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THE RESEARCH OF THE MAIN FACTORS, WHICH OCCUR IN THE DEEP-DRAWING PROCESS, ON THE SIZE ACCURACY OF PIECES

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ABSTRACT

This papers presents the extent to which different parameters of the drawing process influences (the friction coefficient μ, the radius of punch r_p, the drawing ratio m, the thin ratio m_y, the piece' s height h, the tensile strength R_m) both the thickness of a little cylindrical drawing piece and the optimizing ratio. The interest is turned to the variation thickness in the radius region wall-base, because here exists the danger of appearance of breaks. This study is made with the aid of Taguchi method using the quality of loss function, which supposes the establishing of a minimal level and a maximum level for the factors previously mentioned, the determination of experimentation matrix and the attainment of the degree of influence of each factor on the output values. Consequently, a little variation of the thickness of the piece in the longitudinal section, respectively a high optimizing ratio is checked for the maximum value of drawing ratio, the minimum value of the depth of the piece and the low value of the radius of the punch.

KEYWORDS: Taguchi method, deep-drawing, modelling, research area etc.

1. INTRODUCTION

The Taguchi method aid to go into influence of the principal factors of the drawing process (the friction coefficient, the punch radius, the ratio drawing, the ratio thinning, the hight of piece, the strength) about the thickness variation of piece in the radius punch area seeing that here is the danger apperance of the breaks.

The influence of different factors in the drawing process on (the friction coefficient, the punch radius, the ratio drawing, the ratio thinning, the height of the piece, the strength) on the variation of the piece thickness in the radius punch area, having in view the fact that this is where there is a risk for breaks, has been demonstrated through the Taguchi method. The small cylindrical piece was obtained through deep drawing without the intentional modification of the blank thickness (sheet A3k, A5), starting from a band-blank, B = 22 mm wide and g = 0,4 mm thick, which was topped for an easy deformation. The dimensions of the punch and die resulted from the experimental programs necessary to obtain the matematics models of level 2 with interactions of important characteristics of deep-drawing (m, m_y) [1].

In this paper the dimensions coresponding for the experiment 8, of the experimental programme have been considered (tab.1), in which: d_p – the punch diameter, d_m – the die diameter, j – the working part clearance, $h_2^{'}$ – the height of cylindrical thin-walled, h – the height of thinned cylindrical wall , m – the ratio drawing without thinning allowable, m_y – the thinning coefficient allowable, m_{glt} – the total gross coefficient allowable, r_p = 2mm – the punch radius with flat head.

Table 1. Values correspondent to experiment no 8 from the experimental programme

Nr exp	d_p [mm]	d_m [mm]	j/2 [mm]	$h_2^{'}$ [mm]	h [mm]	m	m_y	m_{glt}
8	7,7	8,5	0,4	0.1	4.6	0.58	1	0.58

2. TEORETICAL PRINCIPLES

The loss of quality for any product are expressed by costs of defects, as well as costs of tracking and prevention. The function of „loss of quality" allows the quantification in the form of financial losses of the products quality, processes and services.

In Taguchi's conception [3], the optimum value of quality characteristic which coresponds to minimum financial expenses and maximum of performance, (X_0) is the aim value and can corespond to the rated value (X_N). After the assignation of the optimum value one should have in view that the variation of the effective values (X_i) be smaller. According to this concept the mathematical model F(X) is a square function which describes the product's quality losses, depending on the δ_i deviation in contrast with the real values. This model is described in the relation:

$$F(X)=K\delta_i^2=K(X_i-X_0)^2 \qquad (1)$$

where: F(X) – the value of quality loss / unit of product; $\delta_i = X_i - X_0$ represents the deviation from the aim value; X – the value of measured characteristic; X_0 – the optium l value of the characteristic; K – the coefficient which the transforms the characteristic of quality in monetary units. The function F(X) refers to one alone product or experiment of the same type. When more products (experiments) are taken into account, then the „mean of deviation – m" is used. It is demonstrated that the function of quality loss is as follows:

$$F(X) = K\frac{1}{n}\sum_{i=1}^{n}(X_i - m + m - X_0)^2 =$$
$$K[\sum_{i=1}^{n}(X_i - m)^2 \cdot \frac{1}{n} + (m - X_0)^2] = \qquad (2)$$
$$K[S^2 + (m - X_0)^2],$$

where: n – the number of products (experiments); S^2 – the variance; $m = \overline{X}$ - the mean value.

