STRUCTURE AND PROPERTIES OF FERRITE - BAINITE STEELS

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ABSTRACT

Ferrite - bainite steels have been developed and are applied to automotive parts such as for example wheels. An optimized wheel is a wheel specially designed to minimize its weight. The overall geometrical shape of the disc and rim are very often fixed and cannot be modified, so that the only possibility of reducing the weight is to reduce the thickness of the blank. This has an immediate effect of increasing the service stress, making it essential to improve the mechanical strength of the material employed. Samples of a C-Mn-Mo steel have been rolled at the laboratory rolling mill TANDEM in VSB-TU Ostrava. The samples have been cooled under different cooling pattern after hot rolling. Microstructure and mechanical properties have been determined on the finished hot rolled sheets. The effect of cooling temperature on microstructure and mechanical properties of a C-Mn-Mo steel is discussed.

KEYWORDS

Ferrite - bainite steel, laboratory rolling

INTRODUCTION

The automobile industry has made efforts to reduce body weight to economize fuel consumption and to strengthen the body for the improvement of safety. In order to meet these demands, the use of hot rolled high strength steel for wheels, bumpers and chassis parts has been tried, and number of applied parts has increased year after year. Several kinds of high strength strip steels such as Dual-phase steel [1] composed of ferrite and martensite and Ferrite-Bainite steel [2] have been developed and applied to automotive parts.

Distinguishing between the various eutectoid transformation products of steels is a difficult task. Bainite can appear in numerous forms. Isothermal transformation of austenite give upper or lower bainite. The situation is more complicated during continuous cooling transformations of austenite. Then, extensive amount of microstructures can be observed [3] . During a very slow cooling a grow of acicular ferrite is connected with further component which can consist of carbide, martensite and austenite in addiction to carbon content in austenite, diffusion kinetics of carbon, chemical composition of steel, etc. Upper or granular bainite rise also in high strength steels with %C bellow 0,1 at higher cooling rates [4].

In this paper, the effect of cooling temperature on microstructure and mechanical properties of a laboratory rolled C-Mn-Mo steel is discussed.

EXPERIMENTAL PROCEDURE

Material

The experimental alloy used in this study was prepared as a 40 kg melt and cast to slabs. The dimension of these slabs was as followed: 20 mm (thickness), 37 mm (breadth), 111 mm (length). The final chemical analysis was of the following chemical composition: 0.065 pct C, 1.48 pct Mn, 0.295 pct Si, 0.031 pct P, 0.026 pct S, 0.16 pct Mo, 0.030 pct Al, 0.0007 pct Ca. Blanks (18 mm x 35 mm x 109 mm) were machined from these slabs.

Hot rolling and controlled cooling

The blanks were reheated at 1200 °C for 10 minutes, hot rolled to 2.0 mm thick plates and control cooled under different cooling pattern on the laboratory reversible two - high rolling mill TANDEM [5,6]. The rolling mill TANDEM is equipped by the simple quenching gadget (the foldaway part of conveyer behind the second rolling mill with quenching tub). Spraying of rolling stock with cooling water is carried out by two slot nozzles with controllable supply of water. These nozzles are horizontally adjustable bellow and under specially adapted section of roll table (controlled cooling). Full details of the hot rolling of specimens including reductions may be found in Ref. [7]. After hot rolling the blanks were cooled from finished temperature at 900 °C to a coiling temperature at 200, 250, 300 °C, respectively. The plates were immediately after cooling stored in an annealing furnace at 200, 250 and 300°C, respectively, for one hour (to simulate coiling after hot rolling and cooling).

Microstructural analysis and tensile properties

The microstructural analysis was conducted on through-thickness sections from specimens using optical microscopy and improved etching technique to identify the nature and the amount of the various microconstituents. Specimens for the microstructural analysis were polished and etched with 2 % Nital solution and also with improved etching technique (mixture of 1 % sodium metabisulfite in distilled water and 4 % picric acid in ethyl alcohol in 1 : 1 volume ratio) to develop better contrast needed to differentiate between various microconstituents [8]. The microhardness measurements of phases were not performed because of fineness of grains. The mechanical properties were evaluated on a ZD10 tensile testing machine using a crosshead speed of 0,508 mm per minute to failure. Yield strength (0,2% offset) and ultimate tensile strength (TS) values were determined in the conventional manner and uniform elongation was measured at the maximum load on the load-elongation charts.

