6th Research/Expert Conference with International Participation
"QUALITY 2009", Neum, B&H, June 04 – 07, 2009

MATHEMATICAL MODEL AND STATISTICAL ANALYSIS OF THE TENSILE STRENGTH (*Rm*) OF THE STEEL QUALITY J55 API 5CT BEFORE AND AFTER THE FORMING OF THE PIPES

Fehmi Krasniqi, University of Prishtina
Mechanical Engineering Faculty
Prishtina, Kosova
E- mail: fehkrasniqi@yahoo.com

Malush Mjaku,
Ministry of Education, Science and Technology,
Prishtina, Kosova
E- mail: malushmjaku@yahoo.com

Bajrush Bytyçi, University of Prishtina,
Mechanical Engineering Faculty
Prishtina, Kosova
E- mail: b_bytyqi@yahoo.com

Hysni Osmani, University of Prishtina,
Mechanical Engineering Faculty
Prishtina, Kosova
E- mail: hysniosmani@yahoo.com

SUMMARY
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 (tensile strength (Rm)) 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).
Applying this work, the results obtained in an experimental method are shown in the table and are processed in an analytical way, implementing the one factored experiments.

Key words: One-factor experiments, steel coils, pipe, tensile strength *(Rm)*.

1. INTRODUCTION

During technological process of pipe production with rectilinear seam entrance, a 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 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 Ø139.7x7.72 *mm* and pipe Ø219.1x7.72 *mm* [1]. These three conditions, express three levels (1, 2 and 3) of quality factor "deformation level". For each level 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's criteria. Calculating indicator is tensile strength *(Rm),* marked with *y.*

Table 1. Results

Reiterations/Levels	1	2	3
1	57	61	60
2	56	61	54
3	57	60	56
4	57	60	56
5	53	63	53
Sum y_{i+}	280	305	279 $y_{++} = 864$
Average values $\overline{y}_{i+}$	56 $\overline{y}_{1+}$	61 $\overline{y}_{2+}$	55.8 $\overline{y}_{3+}$

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] :

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

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

$$\overline{m} = \frac{1}{n} \cdot y_{++} \qquad \overline{a}_i = \frac{1}{p} y_{i+} - \overline{m} \qquad \ldots (2)$$

Based on values from table 1 and formulas (2) we will have:

$$\overline{m} = \frac{1}{15} \cdot 864 = 57.60$$
$$\overline{a}_1 = 56.20 - 57.60 = -1.60$$
$$\overline{a}_2 = 61 - 57.60 = 3.40$$
$$\overline{a}_3 = 55.80 - 57.60 = -1.80$$

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

$$\begin{aligned} y_{1j} &= 57.60 + (-1.60) + \varepsilon_{1j} \\ y_{2j} &= 57.60 + 3.40 + \varepsilon_{2j} \\ y_{3j} &= 57.60 + (-1.80) + \varepsilon_{3j} \end{aligned} \qquad \ldots (3)$$

2.2. Statistical Analysis

2.2.1. Variance Analysis

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

$$S = S_g + S_p \qquad \ldots (4)$$

Value of summary of error squares S_g is:

$$S_g = \sum_{i=1}^{\mu}\sum_{j=1}^{p} y_{ij}^2 - \frac{1}{p}\sum_{i=1}^{p} y_{i+}^2 = \sum_{i=1}^{3}\sum_{j=1}^{5} y_{3,5}^2 - \frac{1}{5}\sum_{i=1}^{3} y_3^2 = 46.80$$

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

$$S_p = \frac{1}{p}\sum_{i=1}^{\mu} y_{i+}^2 - \frac{1}{\mu \cdot p} y_{++}^2 = \frac{1}{5}\sum_{i=1}^{3} y_{i+}^2 - \frac{1}{3\cdot 5} y_{++}^2 = 86.80$$

2.3. Control of Hypothesis, upon equality of the effects

For this is required control of hypothesis based the equality of the effects a_i. According to the equation (2), Hypothesis of equation of the effects H_o, will take the form [4]:

$$\sum_{i=1}^{\mu} \overline{a}_i = 0 \quad H_0 : a_1 = a_2 = \ldots = a_\mu = 0 \qquad \ldots (5)$$

Alternative hypothesis is:

$$H_1 : \; a_i \neq 0 \qquad \ldots (6)$$

Table 2. Summary table of variance analysis

Reason of change	Sum of squares	No. of DOF	Average square of deviations
Processing	$S_p = 86.80$	$\mu - 1 = 2$	$s_p^2 = 43.40$
Reasons of the case	$S_g = 46.80$	$n - \mu = 12$	$s_g^2 = 3.90$
Sum of deviations	$S = 133.60$	$n - 1 = 14$	

Value of calculated Fisher's criteria is :

$$F_c = \frac{s_p^2}{s_g^2} \qquad \ldots (7)$$

$$F_c = \frac{43.40}{3.90} = 11.12$$

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

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

Then, with level of importance $\alpha = 0.05$ hypothesis H_0 is rejected 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 which levels are with important changes, first is required to calculate minimal valid difference $\Delta_{ik}(\alpha)$ for level of importance α = 0.05.