The closer the medium values $(\overline{X})$ are to the desired value X_0 the smaller the dispersion S^2 is, and the performances of the experiment are higher. The two components are analysed together and they constitute a optimization coefficient.

Thus, the folowing are demonstrated:

1) the characteristic of maximization for a collectivity of becomes:
2)

$$F(X) = K\cdot\frac{1}{\overline{X}^2}[1+\frac{3}{\overline{X}^2}S^2] \; ; \qquad (3)$$

3) the raport of performance signal / noise is calculated with the relation:

$$S/N = 10\log\left(\frac{1}{\overline{X}^2}\right)\cdot\left[1+3\left(\frac{S}{\overline{X}}\right)^2\right] \quad [dB]. \quad (4)$$

3. THE INFLUENCE OF DIFFERENT FACTORS ON THE MAIN STATISTICAL PARAMETERS

This study has as data base the values of thickness of piece wall as a result of drswing simulation with softwear MARC-Mentat for the working part coresponding to experiment no. 8 from experimental program and the materials A5, A3k.The values of thickness extracted from simulations (for ex. fig 1 for experiment no 1) resulted in [inch] are converted in [mm] and centralizated in the table 3. The research intends to determine the influence and extent of each input both on the piece and on the performance ratio.

The calculation of experimental matrix

The influence factors, presented in table, 2 will be taken into account, on two value levels: level 1 which coresponds to the minimum values and level 2 which coresponds to the maximum values. A number of 8 experiments were done by the help of MARC-Mentat programme, having the influence factors combined on the two levels, as in table. 3.

Table 2. The values of influence factors on the material's thickness in the junction area coresponding to the punch radius

The simbol of factor	The input factors [UM]	Level 1	Level 2
A	The friction coefficient, μ	0.06	0.16
B	The punch radius, r_p [mm]	2	3.4
C	The drawing ratio, m	0.5	0.65
D	The thin ratio, m_y	0.6	1
E	The height of piece, h [mm]	4	4.6
F	The strength, σ_r [N/mm^2]	333	366

For the realisation of this study have been chosen the thickness in the nodes 6, 7, 8, 9, 10 (measured from axis of piece towards the edge – corresponding to the juncture of the wall to the basis – on the wall length, in longitudinal section), because these are under the highest pressure, and the values areshown in table . 3.Since for keeping the quallity of the product, the thickness must have as uniform as possible values,close to the nominal values, there has been elected for the study the maximization characteristic for a collectivity (of nodes).

The steps of calculation:

a) the medium value of thickness for each of the 8 experiments is calculated with the relation:

$$\overline{X} = \frac{1}{5}\sum_{1}^{5}x_i \qquad (5)$$

b) the general medium value for all experiments is calculated with the relation:

Table 3. The medium value $\overline{X}$, of parameter S of estimation of the variance and of the ratio of optimization

Cv nr.	The input factors						The values of the thickness [mm]					$\overline{X}$	S	S/N
	A	B	C	D	E	F								
	μ	r_p	m	m_y	h	σ_c	Nodul 6	Nodul 7	Nodul8	Nodul 9	Nodul 10			
1	1	1	1	1	1	1	0.333	0.326	0.336	0.357	0.382	0.347	0.021	9.244
2	1	1	1	2	2	2	0.282	0.286	0.317	0.353	0.381	0.324	0.038	9.974
3	1	2	2	1	2	2	0.352	0.358	0.369	0.383	0.391	0.371	0.015	8.645
4	1	2	2	2	1	1	0.343	0.355	0.370	0.385	0.393	0.369	0.018	8.682
5	2	1	2	1	1	2	0.389	0.379	0.371	0.374	0.375	0.378	0.006	8.460
6	2	1	2	2	2	1	0.381	0.370	0.366	0.369	0.375	0.372	0.005	8.586
7	2	2	1	1	2	1	0.251	0.280	0.314	0.348	0.376	0.314	0.045	10.320
8	2	2	1	2	1	2	0.287	0.317	0.348	0.374	0.389	0.343	0.036	9.412
												$\overline{\overline{X}}$		$(S/N)_M$
												0.352		9.165

Tabelul 4. The values of the mean deviations of the thickness vs. the general mean

The factors	The deviations (E)	
	Level 1	Level 2
A	0.000425	-0.000425
B	0.002933	-0.002933
C	-0.020296	0.020296
D	0.000095	-0.000095
E	0.007052	-0.007052
F	-0.001553	0.001553

