THE EFFECT OF COLD FORMING ON THE MECHANICAL AND STRUCTURAL PROPERTIS OF SELECTED STEELS

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Received 14.10.2012; accepted in revised form 06.12.2012

Abstract
Contribution shows the possibility the secondary reinforcement of the selected types of steel, by the influence the influence of strain hardening. The experimental samples were exposed to intense light temperature annealing (200 ° C, 300 ° C, 500 ° C) for 20 minutes, after 20 minutes followed cold forming with a reduction 10 % of thickness. We observed the change of strength, ductility and the microstructure of forming material.

Keywords: strain hardening, forming, low-temperature annealing, tensile strength, reduction

1 Introduction

Improving the physical properties of materials**,** improving the mechanical properties of steel**,** reducing weight construction and improvement of the economic advantages of the used materials is currently the basic requirements of industrial demand. One of the engineering technological advances is cold forming of material, it is combination of low-temperature annealing and forming, where occur a plastic deformation.

The plastic deformation of the material changes his mechanical and physical properties. This phenomenon we should call a strain hardening of metals and alloys**.** The physical principles of reinforcement material is very complex and not yet sufficiently explained**, t**here are only different hypotheses**,** but all of them are based on the same basis [1,2,3,4].

2 Experiment

Characteristics of experimental material

The realization of the experiment has been chosen three different kinds of steel properties, chemical composition and structural construction.

Steel 11 523 (chemical composition in the Table 1). Unalloyed structural fine-grained steel appropriate for welding. Bridge and other welded constructions, bent profiles, welded constructions from hollow profiles and parts of machines, cars, motorcycles and bicycles. Parts of thermal energy facilities and parts of pressure containers made from bars.

Table 1 *Chemical composition of steel STN 11 523*

Steel	Chemical composition [%]					
STN 11 523	C	Si	Mn	P	S	N
	0,20	0,55	1,60	0,04	0,04	0,009

Table 2 *Chemical composition of steel STN 15 230*

Steel	Chemical composition [%]					
STN 15 230	C	Si	Mn	V	$S_{max.}$	$P_{max.}$
	0,24-0,34	0,17-0,37	0,40-0,80	0,10-0,20	0,035	0,0035

Steel 15 230 (chemical composition in tth Table 2). The Steel with good welding and workability. Suitable for heat treatment, surface hardening, chemical heat treatment and nitriding. For highly stressed heat-treated machine parts and nitrided parts including nitrided cogwheels. Due to high harden ability it is also suitable for big forgings.

Steel HARDOX 400 (chemical composition in the Table 3) HARDOX 400 is the most popular of the HARDOX abrasion-resistant steel products. Thanks to its high toughness and problem-free weld ability, it is often used as abrasion-resistant and structural steel at the same time.

Table 3 *Chemical composition of steel HARDOX 400*

Steel	Chemical composition [%]													
HARDOX 400	C	Si	Mn	P	S	B	Nb	Cr	V	Cu	Ti	Al	Mo	Ni
	0,20	0,60	1,60	0,02	0,01	0,005	0,04	0,70	0,09	0,40	0,04	0,015	0,70	2,00

<u>Annealing process</u>

Samples for annealing process was manufactured in accordance with norm STN 42 0321 by universal milling machine FA 3 U. After these experimental samples was clearly and unequivocally marked.

The specimens were exposed to various temperatures (200 °C, 300 °C a 500 °C) during of the low temperature annealing withstand 20 minutes on these temperatures. The annealing process was implemented at TnUAD in the heavy laboratories when for annealing was used the electric arc furnace of type ELEKTROBAD FRANKENHAUSEN – Typ 60-2a.

<u>Implementation of cold forming</u>

Immediately after annealing process the samples were relocated to duo rolling machine where were intensively formed. Aim of forming process was achieved of reduction 10 % in the material thickness. Cold rolled was implemented at Alexander Dubček University of Trenčin.

3 Evaluation of measurement results

Table 4 *Measured mechanical properties*

Steel	Standard			200 °C			300 °C			500 °C		
	Rm [MPa]	$Rp_{0,2}$ [MPa]	A [%]	Rm [MPa]	$Rp_{0,2}$ [MPa]	A [%]	Rm [MPa]	$Rp_{0,2}$ [MPa]	A [%]	Rm [MPa]	$Rp_{0,2}$ [MPa]	A [%]
11 523	503,61	387,51	29,2	571,98	501,19	14,2	573,5	530,9	14,2	624,43	586,4	7,50
15 230	571,65	207,39	19,2	620,87	352,51	14,2	631,6	398,0	11,7	646,59	395,6	13,3
HARDOX 400	1290,35	1102,47	9,20	1364,33	1257,95	8,40	1341,4	1263,6	9,20	1008,46	920,29	9,20

For observation of changes basic mechanical properties of the annealed and rolled samples in comparison with reference standard we had to perform the static tensile test in accordance with norm STN EN ISO 6892 – 1 by universal tensile machine Instron 5500 R. The static tensile test was implemented at TnUAD where we registered breaking stress, yield point and ductility of experimental and standard samples.

