THE INFLUENCE OF COLD ROLLING ON THE MECHANICAL CHARACTERISTICS FOR DRAWING STEELS

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ABSTRACT

The paper presents the changes of the mechanical and technological characteristics of steel for deep drawing, cold rolled and recrystallization heat treated. The research was conducted on samples taken from cold rolled strip, treated and rerolled after the ARCELOR MITTAL technology and, for comparison samples sampled from the steel strip before cold deforming (hot rolled) were used as blank tests. The thermal processing of the cold deformed samples, having different degrees of deformation "ε" (2.2% ; 6.5% ; 15.2%; 32.5% ; 50.0% ; 65.0%) and of the blank tests (ε = 0%) were carried out under industrial conditions in a bell furnace.

KEYWORDS: drawing steel, mechanical characteristics, deformation degree, recrystallization

1. Introduction

The research was made on samples sampled from the rolled strap, treated and rerolled after the present technology. For comparison blank samples were taken from the hot rolled strap. For the samples with different degrees of deformation taken from rolling and industrial thermal treated in bell furnace subsets of samples were made from the directions of 0°, 45° and 90° against the rolling direction.

The chemical composition of the analysed steel is presented in table 1.

Table 1. The chemical composition of the steel specimens used in experiments.

C	Mn	Si	S$_{max}$	P$_{max}$	Al
[%]					
0.04	0.25	0.1	0.009	0.012	0.05

In order to establish the influence of the cold deformation degree on the steel straps' properties, samples were sampled from a coil deformed on the continuous milling machine TANDEM with five four-high stands with the working cylinders' diameter of 550 mm. To obtain samples with different degrees of deformation the rolling process was started and when the normal running regime was reached, the mill was stopped and cut off parts of the strap between the stands. To achieve deformation degrees lower than 20%, the rolling process was continued only with the first stand.

2. Experimental Research

Samples with different deformation degrees were taken – 2.2% ; 6.5% ; 15.2%; 32.5% ; 50.0% ; 65.0% and in fig.1 is presented the variation of the mechanical characteristics relative to these cold deformation degrees.

The samples with the specified deformation degrees were treated under industrial conditions in bell furnace according to the diagram in fig.2.
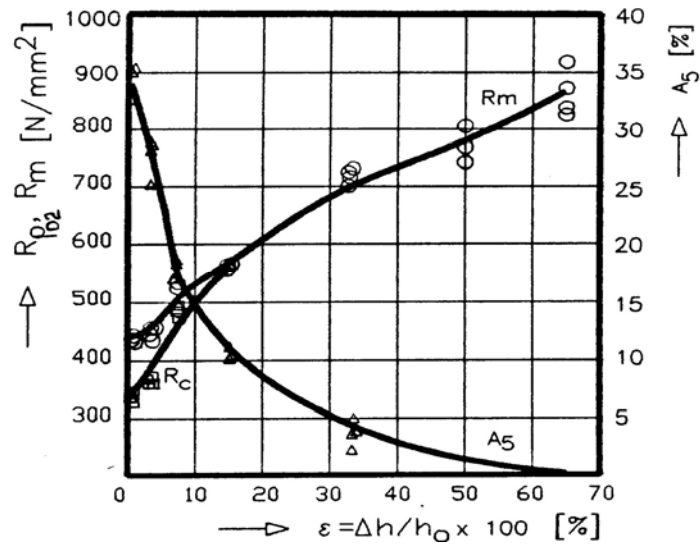
Fig. 1. Variation of the mechanical characteristics (ultimate strength, yield strength and breaking elongation) for the cold deformed samples with different degrees.
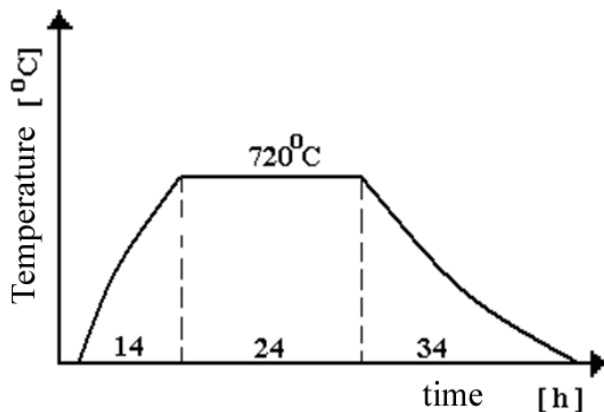

Fig. 2. Diagram of thermal treatment conducted in industrial conditions, for the cold deformed samples with different deformation degrees.

