PHYSICAL ANALISE AND CUTTING FORCES IN BEVEL GEAR MACHINING PROCESS

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Abstract: *In order to calculate machining forces it is necessary to know the chip volume and the phisical model of the bevel gears machining process. It is considered the theory of transfer energy routes and energy quantum aplicable to this process.The force variation in time diagram was established.*

Key words: *bevel gears machining, cutting forces, physical model*

1. INTRODUCTION

In the process of bevel gear machining there is a periodically varying chip section during the material removal and the cutting force also varies during this process. Physical analise and accurate modelling of the cutting forces is required to predict the cutting forces, vibration, surface quality and stability of machining process.

A number of different methods to predict cutting forces have been developed over the last years. These models can be classified into three major categories: empirical, analyticaland mechanistic methods [1,2,3,4,5]. In the empirical methods, a number of machining experiments are performed and performance mesures such as cutting forces, tool life and tool wear are measured. These responses are then correlated to the cutting conditions using empirical functions and require a lot of experimentation. Analitical approaches model the physical mechanisms that occur during cutting. This include complex mechanismssuch as high strain rates, high temperature gradiens and combined elastic and plastic deformationsand it's not yet completly solved. Mechanistic models predict the cutting forces based on a method that assumed cutting forces to be proportional to the chip cross-sectional area.

The constants of proportionality are called the specific cutting pressures and depend on the cutter geometry, cutting conditions, insert grade and workpiece material properties.

As shown in Figure 1, the cutter turns on its own axis O_c. As the cutter moves round the rotor axis O, the gear blank rotates and the cutter will machine the flanks of bevel gear tooths

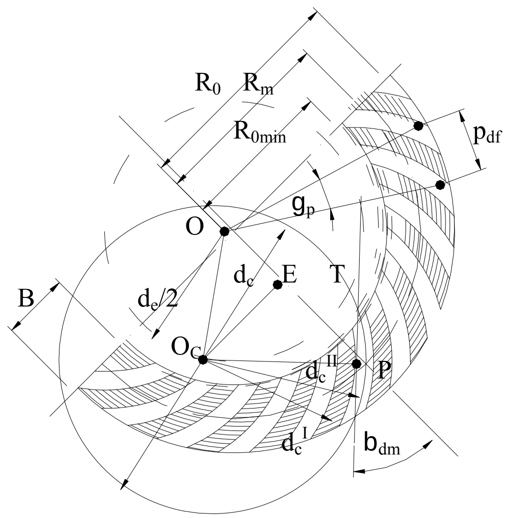


Fig.1. Bevel gear cutting process

The shaded area from Figure 2 is the sectional forms of undeformed chip.

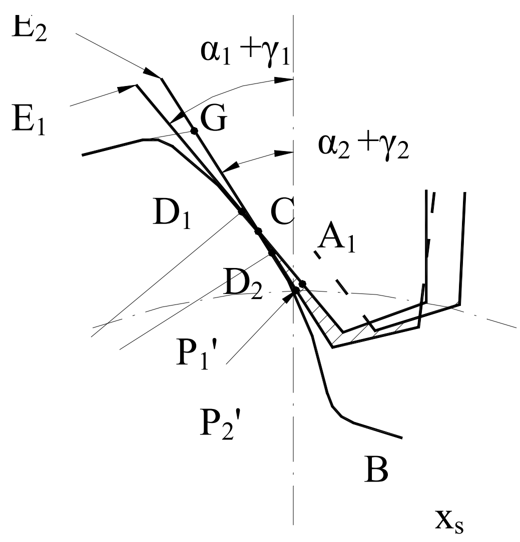


Fig. 2. The sectional of undeformed chip

2. MODELING OF PHYSIC WEARING PROCESS OF THE CUTTERS OF THE MILLING HEAD

In order to elaborate a mathematic model of the wear process for the cutters of the milling head for bevel gears, it is considered the set N_1 as the totality of particles of a cutter of the milling head (considered cutter number 1). N_1 consists of a reunion of two complementary subsets V_1 and W_1 [5]:

$$V_1 \bigcup W_1 = N_1 \qquad (1)$$

where:

V_1 - contain the particles included in cutter number 1 during the cutting process

W_1 - contain the particles departed from the cutter number 1 during the cutting process, due to the different forms of the wear process.

