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TESTING OF THE PARAMETRES OF THE Q-P PROCESS IN HIGH STRENGTH LOW-ALLOYED STEEL

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Abstract: *The mechanical properties of new types of materials are dependent on their composition and the distribution of their microstructure. These microstructures are obtained innovative heat and thermo mechanical treatments. One of these is the Q-P process. During the Q-P process untransformed austenite is stabilized in a martensite matrix and carbides are suppressed in nucleation (Edmonds et al., 2006). The process was optimized in new low-alloy steel 42SiCr with the aim of creating a steel with ultimate strength 2000MPa and ductility over 10%. The resulting structure was analyzed using light and laser confocal microscopy. The quantity of the residual austenite was measured with X-ray diffraction analysis. The mechanical properties were validated with a tensile test.*
Key words: *Q-P process, low – alloyed high strength steel.*

1. INTRODUCTION

Industry is increasingly demanding materials with a good combination of mechanical properties, i.e. ultimate strength and ductility, at low cost. New trends are to reduce costs by reducing the content of high-alloy and creating the final microstructure using new heat and thermo mechanical treatments. One of these is the Q-P process. Achieving a good combination of strength and ductility can only be achieved by altering parameters such as length of heating, cooling rate, time and temperature quenching. All these parameters depend on the dimensions of the specimen, the chemical composition and other parameters of the components.

2. Q-P PROCESS

The quenching and partitioning process (Q-P process) consists of quenching at intervals between martensite start and martensite finish temperatures. After quenching, the temperature is held to stabilize untransformed austenite partitioning carbon. The carbon diffuses from the saturated martensite. This process is different from quenching and tempering (Fig.1).

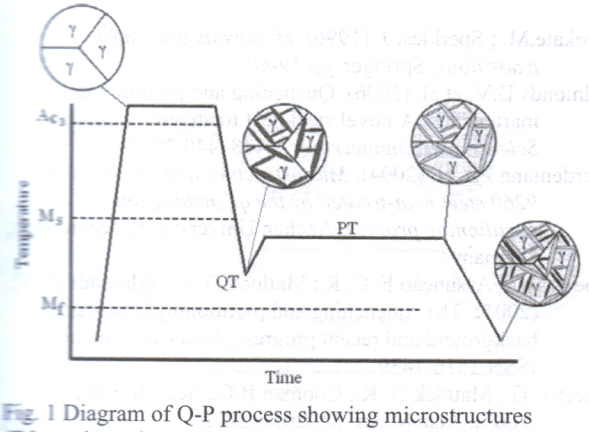


Fig. 1 Diagram of Q-P process showing microstructures (Edmonds et al., 2006)

During normal quenching and tempering, carbide is formed, but the Q-P process suppresses the creation of carbide using a suitable combination of heat treatment and alloying to stabilize the untransformed austenite.

The final structure consists of martensite and stabilized retained austenite. This structure ensures high ultimate strength and at the same time keeps very good ductility values (Gerdemann , 2004)(Speer et al. 2005).

3. EXPERIMENT

The aim of experiment was to propose parameters for a new heat treatment method with strength over 2000MPa and ductility over 10%. The first step towards optimization was to define a suitable austenization temperature, cooling rate and the stabilizing salt bath temperature. 42SiCr steel was used for the experiment. The main components this steel influencing stabilization of untransformed austenite and hardening solid solution are silicium, chromium and manganese. The quantity of all the components is less than 5%, which makes it economically viable. The basic microstructure was ferrite-pearlite with a higher proportion of pearlite. The hardness was 295HV in its base state (Fig.2).

Six heat treatment regimes were designed for testing the influence of Q-P process (Table. 1). The time of heating was between 20 - 30 min, the length of holding in salt bath was 5 – 10 min. The time in salt bath was established on the basis of dilatometric analysis so the temperature laid between martensite start and martensite finish temperatures. Dilatometer analysis showed the temperature of martensite start to be 305°C. To find the influence of cooling rate, two specimens were cooled in the water for 2s and then put in the salt bath . The specimens tested in this regime were 55 x 18 x 25 mm.

The final structure was evaluated with light and confocal laser microscopy. The sample was etched using 3% Nital. The structure of the heat treated specimens consisted of acicular martensite and retained austenite foil a few tens of μm thick

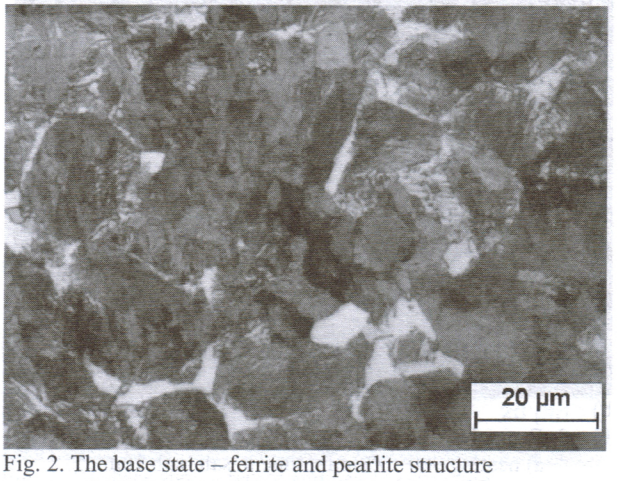


Fig. 2. The base state – ferrite and pearlite structure which were not visible with light microscopy.

