POLISH ACADEMY OF SCIENCES - MATERIALS SCIENCE COMMITTEE
SILESIAN UNIVERSITY OF TECHNOLOGY OF GLIWICE
INSTITUTE OF ENGINEERING MATERIALS AND BIOMATERIALS
ASSOCIATION OF ALUMNI OF SILESIAN UNIVERSITY OF TECHNOLOGY
Conference Proceedings
11th INTERNATIONAL SCIENTIFIC CONFERENCE
ACHIEVEMENTS IN MECHANICAL & MATERIALS ENGINEERING

Thermomechanical treatment of HSLA steel QStE 480MC

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The paper relates the microstructure of high strength low carbon microalloyed QStE 460 MC steel with its properties resulting from various defined conditions of austenitization, forming and cooling. Parameters of austenite transformation in the deformation-free state as well as after controlled deformation in temperature region of spontaneous and retarded recrystallization of austenite were analyzed. Simulation of the controlled rolling and the controlled cooling process was used to determine the parameters of austenite transformation and to analyze the development of structural characteristics and mechanical properties of the steel.

1. INTRODUCTION

The recently developed high strength low alloyed steels, mainly those with low and very low content of carbon (structural steels and steels for gas pipelines), with better mechanical properties and lower price possess mostly non-tempered structures developed during controlled rolling and controlled cooling of conditioned austenite. The final microstructures are mixed structures of polygonal ferrite, pearlite, bainite and martensite, formed as a result of controlled cooling of the deformed austenite [1-3]. The present approach to classification of steels is based in the first place on defining of their service properties and in the second place on their chemical composition.

Another group of steels, which have been developed for automobiles and machine parts, are materials with the required strength exceeding 1000 MPa secured by martensitic or mixed martensitic-bainitic structure [4]. The new steels which are produced by controlled rolling and transformation strengthening is effective to reach better toughness, as well as the plastic properties exhibit very attractive values. Forced cooling, which was introduced successfully into the production of steel strips can represent the technological input, which balances the price level and the properties of steel.

The aim of the present paper was to investigate the influence of reheating temperature, range of austenite deformation and the cooling rate on the austenite conditioning before transformation starts. Rapid cooling of such conditioned austenite structure can optimize the

* Authors participate in the CEEPUS No PL-013/02-03 project headed by Prof. L.A. Dobrzański.

development of steel structure which could provide the required properties of intended manufactured product.

2. MATERIAL AND EXPERIMENTAL

The experimental material has been high strength low carbon microalloyed QstE 460 MC designed for automotive products. It was produced by hot rolling in a form of a semi-finished 32 mm thick plate. The semi-finished product was used to cut the specimens for the entire experimental programme. The local chemical analysis determined the chemical composition of the steel (% by weight) which is as follows: C 0.09; Mn 1.12; Si 0.02; P 0.01; S 0.009; Nb 0.04; Ti 0.07; Al 0.005, and V 0.003.

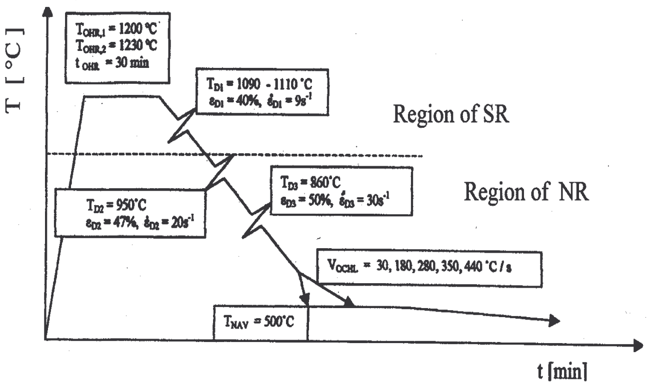

Figure 1. Controlled rolling deformation programme.

The experimental programme consisted of several stages. The mechanical properties of steel are strongly affected by the initial size of austenite grains, and because of that, the considerable attention was paid to the controlt of this structure parameter. The effect of reheating temperature on initial size of austenite grains was studied in temperature interval of <1000, 1230> ^{o}C and the heating time was varied within the interval of <30, 120> minutes.

The dilatometry measurements were used to determine the critical austenite transformation temperatures under deformation-free conditions at defined rates of cooling.

