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EFFECT OF CHEMICAL COMPOSITION ON THE ELONGATION PROPRIETIES

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Abstract: *Alloying elements influence the mechanical properties of the metal sheet that will be subject to plastic deformation. Research has allowed the determination of an empirical relationship which allows the calculation of the elongation if the chemical composition is known. Also it has been established which is the most important alloying element that influences the elongation.*
Key words*: chemical composition, elongation, equation, manganese*

1. INTRODUCTION

Alloying elements and chemical composition from the material structure affect its mechanical characteristics and technological properties (Kudrya, A. V. et al., 2008). The characteristics of thin steel sheets are affected (Panigrahi, B.K. et al., 2009) not only by their carbon content, but also by the quantity of accompanying elements, elements from raw materials, added from the process or from the environment. In the category of additional elements there are: manganese (Domínguez, C. et al., 2002), (Nam, S.W. & Lee D.H., 2000), silicon, aluminum, sulfur, phosphorus, oxygen, hydrogen, nitrogen. The quantity of accompanying elements which compose these materials is limited at a maximum value by the Romanian standard SR EN 10130 + A1: 2000.

2. EXPERIMENTAL RESEARCH

The aim of the research study, in this paper, is to study the quantitative and qualitative influence of the chemical elements contained in the thin steel sheets on the elongation and to establish a regression equation which can reflect better the dependence between parameters.

The first objective was to analyze the chemical composition of the metal sheet and then the effect on elongation when the quantity of alloying elements is changed. Throughout this study, we have been trying to develop empirical mathematical models between elongation and the elements that form the chemical composition of the metal sheet.

Composition of the metal sheet was determinate using spectroscope with atomic emission POLYVAC.

The tensile tests were made on Tinius-Olsen equipment with the force domain between 3 kN and 150 kN. A strain gauge type Epsilon 3542-050 M-020-ST, B1 class was used. The elongation speed was constant. The engineering strain or elongation is computed as $(L - L_0) = L_0$, with L and L_0 being the current and initial extensometer lengths (Cabezas E.E. & Celentano, D.J., 2004).

The sheets studied are thin table of cold rolled steel for drawing operation, in according with standard SR EN 10130 + A1: 2000.

The specimens were extracted from 2 mm thick sheets. The axis of the specimen was at 90^o form rolling direction. The samples were taken from different places of a roll of sheet.

The research studies made to obtain elongation used a group of 26 data sets. The result was taken into account based on the values obtained from three samples taken from the roll sheet.

Chemical composition limits of the values for the sudird thin steel sheets are presented in Table 1 and the parameters determined in the tests are noted in Table 2.

After statistical processing and analysis of the obtained data we have established the following types of regression equations for the dependence between the studied parameters:
- linear, equation (1)
- exponential, equation (2)

$$A_{80} = 42.184 + 31.754\cdot[\%C] - 12.856\cdot[\%Mn] - 16.647\cdot[\%Si] - 42.517\cdot[\%S] - 87.689\cdot[\%P] + 0.001\cdot[\%Al] \quad (1)$$

$$A_{80} = 30.990 \cdot [\%C]^{0.034} \cdot [\%Mn]^{-0.103} \cdot [\%Si]^{-0.003} \cdot [\%S]^{-0.011} \cdot [\%P]^{-0.0358} \cdot [\%Al]^{0.011} \quad (2)$$

The intensity of the link between elongation A_{80} and the independent parameters – the chemical elements is given by the linear correlation coefficient, R. The share, which affects simultaneous the independent parameters from each equation, on the characteristic of A_{80}, is given by the determination coefficient, R^2. The values of the determination coefficient and correlation coefficient for the two kinds of regression equations are presented in Table 3.

The analysis of these values shows that equation (1), linear regression, offers the best mathematical representation for determining the A_{80} elongation according with chemical composition of the metal sheet because the value of linear correlation coefficient R = 0.828 is higher than the one from equation (2).

The value obtained for R_2 shows that the studied chemical elements influence the elongation A_{80} with a share of 68.56%. The determination coefficient indicates a strong link between the elongation A_{80} and chemical elements contained by the studied metal sheets.

The accuracy of linear regression equation is expressed by the values of the following indicators:
- s = 1.215, which explains that the linear regression equation has the lowest average quadratic residue;
- $C_V\%$ = 3.171%, which indicates a small variation between the values obtained experimentally and those calculated with the linear regression equation.