RESULTS AND DISCUSSION

Figures 1-4 illustrate the range of optical microstructures observed in different specimens cooled from 900 °C and coiled at various temperature after etching in 2 % Nital solution and in improved etching technique, respectively. All the specimens had a dual-phase microstructure of granular bainite grains in a ferrite matrix. The specimens contained some third microconstituent in addition, see Figures 1,2 properly The third microconstituent is more distinct after improved etching, see Figures 3,4. In Figures 3,4, the gray-etching phase is ferrite, the black-etching phase is granular bainite and the white phase is carbide as product of transformation of retained austenite. The white phase corresponds with the third miroconstituent apparent in Figure 1 and 2.

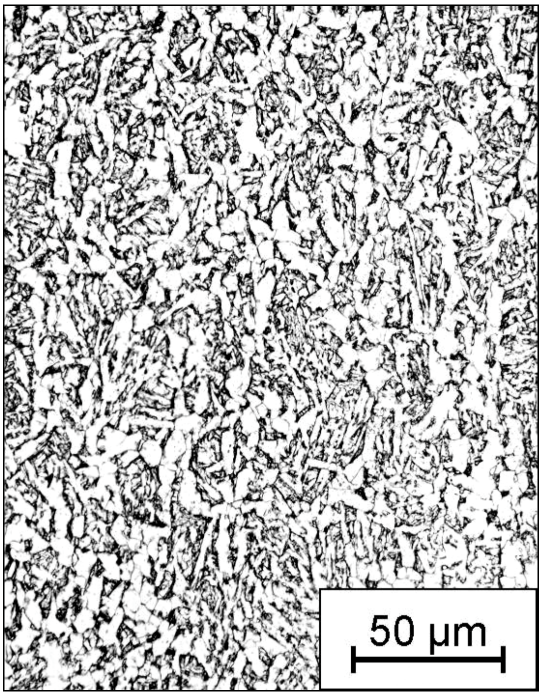

Fig. 1 Optical micrograph of specimen coiled at 250°C (2 % nital)

Fig. 2 Optical micrograph of specimen coiled at 300°C (2 % nital)

Table 1. Mechanical properties

Coiling Temperature [°C]	YS (0,2 %) [MPa]	TS [MPa]	A [%]
200	437	590	19,2
200	444	594	18,0
250	437	587	20,0
300	438	576	20,4

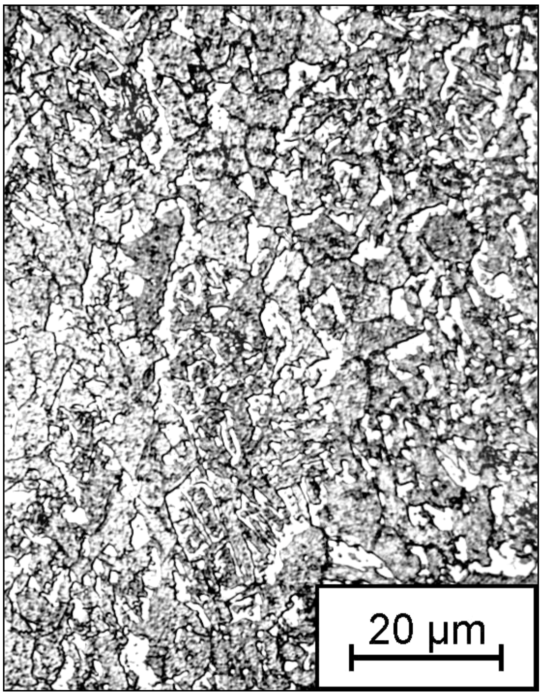

Fig. 3 Optical micrograph of specimen coiled at 250°C (improved etchant)

