PROCESSING AND ANALYSIS OF EXPERIMENTAL DATA FOR THE IMPACT TOUGHNESS OF THE STEEL QUALITY USING DESIGN EXPERT SOFTWARE

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ABSTRACT
In this paper the plate from the steel of quality grade J55 API 5CT and the process of pipe forming Ø139.7x7.72 mm and Ø219.1x7.72 mm with rectilinear seam is analysed.
The impact of deformation level in the cold and mechanical properties of the steel coils before and after the forming of the pipes are elaborated and processed through Design Expert Software*. For analysis it was used the planning method of the experiment. It was built the mathematical model for the experiment with one index (impact toughness - Kv) and with one factor (level of deformation in the cold), and with few levels and two blocks (before and after the forming of the pipes). Statistical analysis of experimental data for models of plate and pipe were obtained through* Design Expert Software*.* B*ased on such date graphic representation for the influence of deformation rate on Charpy-*V *notch energy was generated.*
Application of the Design Expert Software *helps quick and correct combinations of three criteria (treatments) in order to estimate the level of deformation throughout the bending of sheet and calibration, influence of the decrease of impact toughness during the forming of pipes.*
Keywords: D*esign Expert Software, one-factor experiments, steel coils, pipe,impact* toughness

1. INTRODUCTION
During technological process of pipe production with rectilinear seam entrance, a factor with significant impact is cold plastic deformation realized based on the deformation forces in inflexion throughout formation process of pipe calibration. It is more likely that the impact will be bigger as long as diameter of the pipe is smaller. To invent and assess this impact in mechanical attributes, extension in pulling, we have planned the experiment in three conditions of the material: preliminary steel coil, pipe Ø139.7×7.72 mm and pipe Ø219.1×7.72 mm [1]. These three conditions, express three levels (1, 2 and 3) of quality factor "deformation rate". For each deformation rate there have been conducted 5 experiments in inflexion [3].
Specimens have been taken in direction of pipe's axis and experiments have been conducted based on application of fortuity criteria.
Calculating indicator is impact toughness (Kv), marked with y.

Table 1. Results

Reiterations/ Levels	Plate R=inf.	Pipe R=110[mm]	Pipe R=70[mm]
1.	197	187	186
2.	208	190	176
3.	201	193	181
4.	197	197	171
5.	195	191	171
Sum y_{i+}	998	958	885 $y_{++}=2841$
Average values $\bar{y}_{i+}$	199.6 $\bar{y}_{1+}$	191.6 $\bar{y}_{3+}$	177 $\bar{y}_{2+}$

2. MATHEMATICAL MODEL AND STATISTICAL ANALYSIS

2.1. Mathematical Model

Mathematical model which is predicted to reflect such a study is composed from a system by n equations forms [5] :

$$y_{ij}=\bar{m}+a_i+\varepsilon_{ij} \tag{1}$$

The formulas for calculation of round constant in which are based all observing results of index/indicator y ($\bar{m}$) and effects ($\bar{a}_i$) are:

$$\bar{m}=\frac{1}{n}\cdot y_{++} \qquad \bar{a}_i=\frac{1}{p}y_{i+}-\bar{m} \tag{2}$$

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

$$y_{1j}=189.40+10.20+\varepsilon_{ij}$$
$$y_{2j}=189.40-12.40+\varepsilon_{2j}$$
$$y_{3j}=189.40+2.20+\varepsilon_{3j} \tag{3}$$

2.2. Statistical Analysis

2.2.1. Analysis of variance

Total sum of the squares of differences (deviations) of the measured values from the average is composed by two components [2]:

$$S = S_g + S_p \tag{4}$$

Value of summary of error squares S_g is:

$$S_g=\sum_{i=1}^{\mu}\sum_{j=1}^{p}y_{ij}^2-\frac{1}{p}\sum_{i=1}^{p}y_{i+}^2=\sum_{i=1}^{3}\sum_{j=1}^{5}y_{3,5}^2-\frac{1}{5}\sum_{i=1}^{3}y_3^2=332.40$$

In similar method we will have also the value of deviation of experimental mistake.

$$S_p=\frac{1}{p}\sum_{i=1}^{\mu}y_{i+}^2-\frac{1}{\mu\cdot p}y_{++}^2=\frac{1}{5}\sum_{i=1}^{3}y_{i+}^2-\frac{1}{3\cdot 5}y_{++}^2=1313.20$$

Table 2. Summary table of variance analysis

Reason of change	Sum of squares	No. of DOF	Average square of deviations
Processing	$S_p = 1313.2$	$\mu - 1 = 2$	$s_p^2 = 656.6$
Reasons of the case	$S_g = 332.4$	$n - \mu = 12$	$s_g^2 = 27.7$
Sum of deviations	$S = 1645.4$	$n - 1 = 14$	

Calculated value of Fisher's criterion is:

$$F_c = \frac{s_p^2}{s_g^2}; \quad F_c = \frac{656.60}{27.70} = 23.70 \tag{5}$$

For level of importance α = 0.05 limit value of Fisher's criterion:

$$F_{t\ \alpha;2;12} = F_{t\ 0.05;2;12} = 3.89;\ F_c = 11.12 > F_t = 3.89$$

Then, with level of importance α = 0.05 hypothesis H_0 is rejected and effects a_i i=1,2,3 are accepted.

