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Thermo-mechanical processing of low alloy TRIP steel

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Low alloy TRIP (transformation induced plasticity) steel was investigated after different thermo-mechanical processing (TMP) consisting of high temperature deformation followed by isothermal holding in the bainite region and cooling to room temperature. The microstructure of processed specimens was characterised by the means of light and electron microscopy. Varying TMP changed volume fraction of retained austenit, which was measured using X-ray diffractometer.

1. INTRODUCTION

TRIP effect is used for production of steels with high strength and high formability. The remarkable strength to ductility balance results from strain-induced transformation of retained austenite to martensite during plastic deformation. The retention of austenite is obtained by combination of appropriate chemical composition and thermo-mechanical processing of steel. The presence of austenite in the initial microstructure appears to be critical to the achievement of the desired properties. The retained austenite volume fraction is a key factor in controlling final mechanical properties, but there are also other important parameters, such as the morphology, particle size and mechanical stability of retained austenite.

TRIP effect was first recognised by Zackay [1] in metastable austenitic stainless steels. These steels had high additions of Cr and Ni, which made them very expensive and limited their use only to special applications. Increasing attention has been recently paid to low alloy C-Mn-Si steels with a multiphase microstructure consisting of a ferrite matrix, dispersion of bainite, metastable retained austenite and martensite, quite different from previously used fully austenitic TRIP steels [2].

Low alloy TRIP steel properties are very desirable for thin sheets applied in automobile industry, in order to improve productivity and reduce auto body weight. The need of materials, which would be used in special forming technologies, has been increasing.

2. EXPERIMENTAL PROGRAM

The low alloy multiphase steel with following chemical composition was used in this study: 0,18% C, 1,45% Mn, 1,9% Si, 0,02% P, 0,07% S. Seven different TMP methods were applied (Table 1). TMP consisted of austenitization at temperatures of 850, 900 and 950 °C, slow cooling to finish forming temperature ranging from 700 to 610 °C and a compression deformation of 30%, rapid cooling and 300 s hold at the temperature of 400°C [3].

The microstructure was characterised with the use of optical metallography, transmission electron microscopy (TEM) and scanning electron microscopy (SEM). Specimens for optical microscopy were etched with 3% nital. From metallographic samples were prepared extraction carbon replicas for TEM. Volume fraction of different phases was determined by quantitative evaluation and X-ray diffraction phase analysis.

Each specimen was cut alongside transversal axis and a metallographic sample was prepared. Desired deformation and TMP could be found only in the narrow middle area which was controlled by thermocouples fixed to the surface of specimen in its central part. Along the longitudinal axis of the specimen different microstructures were observed. Only the microstructure of the central region will be further discussed.

Table1. Thermo-mechanical processing of specimens

T1	950°C/900s	710°C/16s, 30%, water	400°C/300s
T2	950°C/450s	710°C/16s, 30%, water	400°C/300s
T5	950°C/450s	610°C/16s, 30%, water	400°C/300s
T4	900°C/450s	660°C/16s, 30%, water	400°C/300s
T5	850°C/450s	710°C/16s, 30%, water	400°C/300s
T6	850°C/450s	700 °C/16s, 30%, CO_2	400°C/300s
T7	850°C/450s	700 °C/16s, 50%, CO_2	400°C/300s

3. RESULTS AND DISCUSSION

The specimens with higher austenitization temperatures (T1, T2, T3, T4) showed heterogeneous ferritic - bainitic microstructure (Fig.1). Volume fraction of ferrite was counted from optical micrographs using image analysis system Lucia. Special macro was developed for determination of different phase volume fraction. The macro enables to distinguish dark (bainitic) and light (ferritic) spots on digitised optical micrographs.

Similar fine grained, homogeneous structures of specimens T5, T6, T7 (Fig.2) were evaluated using the same image analysis system. However, it was impossible to distinguish fine ferritic grains in optical micrographs and therefore scanning electron micrographs had been used. Bainitic areas had to be marked manually before applying evaluation macro mentioned above. Volume fraction of austenite was determined by X-ray diffraction phase analysis for all specimens except of T1. The results are shown in Table 2. The highest amount of retained austenit was detected in specimen T2; satisfactory results were obtained in specimens T5, T6 and T7.