Tabelul 5. The deviations of mean values of the ratio $(S/N)_i$ vs. the general mean value

The factors	The deviations (S/M)	
	Level 1	Level 2
A	-0.029018	0.029018
B	-0.099167	0.099167
C	0.572067	-0.572067
D	0.001890	-0.001890
E	-0.215928	0.215928
F	0.042737	-0.042737

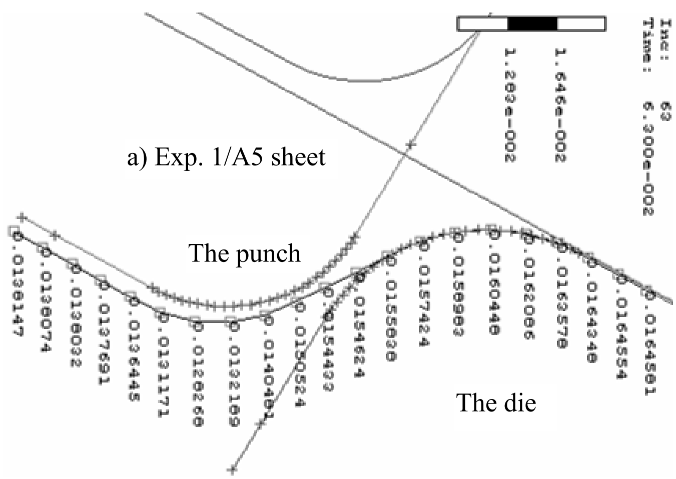
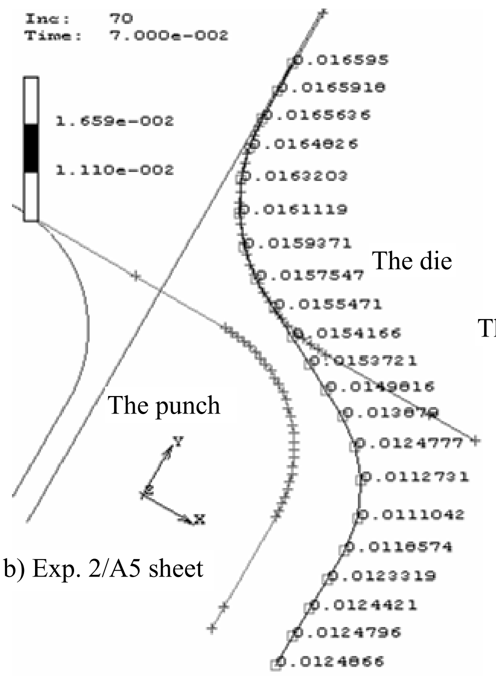
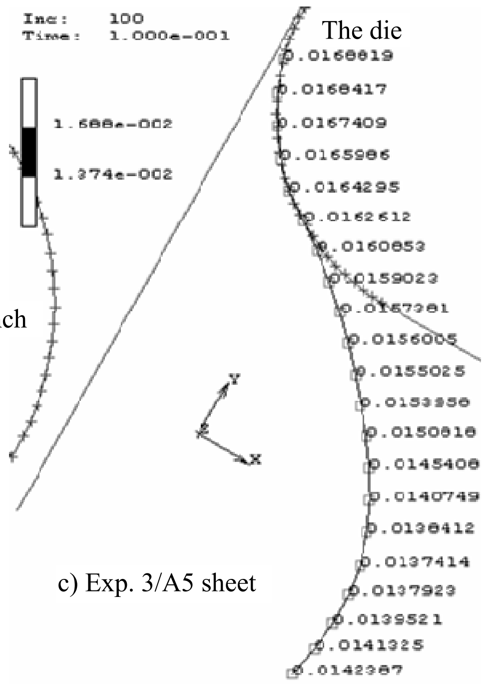


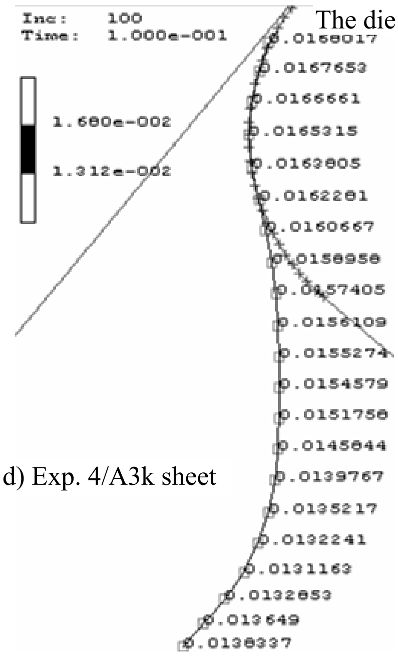
Fig. 1. The thickness of walls piece in cross longitudinal, on the punch radius, for the all 8 experiment, necessary for the aplication of method Taguchi method



