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MATHEMATICAL MODEL AND STATISTICAL ANALYSIS OF THE ELONGATION (A2) OF THE STEEL J55 API 5CT BEFORE AND AFTER THE DEVELOPMENT OF THE PIPES

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ABSTRACT
Object of this study is the tin of quality from the steel quality J55 API 5CT and the process of pipe forming ∅139.7x7.72 mm, and ∅219.1x7.72 mm with rectilinear seam. Aim of this paper is to study the impact of deformation level in the cold and mechanical properties of the steel coils before and after the formation of the pipes. For the realization of the project we have used the planning method of the experiment. We have built the mathematical model for the experiment with one index (extension A_2) and with one factor (level of deformation in the cold) and with few levels and two blocks (before and after the formation of the pipes). The statistical processing of the experimental results is done through program "Design Expert" and as well in analytical way.
Keywords: One-factor experiments, steel coils, pipe, percentage elongation (A_2)

1. INTRODUCTION
During technological process of pipe production with rectilinear seam entrance, factor with significant impact is plastic deformation in the cold which is realized based on the deformation forces in inflexion throughout formation process of pipe calibration. It is more likely that impact will be bigger as long as diameter of the pipe is smaller. To invent and assess this impact in mechanical attributes, extension in withdrawing, we have planned the experiment in three conditions of the material: preliminary steel coil, pipe Ø139.7x7.72 *mm* and pipe Ø219.1x7.72 *mm*. These three conditions, express three levels (1, 2 and 3) of quality factor”deformation level”. For each level have been conducted 5 experiments in inflexion. Champions have been taken in direction of pipe's axis and proves/experiments have been conducted based on application of fortuity's criteria. Calculating indicator/index is percentage of elongation (A_2), marked with *y*

Table 1. Results

Reiterations / Levels	1	2	3
1.	34	29	28
2.	34	28	29
3.	35	30	31
4.	36	30	32
5.	41	28	32
Sum y_{i+}	180	145	152 $y_{++} = 477$
Average values $\bar{y}_{i+}$	36 $\bar{y}_{1+}$	29 $\bar{y}_{2+}$	30.4 $\bar{y}_{3+}$

2. MATHEMATICAL MODEL AND STATISTICAL ANALISYS

2.1. Mathematical Model

Mathematical model which is predicted to reflect such a study is composed from a system by *n* equations forms:

$y_{ij} = \overline{m} + a_i + \varepsilon_{ij}$ (1) $\qquad \sum_{i=1}^{\mu} \overline{a}_i = 0$ (2)

Emerge formulas for calculation of round constant to which are spread all observing results of index/indicator y ($\overline{m}$) and effects ($\overline{a}_i$).

$$\overline{m} = \frac{1}{n} \cdot y_{++} \qquad \overline{a}_i = \frac{1}{p} y_{i+} - \overline{m} \tag{3}$$

Based on values from table 1 and formulas (3) we will have:

$$\overline{m} = \frac{1}{15} \cdot 477 = 31.8$$

$\overline{a}_1 = 36 - 31.8 = 4.20$; $\quad \overline{a}_2 = 29 + (-31.80) = -2.80$; $\overline{a}_3 = 30.40 + (-31.80) = -1.40$

With replacement of effects values in equations (1) mathematical model will have this form:

$$y_{1j} = 31.80 + 4.20 + \varepsilon_{1j};\ y_{2j} = 31.80 - 2.80 + \varepsilon_{2j};\ y_{3j} = 31.80 - 1.40 + \varepsilon_{3j} \tag{4}$$

2.2. Statistical Analysis (Variance Analysis)

Total sum of the squares of differences (deviations) of the measured values from the average is composed by two components:

$S = S_g + S_p$ (5)

Value of summary of error squares S_g is:

$$S_g = \sum_{i=1}^{\mu}\sum_{j=1}^{p} y_{ij}^2 - \frac{1}{p}\sum_{i=1}^{p} y_{i+}^2 = \sum_{i=1}^{3}\sum_{j=1}^{5} y_{3,5}^2 = 15357 - \frac{1}{5} \cdot 76529 = 51.20$$

$$S_p = \frac{1}{p}\sum_{i=1}^{\mu} y_{i+}^2 - \frac{1}{\mu \cdot p} \cdot y_{++}^2 = \frac{1}{5}\sum_{i=1}^{\mu} y_{i+}^2 - \frac{1}{3 \cdot 5} y_{++}^2 = \frac{1}{5} \cdot 76529 - \frac{1}{15} \cdot 227529 = 137.20 \tag{6}$$

