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THE IMPROVEMENT OF RESISTANCE CHARACTERISTICS OF STEELS THROUGH COLD PLASTIC DEFORMATION

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ABSTRACT
The application of a pressing along the generatrix for some steel laminates for general use, with diameters between 6-16 mm, leads to ensuring an important improvement of resistance characteristics, especially the flow limit.
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1. FOREWORD
The following paper shows the results obtained through the application of the mentioned procedure as well as the optimum domain of chemical composition and deformation degrees, in order to get an optimum correlation between the resistance and plastic characteristics of steels. Steels which are the main objective of the presented study, are part of the categories of round wire of laminated steel and concrete steel laminated in heat, with chemical composition like steels for general use for construction (less type OL70), quality carbon steels for heat treatments aimed at machines manufacture and concrete laminated steel at heat with periodical or smooth / fine profile

2. EXPERIMENTS.
The utilization characteristics of these steels, and especially flow limit (apparent Re_H or technical $Rp_{0,2}$) and tenacity, are influenced by a complex of factors including the chemical composition and deoxidation practices used for elaboration, the regime of temperatures and the deformation degree in lamination, the width of the products.
Regarding the mechanical characteristics of this products the following mentions must be made:
a. the contain of carbon through influencing the pearlite/ferrite proportion and the contain of manganese through the alloying effect of ferrite, are the main controlling factors to reach the guaranteed resistance characteristics. The structure modifications that ensure the improvement of resistance characteristics have adverse effect on plastic characteristics
b. the majority of products of general use steel are delivered in hot deformation status. Once the width of the product increases – as an effect of temperature increase at the end of lamination and decrease of cooling speed, at the same chemical composition, the wider products have less resistance characteristics than thiner products.
I chose the concrete irons as a first application of the studied procedure because:

- they are the steels with a contain of carbon within the limits of the theoretical interval;
- on of the compulsory characteristics at the reception of these steels isfloe limit, on which the pressing by generatrix has an absolute influence;
- they are not very pretentious form a dimensional point of view;
- can substantially increase sales value if delivered with higher resistance characteristics;

- the require restrictions for chemical composition, more precisely the limitation of contains of alloying elements (calculus relations for CE), and thus the value of resistance characteristics cannot be influenced through alloying.

For the research regarding the influence of plastic deformation at cold through the application of force on generators over the resistance characteristics of carbon not-alloyed steels, we used wire samples 6 mm diameter, with lengths between 500 and 1500mm. The wire was taken from the heart of wire in order to avoid the results be influenced by the way of cooling of wire (eventually not uniform) and in order to ensure very similar conditions at trials.

The samples taken on plastic deformation at cold and determination of characteristics, were used as such, without any preliminary pre-work, in order to reproduce very accurately and application of this process directly on industrial products.

The steel charge that were used for quasi-industrial trials have carbon contains between the limits 0,07-0,14%. The chemical composition of the studies charges is shown in table 1.

Table 1 Chemical compositions of experimental charges

Charge	Chemical composition, %								
	C	Mn	Si	S	P	Cr	Ni	Cu	Al
1	0,07	0,32	0,01	0,030	0,016	0,06	0,07	0,07	-
2	0,11	0,50	0,01	0,045	0,020	0,08	0,06	0,12	-
3	0,09	0,53	0,01	0,028	0,016	0,06	0,09	0,12	-
4	0,07	0,34	0,01	0,030	0,018	0,10	0,10	0,15	-
5	0,14	0,53	0,22	0,030	0,017	0,06	0,06	0,09	0,007
6	0,09	0,37	0,22	0,043	0,015	0,08	0,06	0,09	0,006
7	0,08	0,46	0,01	0,040	0,016	0,07	0,10	0,10	-

Six samples were taken out of each charge, out of which one is the etalon sample (E) and the others (1,2,3,4,5) were exposed to cold deformation on generatrix with different deformation degrees. The deformation degree was determined using the following relation $\varepsilon = \frac{d_0 \quad d}{d_0} \quad 100$

in which e represents the degree of deformation [%], Do – the initial diameter of the sample, [mm] and D – the final diameter of the sample [mm].

The study undertaken before, using a deformation through pressing on generatrix for steel products with diameters between 6 and 8 mm, showed the fact that it is possible to obtain a significant growth of resistance characteristics and especially flow limit (proportion $Rp_{0,2}/R_m$=0,70-0,98) when relatively small degrees of deformation are applied (table 2).