2.3. Comparison of the effects

2.3.1. Comparison of the effects according to minimal valid difference

To emphasize which levels are with important changes, first is required to calculate minimal valid difference

$\Delta_{ik}(\alpha)$ for level of importance α=0.05

$$\Delta_{ik}(\alpha) = \sqrt{s_g^2\left(\frac{1}{p_i} + \frac{1}{p_k}\right)(\mu-1)F_{(\alpha;\mu-1;n-\mu)}} = \sqrt{27.70\left(\frac{1}{5} + \frac{1}{3}\right)\cdot 2\cdot 3.89} = 13.37$$

Based on the criterion (6) levels of effects "*i*" and "*k*" factor, so it compares $\bar{a}_i$ and $\bar{a}_k$:

$$|\bar{a}_i - \bar{a}_k| > \Delta_{ik}(\alpha) \quad |10.20 - (-12.40)| = 22.60 > 13.37$$
$$|\bar{y}_{i+} - \bar{y}_{k+}| > \Delta_{ik}(\alpha) \quad |199.60 - 177| = 22.60 > 13.37 \tag{6}$$

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

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 other criteria, 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 [2]:

$$s_{\bar{y}_{i+}} = \sqrt{\frac{1}{p}s_g^2} = \sqrt{\frac{1}{5}\cdot 27.70} = 2.35 \tag{7}$$

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_α and standard mistakes of levels, calculation of minimal valid deviations according to the formula:

$$R_q = r_\alpha(q, f)\cdot S_{\bar{y}i+,q} = 2,3,\ldots,\mu \tag{8}$$

$$R_2 = 3.08\cdot 2.35 = 7.238 \quad \text{and} \quad R_3 = 3.23\cdot 2.35 = 7.590$$

Minimal valid deviation will be: $\bar{y}_i - \bar{y}_k \geq R_q$ (9)

3. Statistical Analysis of Experimental data through "Design Expert" Program

Response 1 Charpy V-notch energy,

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

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	1313.20	2	656.60	23.70	< 0.0001	significant
A-Deformation rate, R	1313.20	2	656.60	23.70	< 0.0001	
Pure Error	332.40	12	27.70			
Cor Total	1645.60	14				

The Model F-value of 23.70 implies the model is significant. There is only a 0.01% chance that a "Model F-Value" this large could occur due to noise.

Values of "Prob > F" less than 0.0500 indicate model terms are significant.
In this case A are significant model terms.

Treatment Means (Adjusted, If Necessary)

	Estimated Mean	Standard Error
1-Plate, R = infinit	199.60	2.35
2-Pipe, R = 110	191.60	2.35
3-Pipe R = 70	177.00	2.35

Treatment	Mean Difference	df	Standard Error	t for H_0 Coeff=0	Prob > |t|
1 vs 2	8.00	1	3.33	2.40	0.0333
1 vs 3	22.60	1	3.33	6.79	< 0.0001
2 vs 3	14.60	1	3.33	4.39	0.0009

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

The Diagnostic Statistics through the Diagnostic Plots to look at the:
1) Normal probability plot of the studentized residuals to check for normality of residuals;
2) Studentized residuals versus predicted values to check for constant error;
3) Externally Studentized Residuals to look for outliers, i.e., influential values;
4) Box-Cox plot for power transformations,
are OK. We can proceed with the Model Graph.

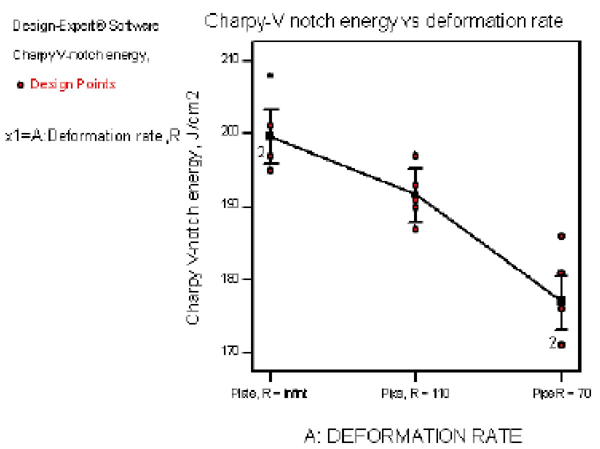

Figure1. Graphic representation for the influence of Deformation rate on Charpy V notsh energy, obtained through Design-Expert Software.

3. 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 = 0.0001, are confirming that during the forming of pipes, the level of deformation throughout the bending of sheet and calibration, influence the decrease of impact toughness.
With increasing of the deformation level results that impact toughness decreased, and these decreasing is more significant for the pipe with diameter Ø139.7×7.72 [mm] (R=70 mm) than the pipe with diameter Ø219.1×7.72 [mm] (R= 110mm), so this must be considered from the producers and users of pipes.

4. REFERENCES

[1] Standard, API Specification 5CT, Washington 2000.
[2] V. Kedhi, *Methods of planning and analysis of experiments*, Polytechnic Faculty, Tirana, 1984.
[3] Standard, ASTM-A370, Washington 2000.
[4] Douglas C. Mongomery, *Statistical controll of quality*, McGraw-Hill, 2000.
[5] I. Pantelič, *Uvod u teoriju inžinjerskog eksperimenta*, Radnički Universitet, Novi Sad 1976.
[6] Software Design-Expert.