ANNALS of Faculty Engineering Hunedoara – International Journal of Engineering
Tome XVIII [2020] | Fascicule 3 [August]

ANNALS of Faculty Engineering Hunedoara – International Journal of Engineering
ISSN 1584 - 2665 (printed version); ISSN 2601 - 2332 (online); ISSN-L 1584 - 2665

[1.]Malush MJAKU

ANALYSIS OF EXPERIMENTAL DATA FOR THE IMPACT TOUGHNESS (K_V) OF THE STEEL QUALITY J55 API 5CT USING DESIGN EXPERT SOFTWARE

[1.]Faculty of Computer Science, University of Prizren, Prizren, KOSOVO

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 mechanical properties of the steel coils before and after the forming of the pipes and impact of deformation level in the cold are represented using Design Expert Software. For analysis is used the planning method of the experiment. Mathematical model is built for the experiment with index of impact toughness - Kv and with factor of level of deformation in the cold, also are used few levels and two blocks, in both phases: before and after the forming of the pipes. Statistical analysis of experimental results for models of plate and pipe are obtained through Design Expert Software. Based 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: Toughness, factor of experiments, steel coils, pipe, software

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 format ion 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 direct ion of pipe's axis and experiments have been conducted based on applicant ion of fortuity criteria. Calculating indicator is impact toughness (Kv), marked with y. The results obtained of impact toughness are given in Table 1.[1].

Table 1. Results – Charpy V notch energy

Reiterations/ Levels	Steel coils 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

— Mathematical Model

Mathematical model which is predicted to reflect such a study is composed from a system by n equations forms [2]:

$$y_{ij} = \overline{m} + a_i + \varepsilon_{ij} \quad (1)$$

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

$$\overline{m} = \frac{1}{n} \cdot y_{++} \qquad \overline{a_i} = \frac{1}{p} y_{i+} - \overline{m} \tag{2}$$

Using replacements based on equations (2) in equations (1), the mathematical model will become:

$$\begin{aligned} y_{1j} &= 189.40 + 10.20 + \varepsilon_{1j} \\ y_{2j} &= 189.40 - 12.40 + \varepsilon_{2j} \\ y_{3j} &= 189.40 + 2.20 + \varepsilon_{3j} \end{aligned} \tag{3}$$

— **Statistical Analysis / Analysis of variance**

Total sum of the squares of differences (deviations) of the measured values from the average is composed by two components [3]:

$$S = Sg + Sp \tag{4}$$

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	$S_p = 1313.2$	μ-1= 2	$S_p^2 = 656.6$
Reasons of the case	$S_g = 332.4$	n-μ= 12	$S_g^2 = 27.7$
Sum of deviations	S = 1645.4	n-1=14	

Calculated value of Fisher's criterion is:

$$F_c = \frac{S_p^2}{S_g^2}; \qquad F_c = \frac{656.60}{27.70} = 23.70 \tag{5}$$

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

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

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

— **Comparison of the effects**

» **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 $\bar{a}_k$:

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

» **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 below. For case when number of proves/experiments p in every level is same, standard mistake is calculated [4]:

$$S_{y_{i+}} = \sqrt{\frac{1}{p} S_g^2} = \sqrt{\frac{1}{5} \cdot 27.70} = 2.35 \tag{7}$$

By statistical tables, for α = 0.05 and number of degrees of freedom f = n-μ=15-3=12, are with row for q = 2, 3 valid deviation: 0.05 (2;12) = 3.08 and r 0.05(3;12) = 3.23.

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

$$R_q = r_a(q,f) \cdot S_{\bar{y}_{i+}} = 2,3,\ldots,\mu \quad (8)$$

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

Minimal valid deviation will be:

$$\bar{y}_i - \bar{y}_k \geq R_q \quad (9)$$

3. STATISTICAL ANALYSIS OF EXPERIMENTAL DATA THROUGH ,DESIGN EXPERT PROGRAM

Response 1 Charpy V- notch energy
ANOVA for selected factorial model
Analysis of variance table [Classical sum of squares - Type II]

Table 3. Sumary table for one-way between-subjects design

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- Def. Degree	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 [5].