The results referring to the mechanical characteristics for different degrees of deformation and after the chosen thermal treatment according to the diagram in figure 2 under industrial conditions in bell furnace are presented graphically in figures 3 and 4. Fig. 3 shows the influence of the deformation degree on the mechanical characteristics R_m, $R_{p0.2}$ and A_5 for the rolled samples with different deformation degrees "ε" ($\varepsilon = \Delta h/h_o \times 100$) on samples taken after the rolling direction. In fig. 4 are presented the variations of the mechanical characteristics depending on the deformation degree for the samples treated under industrial conditions in bell furnace, according to the diagram in fig. 2 for samples sampled from the three directions of 0°, 45° and 90° relative to the rolling direction. The sample characterizing the

drawing (the drawing behaviour) was determined by calculating the anisotropy factors on the three directions with the formula:

$$r = \frac{\log \dfrac{b}{b_0}}{\log \dfrac{g}{g_0}}$$

where: r – anisotropy factor (r_o, r_{45}, r_{90});

b_o, b – width of sample before and after deformation at the tensile test;

g_o, g – thickness of sample before and after deformation at the tensile test.

The average anisotropy factor was calculated with the formula:

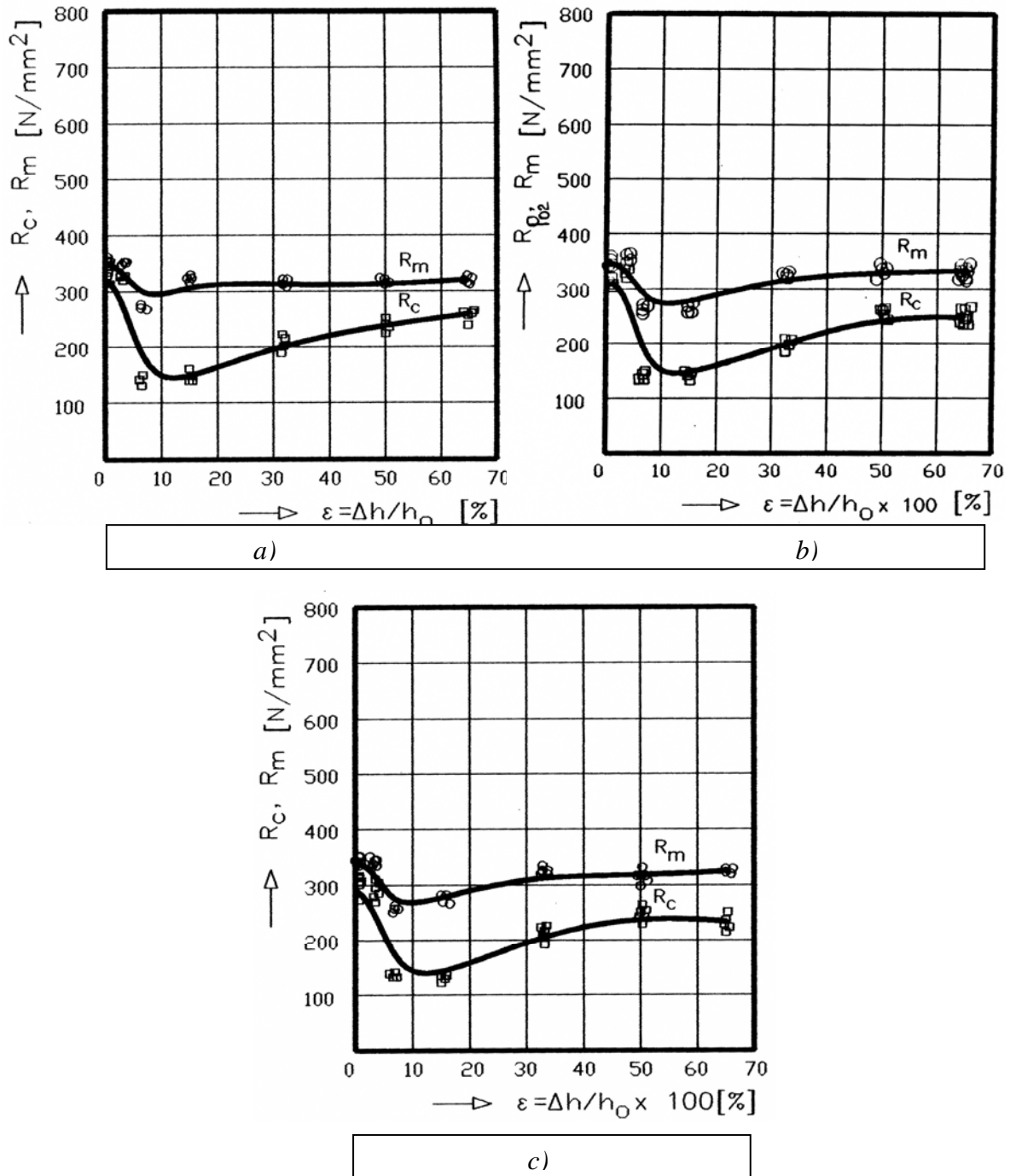$$r_m = \frac{r_0 + 2r_{45} + r_{90}}{4}$$

