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INFLUENCE OF LOW TEMPERATURE THERMOMECHANICAL TREATMENT ON CARBIDE MORPHOLOGY OF RST37-2 STEEL

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Abstract: *High formability of steel is a very important parameter for cold forming of steel. Cold formability depends not only on chemical composition of steel, but also on the initial microstructure and the whole processing history. Spheroidization annealing lasting several hours can be used to improve formability, however it also increases time and energy consumption of the processing. This paper presents a new processing modification, which can lead to significant shortening of carbide spheroidization times on the one hand and on the other hand also to intensive refinement of grain size even for low-carbon steels. Microstructures with spheroidized cementite were obtained by several second lasting processing which consisted of heating to the temperature close to A_{c1} and intensive deformation.*
Key words: *formability, spheroidization, spheroidization annealing*

1. INTRODUCTION

Cold formed parts are used in a wide range of applications which do not come only from the machining industry. Their formability is conventionally improved by soft annealing that increases their ductility and machinability. These processes are characterised by their high energy demands because very long processing times are necessary for spheroidization of microstructure. One of the main aims of the research is therefore to propose new processing with shorter processing times (Karadeniz, 2008; Chen-Chia et al., 1986).

Annealing time depends mostly on carbon content and also on the amount of alloying elements which decrease carbon infusibility in ferrite or stabilise cementite. Another important factor is the initial microstructural state of material. Precipitation of carbides from bainite or martensite and their redistribution is much quicker than carbide spheroidization from lamellar pearlite. It is in some cases necessary to prolong the annealing hold to several dozens of hours (Ptáček, 2002; O´Brien & Hosfort, 1997).

Spheroidized microstructure has better cold formability due to the lower yield strength, which is influenced by the morphology and distribution of ferrite and carbides. Spheroidization can occur according to one of the following methods (Kamyabi-Gol & Sheikh-Amiri, 2010):

a) Isothermal annealing at temperature slightly under A_{c1}
b) Heating at temperature just above A_{c1} with subsequent cooling in furnace or with a hold immediately under A_{c1} temperature
c) Cyclical heating and cooling, so that the temperature oscillates around A_{c1} temperature.

The main aim of the experimental program was the development of an energetically undemanding technological process of low temperature thermo-mechanical processing with incremental deformation for a low carbon steel RSt37-2. Shorter annealing times are typical for this process and resulting spheroidization of microstructure with more homogeneous distribution of carbides.

2. EXPERIMENTAL PROGRAM

The experimental program was carried out on low carbon steel RSt37-2 (S232 JRC). It is an unalloyed structural steel; its initial state was cold formed. Initial microstructure was ferritic-pearlitic with lamellar morphology of pearlite. Ultimate strength of the steel in initial state reached 546 MPa, yield strength 477 MPa, ductility 21% and hardness 201 HV10.

The experimental program was divided into two parts. In the first stage conventional soft annealing was performed. In the second stage low temperature thermo-mechanical processing with integrated incremental deformation was carried out. Microstructures were analysed by light microscopy and laser scanning confocal microscopy and mechanical properties were evaluated by hardness test.

2.1 Conventional heat treatment

First of all, conventional heat treatment of the experimental steel was done in the furnace. Material obtained by this soft annealing process was used as reference material to be compared with the results achieved from the new unconventional thermo-mechanical treatment. Heating temperature of 700°C and a hold of 2 hours were applied with cooling in the furnace.

2.2 Low temperature thermo-mechanical treatment

Low temperature thermo-mechanical processing was carried out on a thermo-mechanical simulator to ensure precise temperature and deformation control. Several parameters have to be optimized to obtain suitable morphology and distribution of carbides and intensive grain refinement. These parameters include heating rate and temperature, temperature hold, applied deformation and cooling rate.

Several heating temperatures around A_{c1} were tested in the first step of the experimental program (Tab. 1). Temperatures of 700, 720, 740 and 760°C were chosen with heating rate of 30°C/s. A hold lasting either 10 or 100s was carried out at each heating temperature. At the end of the hold, just before free cooling in air began, a two-stepped deformation cycle consisting of tension and compression loading was applied. The overall logarithmic deformation was $\varphi = 0.8$. The same processing only without deformation steps was repeated for heating temperature of 740°C to obtain some comparison with undeformed specimens.

The influence of a higher number of incremental deformation steps on a more homogeneous distribution of carbides and ferrite refinement was tested in the second step of experimental program. While keeping other parameters untouched, the number of deformation steps varied in turns from 4 to 6 and finally to 8 (Tab. 1). Because it can be assumed that for intensive spheroidization of carbides lamellar pearlitic colonies must be not only broken into smaller areas but also dispersed, only two deformation steps were applied at 740°C in the next processing strategies. Tensile deformation of $\varphi = 0.3$ was carried out in the first step and intensive compression deformation of $\varphi = 1.7$ in the second one (Tab. 1).

