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VIBRATION REDUCTION AT GEAR WEEL WORM CUTTING

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Abstract*: One of the reasons causing vibration for gear hob toothing is the shock at the tool's entry, which is generated by the great length of the cutting edge entering the metal at the same time. This paper proposes a fragmentation of the cutting edge so that its length is much smaller. Moreover, the cutting scheme is also changed, so that the entire tooth line of the piece is made with four consecutive teeth of the tool.Therefore, the impact force input generating shock and vibration is significantly reduced.*
Keywords: *Gear processing, hobbing, carbide plates cutting tools*

1. INTRODUCTION

The proper running of a machine-tool is mainly linked to the friction control, as well as to the maximum reduction of vibrations.
Both friction and vbrations appear within the dynamic system of the machine tool. In order to perform an easy, accurate analysis of the basic elements mentioned above, it is necessary to know the particularities of this system. Among these, the most important are the following:

- The dynamic system of the machine-tool is a closed system;
- The interaction between the elements of the working process is produced only by the elastic system.

As far as the first characteristic is concerned, it is noticed that the elastic system is subject to changes, due to the cutting force. The effect of deformation (vibration) is that the relative position tool – piece is changed. This aspect produces variations of the chip's section, having negative effects on the cutting force variation.
This is just one argument to assert the control and maximum reduction of the vibrations. On the other hand, they cannot be avoided. Generally speaking, vibrations represent movements of the elastic system around its balance position. Under these circumstances, it is possible that the variation of the cutting force appears at a given moment, for different causes. This change triggers the variation of the relative position of the piece-tool, which naturally produces the variation of the cutting force. Thus, one obtains vibrations that can keep producing themselves. On such cases, the vibrations' amplitude increases continuously until its limitation by the machine's antivibration system.

2. THE INFLUENCE OF THE SIZE OF THE CUTTING EDGE ON THE CUTTING FORCE WHILE TOOTHING

The only possibility of changing the length of the cutting edge is that of manufacturing it out of sintered carbide detachable small plates for the cutting process submitted to analysis – gear hob toothing. The problem raised by such a constructive option is that of setting the optimal arrangement of the plates on the line so that a reduction of the cutting force is reached.
Next, it is aimed to emphasize the way in which the type of plate arrangement can influence the value of the cutting force, under the circumstances when the oter parameters (speed, feed) remain constant.
In figure 1 one can notice the section of the chip removed by a complete lateral cutting edge.

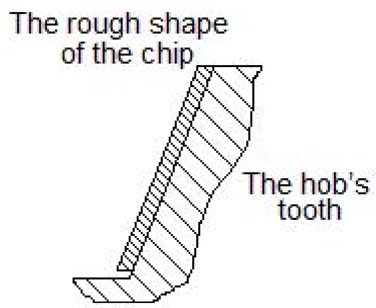

Figure 1 The chip's section removed by a complet lateral cutting edge

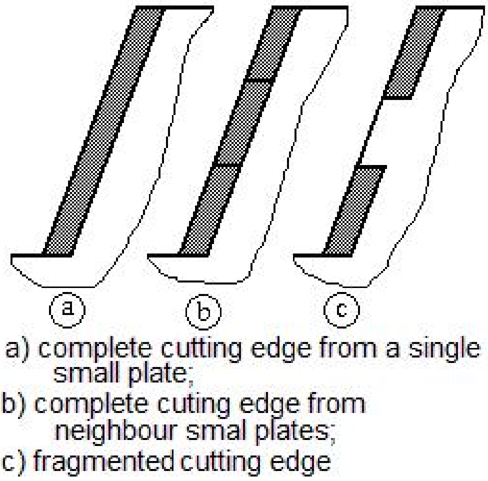

Figure 2 The plates arrangement on the cutting edge

A plate arrangement such as in figure 2 corresponds to a tooth such as the one in figure 1. The small plates arrangement, such as the one in figure 2a, presents a complete single casting cutting edge and has the disadvantage of using unstandardized carbide insert plates; due to the fact that their length is relatively high, there is a high risk of breaking, apart from holding difficulties. Moreover, this type of plates needs specialized technologies of pressing and sintering, which represents an expensive aspect limitating their use.
The arrangement in figure 2b presents a complete cutting edge, performed out of several pieces. In this case, the cutting edge is created out of square –shaped or triangular – shaped small plates, as it can be seen in figure 3.
A cutting edge such as the one in figure 3 a is impossible to be perfomed, as it is not recommended to hold two plates net to each other, due to the vibrations and oscillations during the cutting process. The version in figure 3 b solves this aspect but presents technological holding difficulties.

