CONTRIBUTIONS TO THE QUALITY STUDY OF THE PARTS MADE OF MALLEABLE IRON (Fgn 700-2), 52-54 HRC HARDENED, USED FOR MANUFACTURING CRANKSHAFTS

Ilarion BANU, Viorel NICOLAE
University of Pitesti, Romania

Abstract: The paper presents the analyze of quality degradation of the parts thermal treated by hardening, processed by turning in treated state. Facing the crankshafts even in the treated state, without grinding, was the objective of the analyze. The analyze was done based on the theory of loss quality of the processed surface, used by prof. Taguchi [1].

Keywords: quality, malleable iron, crankshaft, Taguchi loss function.

THE DECISION CRITERIA FOR CHOOSING THE OPTIMUM TECHNOLOGICAL PARAMETERS

The decision criteria choose was "the loss quality of the processed surfaces" [1]. This criteria consists in minimizing the roughness R_{zISO}, by the following Taguchi relation:

$$\frac{S}{Z} = -10\log(s_{Rz}^2 + \overline{R}_z^{\,2}),[dB] \quad (1)$$

with:

S - signal
Z - noise
$\overline{R}_z$ – arithmetical average of the measured values;
s_{Rz} – standard deviation of the measured values.

SETTING THE VALUES OF THE FACTORS VARIATION INTERVALS AND OF THEIR CODES

They are presented in Table 1.

Table 1. The values of the factors variation intervals.

		Levels	
Independent variables (explicative)	Code	-1	+1
Natural factors			
Cutting depth, mm	*t*	0,5	1
Longitudinal feed, mm/rot	*s*	0,06	1,2
Main shaft speed, rot/min	*n*	1200	1500
Knife's nose radius, mm	*r*	0,5	3

DETERMINATION OF TESTING LEVELS

In the experiments plan, the {T, N, S, R} values (see Table 2) are the codes of the {t, s, n, r} values that are not take into consideration the measure units and they are calculated with the relations:

$$T = \left[\frac{2\cdot t_i - (t_{\max} + t_{\min})}{2}\right] / \left[\frac{t_{\max} - t_{\min}}{2}\right] \quad (2)$$

- If $t_i = 0{,}5$; $t_{max} = 1$; $t_{min} = 0{,}5$ => $T = \left[\frac{2\cdot 0{,}5 - (1+0{,}5)}{2}\right] / \left[\frac{1-0{,}5}{2}\right] = -1$

➢ If t_i = 1,0; t_{max} = 1; t_{min} = 0,5 => $T = \left[\frac{2 \cdot 1 - (1 + 0{,}5)}{2}\right] / \left[\frac{1 - 0{,}5}{2}\right] = +1$

$$S = \left[\frac{2 \cdot s_i - (s_{\max} + s_{\min})}{2}\right] / \left[\frac{s_{\max} - s_{\min}}{2}\right] \qquad (3)$$

➢ If s_i = 0,06; s_{max} = 1,2; s_{min} = 0,06 => $S = \left[\frac{2 \cdot 0{,}06 - (1{,}2 + 0{,}06)}{2}\right] / \left[\frac{1{,}2 - 0{,}06}{2}\right] = -1$

➢ If s_i = 1,2; s_{max} = 1,2; s_{min} = 0,06 => $S = \left[\frac{2 \cdot 1{,}2 - (1{,}2 + 0{,}06)}{2}\right] / \left[\frac{1{,}2 - 0{,}06}{2}\right] = +1$

$$N = \left[\frac{2 \cdot n_i - (n_{\max} + n_{\min})}{2}\right] / \left[\frac{n_{\max} - n_{\min}}{2}\right] \qquad (4)$$

➢ If n_i = 1200; n_{max} = 1500; n_{min} = 1200 =>

$$N = \left[\frac{2 \cdot 1200 - (1500 + 1200}{2}\right] / \left[\frac{1500 - 1200}{2}\right] = -1$$

➢ If n_i = 1500; n_{max} = 1500; n_{min} = 1200 =>

$$N = \left[\frac{2 \cdot 1500 - (1500 + 1200}{2}\right] / \left[\frac{1500 - 1200}{2}\right] = +1$$

$$R = \left[\frac{2 \cdot r_i - (r_{\max} + r_{\min})}{2}\right] / \left[\frac{r_{\max} - r_{\min}}{2}\right] \qquad (5)$$

