THE MATHEMATICAL SIMULATION OF THE WORKING ACCURACY DURING COLD GEAR GENERATION THROUGH INTERMITTENT BLOW

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Abstract: The dimensional accuracy of the tooth systems obtained through cold plastic deformation represents an important scope in the study of qualitative aspect concerning worked materials in general, in our case of the cold deformation process through intermittent blow.
This paper presents the mathematical model used to calculate the working accuracy expressed through the diameter over the rolls and the outer diameter of the cold gear generated parts, function of the hardness of the material and the diameter of the semi-product.
The results obtained allow designers to use the necessary data base in applying and expanding this highly productive and without material losses procedure.

1. INTRODUCTION

The mechanical treatment of tooth systems through cold plastic deformation has multiple advantages to other technological treatments, such as: high productivity, material saving, improved physico-mechanical qualities of the worked area, highly accurate parts that do not need further working, reduced cost of the product.
The above mentioned advantages led to the apparition and use of various working procedures such as the intermittent blow procedure (hammering) which is the subject of this study. The paper presents the results of the research made in the case of cold gear generation through intermittent blow concerning the mathematical simulation of the working accuracy expressed by the diameter over the rolls and the outer diameter function of the hardness of the material and the outer diameter of the semi-product.

2. THE PRINCIPLE OF THE GEAR GENERATION PROCEDURE THROUGH INTERMITTENT BLOW

Fig. 1 presents the scheme of gear generation through intermittent blow. The rolls – position 2, have an identical profile to the one of the root of the tooth which is being made, and rotate planetary with the speed n_1 around the axes which are perpendicular on the longitudinal axis of the part to be worked 1.
The axes of the rolls are displayed eccentrically in comparison with the axes of the blow heads which rotate with the speed n.
By using this display of the rolls, at each rotation of the part, the rolls enter and as a result of the planetary movement the root of the teeth is made on a certain length and the part has an indexing movement n_d, after this it moves with the axial feed s_a, and the cycle repeats, while the axial motion of the part continues until the entire length of the tooth system is done.
If one uses this gear generation procedure, the actual deformation area is relatively small as a result of the planetary movement of the rolls, of the step by step indexing of the part and of the axial feed of the part, thus the gears are gradually generated.

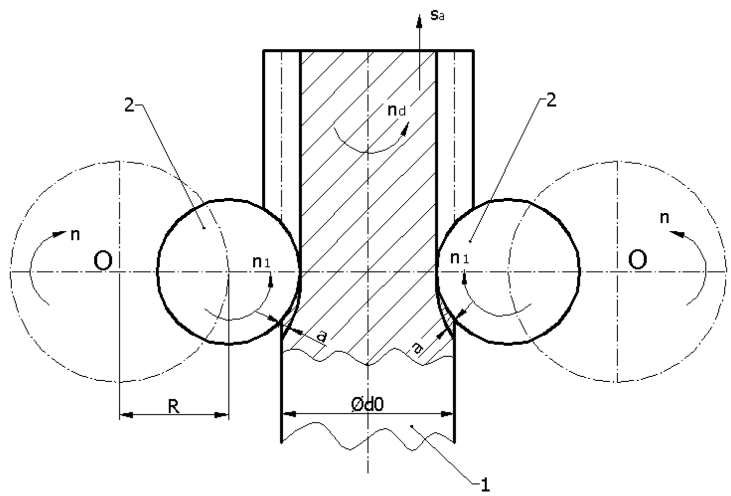


Fig.1. The scheme of the gear generation procedure

It is obvious that when the rolls - 2 get in contact with the material they deform, they rotate with a speed n_1 on the material of the semi-product and on the worked surface. This is the reason why it is said that we are dealing with a rotation of the roll and by taking this into consideration the deformation is done by rotation.

3. THE PARAMETERS OF THE DIMENSIONAL PRECISION

A claw coupling uses axial involute tooth systems in order to transfer a moment of rotation between two axles, the main criterion of the assemblage accuracy is that there should be a minimum clearance between the flanks.

When the assemblage is designed, the minimum thickness of the tooth is established on the divided circle for the axle-part, and the minimum thickness of the empty spot on the indexing circle on the hub.