It is considered that both the milling head and the cutter where chosen according to the quality of the work material.

It is noted V_i an element of the set V and with W_i the elements of the set W. A mathematic algorithm can be associated with the wear process of the cutters of the milling head, the correspondence between the phases of the cutting process and the algorithms elements being stated below:

$$V_{10} \bigcup W_{10} = N_1 \ , \qquad (2)$$

for the first interaction tool-working part, and as follows for the next interactions:

$$\begin{aligned} V_{11} \bigcup W_{11} &= N_1 \\ V_{12} \bigcup W_{12} &= N_1 \\ V_{13} \bigcup W_{13} &= N_1 \\ &\vdots \\ V_{1k} \bigcup W_{1k} &= N_1 \end{aligned} \qquad (3)$$

where: $V_{11} = V_{10} \bigcup Z_{11}$

and Z_{11} represents all the particles included in the cutters wear quantity for the first interaction tool – part.

It can be also, considered:

$$V_{12} = V_{11} \bigcup Z_{12} = V_{10} \bigcup Z_{11} \bigcup Z_{12} \qquad (4)$$

in which Z_{12} represents all the particles included in the cutter wear quantity for the second interaction tool-part.

$$
\begin{aligned}
V_{13} &= V_{12} \bigcup Z_{13} = V_{10} \bigcup Z_{11} \bigcup Z_{12} \bigcup z_{13} \\
V_{14} &= V_{13} \bigcup Z_{14} = V_{10} \bigcup Z_{11} \bigcup Z_{12} \bigcup Z_{13} \bigcup Z_{14} \\
&\vdots \\
V_{1k} &= V_{1k-1} \bigcup \cdots \bigcup Z_{1k} = V_{10} \bigcup Z_{11} \bigcup Z_{12} \bigcup Z_{13} \bigcup \cdots \bigcup Z_{1k}
\end{aligned}
\tag{5}
$$

It is than possible to consider the following equation system for the wear of the cutter number 1, which consists of N1 particles:

$$
\begin{aligned}
Z_{11} &= C_{W_{11}}^{W_{10}} \\
Z_{12} &= C_{W_{12}}^{W_{11}} \\
Z_{13} &= C_{W_{13}}^{W_{12}} \\
&\vdots \\
Z_{1i} &= C_{W_{1i}}^{W_{1i-1}} \\
&\vdots \\
Z_{1k} &= C_{W_{1k}}^{W_{1k-1}}
\end{aligned}
\tag{6}
$$

Considering the reunion of the left side members of the equations and the reunion of the right side members of the equations, the result is :

$$
Z_{11} \bigcup Z_{12} \bigcup Z_{13} \bigcup Z_{14} \bigcup \cdots \bigcup Z_{1k} = C_{W_{11}}^{W_{10}} \bigcup C_{W_{12}}^{W_{11}} \bigcup C_{W_{13}}^{W_{12}} \bigcup \cdots \bigcup C_{W_{1k}}^{W_{1k-1}} \tag{7}
$$

where: $$Z_{11} \bigcup Z_{12} \bigcup Z_{13} \bigcup Z_{14} \bigcup \cdots \bigcup Z_{1k} = W_{1k} \tag{8}$$

Because : $$W_{1k} = C_{N_1}^{V_{1k}}, \tag{9}$$

the equation (4.)can be written as:

$$
\bigcup_{1(1,1,\cdots k)} C_{W_{1i}}^{W_{1i-1}} = C_{N_1}^{V_{1k}} \tag{10}
$$

where:

$C_{W_{1i}}^{w_{1i-1}}$ is the complement of the set $W_{1,\, i\text{-}1}$ reported to the set of particles W_i

$C_{N_1}^{V_{1k}}$ is the complementary set of the set V_{1k} reported to the set of particles N_i

The equation (10) represents the general equation of the wearing process of a cutter from the milling head (number 1). The milling head has n cutters which wear during the cutting process.

