10th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2006, Barcelona-Lloret de Mar, Spain, 11-15 September, 2006

MICROSTRUCTURE DEVELOPMENT IN TRIP STEEL AFTER SIMULATED THERMO-MECHANICAL PROCESSING

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ABSTRACT

Low alloy multiphase steel with the following composition was used in this work: 0.18% C, 1.45% Mn, 1.9% Si, 0.02% P, 0.07% S with 0.05% Nb. The steel was processed by several thermo-mechanical processing (TMP) methods consisting of high temperature deformation followed by different numbers of deformations, subsequent isothermal holding in the bainite region and cooling to room temperature. The microstructure was characterised with the use of light microscopy (LM), transmission electron microscopy (TEM) and confocal laser scanning microscopy. Extraction carbon replicas for TEM were prepared from metallographic samples. Volume fraction of different phases was determined by image analysis and X-ray diffraction phase analysis.

Keywords: low-alloy TRIP steel, thermo-mechanical processing, transmission electron microscopy

1. INTRODUCTION

Transformation induced plasticity steels (TRIP) belong to the group of advanced high strength steels (AHSS) and their use in the automotive industry has been increasing due to their excellent mechanical properties. The remarkable strength to ductility balance obtained in TRIP steels results from strain-induced transformation of retained austenite to martensite during plastic deformation [1]. The amount, morphology and stability of retained austenite is therefore important for the mechanical properties of TRIP steel. Convenient phase composition, uniform distribution of individual structural components and small grain size also play an important role in the utilization of the TRIP effect.

TRIP steels usually possess a multiphase ferritic-bainitic microstructure with a high content of retained austenite. Austenitic islands have to be dispersed at the grain boundaries of fine-grained proeutectoid ferrite and in bainitic ferrite. Special thermo-mechanical processing methods have to be used to achieve multiphase microstructure of TRIP steels [2].

Since the late 1970s different TRIP steels have been developed on the base of low alloyed manganese steels with a high content of silicon and microadditions of niobium, aluminium, copper or phosphorus [3]. Niobium is one of the most frequently used micro alloying elements because of its strong effect on the microstructural and mechanical properties of steel [3,4]. The microaddition of niobium is used to obtain a finer ferrite grain and to increase stability of retained austenite. Niobium inhibits recrystallization of austenite by a strain induced precipitation and retards the kinetics of the austenite to ferrite transformation. Niobium in TRIP steels also increases the amount of retained austenite by retarding the precipitation of carbides during the bainite transformation [4].

2. EXPERIMENTAL PROGRAMME

Low alloy C-Mn-Si-Nb multiphase steel was used in this work (Tab.1). Specimens were machined from forged bars and then processed by a thermo-mechanical processing simulator. The simulator allowed temperature control and application of various numbers of tensile and compression deformation during the processing. Deformation temperature was monitored by thermocouples fixed to the surface of the central part of specimen.

Tab.1: Chemical composition of TRIP steel.

Element	C	Mn	Si	P	S	Cr	N i	Cu	Nb
Weight %	0.19	1.39	1.92	0.012	0.006	0.04	0.04	0.04	0.09

Various strategies of TMP with different numbers of deformation steps were applied to specimens S1-S7 (Tab 2, Tab3). Niobium can be present in the microstructure of steel either as precipitated particles (Nb(CN)) or dissolved in solid solution and its effect on the microstructural and mechanical properties of TRIP steels is different in each case. A high austenitization temperature of 1230°C ensures dissolution of niobium particles in austenite, so this temperature used for all specimens. Determination of the most suitable austenitization temperature is described elsewhere [5]. A holding time of 300s at 420°C and subsequent air cooling to room temperature was also applied to all specimens.

Table 2:Thermo-mechanical processing of specimens S1-S5.

Specimen	Austenitization [°C] / [s]	1st deformation step (compression) [°C] / [%]	2nd deformation step (tension) [°C] / [%]	3rd deformation step (compression) [°C] / [%]	4th deformation step (tension) [°C] / [%]
S1	1230 / 5	1100 / 50	750 / 30	-	-
S2	1230 / 5	1100 / 50	750 / 34	670 / 34	-
S3	1230 / 5	1100 / 50	750 / 25	700 / 25	640 / 25
S4	1230 / 5	1100 / 50	780 / 35	740 / 35	680 / 40
S5	1230 / 5	1100 / 25	1100 /25	750 / 50	680 / 50

Table 3: Thermo-mechanical processing of specimens S6-S7.