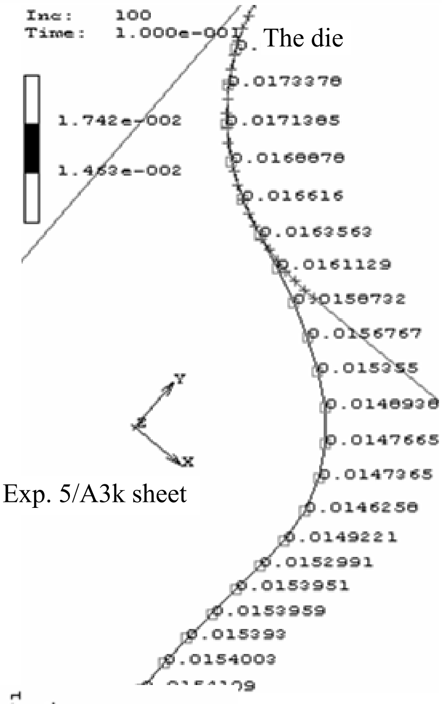
b) Exp. 2/A5 sheet



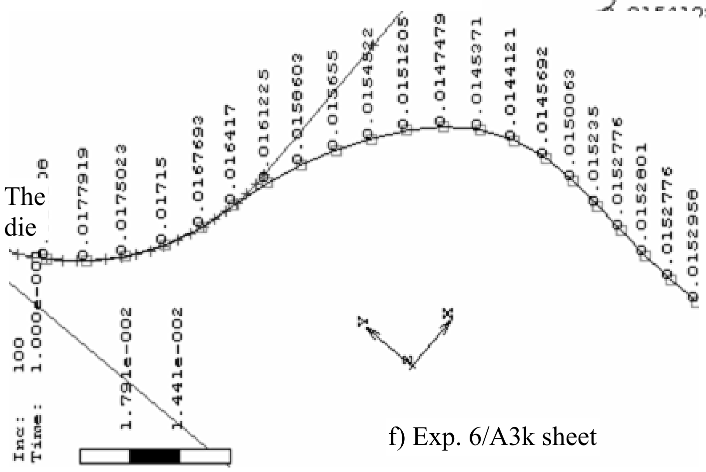
c) Exp. 3/A5 sheet



d) Exp. 4/A3k sheet



e) Exp. 5/A3k sheet



f) Exp. 6/A3k sheet

$$\overline{\overline{X}} = \frac{1}{8}\sum_{1}^{8}\overline{X}_i \qquad (6)$$

c) the variance S_i for each experiment is calculated with the relation:

$$S_i = \sqrt{\frac{1}{5}\sum_{n=1}^{5}(X_n - \overline{X}_i)^2} \qquad (7)$$

d) the raport of performance $(S/N)_i$ is calculated with the relation:

$$(S/N)_i = -10\log\left(\frac{1}{\overline{X}_i^2}\right)\left[1+3\left(\frac{S_i}{\overline{X}_i}\right)^2\right] \quad [\mathrm{dB}] \qquad (8)$$

e) the medium values of thickness, maked with $\overline{A}_1, \overline{A}_2, \overline{B}_1, \overline{B}_1, ...\overline{F}_1, \overline{F}_2$ for each input factor, corresponding to level 1 or 2:

$$\overline{A}_1 = \frac{1}{4}\sum_{i=1}^{4}\overline{X}_{i(A1)} \quad , \quad \overline{A}_2 = \frac{1}{4}\sum_{i=1}^{4}\overline{X}_{i(A2)} \qquad (9)$$

