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RESEARCH ON THE EFFECT OF THERMOMECHANICAL TREATMENT APPLIED ON LOW ALLOY STEEL FOR CONSTRUCTION

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ABSTRACT: Plastic deformation applied during the heat treatment is a method of hardening steel.The paper presents the results obtained by applying low-temperature thermo-mechanical treatment on 19M14 steel grade. It was studied the variation of mechanical characteristics (R_m, R_e and A) for three variants of cooling after deformation: air cooled, quenching respectively quenching followed by tempering. The tests were carried out at different deformation degrees, and at different temperatures (700°C, 720°C, 740°C).
Keywords: ausforming, plastic deformation, mechanical characteristics, steel

1. INTRODUCTION

The thermo-mechanical treatment consists of overlapping over the thermal cycle of hot or cold plastic deformation. The final result consist in obtaining an appropriate structure and properties, considering a high density of dislocations [1] and a specific distributions of the structural imperfections given by plastic deformation [2].

Ausforming is a thermo-mechanical treatment [3,4,5,6] were plastic deformation is conducted in the temperature range of thermodynamically stable austenite, i.e. at temperatures below the austenite recrystallization temperature and above the point of austenite to martensite transformation [7]. The treatment is shown schematically in Figure1.

In the past the process only applies to alloyed steels with high stability of undercooling austenite in the range 500-550°C, thereby avoiding the decomposition of austenite during deformation [2,6].

This paper presents the results achieved by ausforming of a low alloy steel. The aim is to analyze the effect of ausforming on quality characteristics represented by mechanical resistance (R_m and R_e) and plasticity (A) for different cooling variants after deformation. Attempts have been made for different deformation degrees at different temperatures.

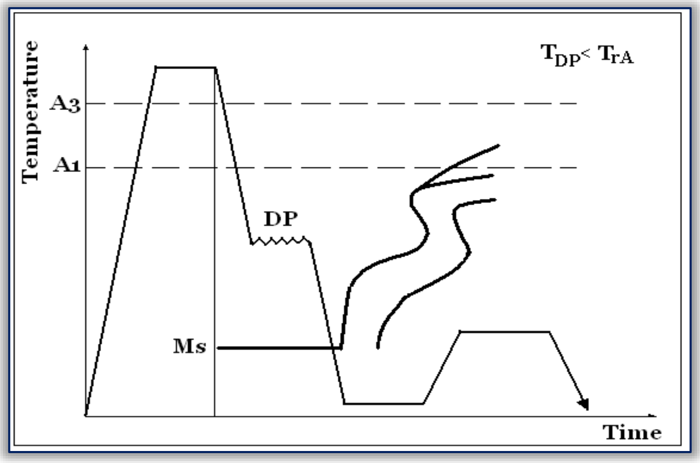

Figure 1. Low temperature thermo-mechanical treatment with subsequent quenching and tempering to martensite DP - plastic deformation, T_{DP} - plastic deformation temperature, T_{rA} - austenite recrystallization temperature [2]

2. EXPERIMENTAL PROCEDURE

The steel grade used in this study has the chemical composition shown in Table 1. According to STAS 438-67 the low alloy steel for construction 19M14 corresponds to PC52 structural steel.

Table 1. Chemical composition of low alloy steel 19M14 (STAS 438-67), %

Steel grade	Type of structural steel	C	Mn	Si	S	P	Cr	Ni	Cu
19M14	PC 52	0,16-0,22	1,2-1,6	0,2-0,55	max.0,04	max.0,04	0,03	0,03	0,03

The applied treatment involves heating the steel in the austenitic domain, followed by cooling to temperatures below the recrystallization temperature (but above the temperature of the start of transformation of austenite into martensite by plastic deformation), deforming with high reduction degrees, and finally cooling which was been made in three variants: air cooled (without thermal treatment), quenching heat treatment, respectively quenching followed by low temperature tempering at 300ºC.

From the isothermal transformation diagram for 19M14 steel results that the austenising minimum temperature is between 920-950ºC. In this study the temperaturechosen was of 950ºC, to ensure a complete transformation.

The recrystallization temperature for the studied steel grade is approx. 760ºC and the martensitic transformation temperature Ms, for a carbon content of 0.1-0.2% is between 470-570ºC. Taking into account that plastic deformation of austenite causes transformation to martensite at temperature superior to Ms point (temperature at which transformation in the absence of deformation does not occur) the temperature of beginning of the martensitic transformation is adopted at 550ºC.