The simulated process of controlled rolling (CR) has been realised in laboratory rolling duo stand mill DUO 206 mm at two temperatures of reheating, 1200^{o}C and 1230^{o}C. The reheating time was of 30 minutes. The plastic deformations applied to specimens in the zones of spontaneous and retarded recrystallization of austenite are defined in the processing scheme illustrated in Fig.1. The process of plastic deformation was followed with rapid shower cooling (RC) at the five following cooling rates: 30^{o}C/s, 180^{o}C/s, 280^{o}C/s, 350^{o}C/s and 440^{o}C/s. The rapid cooling was stopped at 500°C and then simulations of the coiling process with cooling of a coil at 500°C were introduced. To distinquish the structure characteristics of transformed structures the structural analysis was carried out. Static tensile tests were conducted to determine strength and plastic characteristics of the steel

3. RESULTS AND DISCUSSION

The dependence of the austenite grain size and the temperature of reheating for three different dwelling times at reheating temperature is presented in Fig.2. According to the diagram a marked increase in initial austenite grains was observed in a temperature interval between 1050 ^{o}C and 1100 ^{o}C and later after exceeding the temperature of reheating over 1200 ^{o}C. On the basis of austenite grain size analysis results for the subsequent experimental rolling programme two selected reheating temperatures of 1200 ^{o}C and 1230 ^{o}C were selected, whereas the dwelling at the austenitization temperature was 30 minutes.

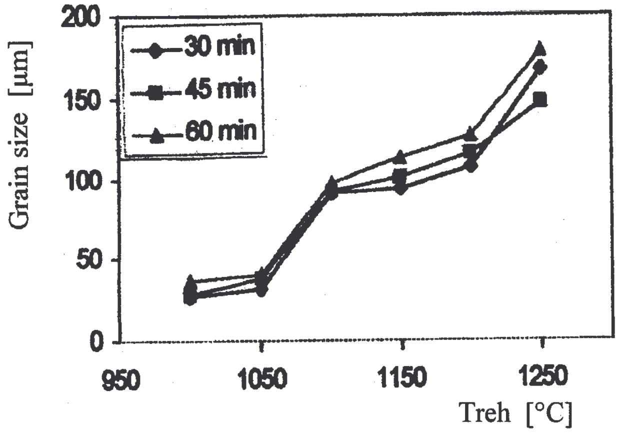

Figure 2. Relationship between grain size and Treh.

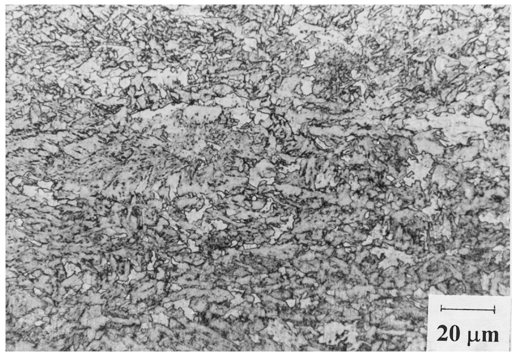

Figure 3. Micrograph of mixed structure resulting from cooling rate of 350 °C/s.

Dilatometry measurements were used to determine critical temperatures of transformation of the experimental microalloyed steel. The following critical temperatures were determined: A_{c1} = 728 °C, A_{r1} = 646 °C, A_{c3} = 882 °C and A_{r3} = 801 °C.

The controlled rolling deformation conditions and applied cooling rates, used in the study according the Fig. 1, influenced the transformation and resulted in formation of the mixture of different structures.

The lowest cooling rate of 30°C/s resulted in the development of equiaxed ferrite-perlite structure regardless the different temperature of austenization. The cooling rate of 180 °C/s produced acicular ferrite and upper bainite while the austenization temperature of 1230°C led to the presence of ultrafine deformation-induced ferrite in the structure. The composed structure formed at the cooling rate of 280 °C/s consisted of upper bainite, acicular ferrite and ultrafine deformation-induced ferrite. The cooling rate of 350 °C/s supported the development of a mixed structure consisting of upper bainite, acicular ferrite and ultrafine deformation-induced ferrite, as dokumented in Fig. 3. The highest cooling rate promoted the development of a mixed structure, similar to former cooling rate of 350 °C/s, consisting again of upper bainite, acicular ferrite and ultrafine deformation-induced ferrite. However, the volume fracture portion of the latter was lower than in the previous stated regime of CR.