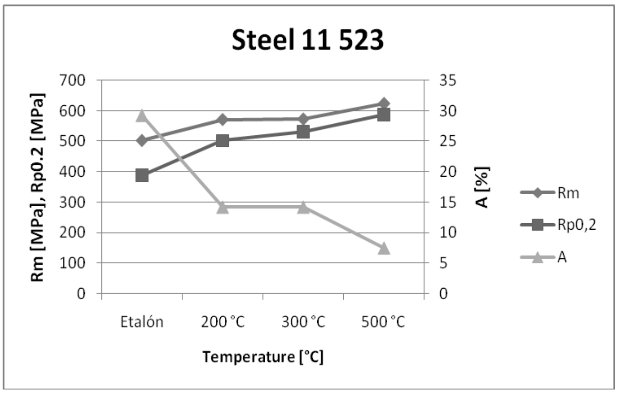

Fig. 1 *Change of mechanical properties steel of type 11 523 after 10 %*

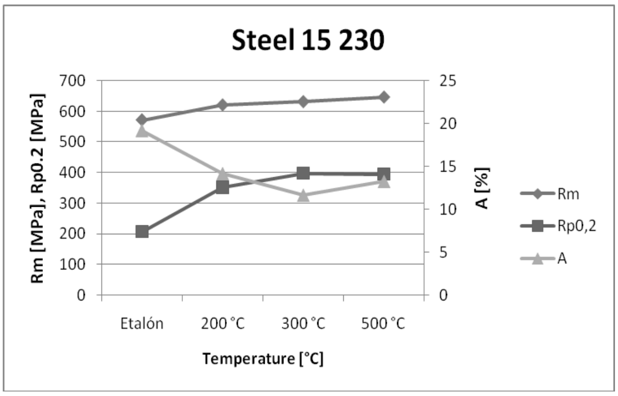

Fig. 2 *Change of mechanical properties steel of type 15 230 after 10 %*

Measured values breaking stress, yield point and ductility of experimental and standard samples are shows in the Table 4. The graphic representation every sample is shows on the figure 1,2,3.

The graphic representation of changes in mechanical properties of steel 11 523 (Fig.1) is show that increasing annealing temperature leads to increasing Rm and $Rp_{0,2}$ while reducing tensibility. The maximum values of breaking stress, agreed yield point occurred after the application of 500 °C annealing temperature.

The course of changes the Rm a $Rp_{0,2}$ of steel 15 230 (Fig.2) is almost identical compared to steel 11 523. After application higher annealing temperature (500 °C) we are observing slight increase values ductility.

The only material for which there was a significant decrease in Rm and $Rp_{0,2}$, after the application of forming at 500 °C, was Hardox 400 (Fig.3). The breaking stress decreased about 300 MPa and agreed yield point about 200 MPa while preserving values standard`s ductility.

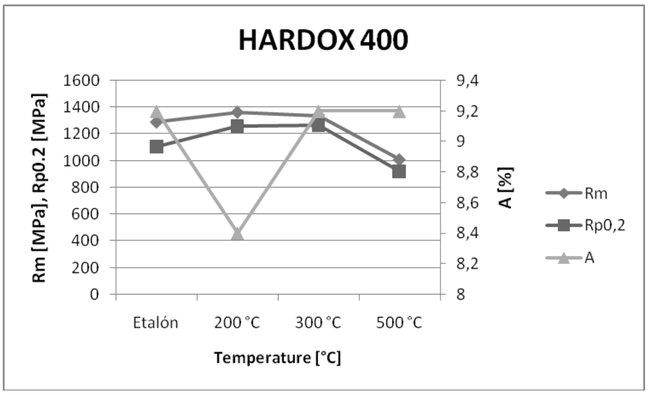

Fig. 3 *Change of mechanical properties steel of type Hardox 400 after 10 % deformation*