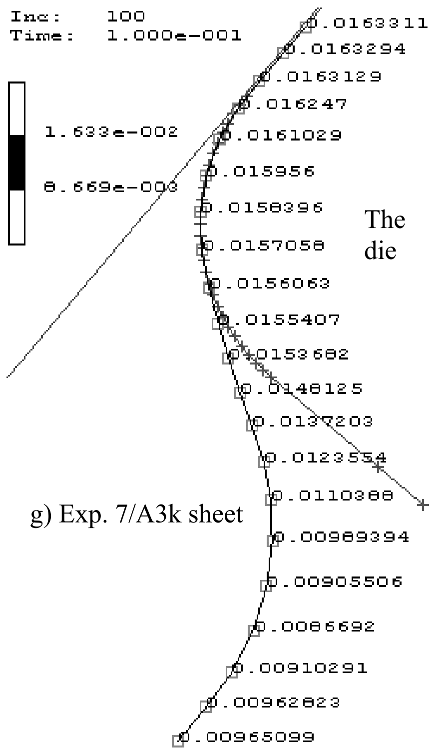
f) the medium deviations of thickness in contrast with the geenral mean of therelations is calculaterd with the relations:

$$E_{A_1} = \overline{A}_1 - \overline{\overline{X}}\ , \ E_{A_2} = \overline{A}_2 - \overline{\overline{X}} \qquad (10)$$

g) the general medium value of the raport of performance (S/N) is calculated with the relation:

$$(S/N)_M = \frac{1}{8}\sum_{i=1}^{8}(S/N)_i \qquad (11)$$

h) the general medium values of the raport of performance (S/N), for the each input factor, corresponding to levels 1 or 2:

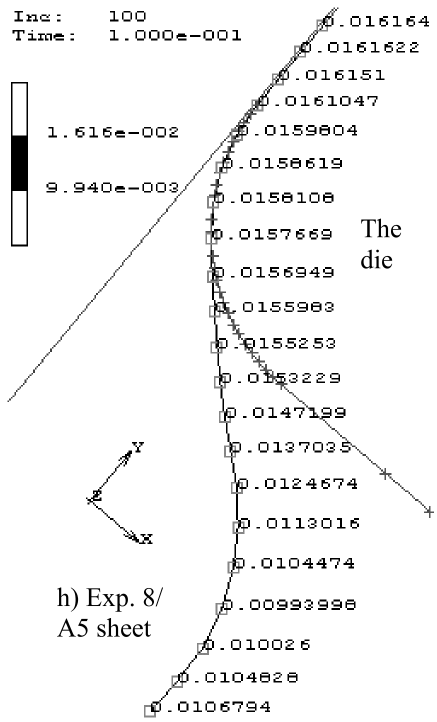


g) Exp. 7/A3k sheet

$$(S/N)_{(A_1)} = \frac{1}{4}\sum_{i=1}^{4}(S/N)_i\ ,\ (S/N)_{(A_2)} = \frac{1}{4}\sum_{i=1}(S/N)_i \qquad (12)$$

i) the deviations of medium values of the raport $(S/N)_i$ in contrast with the general medium value is calculated with relation:

$$(S/N)_{E_{A1}} = (S/N)_{A_1} - (S/N)_M\ ,\ (S/N)_{E_{A2}} = (S/N)_{A_2} - (S/N)_M \qquad (13)$$



h) Exp. 8/ A5 sheet

The results obtained after these steps, were written in tables. 3, 4, 5 and have resulted in the diagrams presented in fig. 2, 3. For the analysis of the diagrams one should take into account the fact that

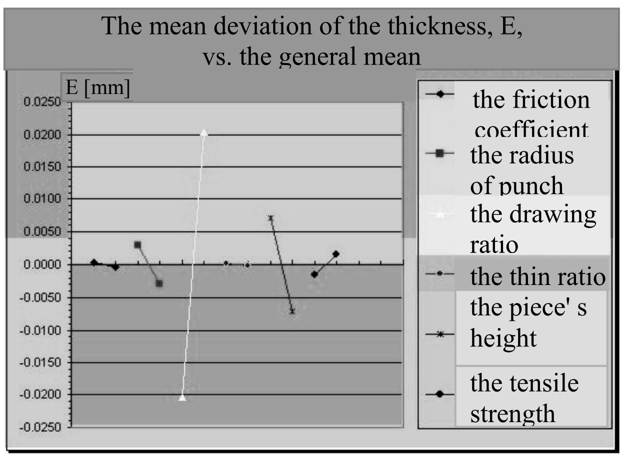


Fig. 2. The influence of the principal factors about the mean deviation of the thickness, E, vs. the general mean of the thickness $\overline{\overline{X}}$

level 1 corresponds to the left end of the represented segments, while level 2 corresponds to the right end of the segment.