Fig. 3 *Variation of the breaking strenght and yield strength for cold rolled samples having different defformation degrees and thermally treated under industrial conditions:*

   a – longitudinal direction;
   b – transversal direction;
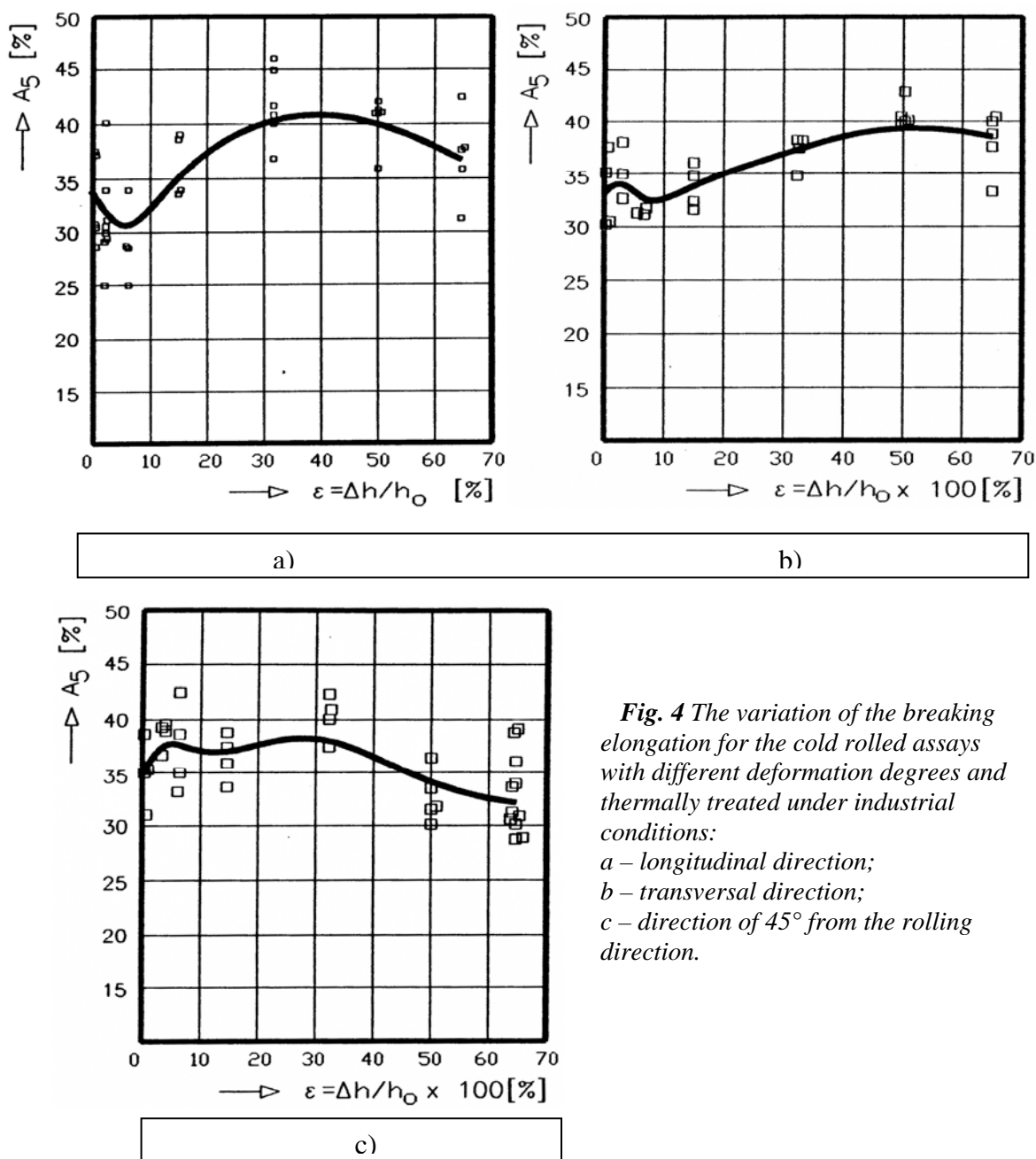   *c –direction of 45° from the rolling direction.*

a)

b)

c)

Fig. 4 *The variation of the breaking elongation for the cold rolled assays with different deformation degrees and thermally treated under industrial conditions:*
a – longitudinal direction;
b – transversal direction;
c – direction of 45° from the rolling direction.

where: r – anisotropy factor (r_o, r_{45}, r_{90});
        b_o, b – the width of the sample before and after the deformation through the tensile test;
        g_o, g – the thickness of the sample before and after the deformation through the tensile test.
        The average anisotropy factor was calculated with the formula:

$$r_m = \frac{r_0 + 2r_{45} + r_{90}}{4}$$

Fig. 5 shows the variation of the anisotropy factors depending on the deformation degree for the experimented treatment.