Table 2. Mechanical characteristics of deforming samples

Nr. crt.	Sample	ε,%	Mechanical characteristics				Increase $R_{p0,2}$,%	Increase R_m,%	R_m/ $R_{p0,2}$	$R_{p0,2}$/ R_m
			Z, %	A, %	$R_{p0,2}$, N/mm^2	R_m, N/mm^2				
1.A	E.1	-	74,68	23,3	265	353	-	-	1,33	0,75
	1.1	4,92	68,68	20,5	310	385	16,98	8,96	1,24	0,80
	2.1	18,03	60,89	14,4	440	455	66,03	25,76	1,03	0,96
	3.1	26,23	64,69	15,8	482	493	81,88	39,20	1,02	0,97
	4.1	29,51	65,60	14,8	507	520	91,32	46,76	1,02	0,98
	5.1	34,43	56,54	10,7	528	537	99,24	51,52	1,01	0,99

The aim was to experiment the same procedure on industrial products with bigger diameters.

In order to do this, samples were taken from steels out of the current production, from steel charges with different chemical compositions and different dimensions of the laminated products.

The samples had lengths between 500-1500 mm. the samples used for trials were collected so that the results of the application of deformation not to be influenced by the cooling way and in order to ensure initial conditions as similar as possible.

The samples exposed to plastic cold deformations and determinations of characteristics were used as such, without any preliminary influence, in order to obtain a very accurate reproduction of this procedure directly on industrial products.

After cold deformation on generatrix, from each charge, some samples were taken in order to determine the mechanical characteristics. Samples were debited at 150mm , according to the prescriptions.

The steel charges that were used for the second set of trials have carbon contains between the limits 0.07-0.22%.

After an analysis of the presented data, it comes out that like in the case of wider industrial products, the effect of plastic deformation by pressing on generatrix shows especially on flow limit, that registers the higher growth rates till deformation degrees of aprox. 30%, after which the growth rate of, flow limit decreases.

The conclusions that can be drowned from the analysis of the presented data, are:

- the plastic cold deformation process by pressing on generatrix applied to industrial products of wire with medium diameter between 6-8 mm and laminated products with width between 12-25 mm, made of steels with less carbon contain, are applied without any difficulty, steels presenting a weak resistance to deformation
- the influence on resistance characteristics is very strong starting even from low deformation degrees (aprox. 12%)
- the growth rate of resistance characteristics is high, till deformation degree of cca. 30%, after which the continuing application of deformation on generators does not lead anymore to high growth of resistance.
- the biggest influence is on floe limit, that registers substantial increases, reaching values similar to those of resistance to breaking for the same type of steels.
- the proportion $Rp_{0,2}/R_m$ increases very much, which constitutes a criteria for determination of steel quality for concrete, which reaches values of cca. 0.99.

In order to set up the technological conditions of the plastic deformation by pressing on generatrix, the data obtained from the experiment in the lab and industrial trials was studied. The analysis of data was based on statistical-mathematical methods, using specific calculus programs.

In order to obtain the correlation between the technological factors that influence the plastic deformation, more precisely the chemical composition of steel and the deformation degree applied, the MATLAB program was used.

We considered 48 sets of data that include the chemical composition of steel, the value of the proportion C/Mn, the value of the reduction degree, applied, as well as determined values flow limit, resistance to breaking, and the calculated value for the proportion $Rp_{0,2}/R_m$.

For each correlation the medium values of the parameters, the correlation coefficient, standard exception from the regression area, and the values of the stationary point (minimum, maximum or medium) are presented. In the following lines, based on the analyzed data, the variation areas obtained and the diagrams of level curves, one can set the technological conditions, respectively the chemical composition and deformation degree which leads to the best correlation with the mechanical characteristics of resistance of the deformed products.

During the experiments it was observed that the substantial influence of the deformation by pression on generatrix process is on flow limit, that registers very high growth at relatively low deformation degrees. Therefore, in the following lines we present the variation areas of flow limit $Rp_{0,2}$, as well as the variations of the proportion $Rp_{0,2}/R_m$, function of independent parameters mentioned before.

The analyzed data are Rp0,2 like an dependent parameter and C, C/Mn, Є like independent parameters .