In fig. 2 one can see how the factors with the greatest influence on the modification of tickness in the punch radius are: the drawing ratio, the height of the piece, the radius of punch.

The following factors have a lower influence: the friction ratio, the thinness ratio, the stress strength. The variation of these factors from level 1 to level 2, according to table no 2, influences the varition of tickness on punch radius, as folows:

- the increase of the friction coefficient determines a slight thinning;
- corresponding to level 2 of punch radius, the punch has a semispherical shape; so, reading the diagram one can reach the conclusion that when this radius becomes bigger the thinness of teh wall increases. It is known that the occuring of breaks or flaws on the punch with semispherical head is more accentuated than on the flat head punch [4].
- at the increase of the drawing coefficient from 0, 5 to 0,65 there appears an increase of medium thickness of the wall from -0,020296 mm to +0,020296 mm in relation to the general mean of thickness;
- the thinness coefficient has a negligible influence on the variation of mean thickness;
- at increase of the piece height from 4 mm to 4,6 mm a diminuation of the medium thickness is observed from +0,007052 mm to -0,007052 mm;
- at increase of the tensile strength from 333 N/mm^2 to 366 N/mm^2 there will be an increase of the medium thickness of the wall from -0,001553 mm to +0,001553 mm in relation to the general mean of thickness. The influence of the other factors is less than that.

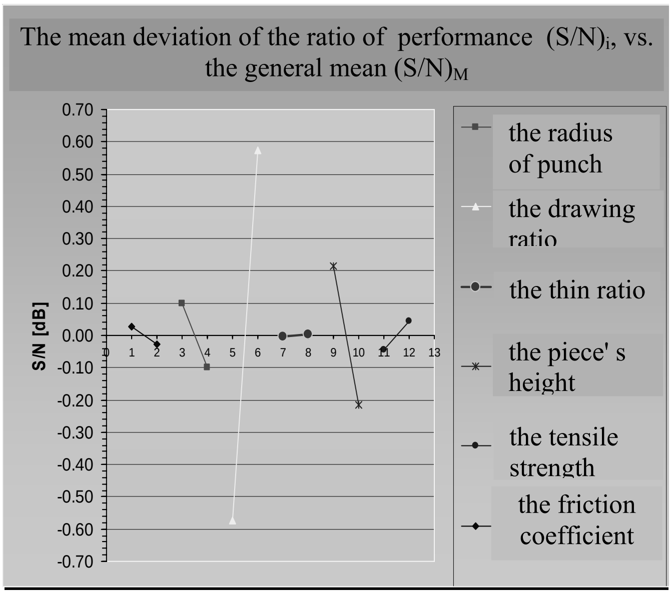


Figure 3. The influence of the principal factors about the mean deviation of the ratio of performance S/N, which reflects the degree of optimization of the values thickness from analysed area

From relations (3) and (4) results than the modification of the function of quality loss depends on the modification of the expression $\frac{1}{\overline{X}^2}[1+\frac{3}{\overline{X}^2}S^2]$, which represents the argument of the raport of performance. In order to maximize the function (3) the above function should be modified, too. The raport of performance S/N is the indicator which describes the level of dispersion and the rate of optimizing for the values of thickness on radius punch area of the piece, in relation to the medium value.

4. CONCLUSIONS

The Taguchi method shows how by having a minimum and maximum level for any input values (the influence factors), in the process, after the experimentation matrix is built, the influence ratio of each factor on the considered output value is obtained. Analysing the effects of factors accoeding to economic criteria, one can establish which of them presents medium values, above the general medium value, in order to obtain optimum quality, able to corespond to maximum performances.The method also permits the determination of the signal / noise (S/N) raport for the measurement of the performances, which for higher algebraic medium values of the factors indicate a lower general loss, i.e. those factors will determine better performances of the process.

The maximum positive values of the medium values deviation of the optimization raport charecteristic to some factors, correspond to the increase of the product quality, because they lead to the increase of wall thickness in the explored area. It can also be observed that the raport of performance S/N has the following maximum values (fig. 3), too: a) 0,572067 dB for level 2 of the drawing coefficient; b) 0,215928 dB for the level 1 of the height of the piece; c) 0,099167 dB for level 1 of the radius punch area. The other factors have negligible influence. As a result, the obtaining of a maximum thickness corresponds to an experiment having the following configuration of input factors: A_1, B_1, C_2, E_1, F_2.

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