International Journal of Thales Engineering Sciences (JTHES)
ISSN (print): 2149-5173

Processing and Analysis of Experimental Data for the Impact Hardness (HV30) of the Steel Quality Using Design Expert Software

MJAKU Malush
University of Prizren, Faculty of Computer Science Prizren, Kosovo
E- mail: malush.mjaku@uni-prizren.com

BAFTIU Naim
University of Prizren, Faculty of Computer Science Prizren, Kosovo
E- mail: naim.baftiu@uni-prizren.com

ABSTRACT

In this paper the sheet metal 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 by the mathematical model for the experiment with one index hardness and a factor (level of deformation in the cold), and with several 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. Based on such graphic representation data for the influence of deformation degree on hardness was generated.

Application of the Design Expert Software helps in 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: Design Expert Software, one-factor experiments, steel coils, pipe, hardness

1 INTRODUCTION

During technological processes 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 the forming 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 degree”. For each deformation rate, there have been conducted five 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 hardness marked with y.

Table 1. Results-HV30

Reiterations / Levels	Sheet metal R=inf.	Pipe R=110[mm]	Pipe R=70[mm]
1.	172	185.28	194.85
2.	172.33	187.14	195.57
3.	180	182.14	195.57
4.	171	185.71	192.28
5.	171.66	179.71	192
Sum y_{i+}	866.99	919.98	970.27 $y_{++} = 2757.24$
Average values $\bar{y}_{i+}$	173 $\bar{y}_{1+}$	184 $\bar{y}_{3+}$	− 194 $\bar{y}_{2+}$

2. MATHEMATICAL MODEL AND STATISTICAL ANALYSIS

2.1. Mathematical Model

Mathematical model which is predicted to reflect such a study is composed by 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:

$$y_{1j} = 183.816 + (-10.426) + \varepsilon_{ij}$$
$$y_{2j} = 183.816 + 10.234 + \varepsilon_{2j}$$
$$y_{3j} = 183.816 + 0.174 + \varepsilon_{3j} \tag{3}$$

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:

$$S_g = \sum_{i=1}^{\mu}\sum_{j=1}^{p} y_{ij}^2 - \frac{1}{p}\sum_{i=1}^{\mu} y_{i+}^2 = \sum_{i=1}^{3}\sum_{j=1}^{5} y_{3,5}^2 - \frac{1}{5}\sum_{i=1}^{3} y_3^2 = 507996 - \frac{1}{5}\cdot 2539458.60 = 104.28$$

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

$$S_p = \frac{1}{p}\sum_{i=1}^{\mu} y_{++}^2 - \frac{1}{\mu\cdot p} y_{++}^2 = \frac{1}{5}\sum_{i=1}^{3} y_{i+}^2 - \frac{1}{3\cdot 5} y_{++}^2 = \frac{1}{5}\cdot 2539458.60 - \frac{1}{15}\cdot 7602372.40 = 1066.90$$

Table 2. Summary table of variance analysis

Reason of change	Sum of squares	No. of DOF	Average square of deviations
Processing	S_p = 1066.90	μ -1 = 2	S_p^2 = 533.45
Reasons of the case	$\boldsymbol{S_g}$ = 104.28	n - μ = 12	S_g^2 = 8.69
Sum of deviations	S = 1171.18	n -1 = 14	

Calculated value of Fisher's criterion is:

$$F_c = \frac{S_p^2}{S_g^2} = \frac{533.45}{8.69} = 61.38 \quad (5)$$

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 the level of importance α=0.05

$$\Delta_{ik}(\alpha) = \sqrt{S_g^2\left(\frac{1}{p_i}+\frac{1}{p_k}\right)(\mu-1)F(\alpha;\mu-1:n-\mu)} = \sqrt{8.69\left(\frac{1}{5}+\frac{1}{3}\right)\cdot 2\cdot 3.89} = 6$$