Limits	Composition, %					
	C	Mn	Si	S	P	Al
Minimum	0.03	0.2	0.005	0.009	0.006	0.016
Maximum	0.08	0.5	0.05	0.018	0.028	0.097

Tab.1. Limits of the chemical steel sheet composition

Limits	Parameters		
	R_e	R_m	A_{80}

	[N/mm^2]	[N/mm^2]	[mm]
Minimum	183.8	315.4	35.4
Maximum	360	381	40.76

Tab. 2. Limits of values for mechanic proprieties

Coefficient	Values	
	$A_{80\ L}$	$A_{80\ E}$
R^2	0.685	0.664
R	0.828	0.815

Tab.3.Values of determination and correlation coefficients

Chemical composition						
	C	Mn	Si	S	P	Al
C	1	0.529**	-0.106	-0.329	0.173	0.315
Mn	0.529**	1	-0.010	-0.146	0.382*	-0.094
Si	-0.106	-0.010	1	-0.144	-0.187	-0.134
S	-0.329	-0.146	-0.144	1	-0.194	0.048
P	0.173	0.382*	-0.187	-0.194	1	-0.013
Al	0.315	-0.094	-0.134	0.0482	-0.013	1
* Relevant to 95%< **Relevant to 99%						

	First iteration		Second iteration	
	$p^i(1)$	Place	$p^i(2)$	Place
C	1.529	2	2.541	2
Mn	1.911	1	3.249	1
Si	1	4÷6	1	4÷6
S	1	4÷6	1	4÷6
P	1.382	3	2.112	3
Al	1	4÷6	1	4÷6

Tab. 4. Values of correlation coefficients and of iterations

We checked using the Fisher test the significance of the linear correlation coefficient from the linear equation and we obtained: $F_c = 6.905 > F_{crt} = 2.63$, the linear correlation coefficient is significant for a significance level of $\alpha = 0.05$ and the number of degrees of freedom $\nu_1 = 6$ and $\nu_2 = 19$. Next we tested the significance of the coefficients from the linear regression equation using Student test. The results of a test for $t_{0,05;\ 19} = 2.093$ indicate that:

$|a| = 42.184 > |\Delta a| = 0.344$

$|b_1| = 31.754 > |\Delta b_1| = 4.864$

$|b_2| = 12.856 > |\Delta b_2| = 0.951$

$|b_3| = 16.647 > |\Delta b_3| = 8.4785$

$|b_4| = 42.517 > |\Delta b_4| = 23.658$

$|b_5| = 87.689 > |\Delta b_5| = 12.495$

$|b_6| = 0.001 < |\Delta b_6| = 3.533$

The coefficient b_6, which indicates the influence of aluminum, is insignificant in statistical terms and can be excluded from the model. It appears that the absolute value of coefficients *a* and b_i (i = 1 ... 5) is greater than the confidence interval of these factors, so these coefficients are significant.

After applying the Fisher test to verify the accuracy of the linear model, we obtained $F_c = 1.477 < F_{critic} = 1.955$, thus the model is reliable.

Chemical elements in the composition of the metal sheets were studied in terms of importance and were put in order after optimization. The optimization of the factors influence was made through correlation analysis that allowed us to determine the statistical relationship between factors. The results obtained from the determination of the correlation coefficients between the elements of the chemical composition and the results of the calculation of the iterations are presented in Table 4.

Graphs for the linkages of correlation for the probabilities of confidence P = 95% and P = 97% are shown in Figure 1.

From the dependency analysis of equation (1) we observed that chemical elements affect in different manner the elongation. If the quantity of the element increases:

- carbon substantially increased A_{80};
- silicon, sulfur and phosphorus decreased A_{80}.

In terms of importance, influence factors may be ordered as follows: *Mn, C, P* şi *Si, S, Al*.3

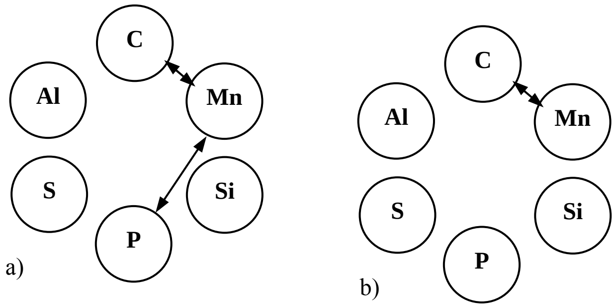

Fig. 1. Ties correlation graphs:
a) confidence probability 95%; b) confidence probability 99%

The analysis of the graphs showed that *Mn* has the largest influence due to the number of links established with other chemical elements. For a confidence probability P = 95%, *Mn* have two links and for P = 99%, *Mn* have only a link. Among other elements of the chemical composition there are no obvious correlation links for confidence probability greater than 95%.

Using graph theory and correlation it was discovered that Mn is the element with the highest degree of influence on the elongation A_{80}.

Additions of *Mn* in rage of 0.25 to 0.30 weight % increase the mechanical properties since coarse precipitates are avoided; the microstructure forming Al-Mn precipitates and a fine lamellar microstructure (Domínguez, C. et al., 2002) and forms a manganese dispersoid of Al_6Mn (Nam, S.W. & Lee D.H., 2000).

3. CONCLUSIONS

The chemical elements form the composition of metal sheets affect in different manner the elongation:

- increasing the content of carbon and aluminum, increases the elongation;
- if manganese, silicon, sulfur and phosphorus increase, the elongation decreases.

The most important chemical element that modifies the elongation is *Mn*, followed by *C* and *P*, and finally *Si*, *S* and *Al*.

Linear equations provide the best mathematical representation for the determination of A_{80} if the chemical composition of metal sheet is known. In the linear equation the coefficient for phosphorus is by far the greatest.

Because the *Mn* exceeds the optimal values (0.25 to 0.30%) a decrease of elongation was observed.

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