2.3. Control of Hypothesis, upon equality of the effects

For this is required control of hypothesis upon the equality of the effects a_i. In conditions when towards the effects it is placed the request according to the equation (2), Hypothesis of equation of the effects H_0, will take the form:

H_0: $a_1 = a_2 = ... = a_\mu = 0$; $\qquad$ Alternative hypothesis is: H_1: $a_i \neq 0$ (7)

$$s_g^2 = \frac{S_g}{n - \mu} = \frac{51.20}{15 - 3} = 4.26 \text{ and } s_p^2 = \frac{S_p}{\mu - 1} = \frac{137.2}{3 - 1} = 68.6 \tag{8}$$

$$S = S_g + S_p = 51.20 + 137.20 = 188.40 \tag{9}$$

Tab.2. Summary table of variance analysis

Reason of change	Sum of squares	No. of DOF	Average square of deviations
Processing	$S_p = 137.2$	$\mu - 1 = 2$	$s_p^2 = 68.60$
Reasons of the case	$S_g = 51.20$	$n - \mu = 12$	$s_g^2 = 4.26$

Sum of deviations	$S = 188.40$	$n-1=14$	

Value of calculated Fisher's criteria is : $F_c = \frac{s_p^2}{s_g^2}$; $F_c = \frac{68.60}{4.26} = 16.10$ (10)

For level of importance $\alpha = 0.05$ limit value of Fisher's criteria is:

$F_{t(\alpha);2;12} = F_{t(0.05);2;12} = 3.89$; $F_c = 16.10 > F_t = 3.89$

Then with level of importance $\alpha = 0.05$ hypothesis H_0 refuses and effects $a_i (i = 1,2,3)$ are accepted.

2.4. Comparison of the effects

2.4.1. Comparison of the effects according to minimal valid difference

To emphasize that which levels are with important changes, first is required to calculate minimal valid difference $\Delta_{ik}(\alpha)$ for level of importance $\alpha = 0.05$.

$$\Delta_{ik}(\alpha) = \sqrt{s_g^2\left(\frac{1}{p_i} + \frac{1}{p_k}\right)(\mu - 1)F_{(\alpha;\mu-1;n-\mu)}} = \sqrt{4.26\left(\frac{1}{5} + \frac{1}{3}\right)2 \cdot 3.89} = 5.24 \quad (11)$$

Based on the criteria (12) levels of effects "*i*" *and "k" factor, so it compares a_i* and a_k.:

$$\left|\bar{y}_{i+} - \bar{y}_{k+}\right| > \Delta_{ik}(\alpha) \quad (12)$$

from application of this criteria result that:

$\left|\bar{y}_{1+} - \bar{y}_{2+}\right| = |36 - 29| = 7 > 5.24,$ Between levels 1 and 2 it has important impact

$\left|\bar{y}_{1+} - \bar{y}_{3+}\right| = |36 - 30.40| = 5.60 > 5.24,$ Between levels 1 and 2 it has important impact;

$\left|\bar{y}_{3+} - \bar{y}_{2+}\right| = |30.40 - 29| = 1.40 < 5.24$ Between levels 2 and 3 it has not important impact;

2.4.2. Comparison of the effects according to collective criteria of deviations

For level of importance 0.05 which is selected, when hypothesis $a_1=a_2$ accepted as true based on the usage of criteria of "minimal valid deviation" which is such with 0.95 probability. Let's accept that hypothesis $a_i=a_j$ is true. Probability since the application of the criteria should result generally true, when we have such three equations, it will be equal with multiplication of probabilities $(0.95)^3=0.857$. In this way "first type of mistake" to revoke a true hypothesis would be: 1-0.857=0.142 (and no more 0.05).To avoid this increment of mistake we should use another crietria, Duncan's collective criteria of deviations which will be described bellow. For case when number of proves/experiments *p* in every level is same, standard mistake is calculated:

$$s_{\bar{y}_{i+}} = \sqrt{\frac{1}{p}s_g^2} = \sqrt{\frac{1}{5} \cdot 4.26} = 0.92 \quad (13)$$

