

## **STUDIES REGARDING THE DEFORMATION FORCES DURING COLD GEAR GENERATION THROUGH INTERMITTENT BLOW**

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**Abstract:** The production of gear wheels through cold plastic deformation is a working process which has expanded a lot recently as a result of increased productivity. Consequently, knowing the dimension of the deformation force which appears is required in order to choose the most efficient machine tool. Experimental researches presented in this paper were meant to determine the deformation forces expressed by two components, the axial and the radial forces which are significant in the gear generation process.

### **1. INTRODUCTION**

The gear generation process with two rolls through intermittent blow (hammering) is one of the most spread cold flow procedures, fact due to a wide range of surfaces which can be thus generated and to the possibilities to use the machine tools specialized for this purpose.

A better technological knowing of this cold flow procedure allowed for the obtaining of parts with different shapes, among which the tooth system with involute profile.

When generating revolution surfaces with two rolls with an axial feed of the semi-product, the technologist has to:

- calculate the diameter of the semi-product;
- choose the right machine tool;
- establish the values of the parameters of the gear generation regime.

One of the most important elements in applying the cold development procedure and choosing the right gear generation machine is represented by the deformation forces.

This paper presents formulas meant to calculate the value of the components of the deformation forces in order to generate external revolution surfaces with two rolls through intermittent blow (hammering), values which can help the technologist in solving the last two above mentioned issues.

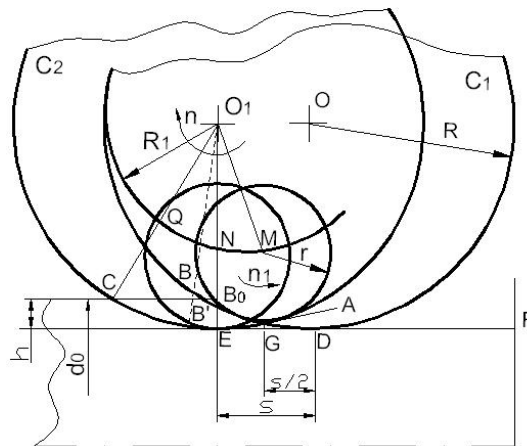
When working with two rolls with an axial feed of the semi-product on a specialized gear generating machine ZRM9, which has a hydraulically feed motion, the parameters of the working regime are:

- $v$ , the blow speed [m/min.];
- $s$ , the axial feed [mm/rot.];
- $h$ , the depth of the profile [mm].

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

Figure 1 presents the kinematics of the gear generation process through intermittent blow (hammering).

The rolls have an identical profile to the one of the tooth gap which is formed; the rolls rotate planetary around the axes on a circle with a radius  $R$ ; the axes are perpendicular on the longitudinal axis of the piece which is being geared.



**Figure 1. The kinematics of the deformation process through intermittent blow**

By this display of the rolls at every rotation of the semi-product the rolls with the radius  $r$  enter and as a result of the planetary movement make the teeth gap on a certain length, this is followed by an indexing movement of the semi-product, after this it moves axially with the feed  $s_a$ , and the cycle repeats, the axial feed continues until the entire length of the tooth system is achieved.

It is obvious that when the rolls with a radius  $r$  get in contact with the material which is being deformed rotate with the rotative speed  $n_1$  on the material of the semi-product, the rolls go on the worked surface.

By using this working procedure of the tooth system the properly deformation area is relatively small as a result of the planetary movement of the rolls, of the step by step indexing of the semi-product and of its axial feed, thus, the tooth system is achieved gradually.

### 3. FORCES WHICH APPEAR IN THE DEFORMATION PROCESS

The value of the deformation force during the working process through cold gear generation represents one of the most important technological factors of the process, and acknowledging it allows on the one hand, the choice of the right machine, and on the other hand, the development of the process in the right direction; this value influences a part of the quality parameters of the generated surfaces.

The forces which appear in the cold gear generation process through the intermittent blow procedure (hammering) are: *the normal gear generation force (radial  $-F_n$ )* – which is perpendicular on the semi-product and *the axial gear generation force  $- (F_a)$*  – which is tangent to the arc of contact tool-semi-product.

They have a dynamic character as a result of the fact that the plastic deformation of the material is produced as a result of the roll's work on the material of the part through intermittent blow. As well, the forces have to be greatly influenced by the quantity of material moved by a blow and by the factors connected to the material's resistance to deformation.

