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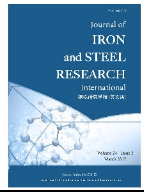

Microstructure failure in ferrite-martensite dual phase steel under in-situ tensile test

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ABSTRACT

To investigate microstructure failure in ferrite-martensite dual phase steel, in-situ observations were performed on multiple plate DP800 specimens during uniaxial tensile tests. Microstructure evolution of the observed region was investigated in details. The experimental data showed that micro-cracks in various regions differed in the initiation time, and micro-failures mainly occurred from the locations with typical characteristics of stress concentration (i. e. ferrite interiors, the interfaces of ferrite-martensite grains and the martensite-martensite interfaces). Growth of micro-crack generally experienced the following stages: cracking from martensite boundaries, tiny particles in ferrite interiors, or martensite interiors, propagating in ferrite, bypassing martensite boundaries, or passing through martensite-martensite interfaces, finally ending on martensite boundaries. Martensite was one important source of micro-failure and changed the propagation of micro-cracks significantly. Microstructure deformation was inhomogeneous in the stage of plastic deformation.

1. Introduction

Ferrite-martensite dual phase (DP) steels have been widely used in automobile industry due to their good mechanical properties[1-3] determined by the microstructure formed in production process[4]. Plenty of studies about microstructure deformation and evolution have been conducted to seek micro-failure mechanism of DP steels[4-16].

Researches showed that martensite failures in DP600 steel mostly occurred as a result of micro-crack initiation at the boundaries with the surrounding ferrite followed by crack propagation to the center of the islands[5] and the damage in DP600 steel was dominated by decohesion from the interfaces between martensite and ferrite[6]. The failure of continuous martensite bands was found during the early stage of deformation[7,8] but it had no substantial contribution to the void nucleation[4]. However, martensite morphology and distribution had a significant impact on the damage accumulation related to the microstructure inhomogeneity[4]. In addition, the influences of martensite on the damage and fracture of the DP steels were investigated by many researchers[9-12]. Based on these studies, the damage initiation and fracture mechanisms of DP steels have been widely studied. However, for a specific micro-crack, it is very important to determine the initial time, the initial location, the propagating rule and the influence factors of the micro-crack due to their significance for understanding microstructure failure, while these issues have not been reported comprehensively yet.

To resolve above-mentioned problems, both the initiation and the propagation of micro-cracks in microstructures of DP800 steel were captured by in-situ observation during the uniaxial tensile tests. Microstructure failures in DP800 steel were investigated and analyzed based on a great deal of in-situ observation data.

2. Experimental Procedures

2.1. Material and specimen

DP800 steel was taken as the main objects. The

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chemical compositions and mechanical properties are given in Table 1. Specimens used in in-situ observation are shown in Fig. 1(a).

More than three specimens were polished using water sandpapers and were etched by 4 vol. % nital before tensile tests. The polished and etched regions are shown in Fig. 1(b). In the observation area on each specimen, martensite fraction was approximately evaluated using PS image processing software.

Table 1
Chemical compositions (mass%) and mechanical properties of DP800 steel

Material	C	S	Si	Mn	P	Cr	Cu	Ni	Mo	YS/MPa	UTS/MPa
DP800	0.16	0.002	0.18	1.51	0.008	0.03	0.006	0.03	0.01	399	755.8

Note: YS—Yield strength; UTS—Ultimate tensile strength.

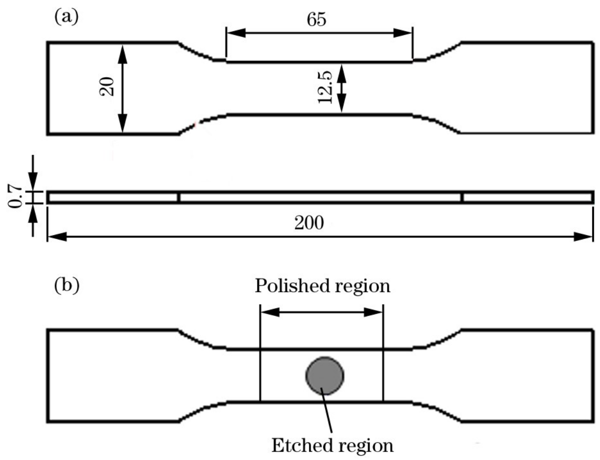


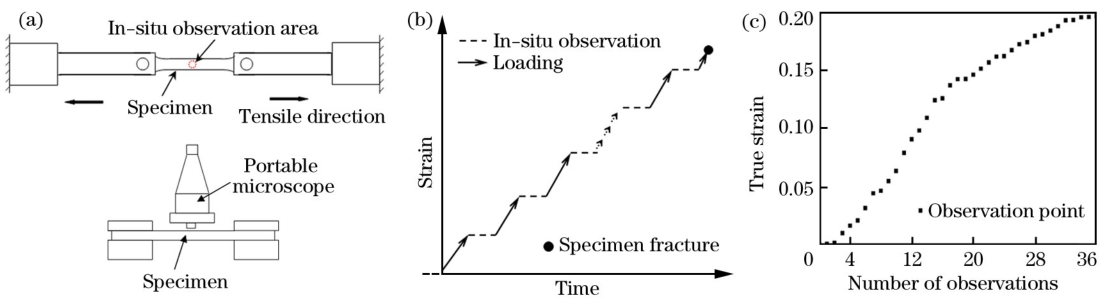
Fig. 1. Schematic diagram of specimen dimensions (in mm) (a) and polished and etched regions (b).

2.2. Testing methods

Static tensile test was performed on the specimens by using the tensile machine, as shown in Fig. 1, and microstructure in the in-situ observation area (Fig. 2(a)) was observed using a BJ-A portable optical microscope at different strain levels. The experimental device is shown in Fig. 2(a). The tensile speed and the strain rate were 0.01 mm/s and 0.000257 s^{-1}, respectively. The process of the in-situ observation is shown in Fig. 2(b). Total 37 in-situ observations were performed on the discussed specimen during the whole process of the tensile test, as shown in Fig. 2(c).

3. Results and Analysis

The initiation and propagation of micro-cracks in the observed microstructure (Fig. 3) with martensite fraction of 32.4% were observed and captured. To simplify the analysis, the observed microstructure was divided into four sub-regions named A, B, C and D. Martensite fractions in four sub-regions were about 30.53%, 33.71%, 36.89% and 24.59%, respectively.



(a) Experimental device; (b) Loading process; (c) Observation points.

Fig. 2. Procedures of in-situ observation.

3.1. Region A

Microstructure evaluation in region A is shown in Fig. 4. Fig. 4 indicates that several micro-cracks marked with arrows began to appear at strain of 0.054. Micro-cracks generally occurred from ferrite interiors and the ferrite-martensite interfaces. Martensite grains changed the propagation direction of micro-cracks and

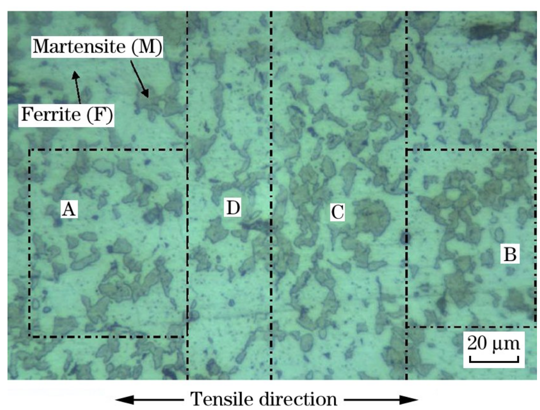


Fig. 3. Microstructure observed in the in-situ observation test.