By statistical tables, for $\alpha = 0.05$ and number of degrees of freedom f = n- μ =15-3=12, are with row for q=2, 3 valid deviation: $r_{0.05(2;12)} = 3.08$ and $r_{0.05(3;12)} = 3.23$

With valid deviations $r_\alpha(q, f)$ and standard mistakes of levels, calculation of minimal valid deviations according to the formula:

$$R_q = r_a(q, f) \cdot S_{\bar{y}_{i+},q} = 2,3,...,\mu \quad (14)$$

$R_2 = 3.08 \cdot 0.92 = 2.83$ *dhe* $R_3 = 3,23 \cdot 0.92 = 2.97$

$\bar{y}_{1+} - \bar{y}_{2+} = 36 - 29 = 7 > 2.97 = R_3,$ q=3-1+1=3 important change;

$\bar{y}_{1+} - \bar{y}_{3+} = 36 - 30.40 = 5.60 > 2.83 = R_2,$ q=3-2+1=2 important change;

$\bar{y}_{3+} - \bar{y}_{2+} = 30.40 - 29 = 1.40 < 2.83 = R_2$, q=2-1+1=2 unimportant change;

3. ANALYSIS OF EXPERIMENTAL DATAS THROUGH PROGRAM "DESIGN EXPERT"

We have used the program Deign Expert 7. Results from analysis of experiment with one quality factor and with three levels are presented in the table 3 and figure 1.

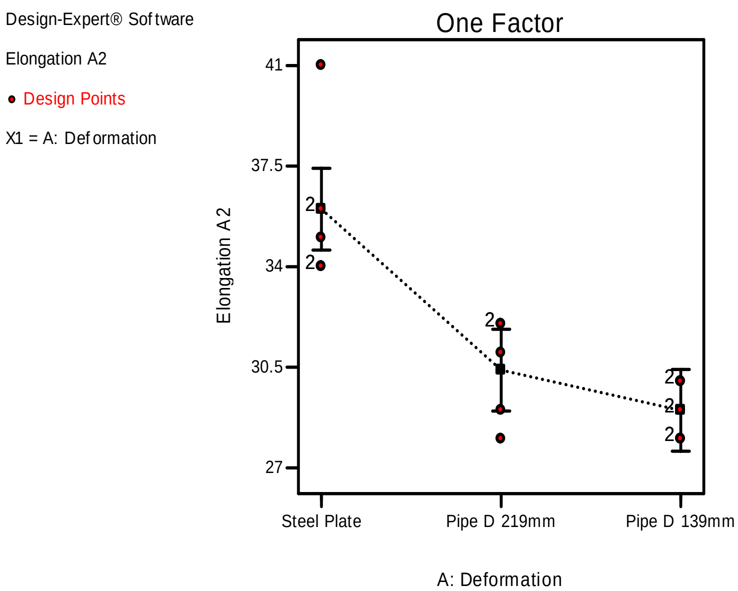
ANOVA: Analysis of variance table [Classical sum of squares - Type II]

Source	Sum of Squares	df	Mean Square	F	p-value Value Prob > F	
Model	137.20	2	68.60	16.08	0.0004	significant
A-Deformation	*137.20*	*2*	*68.60*	*16.08*	*0.0004*	
Pure Error	51.20	12	4.27			
Cor Total	188.40	14				

The Model F-value of 16.08 implies the model is significant. There is only a 0.04% chance that a "Model F-Value" this large could occur due to noise.

Treatment	Mean Difference	df	Standard Error	t for H_0 Coeff=0	Prob > |t|
1 vs 2	5.60	1	1.31	4.29	0.0011
1 vs 3	7.00	1	1.31	5.36	0.0002
2 vs 3	1.40	1	1.31	1.07	0.3050

Values of "Prob > |t|" less than 0.0500 indicate the difference in the two treatment means is significant.



4. DISCUTION/ CONCLUSIONS

In three applied methods (criteria) for results analysis, with degree of decreasing the mistake of the first type, from 0.142, in 0.05 and in p = 0.0004, are confirming that during the forming of pipes, the level of deformation throughout the bending of plate and calibration, influence the decrease of relative elongation. Results are done in "Laboratori mekaniko-metalografik IMK", Ferizaj-Kosovo.

5. REFERENCES

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