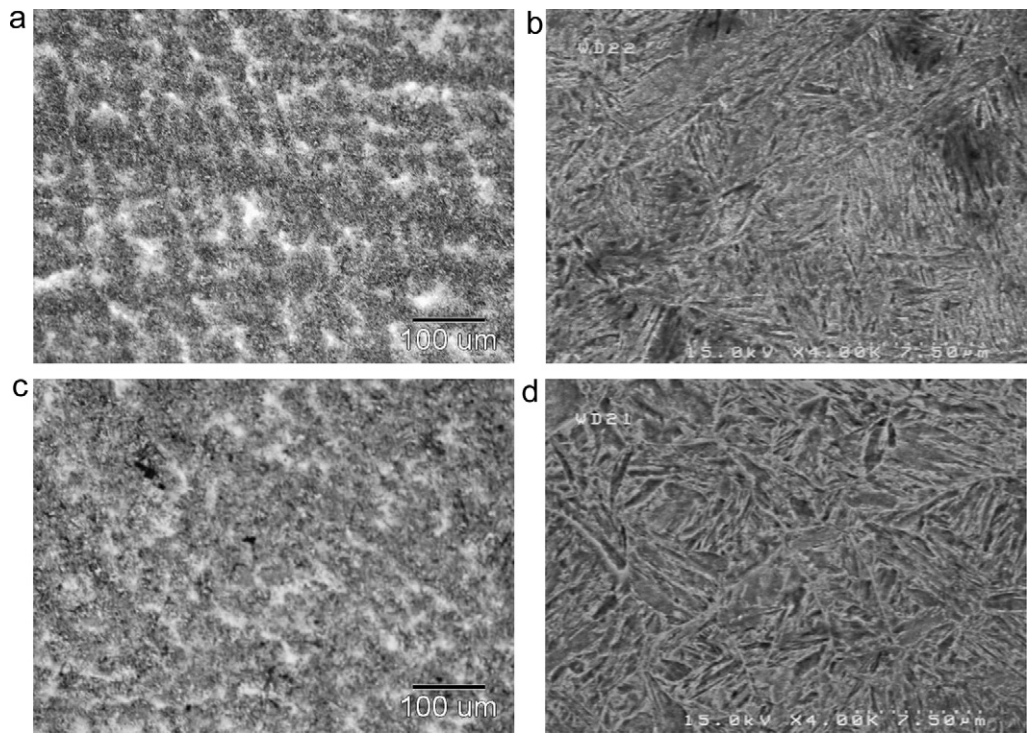


Fig. 1. (a) Mellographic image and (b) SEM micrograph of sample containing 22% volume fraction ferrite. (c) Mellographic image and (d) SEM micrograph of sample containing 34% volume fraction ferrite.

prepared with the purpose of providing a more profound insight on the mentioned aspects. To do so, different holding times at ($\alpha + \gamma$) region were applied to develop different microstructures in producing of AISI 4340 dual phase steel samples. Then, the influence of 3% prestrain at varying temperature of 150–450 °C was studied on room temperature mechanical response of the material, through various mechanical and microstructural evaluations. It should be noted that dynamic strain aging has been guaranteed to take place in the temperature range of 150–450 °C [20,21], yet the main goal of this research was to investigate a narrower temperature range, in which optimized strength values are obtained; while, an examination on the work hardening response of the material at this specific temperature range was also taken into consideration.

Table 1
Chemical composition of the examined steel used in this study (wt%).

C	Si	Mn	P	S	Cr	Ni	Mo	Fe
0.40	0.29	0.62	0.019	0.004	0.73	1.77	0.21	Bal.

2. Materials and methods

AISI 4340 bars, with chemical composition given in Table 1 were examined in this study. In the first stage, considering TTT diagrams of the mentioned steel grade, and by the aid of lever rule at ($\alpha + \gamma$) region, proper time and temperature required to obtain microstructures containing 22% and 34% ferrite volume fractions were calculated. Based on the calculations, the bars were first heated at 900 °C for one hour, intercritically annealed at 738 °C for

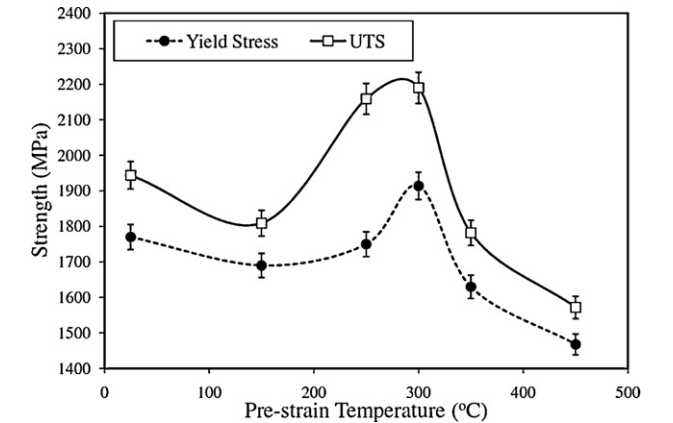


Fig. 2. Variations of yield and UTS vs prestrain temperature for sample with 22% ferrite.

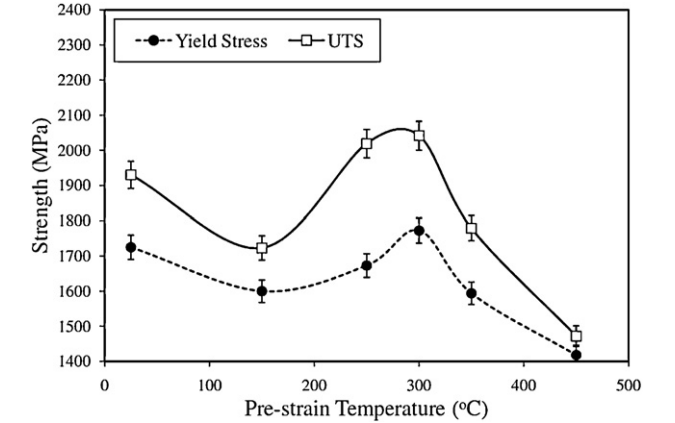


Fig. 3. Variations of yield and UTS vs prestrain temperature for sample with 34% ferrite.

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