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SIMULTANEOUS OPTIMIZATION OF THREE FACTORS RELATING TO QUALITY USING TAGUCHI EXPERIENCES PLANS

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Abstract: *For optimizing certain tehnological factors, characteristics, for a producs or a proces, there are several tehniques available, some of them take account of the factors that might produce errors, imbalances and other tehniques will not. For a product or process that is kept well under control, the external factors that are capable of generating errors are removed, asuring a better stability and control. In the case of dispersion or instability of a product while it is constructed or used, the methods most often used try to diminish or eliminate the errors that are taken into account. The Taguchi strategy, will try to minimize the impact of the parasitic effects (also called noise factors), rather than elimination them, by combining the defined levels set at the beginning for the measured factors. The factors chosen in a test, depends on the criteria which are to be implemented and will be chosen by specialists in the certain field, experts that know the process.*

Key words: *optimized, factors, experiments, quality criteria, robustness.*

1. INTRODUCTION

Taguchi's approach to enhance quality in the design phase involves two steps:

1. Optimizing the design of the product/process (system approach).
2. Making the design insensitive to the influence of uncontrollable factors (robustness)

The objective of the experiment is the optimization of the diameter, roughness and cylinder deviation in the case of a simple, cylinder-shaped part, after outline milling, with the Taguchi approach.

The method was tested for a small series production. Batches of 50 parts were processed and 10 of each being randomly chosen for the purpose of measurement. Four tests have been carried out on each group of 10 parts.

The semi-finished part, used during the experiment, has initially a diameter of 19,5mm. After milling with a TRIAC VMC machining centre, its diameter should reach 17,9±0,05mm.

2. DESCRIPTION OF THE EXPERIMENT

Out of all the factors contributing to the process, three have been selected: the milling machine, the tool feed and the tool speed. Each of them have been tested at two different levels: the real value and the estimated one, technically acceptable for these conditions, table 1. Unfortunately the experiment suffered from some technical and technological constraints.

Table 1

The three factors of experiment and accepted levels

Tested factors		Level 1	Level 2
A	The milling machine	Φ6 with 2 cutting edges	Φ10 with 4 cutting edges
B	The tool feed	40 [mm/min]	65 [mm/min]
C	The tool speed	1500 [rot/min]	1000 [rot/min]

The values measured were synthesized in tables. The standard deviation relative to the measurements in the case of each test was calculated. The standard deviation allows for

the dispersion of these measurements related to their average value.

Standard deviation is given by the formula:

$$s^2 := \sum_{i=1}^{n} \frac{(y_i - y_m)}{n-1} \qquad [1]$$

Where:

- y_i –the values measured in $y_1, y_2, \ldots\ldots y_n$
- y_m – the average of the values measured in $y_1, y_2, \ldots\ldots y_n$
- n – the number of values measured $y_1, y_2, \ldots\ldots y_n$

The criteria concerning quality are: 1) the diameter obtained – which is a target criterion; 2) roughness – a criterion to be minimized and 3) the cylinder deviation – which must also be reduced to the minimum.

In those two cases, the Signal/Noise ratio (S/N) is calculated with:

$$SN := 10 \cdot \left(\log\left(\frac{y_m}{s} \right)^2 - \frac{1}{n} \right) \qquad [2]$$

[dB] – for the target criterion

$$SN := -10 \cdot \log\left[s^2 - (y_m)^2 \right] \qquad [3]$$

[dB]- for the criterion to be minimized

Where:

y_m - the average of the measured values;

s - the standard deviation of the measured values;

n - the number of measures taken.

During an experiment, it is often interesting to consider a lot of criteria about the quality. It is obviously, that the choice of test factors depends on the quality criteria which must be optimized. For every test of an experience plan is made:

- The measurement of the results relatively of the different characteristics which must be optimized;
- The calculation for the Signal/Noise rapport.

Than it is established, for every characteristic the table with the associate answers and graphics. For the optimization using the different quality criteria, first must find the higher algebraic value of Signal/Noise for every test factors. The difficulties issue at the moment is establishing the best possible compromise for equilibration of the battering made at the quality criteria ensemble.

For arbitration with all the desired objectivity, necessary to express the effects Signal/Noise in a manner, this made the comparison much easier.

3. PROCENTUAL CONTRIBUTION CALCULUS OF RATIO SIGNAL/NOISE.

%Contribution S/N Ai=EBI/T*100 [4]

Ai-factor at level 1 or 2;
EBI- the effect S/N for one factor at level 1 or 2
T-the general average for response S/N;

Table 2

a) For Diameter

%Contribution S/N		No. Factors	The effect upon the measured value	
Level 1	Level 2		Level 1	Level 2
-8.116%	8.116%	A	0,168	-0,168
6.165%	-6.165%	B	-0,063	0,063
7.013%	-7.013%	C	0,033	-0,033

Table 3

b) For Roughness

%Contribution S/N		No. Factors	The effect upon the measured value	
Level 1	Level 2		Level 1	Level 2
7.29%	-7.298%	A	0,246	-0,246
-12.80%	12.804%	B	-0,1	0,1
-29.111%	29.111%	C	0,044	-0,044

Table 4

c) Cylinder deviation

%Contribution S/N		**No. Factors**	**The effect upon the measured value**	
Level 1	**Level 2**		**Level 1**	**Level 2**
4.661%	**-4.661%**	**A**	**0,246**	**-0,246**
-7.486%	**7.486%**	**B**	**-0,1**	**0,1**
-0.162%	**0.162%**	**C**	**0,044**	**-0,044**

For every factor, the level which gives the percentage sum of the S/N contribution is chosen much higher, for a 3 characteristics ensemble.