The dependence of force  $F$  can be expressed as a function of the following parameters:

$$F = f(v, s_a, h, D, d, \sigma_c, HB, \alpha) \quad (1)$$

where:

$v$  – is the speed of deformation, expressed in [m/min];

$s_a$  – is the axial feed of the semi-product, expressed in [mm/rot];

$h$  – is the depth of the profile, expressed in [mm];

$D$  – is the diameter of the rolling head, expressed in [mm];

$d$  – is the diameter of the roll, expressed in [mm];

$\sigma_c$  – is the flow resistance of the material, expressed in [daN/mm<sup>2</sup>];

HB – is the hardness of the part's material, expressed in [kg/mm<sup>2</sup>];

$\alpha$  - is the angle of the reference rack.

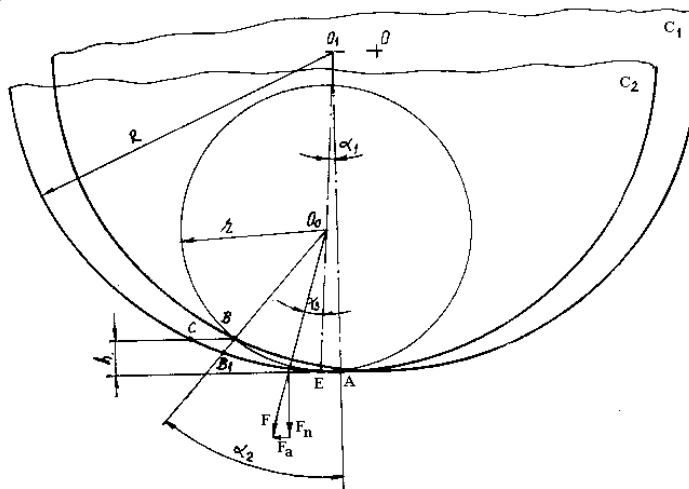
The working force of the roll on the AEC arc varies according to the section of moved material. In A and C the force is null and has a maximum point in the area with the maximum section of surface AECBA. This section approximately corresponds to segment BB<sub>1</sub>, its expression results from figure 2, being given by relation (2):

$$BB_1 = O_1B_1 - OB = R - OB$$

After calculating we get the following expression for BB<sub>1</sub>:

$$BB_1 = R - \sqrt{R^2 - 2s_a h \sqrt{\frac{2R}{h} - 1}} \quad (2)$$

The components of the force for the maximum value of the deformation depth correspond to the situation in figure 2.



**Figure 2. Determining the deformation forces**

The  $r$  radius roll interferes with the part on arc EB and the maximum section on which it works is BB<sub>1</sub>. The arc EB corresponds to the angle  $\alpha_2$  and the center of the roll rotates from the maximum position with the angle  $\alpha_1$ .

The deformation forces develop under the form of a pressure which appears on arc EB and diminish to a radial force to the roll normally situated asymmetrical to arc BE. If this force is under angle  $\alpha_3$  to the part, it will have two components, as follows:

1.  $F_n$ , the radial force (normal) of the part, which is a normal force on the surface of the part;
2.  $F_a$ , the axial force of the part.

From fig. 2 we get the expressions of the components of the deformation force  $F_n$  and  $F_a$ , relations 3 and 4.

$$F_n = F \cos (\alpha_1 + \alpha_3) \quad (3)$$

$$F_a = F \sin (\alpha_1 + \alpha_3) \quad (4)$$

It is obvious that the force which moves the material on a radial direction to the part, meaning the radial force (normal), is the one which presents interest. The other component of the deformation force – the axial force  $F_a$  - is supposed to be as small as possible. In order to have a small axial force the sum of the angles needs to be as small as possible. In order to do so, the radius of the roll  $r$  and the radius  $R$  of the head need to be as big as possible.

#### **4. CONCLUSIONS**

The experimental researches obtained point out the fact that the forces of deformation during cold gear generation through intermittent blow depend on both the parameters connected to the tool, more precisely to the diameter of the rolling head  $D$ , and to the parameters of the working regime which determine the quantity of material moved by the roll, the axial feed of the semi-product  $s$  and the depth of the gear generated profile, relation (2).

The force which moves the material on a radial direction to the part is the one which interests us; this is the normal component  $F_n$  which decreases with the increase of the sum of angles  $(\alpha_1+\alpha_3)$ , relation (3). The axial component of the force,  $F_a$ , needs to be as small as possible, meaning that the sum of angles  $(\alpha_1+\alpha_3)$  has to be as small as possible, relation (4).

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