Table 4. Output of the Multiple Comparisons procedure

Treatment Means (Adjusted, If Necessary)					
	Estimated Mean	Standard Error			
1-R = Inf.	199.60	2.35			
2-R = 110	191.60	2.35			
3-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.

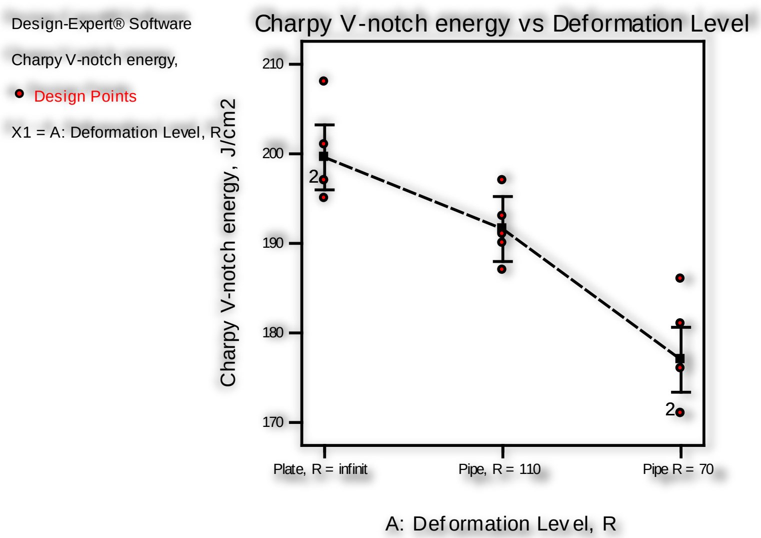

Figure 1. Graphic representation for the influence of Deformation level on Charpy V-notsh energy, obtained through Design-Expert Software [5].

4. CONCLUSIONS

In this papers are applied three methods (criteria). Analysis of results, with degree of decreasing the mistake of the first type, from 0.142, in 0.05 and in p = 0.0001, have confirm 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.

References

[1] Standard, API Specification 5CT, Washington 2000.
[2] V. Kedhi, Methods of planning and analysis of experiments, Polytechnic Faculty, Tirana, 1984.
[3] Glenn Gamst, Lawrence S. Myers, A. J. Guarino, Analysis of Variance Desings, Cambridge University, New York, 2008.
[4] Douglas C. Mongomery, Statistical control of quality, McGraw-Hill, 2000.
[5] Software Design Expert 7.
[6] Chen, Zejun, Xin Chen, and Tianpeng Zhou. Microstructure and Mechanical Properties of J55ERW Steel Pipe Processed by On-Line Spray Water Cooling, Metals 7, no. 4 (2017):150.
[7] Chen, Zejun, Huiquan Han, Wei Ren, and Guangjie Huang, Heat transfer modeling of an annular on-line spray water cooling process for electric-resistance-welded steel pipe, PloS one 10, no. 7 (2015): e0131574.
[8] API specifications 5L. Specifications for line pipe, 43 ed., American Petroleum Institute, 2004.
[9] ASTM. Annual Book of ASTM Standards, 1984.
[10] Burgman P.M. Design of experiments the Taguchi way, Manufacturing Engineering, volume 5, 1985: 44-46.
[11] J. M. Barsom, S. T. Rolfe, Correlations between KIc and Charpy V-notch test results in the transition–temperature range', ASTM STP466, 281–302; 1970, Philadelphia, PA, AmericanSociety for Testing and Materials.
[12] J. F. Knott, Fundamentals of fracture mechanics, 1973, London, Butterworth.

ANNALS of Faculty Engineering Hunedoara – International Journal of Engineering
ISSN 1584 - 2665 (printed version); ISSN 2601 - 2332 (online); ISSN-L 1584 - 2665

Faculty of Engineering Hunedoara,
5, Revolutiei, 331128, Hunedoara, ROMANIA
http://annals.fih.upt.ro