➢ If r_i = 0,5; r_{max} = 3; r_{min} = 0,5 => $R = \left[\frac{2 \cdot 0{,}5 - (3 + 0{,}5)}{2}\right] / \left[\frac{3 - 0{,}5}{2}\right] = -1$

➢ If r_i = 3; r_{max} = 3; r_{min} = 0,5 => $R = \left[\frac{2 \cdot 3 - (3 + 0{,}5}{2}\right] / \left[\frac{3 - 0{,}5}{2}\right] = +1$

THE FRACTIONAL EXPERIMENTS PLAN (EQUIVALENT WITH A TAGUCHI PLAN L_8)

Table 2. The experiments plan completed with the measurement results.

Exp	T	S	N	R	TS	TN	SN	R_z	R_{z2}	R_{z3}	R_{z4}	R_{z5}	Mean $(\overline{R}_z)_i$	STD s^2_{RzISO}	$(S/Z)_i$
1	-1	-1	-1	-1	1	1	1	1.96	1.89	2.04	1.87	1.85	*1.922*	0.07791	-5.6822
2	1	-1	-1	1	-1	-1	1	5.25	5.68	3.65	2.77	3.14	*4.098*	1.295365	-12.665
3	-1	1	-1	1	-1	1	-1	5.74	6.61	7.64	6.64	5.17	*6.36*	0.946018	-16.1642
4	1	1	-1	-1	1	-1	-1	4.61	4.41	4.99	4.89	4.66	*4.712*	0.230911	-13.4745
5	-1	-1	1	1	1	-1	-1	7.78	6.75	6.85	6.17	6.71	*6.852*	0.582426	-16.7476
6	1	-1	1	-1	-1	1	-1	3.62	4.72	3.99	3.48	3.71	*3.904*	0.492778	-11.8988
7	-1	1	1	-1	-1	-1	1	5.04	5.72	4.82	5.31	4.53	*5.084*	0.456651	-7.3158
8	1	1	1	1	1	1	1	7.58	7.7	7.71	7.63	7.69	*7.662*	0.055408	-17.6871
General mean: $M = \frac{\sum_1^8 (\overline{R}_{zISO})_i}{8}$; Average ratio $(\frac{S}{Z})_{med} = \frac{\sum_1^8 (S/Z)_i}{8}$													M = 5.07425		S/Z_{med}= *-12.7044*

The experiments plan is presented in Table 2, together with the measured values for 5 repeats, arithmetical mean of the repeats, general arithmetical mean, standard deviations *s* and the Signal/Noise ratio (S/Z).

PROCESSING THE RESULTS

For the effective values:

- **The average response** for every level of the factor corresponds to the average results of all tests in which the factor is at that level:

$$\overline{T}_{-1} = \frac{1{,}922 + 6.36 + 6{,}852 + 5{,}084}{4} = 5{,}0545 \quad (6)$$

$$\overline{T}_{+1} = \frac{4{,}098 + 4{,}712 + 3{,}904 + 7{,}662}{4} = 5{,}094 \quad (7)$$

The values of the other factors are to be calculated in the same way.

- **The general mean M** of the tests assembly corresponds to the central point of the average responses for the levels of every factor:

$$\frac{\overline{T}_{-} + \overline{T}_{+}}{2} = \frac{1{,}554 + 1{,}8235}{2} = 1{,}68875 = M \quad (8)$$

The same calculation model is applied to S, N, R factors.

- **The effects of the factors** coded with{T, S, N, R} are calculated with [1], so:

$$E(t-) = \overline{T}_{-} - M \;= 5{,}0545 - 5.07425 = -0{,}01975 \text{ (see Table 3)} \quad (9)$$

$$E(t+) = \overline{T}_{+} - M \;= 5{,}094 - 5{,}07425 = 0{,}01975 \text{ (see Table 3)} \quad (10)$$

For the Signal/Noise ratio, the average response, general mean M and factors effects are calculated in the same way. Their values are presented in Table 3; they were obtained with a program realized on Excel software.