The maximum possible duration for plastic deformation at which the steel still remains in the metastable austenite range is determined by using the austenite isothermal transformation diagram. Thereby, result that in the case of the studied steel containing0.19%C heated at 950°C with a maintaining duration of 5 minutes after austenitisation, in order that the rolling to be carried out in the metastable austenite domain and after quenching to achieve a predominantly martensitic structure, the process from austenitisation to quenching immediately following the deformation shall not exceed 0.3 to 0.7s.The cooling rate is determined primarily by the maximum possible process duration, which will be: 950-700/0.3 = 833ºC/s

Given that plastic deformation is followed by quenching (and possibly tempering) cooling rates must be very high, but for the steels containing more than 0.10% carbon as in the case of the studied steel, these speeds will be lower than 400ºC/s.

3. RESULTS AND DISCUSSION

In addition to the practical realization of the heating and cooling parameters, in order to perform the plastic deformation in the metastable austenite domain and to obtain a predominant martensitic structure through quenching, the thermo-mechanical treatment application also requires:

- design and construction of a rolling mill durable enough to withstand more stress than at the usual rolling;
- precise control of the austenitisation and rolling temperature, and in the case of heat treatment of the starting temperature of martensitic transformation;
- achievement of an installation that ensure high cooling rates;
- reduce temperature losses by placing the installation in the vicinity of the rolling housing, training the bar before entering between the rolls at a speed corresponding to the admitted cooling duration and eliminate heat losses at the contact between laminate and cylinders by heating them.

The installation of the Faculty of Engineering Hunedoara meets these requirements.Sample sizes were determined taking into account the perspectives on an industrial scale application of the results obtained and the technical characteristics of the installation.By applying the thermo-mechanical treatment technology in compliance with the parameters set previously, samples were heated to 950ºC, deformed after 0,6s (at different temperatures between 700-750ºC) with deformation degrees expressed by the relative rolling reduction$\varepsilon_h$between 6 and 36% and cooling after deformation. For each of the three cooling variants were determined the mechanical characteristics R_m, R_e and A.

The results on samples subjected to tensile test, after deformation in the above mentioned technological conditions, with or without thermal treatment, were processed and were obtained the graphs from figures 2, 3 and 4. These graphs shows the variation of ultimate tensile strength (R_m), yield strength (R_e) and elongation (A) on temperature and deformation degree for the three variants of cooling.

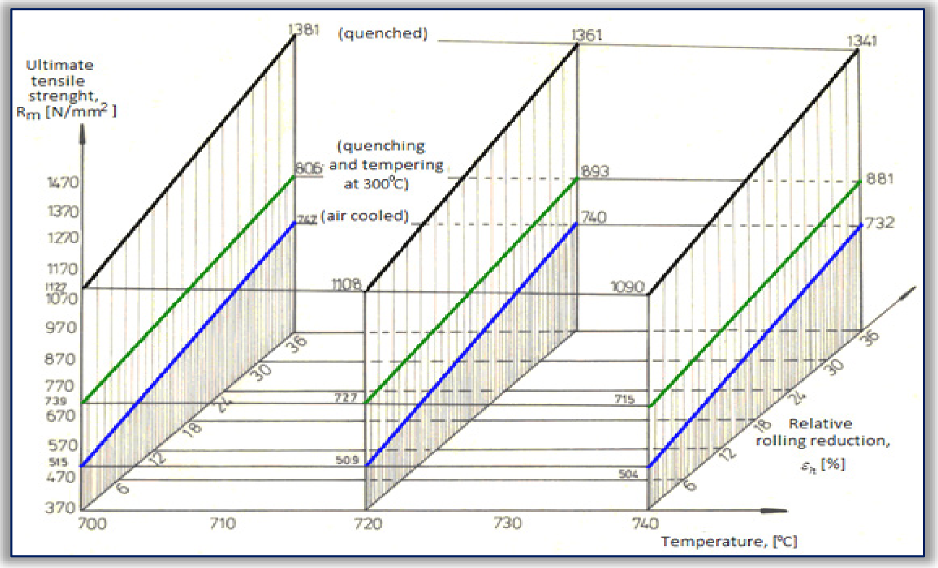

Figure 2. The variation of the ultimate tensile strength with relative rolling reduction at 700°C, 720°C and 740°C, for the three variants of cooling