Table 5

The level which give the percentage sum of the S/N contribution

No.	Factors describe	Level	The characteristics necessary to be optimized		
			a)Diam	b)Rough	c)Cyl dev.
A	The milling machine	Optimum level	2	1	1
		Contrib.	8.116%	7.298%	4.661%
B	The tool feed	Optimum level	1	2	2
		Contrib.	6.165%	12.804%	7.486%
C	The tool speed	Optimum level	1	2	2
		Contrib.	7.013%	29.111%	0.126%

For every factor, the level which give the percentage sum of the S/N contribution is chosen much higer:

A1: -8.116+7.298+4.661=3.798
A2: 8.116-7.298-4.661=-3.798
B1: 6.165-12.804-7.486=-14.125
B2: -6.165+12.804+7.486=14.125
C1: 7,013-29.111-0.162=-22.259
C2: -7,013+29.111+0.162=22.259

The theoretical ratio Signal/Noise, derived in the characteristic optimization, is given by the following expression:

$$\mu = T + [\text{\% contribution sum: A1, B1}\ldots..]*[T]/100 \ [\text{dB}] \quad [5]$$

Table 6

After calculations, the results do not meet

No.	Factors describe	Level	The characteristics necessary to be optimized		
			Diam.	Rough.	Cyl. Dev.
A	The milling machine	1	-8.116%	7.298%	4.661%
B	The tool feed	2	-6.165%	12.804 %	7.486%
C	The tool speed	2	-7.013%	29.111 %	0.126%
Theoretic S/N rapport result, [dB]			43.521	-4.363	-43.398
The average rapport S/N			54.953	-8.591	-49.49

The first sorting is not satisfactory. This sorting favorites roughness and the deviation from cylindricity characteristics.

We need to establish which the factors whose levels we can change are, in order to favors the diameter over the roughness and over the deviation from cylindricity without deteriorating them.

Table 7

After a few iterations the following configuration:

No.	Factors describe	Level	The characteristics necessary to be optimized		
			Diam.	Rough.	Cyl. Dev.
A	The milling machine	2	-8.116%	7.298%	4.661%
B	The tool feed	2	6.165%	12.804%	7.486%
C	The tool speed	2	7.013%	29.111%	0.126%
Theoretic S/N rapport result, [dB]			52.685	-5.617	-48.01
The average rapport S/N			54.953	-8.591	-49.49

It is found that:

• Signal/Noise Ratio relative to the ideal value is approaching;
• Surface roughness must improve;
• The deviation of the cylindricity should decrease.

4. VALIDATION OF THE RESULTS

At the end of the operating activity of the results of an experiment, we have defined for each of the factors, tried optimum levels that turns out favorably compared to one or more of the quality criteria which need to be improved. You then make the assumption that, if all the factors will be set at optimum levels, their individual effects will gather. Starting from this principle, calculating they expected theoretical results. Validation test aims to check the result or outcome of getting physically all factors.

Validation experience which was carried out to confirm these results.

5. CONCLUSIONS

The following conclusions have been reached by analyzing the Signal/Noise ratio results for each of the quality criteria:

In the case of the diameter, the most influential factor is (A) that is “the milling machine” type as the Signal/Noise ratio is maximum when A is at level 2. In the case of the factor “the tool feed” (B), the Signal/Noise ratio is maximum when B, is at level 1; for “the tool speed” (C) —when it is at level 1.

Finally, in the case of the diameter, the configuration: A_2, B_1, C_1 (Φ10 with 4 cutting edges, 40[mm/min], 1500[rot/min]) is obtained.

The configuration for roughness is: A_1, B_2, C_2.(Φ6 with 2 cutting edges, 65[mm/min], 1000[rot/min])

The configuration for cylinder deviation is: A_1, B_2, C_2.(Φ6 with 2 cutting edges, 65[mm/min], 1000[rot/min]).

In the case of simultaneously optimization of the three factors: diameter, roughness and deviation of cylindricity it was find out that:

- S/N relative report is closer than the ideal value;
- The roughness must be better;
- The cylinder deviation must (diminish) decrease.

The results obtained with this method have been experimentally verified and this showed that the quality of the cutting process working is much improved.

The results have been compared with similar data from "Metal Processing". The conclusion is that using the Taguchi method the results reached are as good as other, conventionally obtained results. The approach is different from the usual. The authors intend to apply the methods in tests and experiments related to more complex processes, where the number of factors is much higher and where much more challenging results are expected.

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OPTIMIZAREA SIMULTANA A TREI FACORI LEGATI DE CALITATE, FOLOSIND PLANURILE DE EXPERIENTE TAGUCHI

Abstract: Pentru a optimiza unii factori tehnologici in functie de calitate/pret pentru un produs sau proces, se pot folosi diferite tehnici, care nu iau in considerare factorii care pot produce erori, dar incearca sa elimine factorii externi ce ar putea perturba procesul, asigurand o stabilitate, un control cat mai bun. In cazul dispersiei sau instabilitatii unui produs in timpul fabricatiei sau a utilizarii, metoda folosita cel mai des nu ia in calcul diminuarea sau eliminarea efectelor parazite. Strategia Taguchi, in loc sa elimine efectele parazite (numite surse de zgomot), incearca sa minimizeze impactul lor. In timpul unui experiment, de multe ori se intampla sa se achizitioneze criterii legate de calitate. Este evident faptul ca alegerea factorilor urmariti intr-un test, depinde de criteriile care vor sa fie optimizate.

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