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

$$|\bar{a}_i - \bar{a}_k| > \Delta_{ik}(\alpha); \quad |10.234 - (-10.426)| = 20,66 > 6$$

$$|\bar{y}_{i+} - \bar{y}_{k+}| > \Delta_{ik}(\alpha); \quad |194.05 - 173.39| = 20{,}66 > 6 \tag{6}$$

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, such as 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 [2]:

$$S_{\bar{y}_{i+}} = \sqrt{\frac{1}{p} S_g^2} = \sqrt{\frac{1}{5} \cdot 869} = 13.18 \tag{7}$$

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

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

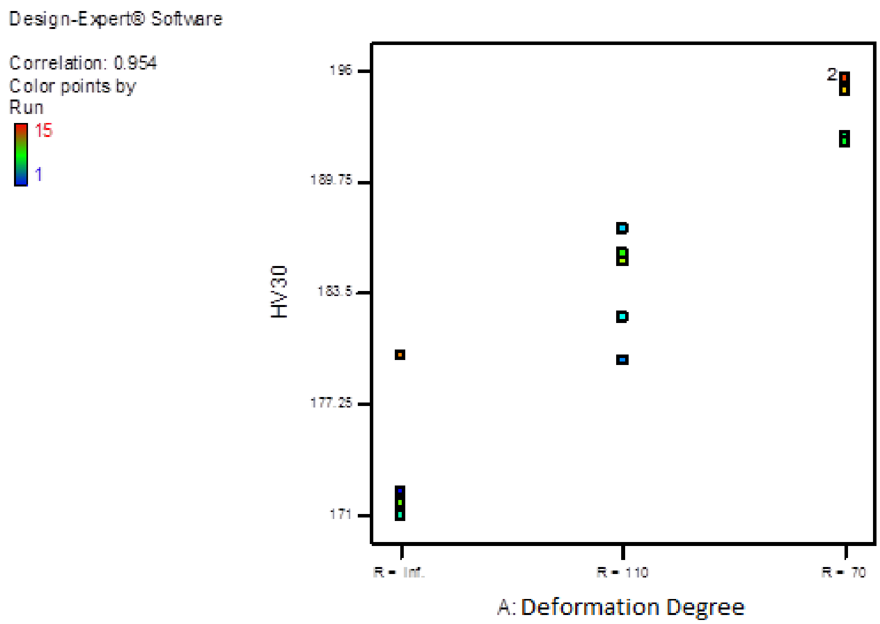
$$R_2 = 3.08 \cdot 13.18 = 40.59 \text{ dhe } R_3 = 3.23 \cdot 13.18 = 42.5$$

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

3. PROCESSING DATA WITH SOFTWARE PROGRAM DESIGN EXPERT 7

Influence of Deformation Degree in Hardness HV30
Table Plan Experiment with Test results, Response 1.

Stand	Run	Blocks	Factor 1 A Def. Degree R [mm]	Response 1 HV30
2	1	Block 1	R = Inf.	172.33
12	2	Block 1	R = 70	195.57
10	3	Block 1	R = 110	179.71
7	4	Block 1	R = 110	187.14
8	5	Block 1	R = 110	182.14
4	6	Block 1	R = Inf.	171
14	7	Block 1	R = 70	192.28
15	8	Block 1	R = 70	192
9	9	Block 1	R = 110	185.71
5	10	Block 1	R = Inf.	171.66
6	11	Block 1	R = 110	185.28
1	12	Block 1	R = Inf.	172
11	13	Block 1	R = 70	194.85
3	14	Block 1	R = Inf.	180
13	15	Block 1	R = 70	195.57



3. CONCLUSIONS

Response 1 HV30

ANOVA for selected factorial model

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

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	1066.92	2	533.46	61.36	< 0.0001	**significant**
A- Def. Degree	1066.92	2	533.46	61.36	< 0.0001	
Pure Error	104.33	12	8.69			
Cor Total	1171.25	14				

The Model F-value of 61.36 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.
Values greater than 0.1000 indicate the model terms are not significant.
If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model.

