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ROBUST OPTIMIZATION OF THE PERPENDICULARITY DEVIATION FOR THE DEEP HOLE DRILLING PROCESS ON FLEXIBLE MANUFACTURING SYSTEMS

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Abstract. The present paper presents a part of a research project, developed in a plant of a multinational supplier from the automotive industry. The need to do those researches was born from the fact that a relatively new type of material (a composite, polypropylene material) was machined on a high speed flexible manufacturing system. For this type of materials, in the technical literature, there are not recommendations for the cutting parameters. Using the Taguchi's Method, for this approach, was a very good idea because, spending the smallest amount possible of resources, there were obtained the desired results. So, in other words, the efficiency was the biggest possible. Practically, in the present industrial trends, that is the target – to obtain maximum efficiency, not only maximum efficacy.

Keywords: robust engineering, efficiency, machining, composite materials, design of experiments

1. Introduction

The demand of this research is a consequence of the fact that, for the polypropylene materials, in the technical literature, it doesn't exists very precise recommendations for the cutting parameters [1]. In consequence, for achieving the maximal efficiency requirements, it was applied the Taguchi Method [2, 3]. In this way, respecting the logical steps presented in the figure 1, were obtained the desired results.

This problem can be solved by implementing several types of design of experiments types and of data analysis methods. It was selected the Taguchi's Method because of his efficiency and of his power – the results obtained, spending less resources (money, time, materials, machine hours, labour, tools, etc.). Practically, this is the reason for that a lot of researches tries to implement the robust engineering with Taguchi's approach, on their works.

2. Research stages

2.1. The logical steps for the research activities

Practically, all the research activity respects the logical flow of the Taguchi's Method presented in figure 1. Here it is the presented application for the optimization of only one critical quality characteristic at a time.

In the figure 2 is presented the array containing all the results of the measurements (for the researched critical quality characteristic) realised on the generated surface.

For each one of the four trials, the cutting process was repeated 10 times, in the same conditions, resetting all the parameters after each drilled hole. For each trial, was calculated the average, the standard deviation and the S/N ratios for the 10 measured values.

The experimental array, presented in table 1, presents the values of the three cutting tested parameters.

Figure 3 presents the results obtained after computing experimental data measured. In this way, there were computed the average factor's effects, the average effects of the S/N ratios. After that, it was possible to choose the optimal factor's combination and to estimate the characteristics.

In the figures 5 and 6 are represented graphically the statistics computed and presented in figure 3: the average effects of the perpendicularity deviation and the average effects of the S/N ratios for the same quality characteristic.

The relation 1, used for minimising the measured critical quality characteristic, is used to compute the S/N ratio. This is the indicator that will help us to take the correct decision in the efficientisation process.