Table 3. The values of the factors effects.

Positions in the experiments	*Effect on the measured value:*		
	Factors	S/Z for the R_a measured value	of the R_a measured value
1_3_5_7	*E(t-)=*	*1.226961*	*-0.01975*
2_4_6_8	*E(t+)=*	*-1.22696*	*0.01975*
1_2_5_6	*E(s-)=*	*0.955985*	*-0.88025*
3_4_7_8	*E(s+)=*	*-0.95598*	*0.88025*
1_2_3_4	*E(n-)=*	*0.707923*	*-0.80125*
5_6_7_8	*E(n+)=*	*-0.70792*	*0.80125*
1_4_7_8	*E(r-)=*	*1.664511*	*-0.22925*
2_3_5_6	*E(r+)=*	*-1.66451*	*0.22925*

Calculation of the interactions between the control factors [1], [3]:

The interactions chosen for this study are for the products: TS→ I(t,s) ; TN → I(t,n); SN → I(s,n).

The calculation relations for the considered interactions start from the interactions effects, e.g. for the E(t,s) effect :

$$E(t-, s-) = E(t-) + E(s-) + I(t-, s-) \quad (11)$$

Reported to the general mean M, will be:

$$E(t-, s-) = T\_S\_ - M \;= (T\_ - M) + (S\_ - M) + I(t-, s-) \quad (12)$$

$$E(t+, s-) = T_{+}S\_ - M \;= (T_{+} - M) + (S\_ - M) + I(t+, s-) \quad (13)$$

$$E(t-, s+) = T\_S_{+} - M \;= (T\_ - M) + (S_{+} - M) + I(t-, s+) \quad (14)$$

$$E(t+, s+) = T_{+}S_{+} - M \;= (T_{+} - M) + (S_{+} - M) + I(t+, s+) \quad (15)$$

So, for example, there could be extracted the interactions:

$$\begin{aligned} I(t-, s-) &= T\_S\_ - M - (T\_ - M) - (S\_ - M); \\ I(t-, s-) &= T\_S\_ - M - E(t-) - E(s-). \end{aligned} \quad (16)$$

For the study of the interactions we used a program realized on Excel software, and the data for the interactions of the S/Z ratio and of the real measured values are presented in Table 4.

Table 4. The values of the interactions of the factors.

Positions in the experiments	*Effect on the measured value:*		
	Interactions	Interactions S/Z	Interactions of the measured values
1_5	*I(t-,s-)=*	*-0.693442607*	*0.21275*
2_6	*I(t+,s-)=*	*0.693442607*	*-0.21275*
3_7	*I(t-s+)=*	*0.693442607*	*-0.21275*
4_8	*I(t+,s+)=*	*-0.693442607*	*0.21275*
1_3	*I(t-,n-)=*	*-0.153665579*	*-0.11225*
2_4	*I(t+,n-)=*	*0.153665579*	*0.11225*
5_7	*I(t-,n+)=*	*0.153665579*	*0.11225*
6_8	*I(t+n+)=*	*-0.153665579*	*-0.11225*
1_2	*I(s-,n-)=*	*1.866882399*	*-0.38275*
3_4	*I(s+,n-)=*	*-1.866882399*	*0.38275*
5_6	*I(s-,n+)=*	*-1.866882399*	*0.38275*
7_8	*I(s+,n+)=*	*1.866882399*	*-0.38275*

