TENSILE PROPERTIES OF DIFFERENT CHEMICAL COMPOSITIONS FOR TRIP-ASSISTED MULTIPHASE STEEL FOR AUTOMOBILE STRUCTURES

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ABSTRACT—The microstructural changes and the tensile properties of TRIP-assisted steels resulting from different chemical compositions were investigated by using SEM, TEM, XRD and UTM. As a result of microscopic observation, the morphology of retained austenite could be characterized by two types: a granular type in steel containing higher Si and a film type in steel having higher C. In the case of the steel containing higher C with a tensile strength of 860 MPa and a total elongation of 38%, the film type retained austenite could be observed among the lath bainitic ferrites. Actually, the metastable retained austenite was required for good formability, which means that the chemical composition plays a significant role in the microstructure and tensile property of TRIP-assisted steel. With respect to the tensile property, each steel type that contained an suitable amount of Si and Mn demonstrated a typical TRIP effect on a stress-strain curve while steel that contained a higher Mn content exhibited similar behaviors, as demonstrated in the dual phase steels.

KEY WORDS : TRIP (Transformation-induced Plasticity), Microstructural change, Tensile property, Chemical composition, Metastable retained austenite, Morphology of retained austenite

1. INTRODUCTION

TRIP (Transformation Induced Plasticity)-assisted multiphase steel with Fe-Mn-Si-C as the basic chemical component is obtained through isothermal treatment in the temperature range for a bainite transformation after a process of intercritical annealing (in the region of ferrite and austenite) that is used to produce the dual phase steels. In fact, intercritical annealing and isothermal treatment has been used as a significant two-stage heat treatment for manufacturing TRIP-assisted steel. Some austenite is transformed into bainite during the process of isothermal treatment and suitable amounts of retained austenite are metastable at room temperature. In general, the TRIP-assisted steel shows the triple-phase microstructure composed of ferrite, bainite and retained austenite after an isothermal treatment (Liu et al., 1990; Sakuma et al., 1991).

The retained austenite of TRIP-assisted steels transforms into martensite through mechanical deformation during the tensile test, and as a result, quite excellent elongation is obtained. This process has been termed, TRIP (Transformation Induced Plasticity).

Since the retained austenite greatly influences the TRIP mechanism, current research focuses on the volume fraction and stability of retained austenite. In addition, the morphology of retained austenite is also taken into consideration.

The TRIP-assisted multiphase steel contains ferrite, bainite, martensite and retained austenite, combined in suitable volume fractions and allows for a wide range of automobile part applications like bumper reinforcement, door impact beam and wheels. A combination of strength-elongation with TRIP assisted steel raises it above the level of high-strength steels that are applied in the automobile industry (Zackay et al., 1967).

The TRIP-assisted multiphase steel can be conducive to automobile safety due to mechanical properties such as high strength and expansive elongation, which means that it can certainly absorb the impact energy at the time of an automobile crash. More importantly, it is now being used for application in impact-absorbing steels with high levels of toughness (Cho et al., 2007).

In this paper, the effects of chemical composition (C, Si, Mn) on the microstructures and the tensile properties of three kinds of TRIP-assisted steels during the process of intercritical annealing and isothermal treatment were investigated. In particular, the morphology of retained austenite was analyzed by metallography over the three kinds of steels with different chemical compositions. Then, the volume fraction of retained austenite after an isothermal treatment was compared for each sample at room temperature. In addition, the changes on the stress-strain curve after a tensile test were examined relative to the chemical compositions (C, Si, Mn).

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2. EXPERIMENT PROCEDURE

2.1. Alloy Design and Fusion
On the basis of Fe-Mn-Si-C, three kinds of TRIP-assisted alloys with different chemical compositions (C, Si and Mn) were designed and those alloys were melted in a VIM (Vacuum Induced Melting Furnace). The chemical compositions of the steels used in this study are shown in Table 1. For the case of HS steel, the composition of Fe-0.15C-1.37Si-1.93Mn was used as a standard sample, as this is a typical chemical composition of low carbon TRIP-assisted steel. For the case of HC, the content of C was increased to 0.27%. In addition, for HM, the content of Si was decreased to 0.86% for the production of the alloy.

2.2. Homogenization and Heat Treatment
The alloy ingots were homogenized and maintained for approximately 12 hours at 1,250°C. Then, the hot rolling was performed while maintaining the finishing temperature at 900°C to produce hot-rolled steel sheets with a final thickness of 1.5 mm. Next, the annealing treatment was processed at the single region of austenite at 900°C for 5 min.

For a significant two-stage heat treatment, intercritical annealing was processed for 5 min. at 780°C, and an isothermal treatment was continuously performed for 100 sec in a salt-bath furnace (NaCl:KCl = 1:1) at 410°C, when rapid cooling was performed in the intercritical range, as shown in Figure 1.

2.3. Microstructure Observation
An observation using TEM was made to compare the morphologies of retained austenite existing at room temperature after an isothermal treatment. Also, SEM was used to observe the secondary phase of multiple structures and the fractured surfaces after a tensile test. A SEM specimen was etched with 2% natal and TEM was Z-polished in 21V and 0.25 mA conditions in the mixed solution of CH₃COOH + HClO₄.

2.4. X-ray Diffraction Test
An X-ray diffraction test was performed to compare the volume fractions of retained steel austenite with different chemical compositions. X-ray diffraction analysis was processed in the range of 2Θ = 60°~90° at a scanning speed of 2°/min. by use of a CuK₀ characteristic X-ray.

2.5. Tensile Test
A tensile test was performed at a strain rate of 1 mm/min at room temperature to compare the tensile characteristics by chemical composition after a two-stage heat treatment. The specimens for a tensile test were made in a plate-shape, 6.0 mm wide, 40 mm long in the marked distance. In this case, the direction of the tensile axis was parallel to the rolling direction.

Table 1. Chemical compositions of steels used in this study. (wt.%)

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>Fe</th>
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</thead>
<tbody>
<tr>
<td>HS</td>
<td>0.15</td>
<td>1.37</td>
<td>1.93</td>
<td>Bal.</td>
</tr>
<tr>
<td>HC</td>
<td>0.27</td>
<td>1.38</td>
<td>1.88</td>
<td>Bal.</td>
</tr>
<tr>
<td>HM</td>
<td>0.16</td>
<td>0.86</td>
<td>1.82</td>
<td>Bal.</td>
</tr>
</tbody>
</table>

Figure 1. Schematic diagram showing heat treatment in TRIP-assisted steel.

Figure 2. SEM micrographs showing the microstructures in the secondary phase: (a) HS; (b) HC; (c) HM steels.