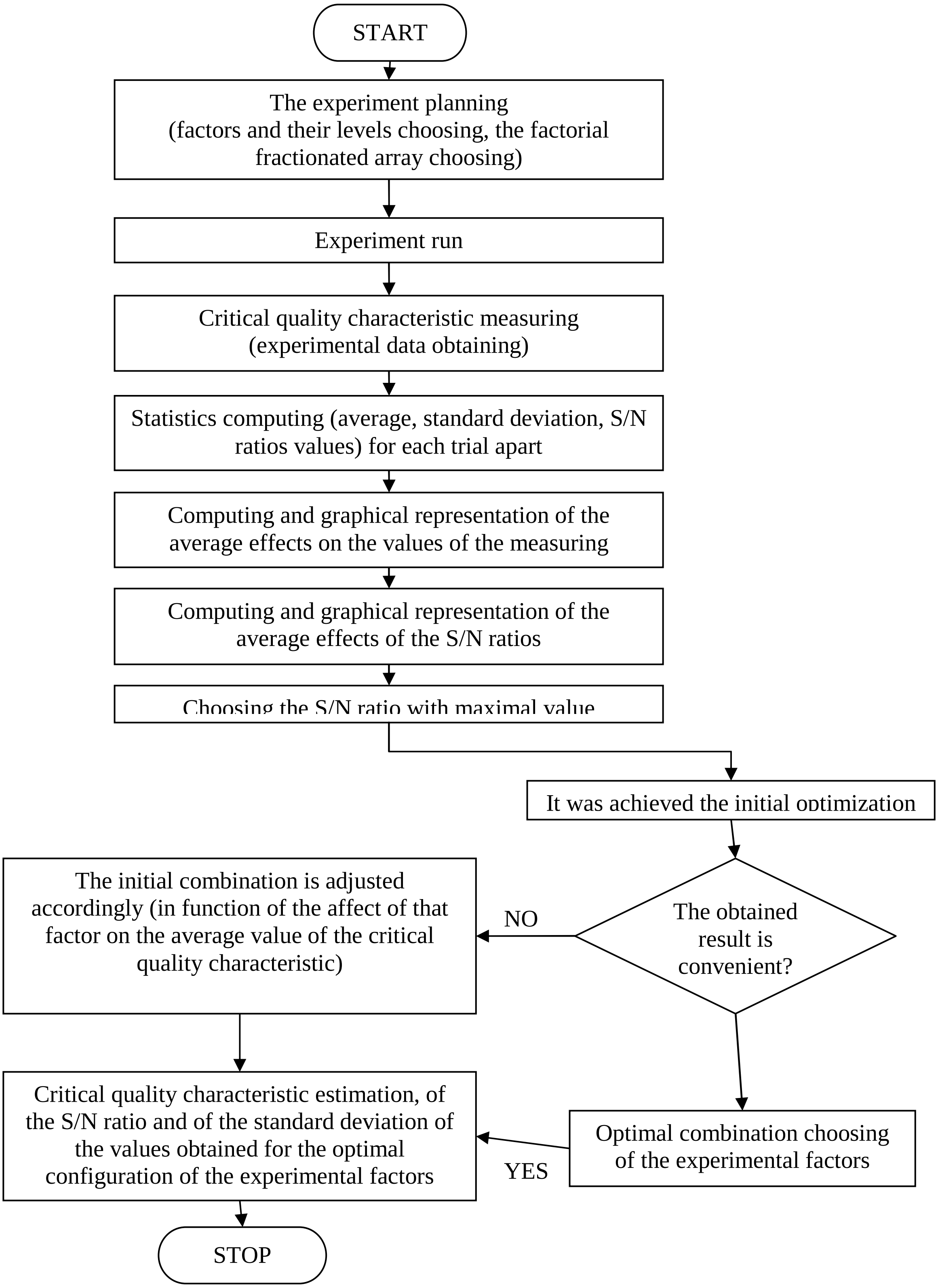


Figure 1. Logical flow of the Taguchi's Method application for the optimization of only one critical quality characteristic at a time

Perpendicularity deviation relative to the base face [µm]

															A	B	C
4	0,066	0,072	0,028	0,027	0,049	0,052	0,032	0,088	0,057	0,073	0,05440	0,02084	24,69307	Group 4	1	1	1
3	0,145	0,127	0,157	0,199	0,134	0,049	0,117	0,186	0,227	0,139	0,14800	0,04928	16,13814	Group 3	1	2	2
2	0,17	0,235	0,185	0,249	0,18	0,18	0,167	0,139	0,102	0,067	0,16740	0,05480	15,08279	Group 2	2	1	2
1	0,14	0,14	0,1	0,203	0,167	0,253	0,256	0,061	0,136	0,152	0,16080	0,06200	15,27232	Group 1	2	2	1
Origin	1	2	3	4	5	6	7	8	9	10	Average	Std. Dev.	S/N Ratio				

Figure 2. Experimental results obtained after running the all 4 trials of the experiment

1. Average factor's effects

A1ave=	0,10120			EA1=	-0,03145
A2ave=	0,16410	Aave=	0,13265	EA2=	0,03145
B1ave=	0,11090			EB1=	-0,02175
B2ave=	0,15440	Bave=	0,13265	EB2=	0,02175
C1ave=	0,10760			EC1=	-0,02505
C2ave=	0,15770	Cave=	0,13265	EC2=	0,02505

2. Average effects of the S/N ratios

A1ave=	20,41561			EA1=	2,61903	% SN A1=	14,716
A2ave=	15,17755	Aave=	17,79658	EA2=	-2,61903	% SN A2=	-14,72
B1ave=	19,88793			EB1=	2,09135	% SN B1=	11,751
B2ave=	15,70523	Bave=	17,79658	EB2=	-2,09135	% SN B2=	-11,75
C1ave=	19,98270			EC1=	2,18612	% SN C1=	12,284
C2ave=	15,61046	Cave=	17,79658	EC2=	-2,18612	% SN C=	-12,28