THE ANALYZE OF THE INFORMATION OFFERED BY THE (S/Z) GRAPHS AND THE MEASURED VALUES

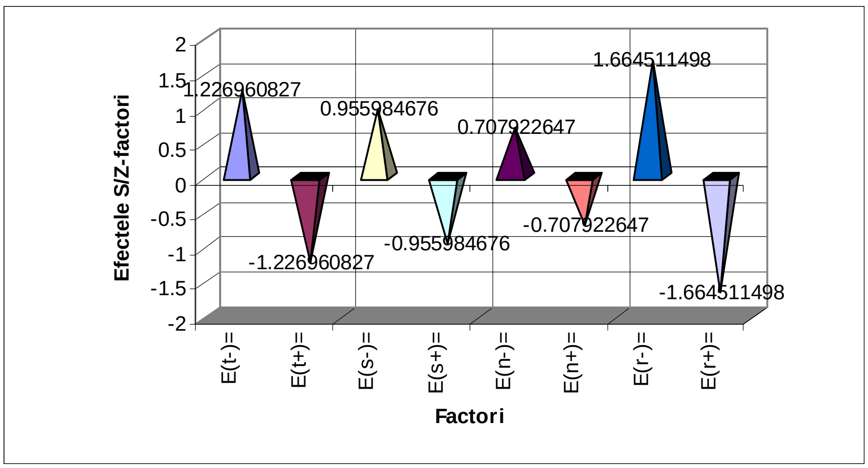

Fig.1 Effects of the technological adjusted parameters (t, s, n, r) on the Signal/Noise ratio for the R_{zISO} roughness of the processed surfaces.

The analyze of the Signal/Noise ratio

From Figure 1 and Table 3 it is obvious that:

- The Signal/Noise effect has a bigger dispersion for the cutting depth *t*, that could be considered at its maximum value (see Table 1);
- The ***s*** feed doesn't determine noises (vibrations), so it could be chosen at the maximum value (1,2 mm/rot);
- The *n* speed has a small influence on the S/Z ratio and on the R_{zIS} quality index, so it could be chosen the maximum speed to increase the S/Z ratio (n=1500 rot/min);
- The knife's nose radius r_ε has an important influence on the quality of the surfaces processed by turning, so the optimum radius will be between the maximum value and the average of the variation interval [2,5 3].

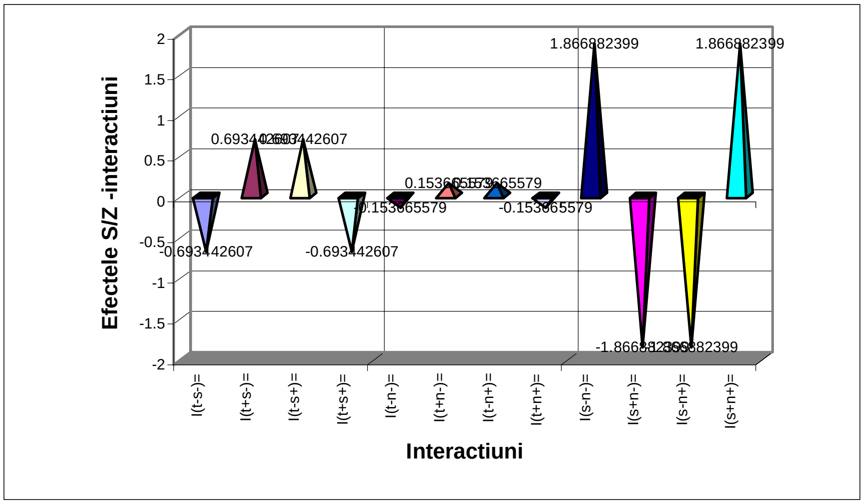

Fig.2. Effects of the interaction of the technological adjusted parameters (t, s, n, r) on the Signal/Noise ratio for the R_{zISO} roughness of the processed surfaces.

The analyze of the interactions between {t, s, n, r_ε} factors (see Table 4 and Figure 2) emphasizes that:

- There is an important interaction between the speed and the tool feed *I(s,n)*, so the recommendation is that these two parameters must be chosen around the average value;
- The *I(t,n)* interactions have a little influence on *I(t,s)*, but could have a negative influence on the cutting process so the quality of the processed surfaces could be affected;
- The *t* speed and *s* feed influence the quality of the processed surfaces.