Generalizing, the following is obtained [5]:

$$\begin{aligned}
&\bigcup 1_{(1,1,\cdots k)} C_{W_{1i}}^{W_{1i-1}} = C_{N_1}^{V_{1k}} \\
&\bigcup 1_{(1,2,\cdots k)} C_{W_{2i}}^{W_{2i-1}} = C_{N_2}^{V_{2k}} \qquad (11) \\
&\vdots \\
&\bigcup 1_{(1,1,\cdots k)} C_{W_{ni}}^{W_{ni-1}} = C_{N_1}^{V_{1k}}
\end{aligned}$$

These equations represent the equation system which can be considered as a mathematic model of the wearing process for one cutter of the milling head.

3. CUTTING FORCES IN BEVEL GEAR MACHINING PROCESS

We consider that the technological system consist from M_1 particles (M particles being cutting piece) and also that the force is a result of the energy introduced in the process by cutting piece[5]. We admit also that the group of the particles from the process wich receive energy, will transmit this energy to the neighbouring particles.

It is considered k transfer energy routes coresponding to each energy quantum. Different forms of energy are conducted on the same routes: heat, light, noise. For each route it is possible to associate a work function f_i, wich can take the value a_i, where a is 0 (if at the end of the route energy $E_i = 0$) or 1 (if $E_i \neq 0$), E_i being energy quantum wich follows i route.

It is possible to write for each collision the totality of work function. For the first collision:

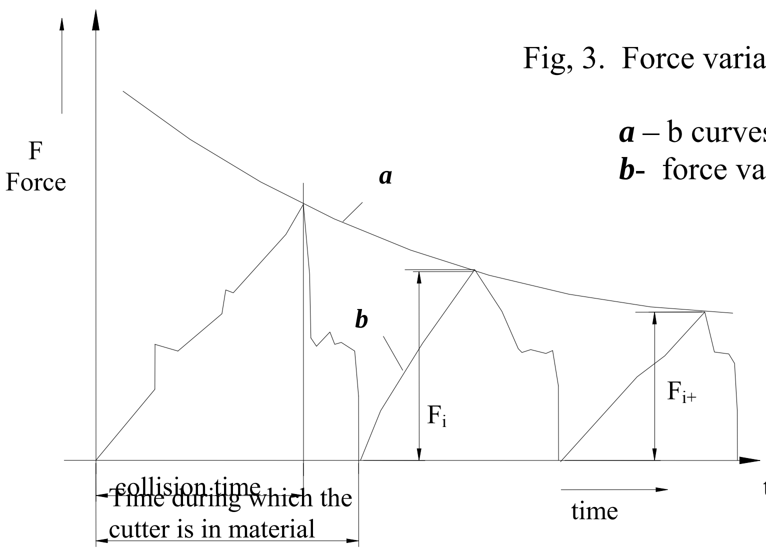
$$F_1 \begin{cases} f_{11}\left(a_{1n_1}, a_{1n_1-1}, \ldots, a_{12}, a_{11}\right) = \alpha_{11} \\ f_{12}\left(a_{2n_2}, a_{2n_2-1}, \ldots, a_{22}, a_{21}\right) = \alpha_{12} \\ f_{1K}\left(a_{Kn_k}, a_{kn_k-1}, \ldots, a_{k2}, a_{k1}\right) = \alpha_{1k} \end{cases} \qquad (12)$$

where: $\Sigma\left(a_{in_1}, a_{in_2}, \ldots, a_{in_k}\right) = M$. The totality M of the particles decrease as a result of the first collision. Will remain into the process M′ particles and the work function for each route will be modified.

It is possible to write the totality of work function for the second collision and for the followings. For the η-1 collison (η is the number of the tool collision necessary for a complete machining) the work function are:

$$F_{\eta-1}\begin{cases} f_{\eta-1,1}\left(a_{1n_1},a_{1n_1-1}\right)=\alpha_{\eta-1,1} \\ f_{\eta-1,2}\left(a_{2n,2},a_{2n_2-1}\right)=\alpha_{\eta-1,2} \\ f_{\eta-1,k}\left(a_{kn_k},a_{kn_k-1}\right)=\alpha_{\eta-1,k} \end{cases} \qquad (13)$$

Equations (10) and (13) can be represented by the theoretical diagram from figure 3 .



Fig, 3. Force variation in time[5]

a – b curves evolute
b- force variation curves

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4.CONCLUSIONS

On these basis it is possible to devellop the study of cutting forces in the definitely conditions of bevel gears machining process.

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