Std. Dev.	2.95	R-Squared	0.9109
Mean	183.82	Adj R-Squared	0.8961
C.V. %	1.60	Pred R-Squared	0.8608
PRESS	163.02	Adeq Precision	15.664

The "Pred R-Squared" of 0.8608 is in reasonable agreement with the "Adj R-Squared" of 0.8961.
"Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. Your ratio of 15.664 indicates an adequate signal. This model can be used to navigate the design space.

Term	Coefficient Estimate	df	Standard Error	95% Low	95% CI High
Intercept	183.82	1	0.76	182.16	185.47
A[1]	-10.42	1	1.08	-12.76	-8.07
A[2]	0.18	1	1.08	-2.17	2.53

Treatment Means (Adjusted, If Necessary)

	Estimated Mean	Standard Error
1-R = Inf.	173.40	1.32
2-R = 110	184.00	1.32
3-R = 70	194.05	1.32

Treatment	Mean Difference	df	Standard Error	t for H0 Coeff=0	Prob > |t|
1 vs 2	-10.60	1	1.86	-5.68	0.0001
1 vs 3	-20.66	1	1.86	-11.08	< 0.0001
2 vs 3	-10.06	1	1.86	-5.39	0.0002

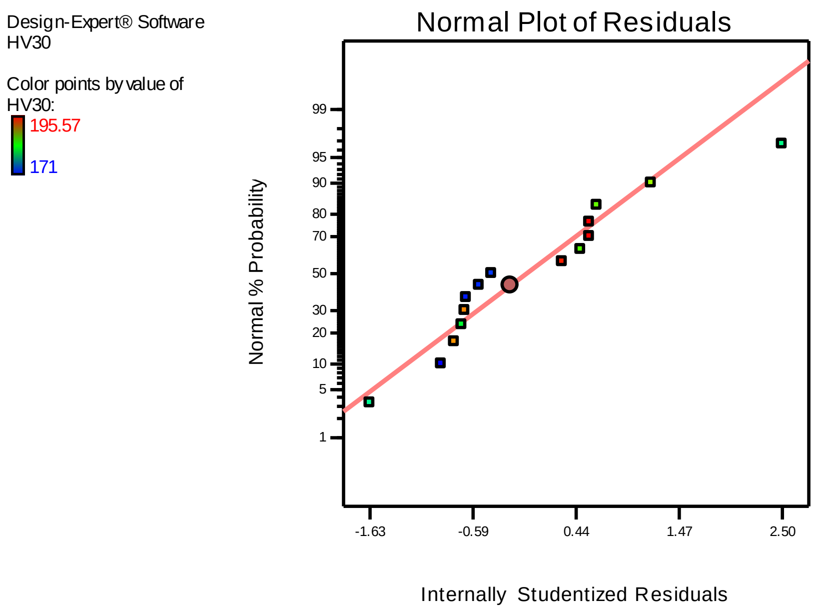
Values of "Prob > |t|" less than 0.0500 indicate the difference in the two treatment means is significant. Values of "Prob > |t|" greater than 0.1000 indicate the difference in the two treatment means is not significant.

Proceed to Diagnostic Plots (the next icon in progression). Be sure to look at the:

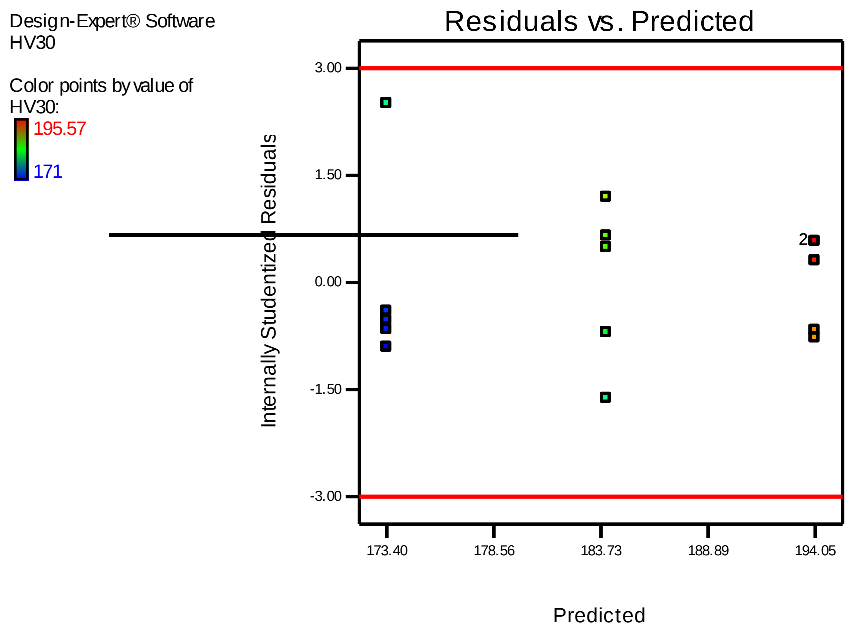
1) Normal probability plot of the studentized residuals to check for normality of residuals.
2) Studentized residuals versus predicted values to check for constant error.
3) Externally Studentized Residuals to look for outliers, i.e., influential values.
4) Box-Cox plot for power transformations.

Diagnostics:

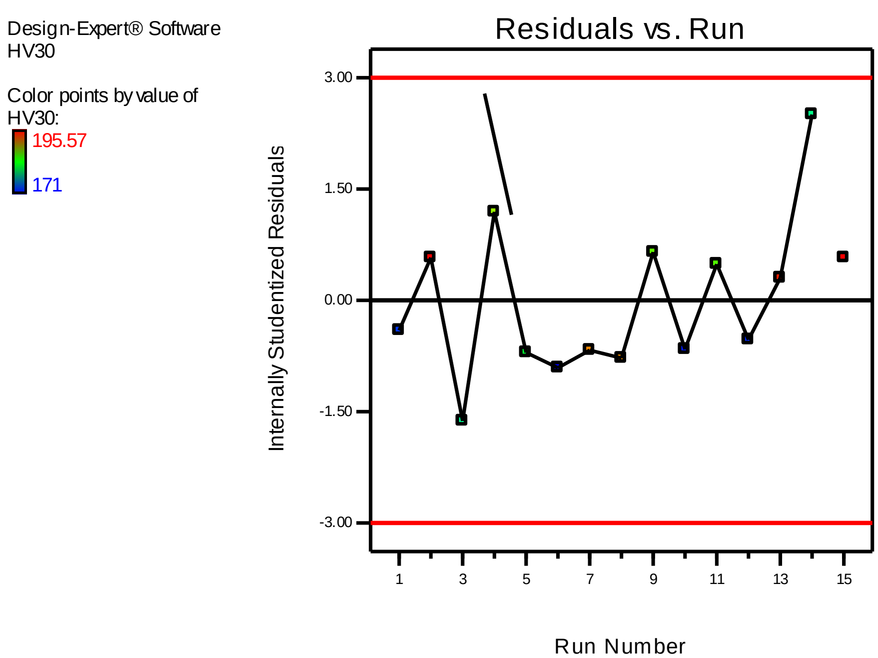
1) Normal probability plot of the studentized residuals to check for normality of residuals.