Strategy	heating 900°C [min]	Cooling in water	Salt bath 250°C [min]
1	25	no	5
2	20	no	10
3	20	no	20
4	30	no	10
5	20	2s	10
6	30	2s	10

Tab. 1. Regime parameters

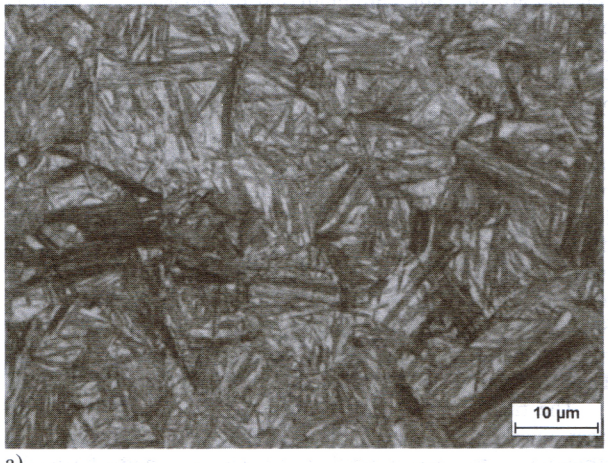
Different sizes of martensite were observed under light and confocal microscopy which were consistent with heat time. (Fig. 3. a, b)

3.1 The results of mechanical testing

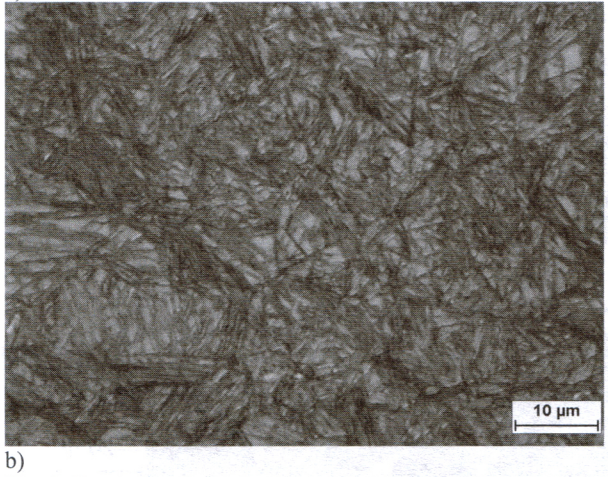
The mechanical properties were evaluated in a tensile test on the mini specimens whose active part was 5 mm long. (Table. 2).

The ultimate strength of the material was 980MPa and its ductility was A_{5mm} = 31 %. The ultimate strength was over 2000MPa and ductility more than 14% higher after heat treatment. The specimen with parameters 900°C/20min – 250°C/10min had the highest ductility; A_{5mm} = 18%.

The resulting strength and ductility values correspond closely with the proportion of retained austenite in the microstructure (Tab. 2), which were measured by x-ray phase diffraction analysis. As the amount of retained stabilized austenite increases, the tensile strength decreases and the ductility increases.



a)



b)

Fig. 3. Examples of final structure
a) heating 900°C/30min, time in salt bath 10min
b) heating 900°C/20 min, time in salt bath 10m

	$R_{p0,2}$ [MPa]	R_m [MPa]	A_{5mm} [%]	Proportion of RA [%]
Basic state	592	981	31	-
(900°C/25min – 250°C/5min)	1657	2157	14	5.1
(900°C/20min – 250°C/10min)	1714	2120	16	4.1
(900°C/20min – 250°C/20min)	1663	2038	18	9.8
(900°C/30min – 250°C/10min)	1728	2054	15	6.9
(900°C/20min – 2s water - 250°C/10min)	1765	2102	14	7.1
(900°C/30min – 2s water - 250°C/10min)	1852	2107	14	7.5

Tab. 2. Results of the tensile test and proportion of residual austenite

This is evident in the regime with parameters 900°C/20min – 250°C/20min where there is over 9% retained austenite. The ductility of this specimen was 18%, but ultimate strength was slightly decreased to 2030 MPa.

4. CONCLUSION

The optimization of the parameters of the Q-P process in a new experimental steel showed us the possibility of creating materials with an attractive combination of mechanical properties such as strength and ductility. The ultimate strength of the heat treated specimens was over 2000MPa and ductility around 15%. X-ray analysis confirmed the presence of retained austenite which was probably laid down as a thin film on the martensite plate. Cooling the sample in a medium with a high cooling intensity (water), and prolonged holding at austenization temperatures were found to be unsuitable treatments because of the resulting coarseness of the acicular martensite and deterioration of the samples' mechanical properties.

Influence and type of quenching and partitioning bath will be tested in the following step.

5. ACKNOWLEDGEMENTES

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