3. The analysis of the results

The influence of the deformation degree on the mechanical characteristics for the analysed steel is highly pronounced in the case of the cold rolled samples, reaching high values for the tensile test, over 800 N/mm^2, for deformation degrees higher than 50%, followed by a drastic shortening of the elongation (in correlation to the occurrence of the fibrous structure at deformation degrees over 50%, a highly noticeable aspect in the longitudinal sections).

Maximum elongations can be obtained for deformation degrees between 30% and 50%, as the elongation is more influenced by the deformation degree than the resistances R$_m$ and Rp$_{02}$. The anisotropy factors grow with the deformation degree, presenting specific evolutions for the three directions of sampling the samples (fig. 12). One can notice that when reducing with 30%, the factors have values corresponding to deep drawing (1.4-1.6), with the smallest differences between the values calculated for the three directions.
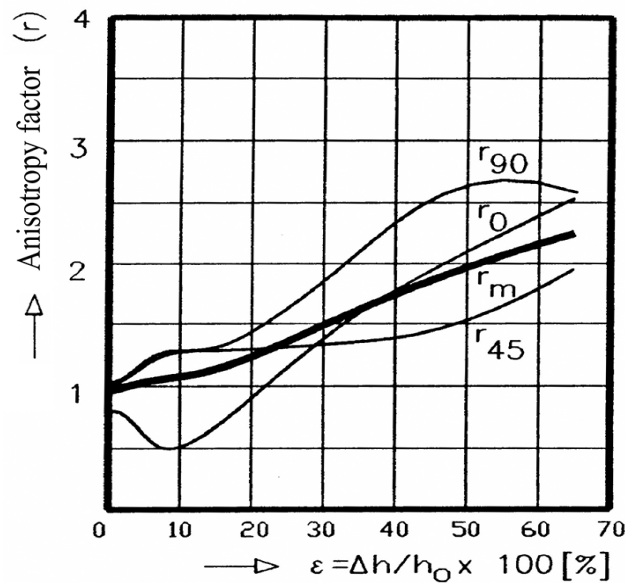

Fig. 5 *Variation of the anisotropy factors depending on the deformation degree for the cold rolled and heat treated assays, under industrial conditions:*
a – longitudinal direction;
b – transversal direction;
c – direction of 45° from the rolling direction.

The direction for sampling the samples for the tensile test, as compared to the rolling direction (0°, 45° and 90°), is important as it highlights the distribution of the mechanical characteristics and of the anisotropy factors in strap's plan, allowing for a better assessment of its behaviour to drawing. It is known that in this case a higher uniformity in the properties' distribution is necessary. It was noticed that usually the elongation has maximum values on the longitudinal direction (0°) and minimum values on the 45° directions, with differences between 10% and 20%. The samples deformed with the degree of 32.5 % had the longest elongations, with minimum differences among the values from the three directions. The flow resistance and the tensile test vary along the three directions within the limits 3%-10% and 3%-6%, obtaining the smallest differences for the deformed samples with 32.5 %.

The anisotropy factors vary a lot along the three directions within the limits of 20%-50%, depending on the deformation degree.

The cold deformation degree has a high influence on the mechanical and technological properties of the chosen deep drawing steel straps, as well as on their distribution on the characteristic directions as compared to the rolling direction (0, 45° and 90°);

Applying some deformation degrees higher than 50% in TANDEM, leads to obtaining ultimate strength of over 800 N/mm^2 and elongations under 2%, for the cold-hardened strap.

The studied mechanical characteristics are especially influenced by cold rolling with small reductions, while rolling with higher reductions only the elongation is strongly influenced.

The deformation degree of 32.5 % and the heat treatment under industrial conditions made in bell

furnace, gave the best results on the values of the characteristics and their distribution in the strap's plan. The values of the mechanical characteristics and of the anisotropy factors (which characterizes the behaviour at drawing the straps) are different along the three directions as compared to the rolling direction.

4. Conclusions

Using some of the cold deformation degrees higher than those strictly necessarily in obtaining the characteristics for deep drawing has the disadvantage that the mechanical resistance increases for the cold-hardened strap at values higher than 800 N/mm^2, which determines higher energy consumption, higher consumption of the plate rolls and difficulties in achieving the thickness tolerances and in smoothness of the strap due to using stronger rolling forces.

The research shows that lower degrees of deformation can also be used to obtain some good characteristics for drawing, when using steels of high purity ($S_{max} = 0.009$ %, $P_{max} = 0.012$%), aspect that in the present industrial conditions no longer creates problems.

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