Convenient combination of fine microstructure and retained austenit volume fraction was found in specimen T5. However, TEM observations revealed small islands of perlite in its microstructure (Fig.3). Desirable microstructure without perlite was obtained when similar TMP with faster cooling was applied to the specimen T6 (Fig.4). Retained austenite was observed as isolated islands in ferrite grains or as a part of bainitic regions and was homogeneously distributed. It was reported that only retained austenite of this morphology transforms to martensites during plastic deformation and thus improves ductility, whereas film-type austenite does not transform to martensite even after large plastic deformation [4].

Table 2. Volume fraction of different phases

Specimen	Ferite [%]	Austenite [%]
T1	41	-
T2	38	22
T3	46	6
T4	49	4
T5	57	18
T6	43	17
T7	48	17

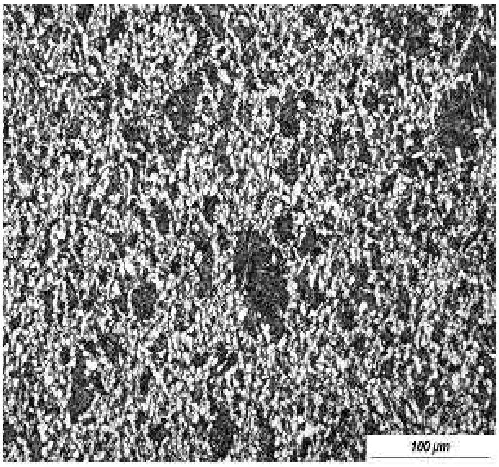

Figure1. Optical micrograph of the specimen T2

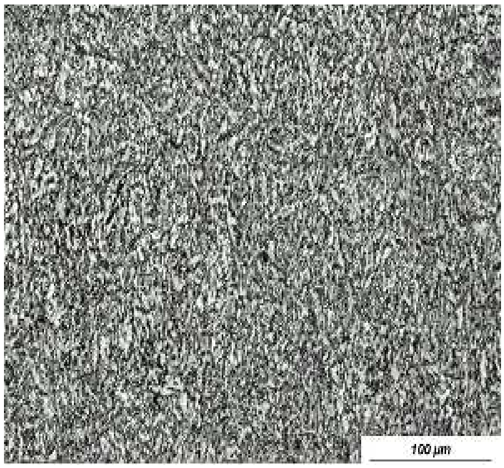

Figure 2. Optical micrograph of the specimen T5

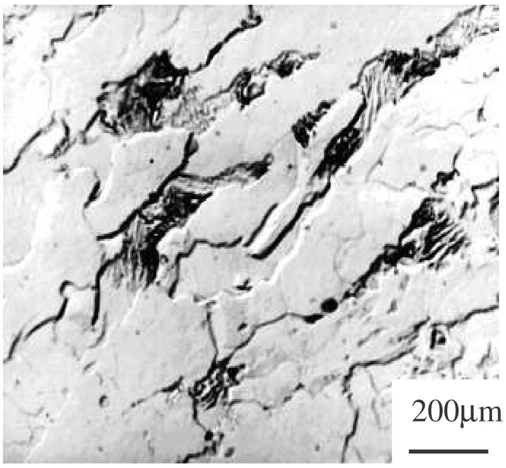

Figure 3. TEM, specimen T5

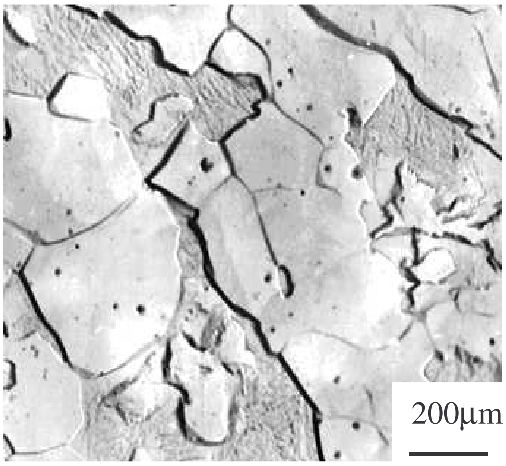

Figure 4. TEM, specimen T6

4. CONCLUSSION

The effects of TMP on microstructure, morphology and volume fraction of retained austenite were investigated using different conditions of intercritical annealing and subsequent heat treatment in the bainitic region. The best ferritic – bainitic fine grained microstructure was for found in specimen T6. This imply that optimum TMP for used TRIP steel consisted of austentitization at the temperature of 850°C followed by deformation at 700°C and rapid cooling to the bainite transformation temperature of 400°C.

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