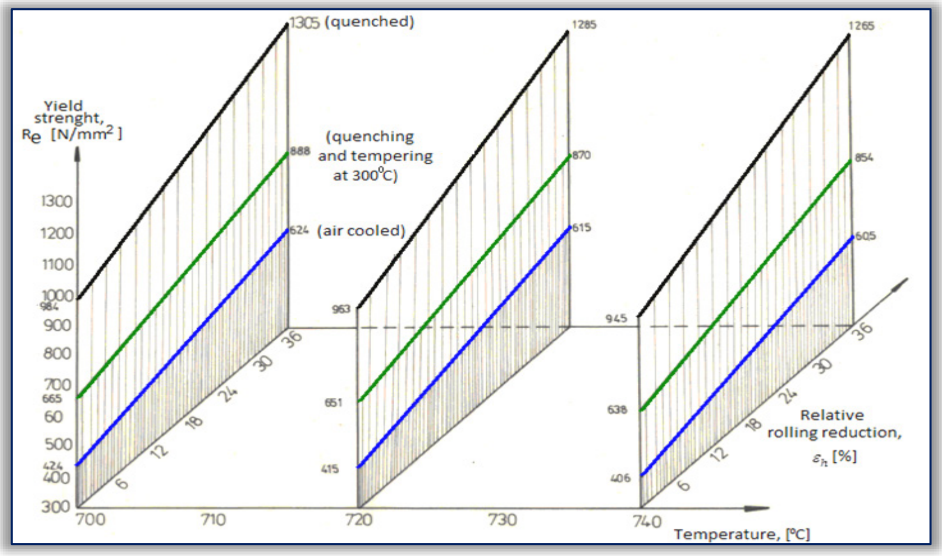

Figure 3.The variation of the yield strength with relative rolling reduction at 700°C, 720°C and 740°C, for the three variants of cooling

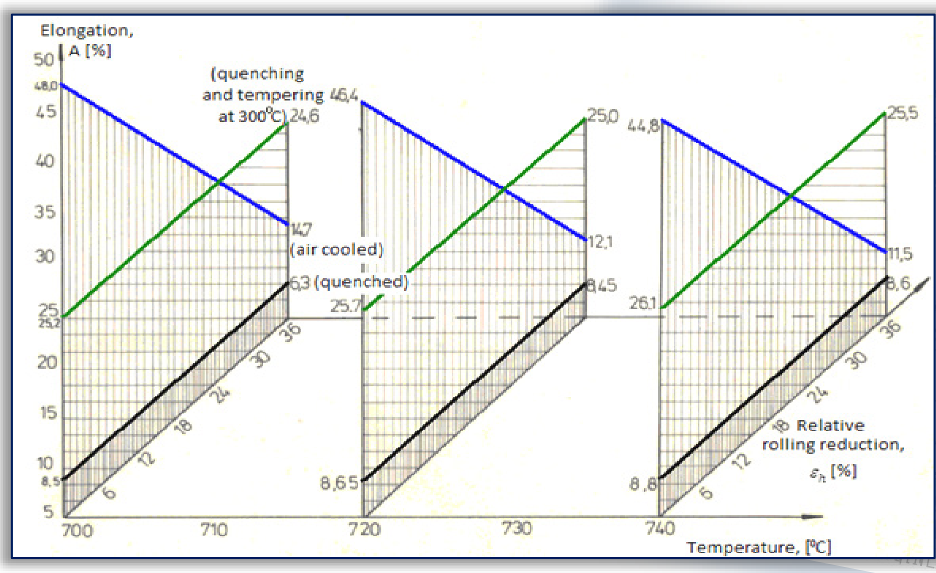

Figure 4. The variation of the elongation with relative rolling reduction at 700°C, 720°C and 740°C, for the three variants of cooling

In the first variant of the thermo-mechanical treatment, the steel sample was air cooled after plastic deformation. In this case were obtained the lowest values for ultimate tensile strength and yield strength, but the elongation had the highest value which decreased with increasing of the deformation degree.

In the second variant, where after the plastic deformation the sample was quenched, there was obtained high value for ultimate tensile strength (R_m = 1381 N/mm^2) and the yield strength (R_e = 1305 N/mm^2) however the elongation is between 6,3% and 8,8%, which means that the plasticity is low.

In the third variant, after plastic deformation the sample was quenched and tempered at 300°C. Analyzing the graph from figure 2 can be seen that the higher ultimate tensile strength (R_m = 893 N/mm^2) was obtained when rolling was carried out at 720°C and the relative rolling reduction is maximum (36%). As regards the elongation the values vary little regardless of the deformation degree or temperature, around 25%. The yield strength (Figure 3) has a maximum value of 888 N/mm^2, when rolling was carried out at 700°C and the relative rolling reduction is 36%.

4. CONCLUSIONS

The thermo-mechanical treatments represents new opportunities to broaden the mechanical properties of steels, and could get slimmer products (decreases the specific consumption of metal) that work at higher technical parameters.

By applying low-temperature thermo-mechanical treatment to 19M14 steel grade they were brought the following contributions:

- the resistance characteristics were increased to values of R_e = 870 N/mm^2 and R_m= 893 N/mm^2 without plasticity expressed by elongation may be affected too much;
- the ausforming steel has a martensitic or bainitic structure;
- they were established the ausforming parameters for 19M14 steel grade;
- by increasing the strength characteristics of the material is realized important material and alloying elements savings.

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