The variation limits of the variables are:C_{min} = 0,07% - C_{max} = 0,22 %; $(C/Mn)_{min}$ = 0,17-$(C/Mn)_{max}$ = 0,35; ε_{min} = 0 - ε_{max} = 38%; $R_{p0,2min}$ = 255 - $R_{p0,2max}$ = 623

The equation of the hiper-surface of regression is:

$$R_{p0,2} = 5064 * C^2 - 5295 * (C/Mn)^2 - 0,1725 * \varepsilon^2 - 5595 * C * C/Mn - 1,945 * C/Mn * \varepsilon + 5,866 * \varepsilon * C + 3274 * C + 3606 * C/Mn + 13,75 * \varepsilon \quad (1)$$

The correlation coefficient for this hypersurface is r=0,98, standard exemption from the regression surface is s=21,13, and the coordinated of the maximum point are; C = 0,2319; C/Mn = 0,2103; ε = 42,62; $R_{p0,2}$ = 649,5.

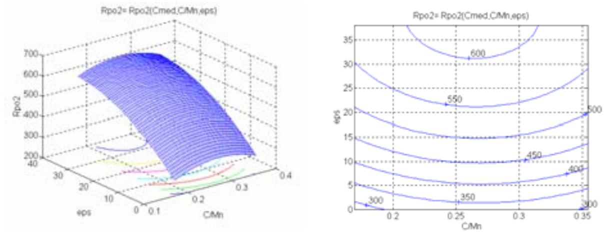

Figure 1. The $R_{p0,2} = R_{p0,2}(C_{med}$, C/Mn, ε) distributionand level curves

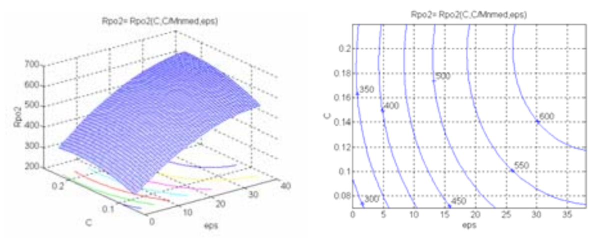

Figure 2. The $R_{p0,2} = R_{p0,2}$(C, C/Mn_{med}, ε) distribution and levell curves

Due to the fact that these hypersurfaces cannot be represented in a tridimensional space, I chose the successive replacement of an independent variable with its medium value, getting to surfaces that can be represented in the tridimensional space and can be interpreted from the technological point of view.
Therefore, we obtain the surfaces that are the object of the following study. Associated to the surfaces we have the level curves for each value of the presented characteristics. Based on these analyses, one can set the maximum level of deformation by pressing on generatrix, that can ensure simultaneously with the increase of resistance of steels and a convenient behavior while processed.
The influence of chemical composition and degree of deformation over the flow limit is highlighted through the regression surface represented by the equation:

$$R_{p0,2} = -5295 * (C/Mn)^2 - 0,1725 * \varepsilon^2 - 1,945 * C/Mn * \varepsilon + 2858 * C/Mn + 14,54 * \varepsilon - 55,1 (\text{for } C = C_{med}) \quad (2)$$

The dependency between the value of flow limit, value C/Mn and the degree of reduction if a constant carbon contain and equal with the medium level on charge is considered, presented by figures 1.a and 1.b is the normal one, technological, in the sense that its value increases continuously with the increase of C/Mn and E, on one hand due to the hardness effect of the two elements and on the other, due to hardness induced by the increasing reduction degrees.

4. CONCLUSIONS

The undertaken analysis through mathematical methods of the obtained data, under the conditions of a plastic deformation at cold on generators, with deformation by pressing on generatrix degrees varying between 2- 40%, highlights the fact that in order to obtain increase of resistance, which would not affect the behavior during processing of steels, one must consider a series of measures such as:
- the carbon contain must be kept under 0,25%, and Mn contain must be kept at the technological limit necessary for carbon not-alloyed steels, respectively under 0,8%.
- the proportion C/Mn must be kept within the interval 0,2-0.3, so that the value of the flow limit and the proportion $Rp_{0,2}/R_m$ can be maintained within the technologically admitted limits.
- the data shown before highlight the fact that the described process cam be applied without any problems directly on industrial products, without a preliminary preparation, getting to important increases of the resistance characteristics.

5. REFERENCES

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