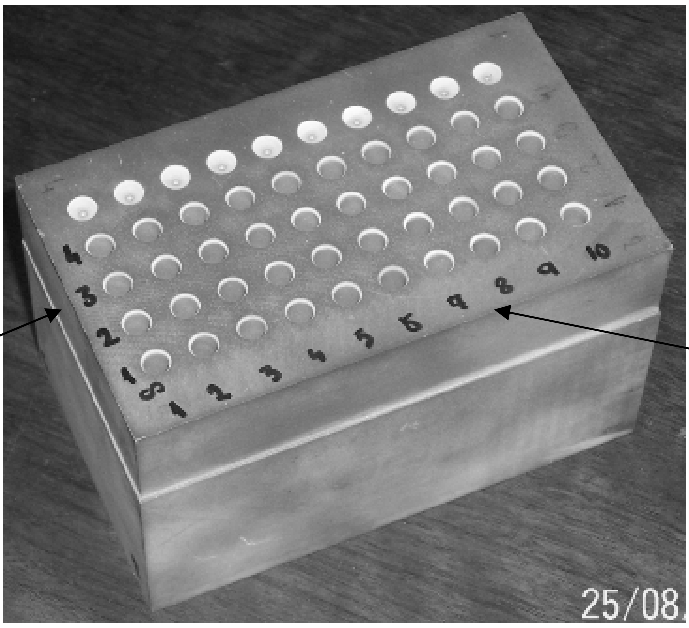
3. Factor's optimal combination choosing

Comb	A1 B1 C1
A1	4 withdraws
B1	n=2500 rot/min
C1	vs=160 mm/min

4. Characteristic's estimations

SN es=	24,69307	(S/N ratio estimated)
perp dev es=	0,05440	(perpendicularity deviation estimation)
std dev es=	0,02084	(standard deviation estimated)

Figure 3. The results obtained after computing experimental data for the perpendicularity deviation optimization case



Trial number (1 to 4)

Repetition number (1 to 10)

Figure 4. The drilled test part [5]

Table 1. Factorial fractionated experimental array, $L_4(2^3)$ – the values of the factors levels, for the deep hole drilling

Controlled factor / Trial no.	Number of withdraws	RPN [rot / min]	Feed [mm/min]
1	4	2500	160
2	4	2000	120
3	5	2500	120
4	5	2000	160

$$S/N = -10 \cdot \log\left(s^2 + \overline{y}^2\right) \text{ [db]} \qquad (1)$$

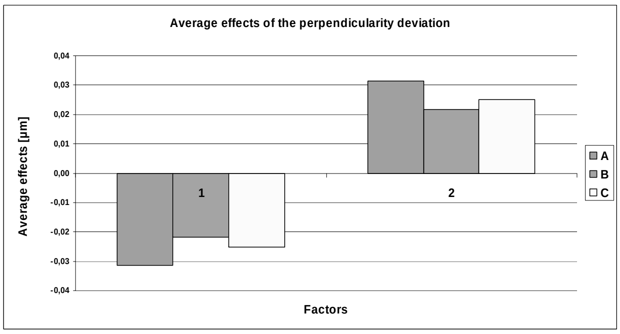


Figure 5. Graphical representation of the average effects of the perpendicularity deviation

From the figure 5 it can be observed that all the three parameters have approximatively the same influence on the perpendicularity deviation. The biggest influence is at the level of the first parameter, the number of withdraws, that must be 4, for an optimal cutting process. The second parameter as influence is the third one tested, the feed of the cutting tool. The last, with the smallest influence on the critical quality characteristic is the second tested parameter, the cutting speed (mentioned by his number of rotations per minute).

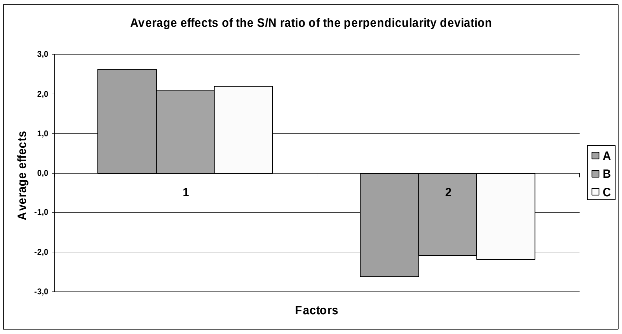


Figure 6. Graphical representation of the average effects of the S/N ratios for the perpendicularity deviation

The optimal combination of the three tested factors can be observed in the figure 6. Practically, to obtain an optimal perpendicularity deviation (minimal) all the three tested parameters must be set upped at their first level.

4. Conclusions

This article presents some results a research project, implemented at industrial level. This fact can prove the fact that it is a reliable one. Practically, the Taguchi Method can help a lot of industrial specialist to solve their problems; the power of this approach is that one that it brings some pure research tools, complicated or relatively complicated, on the industrial field. Only with some basic knowledge of statistics, but with a very big care spent during the research activities, the industrial specialists can bring solutions to important and difficult problems.

For the case presented in this article, for the proposed input data, there were founded some important information on the machining of a Necuron material.

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