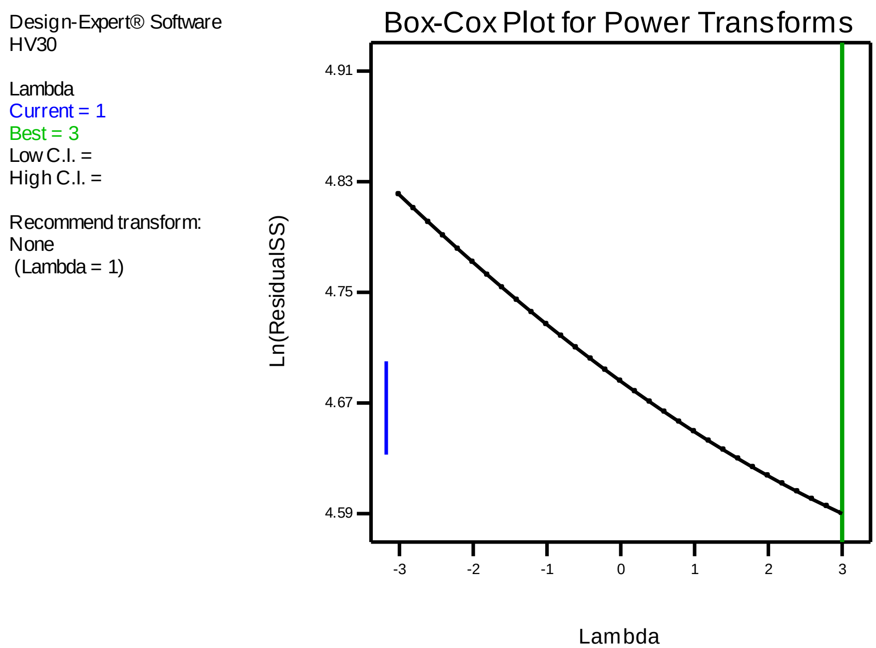
2) Studentized residuals versus predicted values to check for constant error.



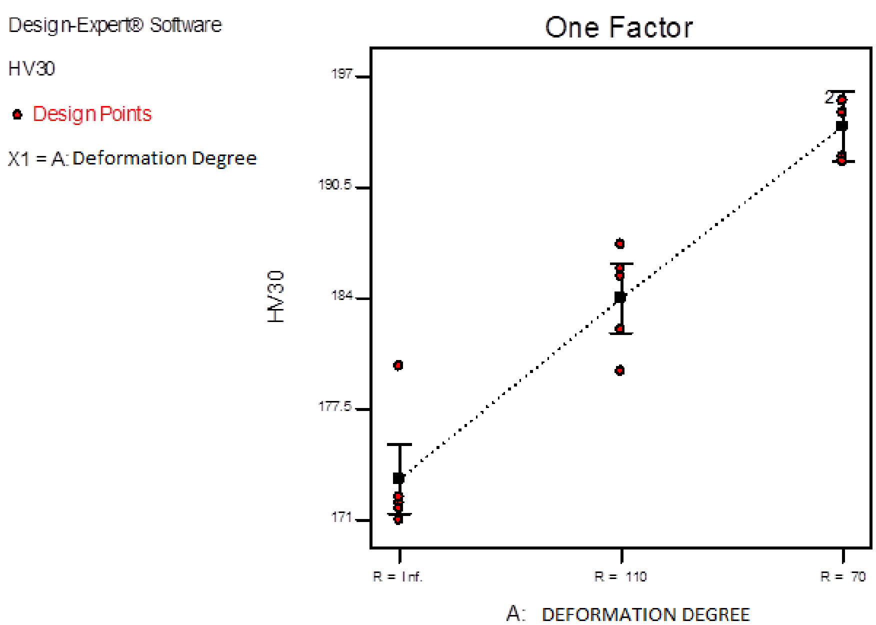
3) Externally Studentized Residuals to look for outliers, i.e., influential values.



4) Box-Cox plot for power transformations.



If all the model statistics and diagnostic plots are OK, finish up with the Model Graphs icon. All our statistics and Diagnostic plots are OK, then we can finish with the Model Graph.
The Model Graph for HV30 vs Deformation Degree



4. CONCLUSION

In these 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, it is confirmed the forming of pipes, the deformation degree throughout the bending of sheet and calibration in the cold, influences in the increase of hardness. The influence is much higher in smaller pipe diameter. Therefore, engineers should take into consideration this fact while producing pipes in cold.

5. 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.