Fig. 4 *Microstructure of steel 11 523 after annealing (by 200°C) and forming*

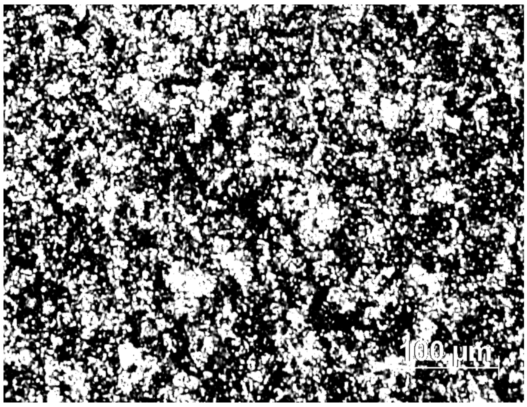

Fig. 5 *Microstructure of steel 11 523 after annealing (by 500°C) and forming*

Fig. 6 *Microstructure of steel 15 230 after annealing (by 200°C) and forming*

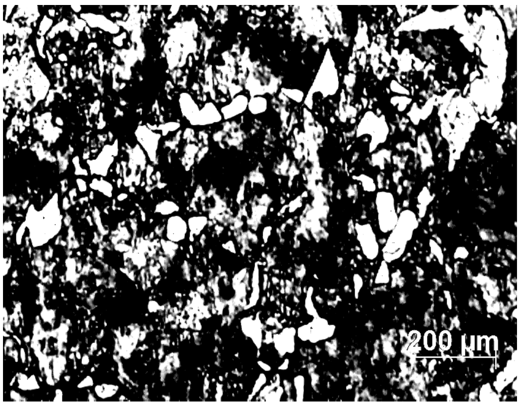

Fig. 7 *Microstructure of steel 15 230 after annealing (by 500°C) and forming*

On the figures from 4 to 9 we can see for example of microstructures of steels which were annealed and formed. The specimens were observed through by microscope of type NEOPHOT 32. The samples were watched by various enlargement. The samples of microstructure were made from the middle bay of experimental samples. In the samples was observed to creation of texture in surface layer of the formed materials. This texture significantly influence to the mechanical properties such as hardness of the materials.

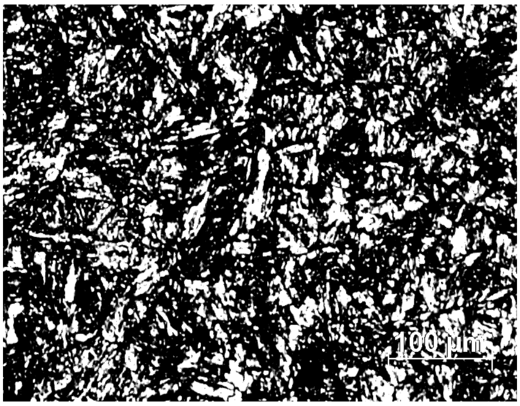

Fig. 8 *Microstructure of steel HARDOX 400 after annealing (by 200°C) and forming*

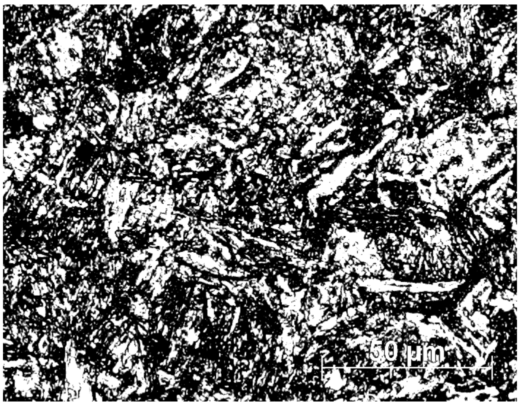

Fig. 9 *Microstructure of steel HARDOX 400 after annealing (by 500°C) and forming*

4 Conclusion

Experiment was shown that is possible to influence of strain hardening increase or change of basic mechanical properties of certain steels.

Steel 11 523: After application of annealing temperature by 300 °C to effect that Rm increase by 12,21 % in compared to standard sample. This value itself increased up to 19,30 % after application of annealing with annealing temperature 500 °C.

Greatest change of mechanical properties of the selected steels was seen in increase $Rp_{0,2}$. By 300 °C itself increase above 26,89 % and by 500 °C up to 33,88 %. The ductility of steel was decreased about 74,2 % after the plastic deformation from annealing temperature (500 °C).

Steel 15 230: Greatest change of mechanical properties was represented to agreed yield point when increase to 41,02 % after annealing temperature by 200 °C. $Rp_{0,2}$ increased by 47 % after forming with heat to 500 °C. The cold rolling by temperature to 500 °C effected that the braking stress increased about 11,92 %.

HARDOX 400: This material had the worst ability to increase of mechanical properties to additional treatment by cold forming. The slight increase of Rm and $Rp_{0,2}$ was observed at forming temperature by 200 °C where Rm increased about 5,4 % and $Rp_{0,2}$ about 12,3 %. The Rm decreased about 21,83 % and $Rp_{0,2}$ about 16% after forming with temperature by 500 °C.

The measured results show that it is possible to increase the base of the mechanical properties of certain types of steels for cold forming.

Possibility increase of mechanical properties used strain hardening is one of the techniques whitch are usage for present industrial demand. Such as weight reduction of construction, saving of materials and increase of strength characteristics of materials in the present economic benefit.

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