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REDUCTION OF SURFACE ROUGHNESS BY TAGUCHI DESIGN: AN APPROACH FOR MILLING PARAMETERS

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Abstract: *The quality performance of a machined product is measured by its geometric dimensioning and tolerancing as well as its surface roughness. The surface roughness should be as smooth as possible for the same price. This geometrical property depends on the combination of the machining parameters. The most important parameters are: feed rate, spindle speed, cutting axial and radial depths.*

However, it is very difficult to define the optimal combination that will provide the smoother surface at lower prices [1]. One of the most important features in the manufacturing industry is to predict the surface roughness and tool life for a particular combination of machining parameters in order to choose the best combination for producing a part [2, 3]. Furthermore, it is always essential to reduce the costs for the quality required.

This work presents a study of a Taguchi design application to optimize surface quality in a CNC milling operation. A L9 orthogonal array was implemented and the ANOVA analysis were carried out to identify the significant factors affecting surface roughness as well as the determination of optimal cutting combination by seeking the best surface roughness (response) and signal-to-noise ratio.

In this study a cylindrical hardened steel (GMTC 1.2738) specimen was machined using a milling tool provided by Palbit® (reference PLUS 49095/WNHU 04T310). The experimental work was done in a Deckel Maho DMC 63V milling machine and the cutting parameters were combined agreeing to the defined Taguchi orthogonal array (table 2). The axial depth parameter was maintained fixed at 0.3 mm. The roughness was measure on three different points of specimen between each experiment using a portable surface roughness tester (Mitutoyo SJ-301).

Table 1 presents the Taguchi orthogonal array, the average of the measured roughness and the signal to noise ratio which, is this case, was chosen the “smaller is the better” [4] in order to minimize the surface roughness. This signal to noise ratio is defined by the equation 1.

$$S/N_s = -10 * \log\left(\frac{1}{n}\sum_{i=1}^{n} y_i^2\right) \qquad (1)$$

where n is the number of observations and y_i is the observed data.

The roughness, as an arithmetic average of the absolute roughness values (R_a) of three measurements, and S/N is signal to noise ratio value are depicted in Table 1 for different cutting speed V_c, feeding rate f_z and radial cutting depth a_e. The three levels of the machining parameters selected for this study are shown in table 1.

Table1

Cutting parameters and their levels

Symbol	Machining parameters	Level 1	Level 2	Level 3
A	V_c: Cutting speed [m/min]	150	180	200
B	f_z: Feed rate [mm/tooth]	0.10	0.150	0.200
C	a_e: Radial depth of cut [mm]	0.075	0.100	0.125

The cutting parameters combination of experiment 5 yields the lower roughness and signal to noise ratio value, table 2.

Table 2

Taguchi orthogonal array, S/N and average roughness values. V_c is the cutting speed, f_z is the feed rate and a_e is the radial depth of cut

Experiment	V_c [m/min]	f_z [mm/tooth]	a_e [mm]	Roughness [µm]	S/N [dB]
1	1	1	1	2,44	-7,776
2	1	2	2	2,39	-7,567
3	1	3	3	2,60	-8,286
4	2	1	2	2,19	-6,834
5	2	2	3	1,94	-5,751
6	2	3	1	2,18	-6,757
7	3	1	3	2,05	-6,217
8	3	2	1	2,28	-7,168
9	3	3	2	2,03	-6,172

The mean S/N ratio for each cutting parameter at levels 1, 2 and 3 can be computed by averaging the S/N ratios for correspondent experiments. The mean S/N ratio for each level of machining parameters is shown in Figure 1, common defined as the mean S/N ratio response for R_a. To clarify the analysis a constant value of 10 was added. One gets a high S/N ratio for smaller variance of surface roughness around the desired value. Nevertheless, the relative importance among the milling parameters for the surface roughness still required to be identified so optimal combinations of the milling parameter levels can be determine more accurately using the ANOVA analysis.

Figure 1 shows the average values of the S/N for the different parameters levels. The lowest S/N is obtained at a cutting speed of 180 m/min reducing the S/N by 40% from 150 m/min. Also, against 150 m/min, the 200 m/min of cutting speed provided lower reduction, 2%. It is also observable in figure 1 that a better machining performance is achieved for larger radial depths cuts than lower ones: showing improvements on S/N of 12% and 15% from 0,075 to 0,100 mm and of from 0,075 to 0,125 mm respectively. The feed rate S/N response, as it may be verified in figure 1, show an almost uniform and independent behavior, varying less than 4%. The combination that minimized the roughness was: cutting speed of 180 mm/min, feeding rate of 0,15 mm/t and a radial depth of cut of 0,125 mm.

The ANOVA analysis allows the determination of most influent parameter in the surface roughness. The results are depicted in table 3.

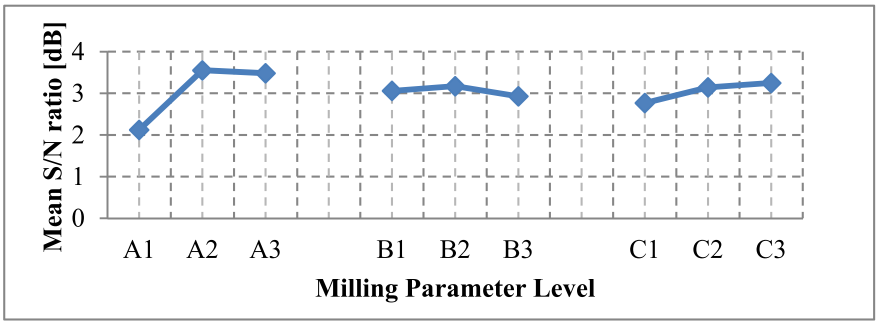

Fig. 1. Mean S/N ratio for R_a

Table 3

ANOVA analysis

Source	**Sum of Squares**	**df**	**Mean Squares**	**F-Ratio**	**P-value**
Main Effects					
V_c	0,266867	2	0,133433	3,52	0,2212
f_z	0,00686667	2	0,00343333	0,09	0,9169
a_e	0,0200667	2	0,0100333	0,26	0,7907
Residual	0,0758	2	0,0379		
Total	0,3696	8			

Evaluating the ANOVA analysis, it is possible to observe that the most important factor is the cutting speed (Vc) with a P-value=0,22 and the feed rate (fz) has the lower effect in the value of roughness, confirming the precious analysis made regarding the S/N evolution of these 3 parameters. However, and due to the low number of degrees of freedom, caution must be taken with the results. Nonetheless, for industrial applications this methodology provides a reasonable and quick approach for obtaining the smoother surfaces in milling processes without augmenting the economic costs.

References

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