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INFLUENCE OF DEFORMATION INTENSITY AND COOLING PARAMETERS ON MICROSTRUCTURE DEVELOPMENT IN QP PROCESS

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Abstract: *The demands are increasing on material properties, lowering the mass of components, and lowering production costs are all strong drivers for the development of low-alloyed steels with high strength, which are economically attractive. New approaches to heat or thermomechanical treatments are therefore being designed for high strength steels which will help to achieve better mechanical properties than by conventional treatments. The aim of the experiment was to develop and optimize a new type of heat treatment based on the Q-P process which should be capable of achieving strengths of up to 2000 MPa with ductility of 10%. Low-alloyed steel 42SiCr was used in the experiment. During the optimization process, the main focus was on the influence of various intensities of incremental deformations in the range of thru strain=5-13.4 and the speed of cooling on the development of the structure.*

Key words: *unconventional treatment, incremental deformation process, new alloying conception, retained austenite*

1. INTRODUCTION

Improving the mechanical properties of steel using various types of heat or thermomechanical treatments instead of increasing the content of alloying elements has been an increasing trend over recent years. The basic principle of these treatments on high-strength steels is to originate bainitic or martensitic structures with suppressed precipitation of carbides and stabilization of retained austenite [1]. This is where the new approaches to heat treatments are very different from conventional ones. One of these techniques is the Q&P process (QP - quenching and partitioning process).

The Q-P process is a new kind of heat treatment which gives rise to a martensitic structure with foliated retained austenite surrounding martensite needles. The proportion of retained austenite, its morphology and distribution have a significant influence on mechanical properties, as does the morphology of martensite.

To obtain the required mechanical properties, the individual parameters of the process must be known. This article deals with the influence of the intensity of deformation and speed of cooling on the development of the structure, stabilization of retained austenite, and on mechanical properties [4].

Deformation of austenitic structures before they break down during cooling causes a fining of the resulting martensite needles, which can result in increased strength and fining of the austenite grains, contributing to stabilization of the retained austenite [3].

1.1 Q-P proces

The principle of the Q&P process [1,5] is rapid cooling of the material far below Ms temperature so that martensite does not transform throughout the volume of the material. The subsequent heating to just below M_s leads to the tempering of the martensite and diffusion or redistribution of excess carbon from the martensite to the retained austenite. Diffusion of carbon from the saturated martensite to the untransformed austenite increases the stability of the retained austenite with subsequent cooling to room temperature. The structure resulting from this process is formed of martensite and stabilized retained austenite. The origin of carbides is suppressed by using an appropriate alloying strategy and heat treatment conditions.

2. EXPERIMENT

A material with a new alloying concept was used for the experiment. It is a low-alloyed high strength steel with carbon content 0.4% - 42SiCr a with a significant amount of silicon about 2%. An increased amount of silicon prevents or at least slows the precipitation of carbides and enables diffusion of carbon to the retained austenite, which leads to its stabilization. The total low content of alloying elements ensures the economic attractiveness of this steel.

The initial structure of the material was formed of a ferrite-pearlite mix (Fig. 1). Ultimate strength in tension was Rm = 981 MPa with a hardness of 295 HV10.

2.1 Thermomechanical treatment

Thermomechanical treatment was carried out on the thermomechanical simulator at UWB at Fortech, which enabled precise control of temperature and deformation regimes including rapid incremental deformation [4].

To obtain good mechanical properties for the experimental material it was essential to optimize the parameters of the thermomechanical process [2]. In this case it meant describing the influence of the intensity of deformation and cooling speed.

A dilatometer was used to measure a temperature of Ms = 289°C and A_{c3} = 840°C. Therefore the heating temperature was 900°C with a holding time of 100 s. Deformation was carried out in the temperature interval between 900°C and 820°C which lasted 10s and was composed of 20 (logarithmic deformation φ=5), 40 (logarithmic deformation φ=10.4) or 60 (logarithmic deformation φ=13.4) incremental tension-compression deformation steps (Fig.2).

After deformation, it was rapidly cooled at 20°C/s to 200°C, when a 10s hold was carried out. Then followed heating to 250°C and isothermic holding for 600s at this temperature. At this temperature the redistributed carbon was diffused and the retained austenite was stabilized.

In further steps of the experiment, the influence of cooling speed from 900°C to 250°C was investigated on the development of the structure, chiefly on the formation of ferrite, pearlite and bainite. Three different cooling speeds were tested; 20 °C/s, 7 °C/s, 4,7 °C/s.