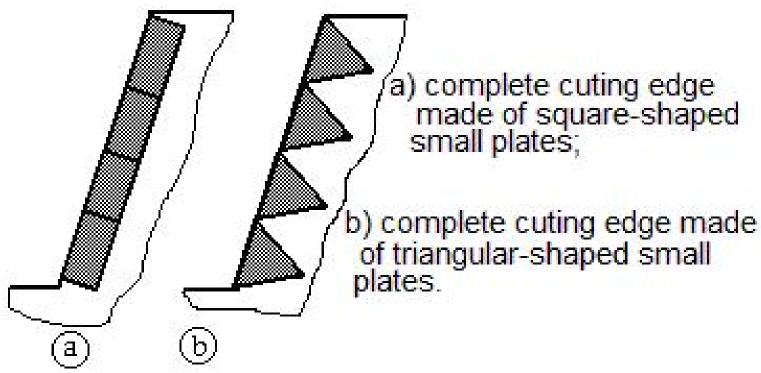

Figure 3 Performing the complete cutting edge on the flank out of small plates

Moreover, due to the impossibility of ensuring the continuity of the cutting edge next to the small plates, an uncut surface results, such as the one in figure 4.
Taking into account the fact that the plate arrangement on the flank, with the aim of totally covering the cutting edge, is the same on each tooth. This signifies that the uncut bumps is transmitted to the next tooth, thus reaching the impossibility of continuing the cutting process, as a result of the contact between the piece and the tool in an area where there is no cutting edge.

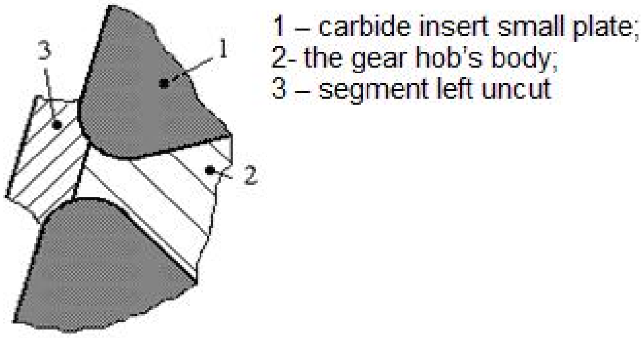

Figure 4 The uncut area next
to the small plates

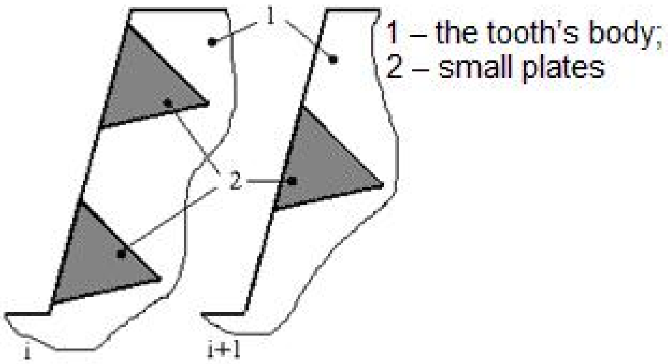

Figure 5 Version of small plate arrangement
on the tooth's line

The plates' arrangement according to figure 2 c is being detailed as follows. As it can be noticed in figure 5, a complete flank line is obtained by using kinematic superposing cutting edges, the *i+1* tooth always removing the area remained uncut by the *i* tooth.

Other methods of arranging the small plates are possible, tus obtaining a flank by the use of three or more cutting edges. In order to see the effect of the cutting edge on the size of the cutting force, we start from the following formula:

$$k_m = F_m / h_m \ b \quad [Nmm^{-2}] \tag{1}$$

If the cutting section, *A*, is maintained constant and if elements *h* and *b* are modified, it is obtained:

$$A = ct = h_{m1} \cdot b_1 = h_{m2} \cdot b_2 \tag{2}$$

If $h_{m1} \langle h_{m2}$ și $b_{_2} \rangle b_2$, then, for $A = h_{m2} \cdot b_2$

it is obtained:

$$k_m = \frac{F_m}{h_{m2} \cdot b_2} \tag{3}$$

Equation (3) shows that the specific pressure (k_m) and the cutting force (F_m) decreases while the average thickness (h_m) increases. Therefore, if we succeed to increase the cutting thickness at the same time with keeping constant the chip's section, then the cutting force decreases. This is performed by using a plate arrangement where a cutting width $b_a \cong \frac{1}{2} b$ is reached for a single pass, in the circumstances where the line's complete cutting is performed every two teeth.