Specimen	Austenitization [°C] / [s]	1st deformation step (compression) [°C] / [%]	2nd deformation step (tension) [°C] / [%]	3rd-10th deformation steps (in turns compression and tension) [°C] / [%]	Cooling rate between 3rd-10th. deformation steps [°C/s]
S6	1230 / 5	1100 / 25	1100 / 25	850-680 / 140	3
S7	1230 / 5	1100 / 25	1100 / 25	850-680 / 140	10

The specimens were cut along their longitudinal axis after processing and metallographic samples were prepared. The microstructure was characterized using light microscopy, transmission electron microscopy and confocal laser scanning microscopy. Extraction carbon replicas for TEM were prepared from electrolitically polished specimens etched in 3% Nital. Plane fractions of bainite and ferrite were determined by quantitative evaluation and the volume fraction of retained austenite was established by X-ray diffraction phase analysis.

3. RESULTS AND DISCUSSION

The TMP schedule of specimen S1 was chosen according to the results of previous experiments [5]. The microstructure of specimen S1 was coarse, ferritic-bainitic (Fig.1). The size of the bainitic blocks was around 60 μm and the volume fraction of ferrite was only 33% (Tab.4). This microstructure is unsuitable for practical use of TRIP steels. Therefore TMP methods with three deformation steps (S2), four deformation steps (S3-S5) and ten deformation steps (S6, S7) were applied to refine the microstructure and improve volume fractions of structural components.

Table 4: Phase fractions of ferrite and retained austenite in specimens S1-S7.

Specimen	S1	S2	S3	S4	S5	S6	S7
Ferrite [%]	33	60	56	51	59	44	31
Retained austenite [%]	10	12	7	8	10	12	11

The third deformation step was carried out at the temperatures of 670°C. Specimen S2 exhibited less coarse ferritic-bainitic microstructure with higher fractions of ferrite than specimen S1. Small pearlitic areas were observed in the TEM micrographs (Fig.2).

The addition of a fourth deformation step brought further refinement of the microstructure. Bainite was in the case of specimens S3-S5 "torn" into smaller areas that were connected by ferritic grains (Fig.3). The islands of M-A constituent and large numbers of Nb(CN) particles in proeutectoid ferrite were found in TEM micrographs (Fig.4).

Despite the high level of deformation, the microstructure of specimens S6 and S7 was coarse with a relatively low fraction of ferrite (Fig.5). Large martensitic islands (Fig 6) and islands of M-A constituent were observed in TEM micrographs of both specimens. Martensite was present in the microstructure either in the blocky form between grains of proeutectoid ferrite or as laths of M-A constituent distributed among the islands of bainitic ferrite.

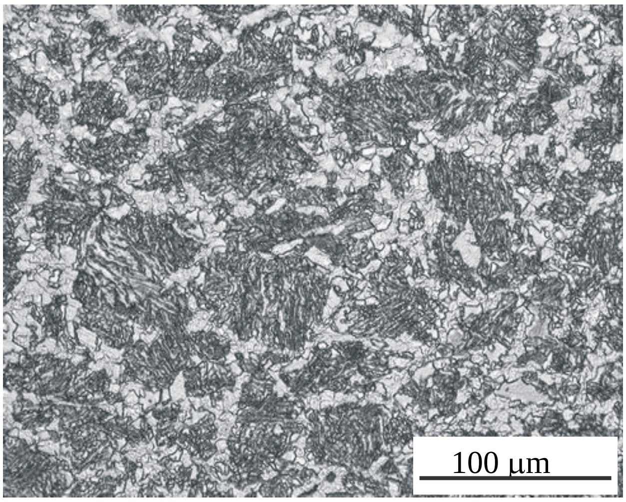

Figure 1. Coarse ferritic-bainitic microstructure, S1, LM, nital.

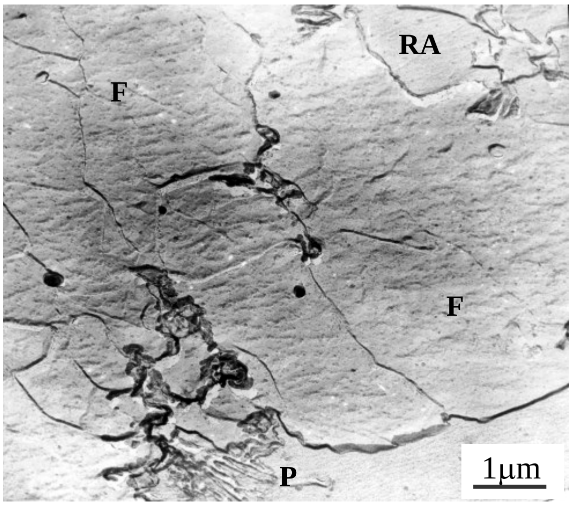

Figure 2. Ferrite grains with pearlite, S2, TEM, nital.