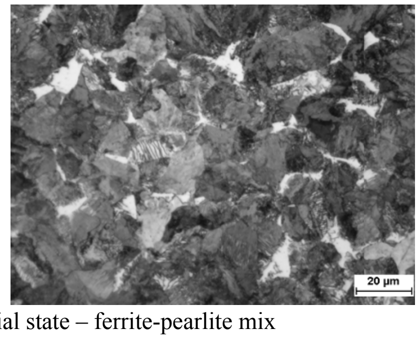

Fig. 1. Initial state – ferrite-pearlite mix

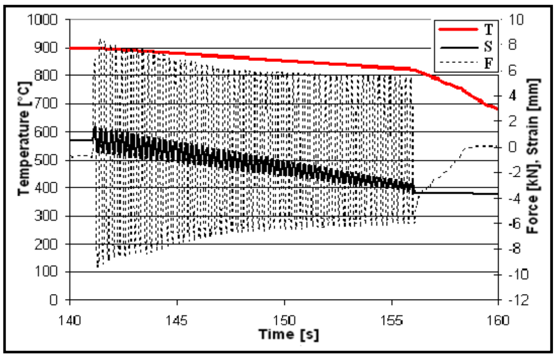

Fig. 2. Incremental deformation process, 20 deformation steps

2.2 Results and discussion

The resulting structures were evaluated using optical and laser confocal microscopy. Mechanical properties were found using a mini-tension test and hardness was measured. The amount of retained austenite was determined using x-ray diffraction analysis.

By increasing the intensity of incremental deformation the influence of any fining of the martensite matrix with bainite and the original austenite grains on mechanical properties was investigated. It was found that increasing the number of incremental steps led to a decrease in strength properties with ultimate strength values of 2081 MPa at 20 deformations and 1914 MPa with 40 deformations with a simultaneous widening of the interval of plastic deformation (Tab.1). At the same time there was also a decrease in the proportion of retained austenite in the structure from 17% at 20 deformations to 13% with 40 deformations. There was no significant difference in mechanical properties when the number of incremental steps was increased to 60. Hardness values for all strategies were around 550 HV10. Increasing the number of incremental deformations on the martensite structure with bainite and retained austenite only caused fining of the grains, and there was no change to the structure (Fig. 3).

At the highest cooling speed of 20°C/s from 900°C to 200°C a fine martensite structure with lower bainite with 13 % retained austenite developed. At lower cooling speeds of 7°C/s a large amount of ferrite occurred and at 4.7°C/s pearlite was observed (Fig. 4). Structural changes led to a lowering of hardness values from 551 HV10 to 509 resp. 515 HV10 and also to a change in mechanical properties. When comparing cooling speeds 20 °C/s and 4.7 °C/s a drop in hardness of 400 MPa was seen and a decrease in ductility of about 7% (Tab.2).

3. CONCLUSION

Thermomechanical treatment with incremental deformation and Q-P process was tested on low alloyed steel 42SiCr. The results showed the possibility of influencing the structure and thus the mechanical properties of the material using individual treatment parameters. Various intensities of incremental

Strategy: 900°C/100s-200°C/10s- 250°C/600s					
Deformation	HV10 [-]	$R_{p0,2}$ [MPa]	R_m [MPa]	A_5 [mm]	RA [%]
20x	551	2068	2081	13	17
40x	548	1498	1914	17	13
60x	540	1490	1940	15	-

Tab. 1. Influence of increasing the number of incremental deformations on mechanical properties

Strategy: 900°C/100s-200°C/10s- 250°C/600s					
Cooling speeds	Deformation	HV10 [-]	$R_{p0,2}$ [MPa]	R_m [MPa]	A_5 [mm]
20°C/s	20x	551	2068	2081	13
7°C/s	20x	509	1464	1879	10
4,7°C/s	20x	515	1221	1662	6

Tab. 2. Influence of cooling speed on mechanical properties

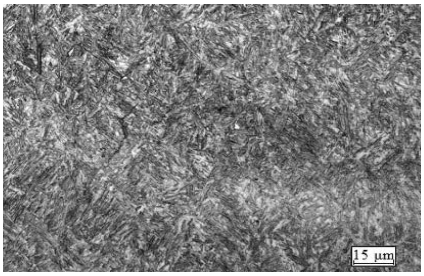

Fig. 1. Martensite matrix with bainite and retained austenite, cooling speed 20°C/s, 40 deformation steps

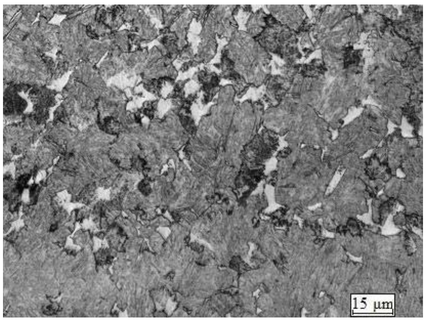

Fig. 4. Martensite matrix with retained austenite and ferrite-pearlite region, cooling speed 4.7 °C/s, 20 deformation steps

deformations and cooling speeds were experimentally tested. An increased intensity of deformations led to a drop in the strength of the material with a strength of 2081 MPa with 20 deformations - (φ = 5) and 1662 MPa with 60 deformations (φ = 13,4), but the plastic behavior of the material increased.

The influence of the cooling speed on the development of the microstructure and its influence on mechanical properties was also investigated. Lower cooling speeds led to creation of a significant portion of ferrite and pearlite. This change to the structure resulted in lower hardness and strength. At a cooling speed of 4.7 °C/s ultimate strength was found to be about 1660 MPa and ductility only 6%. Further optimizing steps will lead to describing further influences of Q&P process on the development of structures.

4. ACKNOWLEDGEMENTS

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