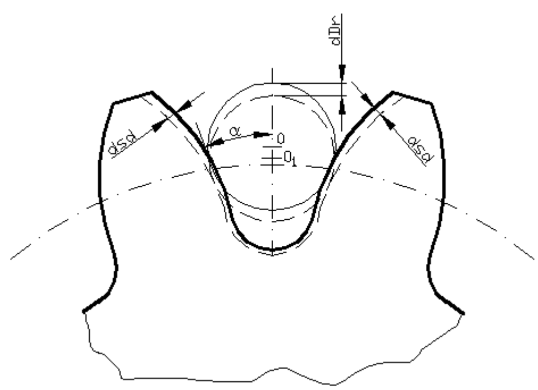


Fig.2 The variation of the diameter over the rolls with the value dD_r

The diameter over the rolls represents the control parameter of the thickness of the tooth or of the empty spot on the divided circle. In the case of external tooth systems with a variation of the tooth thickness on the divided circle ds_d (symmetrical on both flanks), the diameter over the rolls varies with the value dD_r (fig.2), where:

$$dD_r = \frac{ds_d}{\sin\alpha} \tag{1}$$

By taking into consideration the variations of the semi-product's diameter in the given tolerance zone and using two rolls in the given technical parameters, for a correct adjustment of the rolls, the dimensional accuracy imposed by the functional role of the tooth system can be appreciated by using as a control parameter, the diameter over the rolls and the outer diameter.

4. SIMULATING THE PARAMETERS OF THE WORKING ACCURACY

The simulation of the working accuracy expressed through the diameter over the rolls and the outer diameter, was done by treating an involutes profile; the material used for the study was steel OLC25, obtained through hot rolling. The tooth system which has to be obtained after the treatment has the shape of profile J 498 SAE and the dimensional differences are STAS 6858-63.

We have chosen the following independent parameters: the hardness of the material, HB and the diameter of the semi-product, Δd_0. We have followed the influence of these parameters on the absolute variations of the diameter over the rolls dD_r and of the outer diameter dD_e. The diameter of the semi-product for the experiments was calculated with the following relation [8]:

$$d_0 = \sqrt{\frac{\pi}{4}\left\{\frac{\pi D_e^2}{4} - zh\left[g_{d\max} - (b-a)tg\alpha_0^{\bullet}\right]\right\}} \qquad (2)$$

where:

- D_e – is the outer diameter of the tooth system;
- z – is the number of teeth;
- h – the height of the obtained tooth;
- a – the height of the tooth head to be obtained;
- b – the height of the tooth leg to be obtained;
- $g_{d\text{-}max}$ – the maximum thickness of the empty spot on the divided circle;
- $\alpha_0^{\bullet}$ - the pressure angle of the tooth system to be worked.

Table 1 presents the structure of the experimental plan and the values of the independent variables, expressed in natural units according to the three levels (+1, 0, -1). The experimental plan comprised $2^2 + 4$ central experiences.

The experiments pointed out the fact that, for a certain roll-semi-product adjustment, the value of the diameter over the rolls D_r and of the outer diameter D_e, varies from test to test and are different from the established values. An absolute variation of the diameter over the rolls dD_r and an absolute variation of the outer diameter $dD_{e,}$ is represented by the difference between the measured values of the diameter over the rolls and of the outer diameter of the test made with a certain roll – semi-product adjustment, and the calculated values of the two diameters. In order to provide the dimensional accuracy during the working process, it is clearly needed that the value of the diameter over the rolls and of the outer diameter be as close as possible to the values specified in conformity to the control rates of that tooth system.

Table 1. The values of the independent variables

The independent variable	Codified levels	Natural levels
X_1 HB [Kg /mm^2]	-1	145
	0	172
	+1	204
X_2 Δd_0 [mm].	-1	0,01
	0	0,07
	+1	0,14

One needs to maintain the absolute variation of the diameter over the rolls D_r and of the outer diameter D_e in very tight boundaries. These lead to establishing some variation intervals for the process variables which influence the diameter over the rolls and the outer diameter. Thus, one will find new working functions, dD_r and dD_e which will establish within a certain adjustment the boundaries within which the variations of the entering values need to be maintained in order to provide the imposed working accuracy.
In order to eliminate the influence of the tools' inaccuracy on dimensional accuracy, each surface was gear generated with the same set of rolls, within the same assemblage.
As well, the adjustment of the technological system to the dimension was made according to the standard control method.