Fig. 4 shows the dependence of tensile strength R_m and the yield strength R_e on the cooling rates for both austenitization temperatures. Summarising the strength and plastic behaviour of steel in dependence of the cooling rate the strength characteristics increase linearly with the increasing rate of cooling up to the rate of 350 °C/s. Regarding the structure analysis, the reason for strength decrease in case of the highest cooling rate of 440 °C/s could be ferrite portion in the mixed structure which could caused the drop in the tensile and yield strength. The ductility decreases proportionally to the growth of the strength-reaching minimum of 13% at austenization temperature of 1230 °C and at the cooling rate of 350 °C/s, Fig. 5. The relationship between the ratios R_e/R_m, which characterises the suitability of steel for construction forming purposes, and the cooling rate is shown in Fig. 6. The received ratio values were more advantageous when the reheating temperature was of 1230°C. However, for all applied cooling rates higher than 30°C/s the R_e/R_m ratio satisfies the engineering requirements

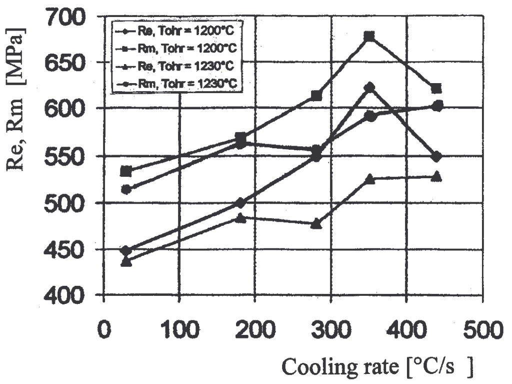

Figure 4. Dependence of Rm and Re on cooling rate

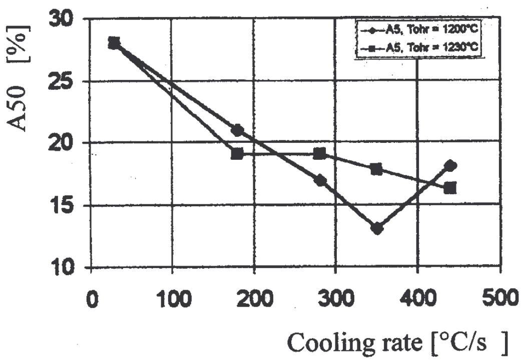

Figure 5. Elongation as the function of cooling rates.

4. CONCLUSIONS

The strength and generated plastic properties indicate that a suitable combination of controlled rolling and controlled cooling parameters regimes might optimise the microstructural characteristics of steel and provide satisfiyng required strength and plastic characteristics of the steel grade QStE 460 MC. As results indicate the most suitable regime from among all the regimes tested was that one which consisted of the austenization reheating at 1230 °C, followed by controlled rolling and rapid cooling at a rate of 350 °C/s which a mixed structure composed of upper bainite, acicular ferrite and ultrafine deformation-induced ferrite was received. The mechanical and plastic data resulting were the most advantageous of all used CR regimes. The thermomechanical process simulation of the steel grade QStE 460 MC where the controlled rolling and cooling parameters were involved provides a evidence that better industrial properties of structural steels for automotive applications can be received by cost atractive thermomechanical treatment which can replace more expensive post-rolling tempering treatment

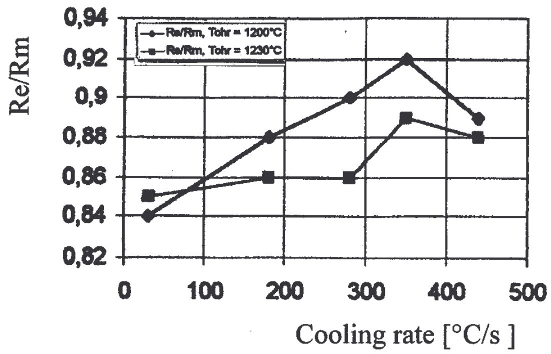

Figure 6. Relationship between Re/Rm ratio and cooling rate.

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