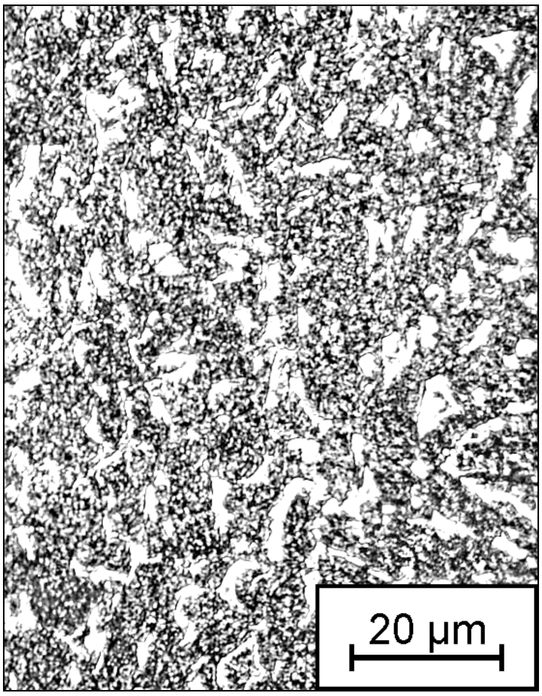

Fig. 4 Optical micrograph of specimen coiled at 300°C (improved etchant)

Values of mechanical properties are listed in Table 1 and results of microstructural analysis are shown in Table 2 The data in Tables 1 and 2, respectively, demonstrate that coiling temperature has an important influence on the mechanical properties and microstructures evolved. The ultimate tensile strength (TS) gradually decreases with increasing coiling temperature and the ductility (A) shows a rather increase as the coiling temperature increases. The influence of coiling temperature on yield strength (YS) is not so evident. The gradual decrease in TS with increasing coiling may be explained in terms of increasing of the amount of the third microconstituent and decreasing of the amount of bainite.

Table 2. Microstructural analysis

Coiling Temperature [°C]	% Ferrite	% Bainite	% Third Constituent
200	24	64,5	11,5
200	22	68	10
250	31	50	19
300	42	31	27

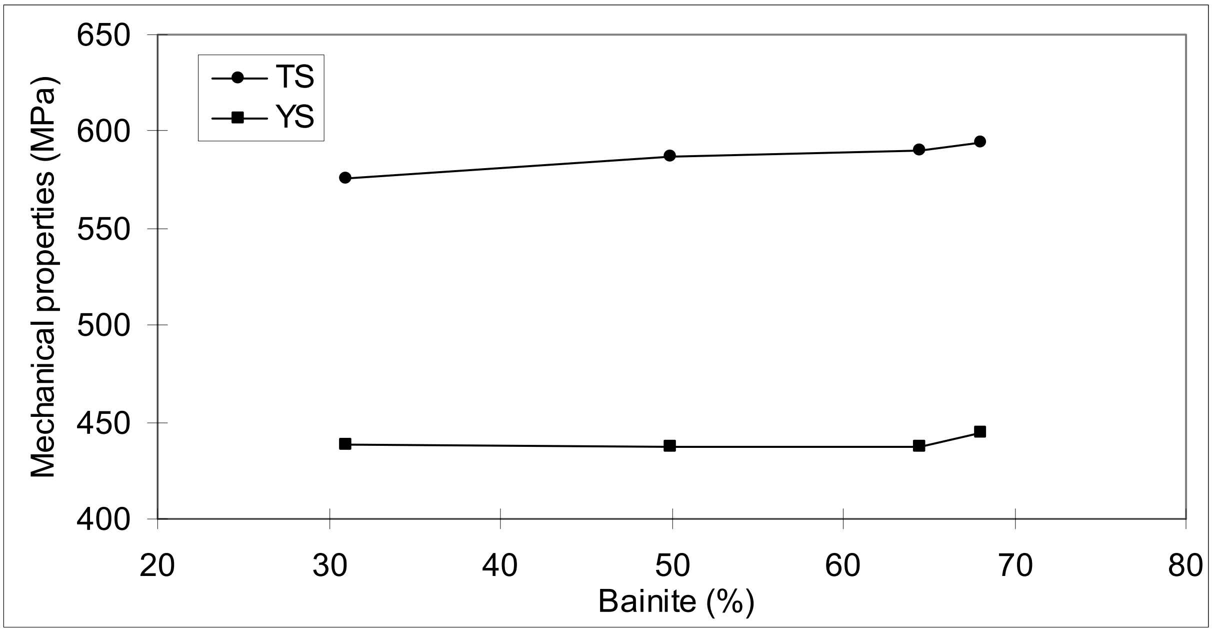

Fig. 5. Mechanical properties as a function of bainite volume fraction.