5. THE RESULTS AND THEIR INTERPRETATION

In order to establish the dependence of the working accuracy P on the two parameters HB and Δd_0 we have taken into consideration that this dependence corresponds to the model:

$$P = C_P HB^a \Delta d_0^b \qquad (3)$$

The final shape of the working functions, such as the absolute variation of the diameter over the rolls, dD_r, and of the outer diameter, dD_e, according to the entering parameters considered by this study, is given in relations 4 and 5.

$$dD_r = 0{,}749 HB^{0{,}89} \Delta d_0^{0{,}259} \qquad (4)$$

$$dD_e = 3{,}013 HB^{0{,}687} \Delta d_0^{0{,}242} \qquad (5)$$

The influence of the selected process factors on the working accuracy represented by the diameter over the rolls dD_r and the outer diameter dD_e, is given by the statistical interpretation of the results of the regression calculus and by the graphical representations in fig. 3 and 4; it can be synthesized as follows:

a. the function chosen as being the variable dependent on the dimensional accuracy of the cold gear generated parts through intermittent blow, is adequate;
b. the coefficients of the standardized equation are significant pointing the fact that the entering variables influence the two parameters of the working accuracy studied by this research;

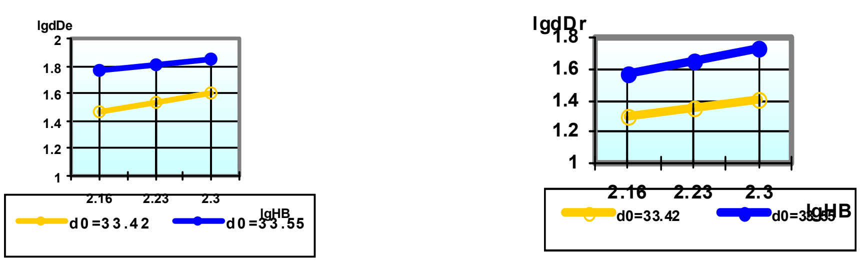
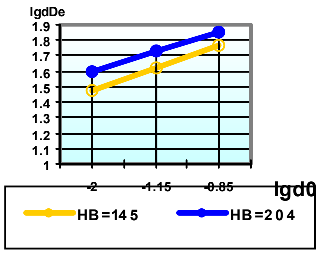


Fig. 3 The influence of the material's hardness on the outer diameter and on the diameter over the rolls

c. coefficients B_1 and B_2 have positive values, thus, an increase of the values of the material's hardness and of the outer diameter would lead to an increase of the outer diameter and of the diameter over the rolls. An increase of the material's hardness from $HB_{min.=}$145 to $HB_{max.}$=204, leads to an increase of the outer diameter with 20…33% and of the diameter over the rolls with 30…42%, fig. 3. At the same time, an increase of the diameter of the semi-product from 33.42 mm to 33.55 mm leads to an increase of the outer diameter with 80...100% and of the diameter over the rolls with 90...108%, fig 4;



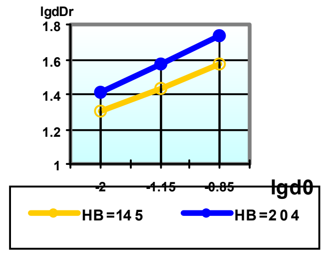


Fig. 4 The influence of the diameter of the semi-product on the outer diameter and on the diameter over the rolls

d. by analyzing the indicators of relative weight we notice that the greatest influence on the dimensional accuracy is given by the diameter of the semi-product and the material's hardness.

The experimental results point out the fact that the dimensional accuracy of surfaces obtained through cold plastic deformation through intermittent blow, represented by the outer diameter and the diameter over the rolls, depends on the parameters considered by this experimental program.

6. CONCLUSIONS

In order to check if the established mathematical models are adequate, we calculated the values of the functions for eight tests and then compared them to the experimental ones, thus, we noticed that the values are quite close. The differences are explained by the errors introduced by the regression functions. We recommend that the treatment should be done with a certain adjustment on homogeneous batches in point of dimension, geometry, material.

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