It is proposed hereinafter the calculation of the cutting force in the situation in which the chip is considered to have variable thickness. This is the actual situation for gear cutting using worm cutters. If the cutting scheme requires for a constant cross-section the decrease of the length and the increase of the thickness we obtain a reduction of the cutting force that also decreases the vibration possibility.

The calculation scheme is shown in figure 6.

It is considered consider the thickness of the chip, *h*,as variable in the direction of the thickness according to a linear law:

$$h = h_1 - X\,\frac{h_1 - h_2}{b} \tag{4}$$

and the specific cutting strength dependent upon the thickness according to the polytrophic law:

$$p_C = k_1 h^{k_2} \tag{5}$$

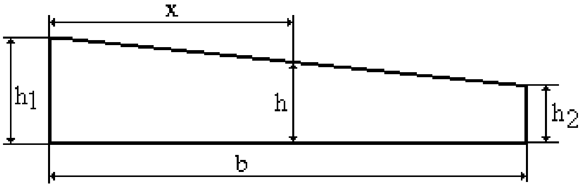

Figure 6. The calculation scheme for the cross-section of the chip

By calculating the cutting force and taking into account the average thickness we obtain:

$$h_m = \frac{h_1 + h_2}{2} \tag{6}$$

and:

$$F = \frac{h_1 + h_2}{2}\,bk_1\left(\frac{h_1 + h_2}{2}\right) \quad \text{or} \quad F = bk_1\left(\frac{h_1 + h_2}{2}\right)^{K_2+1} \tag{7}$$

The equation (7) is equivalent to the equation (1), a fact that confirms the starting hypothesis.

3. THE ANALYSIS OF THE CUTTING MOMENT FOR TOOTHING DEPENDING ON THE LENGTH OF THE CUTTING EDGE

The diagrams of the cutting moment for a continuous line cutting edge and for an interrupted cutting edge will be used, by using a similar scheme to the one presented above. The purpose is to obtain an as low moment variation as possible, which actually means a minimum variation of the cutting force which generates and perpetuates vibrations within the system, as it has already been shown.

Based on the information above, an interrupted cutting edges gear hob was performed, created by changeable sinter carbide insert small plates. The tests were performed at PROMEX Brăila.

The hob is presented in photo 1 and a pair of assemblied knives can be observed in photo 2.

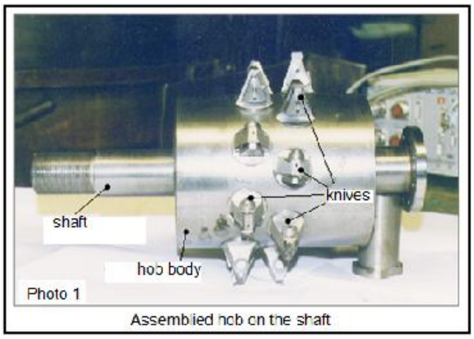

Photo 1

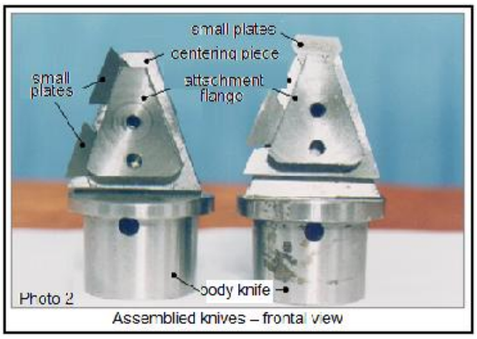

Photo 2

Therefore, a variation of the cutting moment as the one in figure 7 has been emphasized by the experimental measurements for a gear hob with continuous cutting edge on the flank.
If a cutting edge interruption is applied, which is possible by using sintered carbide insert small plates, a variation such as the one in figure 8 resulted.