Heating temp. [°C]	Hold [s]	Def.	φ [-]	Hold after def. [s]	HV 10
700	10		0.83	-	155
720	10		0.83	-	156
740	10	2x	0.83	-	154
740	100		0.83	-	158
760	10		0.83	-	157
740	10	4x	1.6	-	150
740	10	6x	2.5	-	143
740	10	8x	3.4	-	152
740	10	tension/ compression	0.3+1.7	-	166
740	10		0.3+1.7	300	121
740	10	60x + compression	6.7+1.1	-	170
740	10		6.7+1.1	300	130

Tab. 1. Low temperature thermo-mechanical processing

In the last tested processing strategy 60-stepped deformation with φ = 6.7 was applied. The aim was to find out, whether the breaking of lamellar pearlite and recrystallization initiation are more supported by one big deformation of the material, or rather by a large number of small incremental deformation steps. To move broken lamellas apart, one compression deformation of φ = 1.1 was applied at the end of processing (Tab. 1).

To evaluate the influence of diffusion, one variant with and one without the hold after deformation were tested in the last two processing strategies.

3. RESULTS AND DISCUSSION

Conventional annealing in the furnace resulted in ferritic microstructure with spheroidized cementite replacing the initial lamellar pearlitic areas.

First of all the effect of different processing temperatures was analysed for low temperature thermo-mechanical processing. It was found that pearlitic areas remained partially lamellar for lower heating temperatures of 700 and 720°C. From the temperature of 740°C spheroidized carbidic areas were observed in the microstructure. Applied deformation started the process of recovery in all cases and sub-grains were formed in originally deformed ferritic grains. Increasing the number of deformation steps from 4 to 6 and finally to 8 did not cause any significant changes in the microstructure. Intensive refinement of microstructure, breaking of pearlitic areas and redistribution of spheroidized carbides was achieved only when higher deformation of φ = 2.1 was applied in two deformation steps just before air cooling. Ferrite grain size reached in this case about 2 µm.

A very similar structure with newly nucleated subgrains in deformed ferritic matrix was also achieved in the case of 60 step deformation finished by one intensive compression deformation (Fig. 1). This was accompanied by strengthening of microstructure and hardness values of 166 and 170 HV10 were obtained.

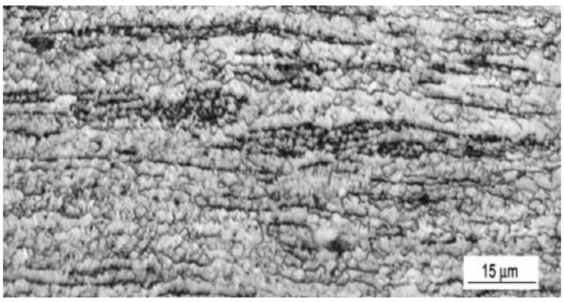

Fig. 1. 60 step deformation followed by one intensive compression deformation

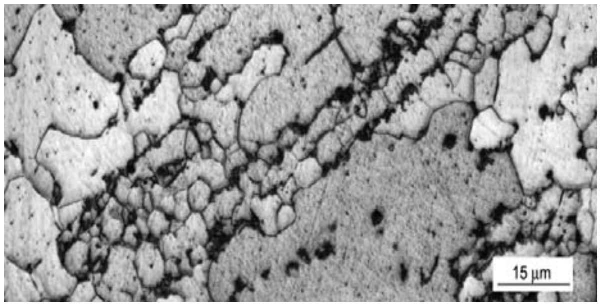

Fig. 2. 60 step deformation followed by one intensive compression deformation and 300s hold at deformation temperature

This was also apparent from the drop of hardness values to 121 resp. 130 HV10, which means a 27% decrease. The processing strategy with 60 deformation steps resulted in this case in a more pronounced coarsening of grains. It was probably caused by higher deformation energy which started a more intensive recrystallization processes.

4. CONLCUSION

A new low temperature thermo-mechanical processing strategy was proposed for a low carbon structural steel RSt37-2, which enables fine microstructures to be obtained with spheroidized carbides in a much shorter time than conventional heat treatment.

It was found that processing at the suitable temperature of 740°C can significantly refine the final microstructure when intensive tensile-compression deformation is applied, and furthermore, intensive spheroidization of carbides can be achieved. Processing conditions must allow the segmentation of pearlite and the applied deformation must separate and redistribute carbide particles at the same time.

In comparison with conventional annealing, the time necessary for spheroidization during thermo-mechanical processing was shortened from several hours to several seconds.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

Karadeniz, E. (2008). Influence of different initial microstructure on the process of spheroidization in cold forging. *Materials and Design,* Vol. 29, (November 2006) pp. 251-256, ISSN 0261-3069

Chen-Chia, C. et al. (1986). Accelerated spheroidization of hypoeutectoid steel by the decomposition of supercooled austenite. *Journal of Materials Science*, Vol. 21, (November 1985) pp. 3339-3344, ISSN 0022-2461

Ptáček, L. et al. (2002). *Nauka o materiálu II.*, Akademické nakladatelství CERM, ISBN 80-7204-248-3, Brno, Czech Republic

O´Brien, J. M. & Hosfort W. F. (1997). Spheroidization of Medium-Carbon Steels. *Journal of Materials Engineering and Performance*, Vol. 6, No. 1, (February 1997) pp. 69-72, ISSN 1059-9495

Kamyabi-Gol, A. & Sheikh-Amiri, M. (2010). Spheroidizing Kinetics and Optimization of Heat Treatment parameters in CK60 Steel Using Taguchi Robust Design. *Journal of Iron and Steel Research International*, Vol. 17, No. 4, (July 2008) pp. 45-52, ISSN 1006-706X