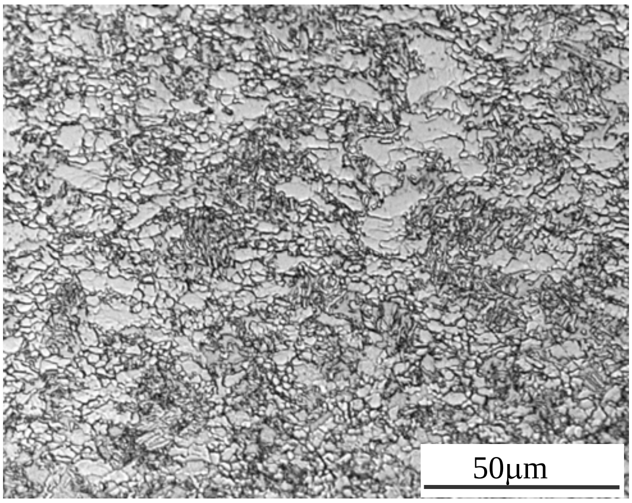

Figure 3. Ferritic-bainitic microstructure, S5, LM, nital.

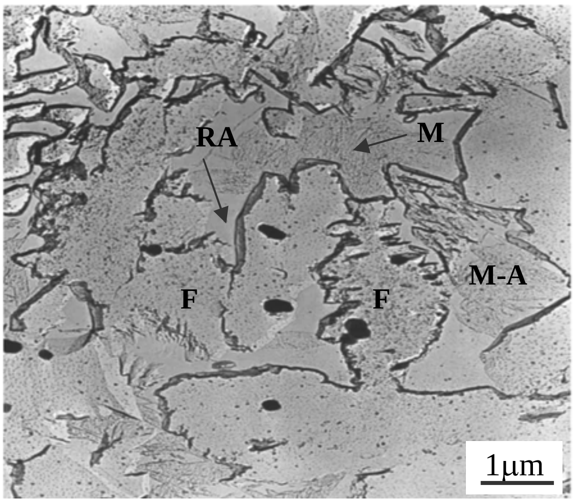

Figure 4. Islands of M-A constituent and ferrite, S5, TEM, nital.

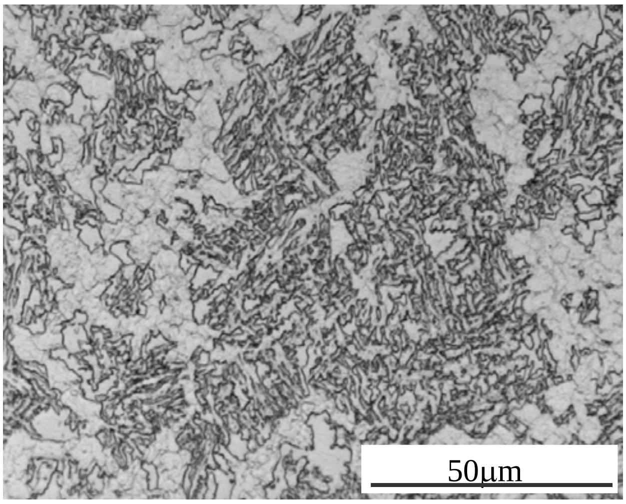

Figure 5. Coarse ferritic-bainitic microstructure, S6, LM, nital.

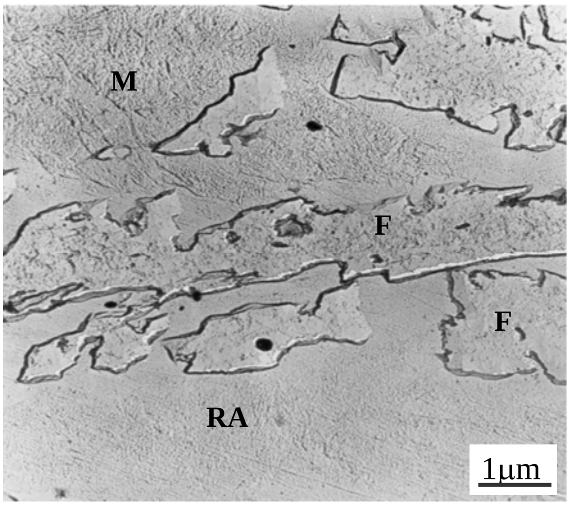

Figure 6. Large island of martnesite and retained austenite, S6, TEM, nital.

4. CONCLUSIONS

TMP with one deformation step (S1) and ten deformation steps (S6, S7) led to very coarse microstructures with relatively low ferrite fractions, which are not suitable for utilization of the TRIP effect.

Application of TMP with four deformation steps (S3-S5) resulted in the refinement of the microstructure and convenient volume fractions of structural components. An average ferritic grain size of about 3μm was achieved. Some larger bainitic blocks still persisted in the microstructures, however the appearance and distribution of bainite in specimens S3-S5 differs from the large compact blocks which were observed in specimens S1-S2 and S6-S7.

Ferritic-bainitic microstructures with different volume fractions of ferrite and retained austenite were observed in all specimens after TMP. Volume fractions of retained austenite (7-12%) were sufficient for TRIP steels in all specimens used in this research. From above mentioned results can be assumed that researched steel possesses relatively wide interval of processing parameters to achieve good stability in technological applications.

5. REFERENCES

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