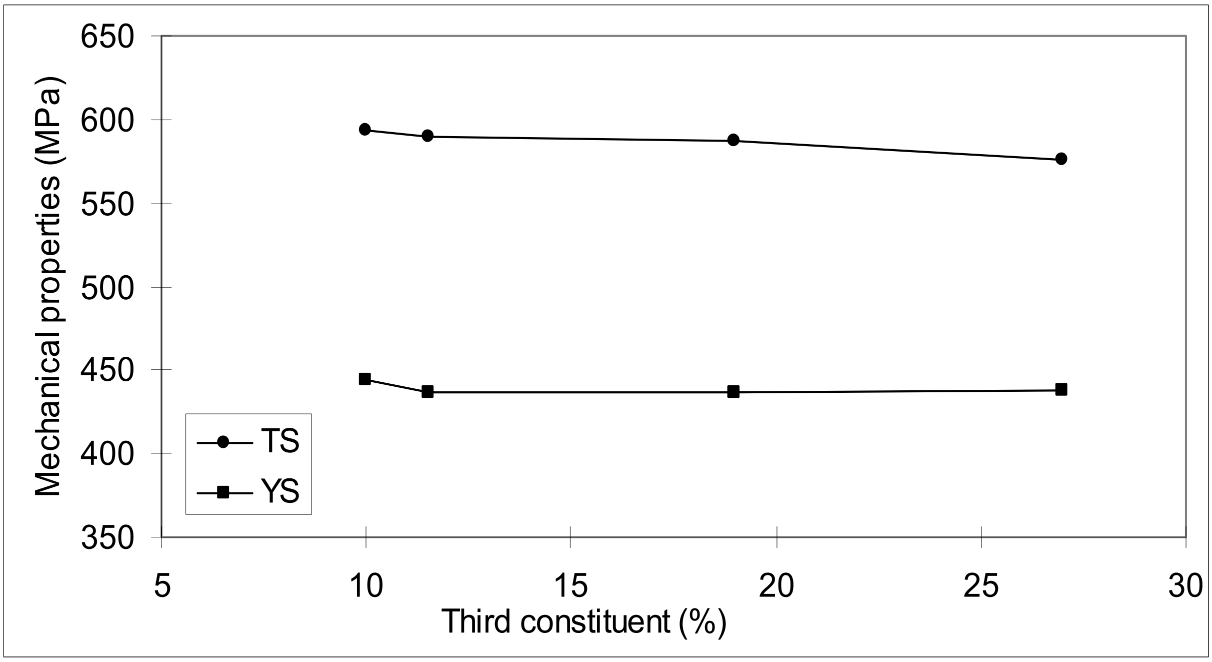

Fig. 6. Mechanical properties as a function of third constituent volume fraction.

To illustrate the effect of microstructure more clearly, the tensile properties in Table 1 are shown as function of phase volume fraction in Figures 5 and 6, respectively. On the basic of the trends in these figures, it appears that the effect of microstructure is following. The

ultimate tensile strength of steel decreases and ductility increases with decreasing of bainite volume fraction and increasing of third microconstituent volume fraction. The influence of microstructure on yield strength is not so evident. As was shown in Ref. [9] a granular bainite need not only consist of stabilized austenite in ferrite matrix, but a part of austenite can transform to carbides and ferrite or to martensite, respectively, during cooling. In this case the third microconstituient is result of transformation of austenite to carbides as results from metallographic observation..

CONCLUSION

Hot rolled sheets of C-Mn-Mo steel have been rolled and controlled cooling at coiling temperature 200, 250, 300 °C, respectively, on the laboratory rolling mill TANDEM at VŠB-TUO. Mechanical properties have been determined as well as metallographic analyses have been performed on finished hot rolled sheets. In the C-Mn-Mo steel trial, for essentially constant finishing temperature examined, the final microstructure, volume fractions of phases, as well as mechanical properties are controlled by the coiling temperature.

Microstructure of all specimens consists of ferrite, bainite and third microconstituent (carbide) as result of austenite transformation. The mechanical properties depend on volume fractions of phases, which change in addition to coiling temperature. The ultimate tensile strength of steel decreases and ductility increases with decreasing of bainite volume fraction and increasing of third microconstituent volume fraction. The influence of microstructure on yield strength is not so evident.

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