THE ANALYZE OF THE MEASURED VALUES ON THE R_{ZISO} (CLASSICAL METHOD)

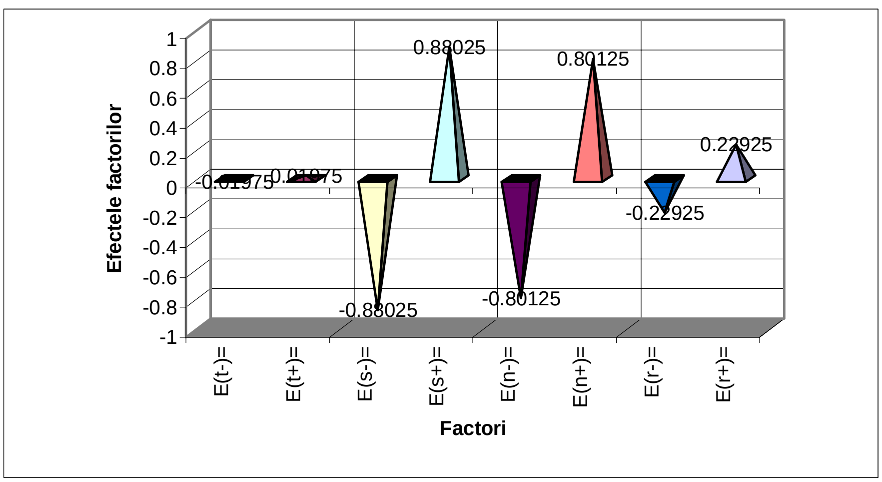

Fig.3. Effects of the technological adjusted parameters (t, s, n, r) on the Signal/Noise ratio for the R_{zISO} roughness of the processed surfaces.

- The effect of the cutting depth in this situation emphasizes that it has no great influence on the quality of the processed surfaces, but the analyze of the S/Z ratio shows the contrary, so the adjusted value could be chosen around the average 5,07 with {-0,13; 0,13};
- The feed has an important effect on the quality, even the S/Z is relatively small, so the value of the *s* feed could be chosen 0,06 mm/rot.;
- The *n* speed (or the cutting speed *v*) made a small noise and could be chosen around the maximum value (1500 rot/min);
- The knife's nose radius has no great values upon the classical method but produces noises, so it is necessary to choose a knife with a radius around the average value 1,5 mm.

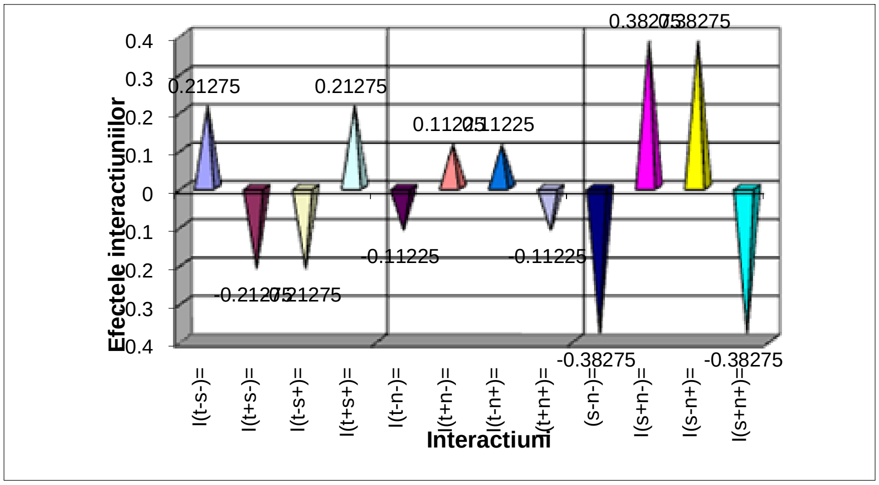

Fig.4. Effects of the interaction of the technological adjusted parameters (t, s, n, r) on the Signal/Noise ratio for the R_{zISO} roughness of the processed surfaces.

- The interactions between *s* and *n* are very important, so the cutting force influences very much the quality of the surfaces;
- The other interactions *{I(ts) and I(tn)}* have a small influence on the quality of the surfaces.

CONCLUSIONS

The conclusions of the study of the influence of some technological parameters {t, s, n, r_ε} on the cutting processing of the Fgn 700-2 iron using ceramic plates are:

- The r_ε nose radius has the great influence on the quality index R_{zISO}, so we have to choose attentively this parameter (the average value of the interval);
- The *s* feed does not produce great noise, so it could be choose to the maximum value;
- The *n* speed does not influence the quality of the surfaces, so it could be chosen at the maximum value;
- The knife's nose radius produces noises in the process, so it should be chosen to the average value.

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