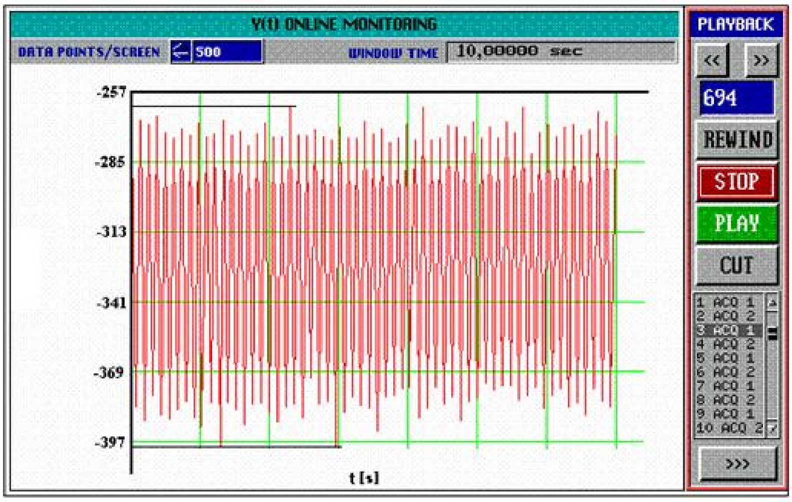

Figure 7 Cutting force variation - classic hob

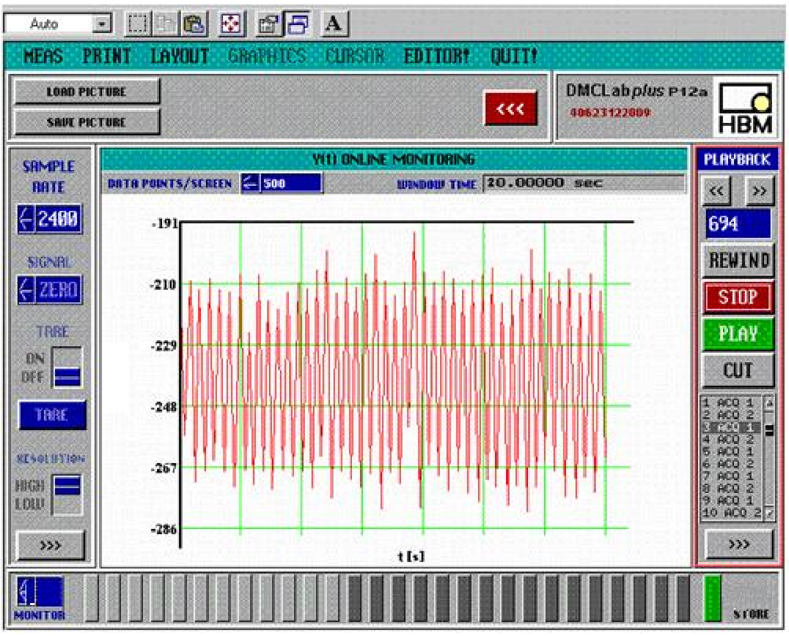

Figure 8 The diagram of the moment's variation
for the proposed hob

As a result of performing the samples and the tests, as well as of studying the results of the analyses, some performances and advantages that the proposed gear hob has, compared to the classic gear hobs, have been highlighted.
The building of such a gear hob allows to assembly a cutting tool which, under concrete working circumstances, has the cutting edges arranged in a patern that the total cutting effort, throughout the entire tool, presents an as good as possible homogenity. The assembling rule or method can be easily guessed, by testing the mathematical pattern for as many combinations of applying the cutting edges on the tooth. The mathematic pattern allows the effort's evolution both throughout the gear hob and on each cutting edge of every single tooth.

4. CONCLUSIONS

In the case of every cutting process, the variation of the cutting force has the effect of introducing the self sustained vibrations into the system. A version of vibration reduction by the decrease of dynamic non-uniformities in the cutting process has been proposed, performed and experimented.
Therefore, by interrupting the cutting edge, the reduction of the cutting force results, which is equivalent to the reduction of vibrations in the elastic system.
Specifically, in the gear tooth processing, reducing the cutting force, which is the main source of vibration, is made by decreasing cutting width while increasing the thickness of chips.
So if it succeeds increasing the thickness of the cutting while maintaining constant chip section, the cutting force decreases. This is done using the placement of the cutting plate so that at a complete passage to achieve an entire cutting width, while the full cutting of the contour is carried out at two teeth.
Besides the vibration reducing the up described method permits also to obtain a higher quality of the processed surface.

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