$$\Delta_{ik}(\alpha) = \sqrt{s_g^2\left(\frac{1}{p_i} + \frac{1}{p_k}\right)(\mu - 1)F_{(\alpha;\mu-1;n-\mu)}} = \sqrt{3.90\left(\frac{1}{5} + \frac{1}{3}\right)\cdot 2 \cdot 3.89} = 5.028$$

Based on the criteria (8) levels of effects "*i*" and *"k"* factor, so it compares a_i and a_k.:

$$|\overline{a}_i - \overline{a}_k| > \Delta_{ik}(\alpha) \quad |3.40 - (-1.80)| = 5.20 > 5.028$$

$$|\overline{y}_{i+} - \overline{y}_{k+}| > \Delta_{ik}(\alpha) \quad |61 - 55.80| = 5.20 > 5.028 \qquad \dots (8)$$

from application of this criteria result that:

$|\overline{y}_{1+} - \overline{y}_{2+}| = |56 - 61| = 5 < 5.028$, between levels 1 and 2 it has important impact

$|\overline{y}_{1+} - \overline{y}_{3+}| = |56 - 55.80| = 0.20 < 5.028$, between levels 1 and 3 it has not important impact

$|\overline{y}_{2+} - \overline{y}_{3+}| = |61 - 55.80| = 5.20 > 5.028$, between levels 3 and 2 it has not important impact

2.4.2. 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]:

$$s_{\overline{y}_{i+}} = \sqrt{\frac{1}{p}s_g^2} = \sqrt{\frac{1}{5}\cdot 3.90} = 0.883 \qquad \dots (9)$$

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:

$$R_q = r_a(q,f)\cdot S_{\overline{y}_{i+},q} = 2,3,...,\mu \qquad \dots (10)$$

$$R_2 = 3.08 \cdot 0.883 = 2.719 \quad \text{and} \quad R_3 = 3.23 \cdot 0.883 = 2.852$$

Minimal valid deviation will be:

$$\overline{y}_i - \overline{y}_k \geq R_q \qquad \dots (11)$$

Now the comparison between levels of averages which are systematized in groups can be done:

$$\bar{y}_{2+} - \bar{y}_{3+} = 61 - 55.80 = 5.20 > 2.852 = R_3 \text{, q=3-1+1=3}$$
$$\bar{y}_{2+} - \bar{y}_{1+} = 61 - 56 = 5.00 > 2.719 = R_2 \text{, q=3-2+1=2}$$
$$\bar{y}_{1+} - \bar{y}_{3+} = 56 - 55.80 = 0.20 < 2.719 = R_2 \text{, q=2-1+1=2}$$

3. DISCUTION/ CONCLUSIONS

Due to the plastic deformation, in cold, which is exercised upon the laminated tin, in warm, during the pipe formation and calibration it came to the strain hardening of steel's quality J55 API 5CT as a consequence of dislocations forming and blockage.

Hypothesis H_0 of effects equation: $a_1=a_2=a_3=...=a_1 \cdot \mu=0$ doesn't exist, while alternative hypothesis H_1 exist at least for one effect $a_i \neq 0$.

As the experimental calculated values of tensile strength *(Rm)* of $F_c > F_t$, with importance level α = 0.05 is accepted, effects (a_i*=1, 2, 3)* are not zero.

Since the effects' difference for of levels "*i*" and "*k*" of factor's level $\bar{a}_i$ and $\bar{a}_k$ is more larger than minimal valid difference $\Delta_{ik}(\alpha)$ for importance level α = 0.05, we have: $|\bar{a}_i - \bar{a}_k| \geq \Delta_{ik}(\alpha)$, therefore it is accepted that levels "*i*" and "*k*" have important differences based on their impact in the experimental results.

While effects' difference of two pairs (2, 3) and (2, 1), with exception of pair (1, 3), of averages of arithmetical values watched in *p* levels probations "*i*" and "*k*" are larger than minimal valid deviations R_q, so: $\bar{y}_i - \bar{y}_k > R_q$. Therefore, from this analysis we can conclude how important are the differences of level's of the two pairs during the research of tensile strength *(Rm)*. Results are done in "Laboratori mekaniko-metalografik IMK", Ferizaj- Kosova.

4. REFERENCES

[1] Standard, API Specification 5CT, Washington 2000.

[2] V. Kedhi, *Metoda të planifikimit dhe të analizës së eksperimenteve,* (Methods of planning and analysis of experiments) Politeknik Faculty, Tiranë 1984.

[3] Standard, ASTM-A370, Washington 2000.

[4] Douglas C. Mongomery, *Controllo statistico di qualità, Parte III:* (Statistical controll of quality), McGraw-Hill, 2000.

[5] I. Pantelic, Uvod u teoriju inzinjerskog eksperimenta, Radnicki Universitet Novi Sad 1976.