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ASPECTS ON SPURS ELASTIC DISTORTIONS AND THE METHOD TO DECREASE THEM

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ABSTRACT: As a consequence of the forces being exercised in the grinding process, the teeth of the tool, as well as those of the gear to be processed suffer a series of elastic deformations, which are, in the end, translated into profile errors. A solution for avoiding these inconveniences is the design of wheel-grinders, which are to keep an even number of contact points throughout the whole processing.

The pressure necessary for the removal of the grinding additions is obtained either by an approaching of the grinder's and gear's axes, thus obtaining a radial advance and a steady gearing, or by the braking of the conducted gear from the grinder gearage – gear that leads to an unsteady gearing. Seemingly, in the first case, the overlapping of the teeth is symmetrical during the gearage, but, because of the drawing in the rotation movement, there appears a discharge of opposite flanks, thus reaching a situation comparable to that of the unsteady gearing, concerning the repartition of forces. This fact especially appears when throughout the whole length of the line of gearing there is an odd number of contact points.

The asymmetrical load of the teeth determines the appearance of a series of elastic deformations, for both the gear's and the grinder's teeth. This deformation leads to the moving of the contact point between the two flanks in comparison with the theoretical contact point of the undeformed teeth. The common normal no longer passes through the theoretical gearing pole, whereas the transmission relation differs from the one that was designed. Furthermore, these deformations cause the section of the material detached from the flank of the processed tooth to be inconstant and, therefore, there arise processing errors, especially profile errors. The sums of the deformations of the gear's and grinder's teeth has a constant part – whose negative influence is eliminated by increasing the number of passes – and a variable part, whose extreme value is determined as the difference of the sums of the grinder's and gear's teeth deformations at the beginning and the end of the grinding, respectively.

The determining of the grinder's or gear's tooth's deformation in the grinding process is difficult, as the grinder gears with the gear conformant to a cylindrical cross-axed gearing. The status of deformation of the teeth in contact can be determined by good approximation, by studying the equivalent gearing. In this case, in correlation with figures 1 and 2, the following can be affirmed.

The normal force that solicits the tooth has a direction according to the gearing line, and is decomposed in its point of application in a component perpendicular on the symmetry ax and another one parallel to the latter. Meanwhile, the relative sliding friction force of the teeth's profiles in the gearing, which shares the relative speed's direction, is decomposed in the same directions.

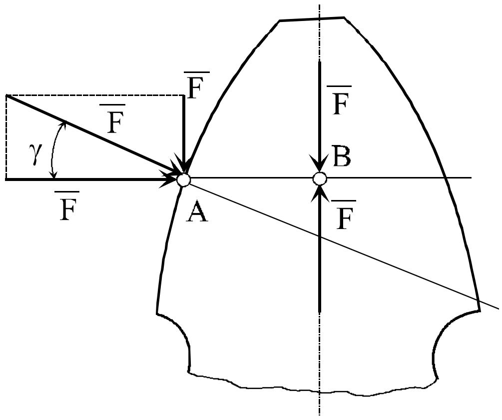

Figure 1
The decomposing of the normal force on the tooth

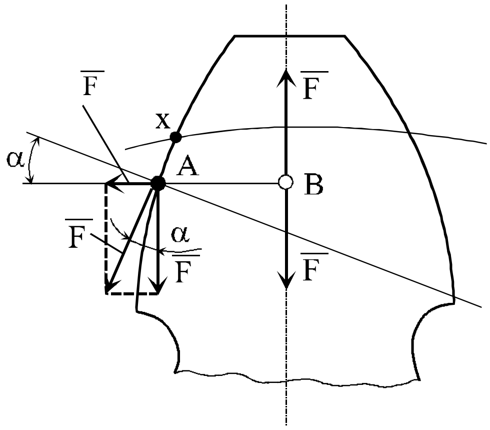

Figure 2.
The decomposing of the friction force on the tooth

The solicitations which appear as a consequence to the forces that take action on the tooth are:

– the positive bending of the tooth, as a consequence to the action of the force Ft which generates a y1 arrow;

– the shredding of the tooth, as a consequence to the action of the force Ft, which generates a y2 arrow;

– the negative bending of the tooth, as a consequence of the action of the couple Fr·AB, which generates a y3 arrow;

– the Fr force, bridged on the tooth's ax, determines the swelling of the section underneath its application point, and moves the point A; this movement can be assimilated to a bending arrow y4[25];

– the F force determines a herzian deformation of the tooth's profile, which can be assimilated to a bending arrow y5;

– the Fft force diminishes the effects of the force Ft, for both bending and shredding, shrinking arrows y1 and y2 by the values y6 and y7;

– the Ffr force, bridged to the point B, compresses the tooth and moves the point A, moving assimilated to the effect of the bending arrow y8;

– the couple Ffr·AB negatively bends the tooth and generates a y9 arrow.

The considerations regarding the effect of the friction force are valid in the case that its direction is in conformance to figure 2, as the direction of the friction force varies on its height, and changes its direction in the gearing pole.

These have been considerations regarding the qualities of elastic deformations which appear in the grinding process. For the expansion of the calculi we recommend to those interested the study of work [26]. Given that which has been presented, it can be concluded that the deformation status of the grinder's teeth and that of the gear are closely dependant to the force F, and the number of flanks in contact at a certain moment.

The prejudicial effect of the teeth's deformations can be diminished either by making an ununiform addition on the gear's tooth, or by modifying the profile of the grinder's tooth according to a series of experiments. Action can also be taken through avoiding an odd number of contact points between the flanks.

Although, in the case of radial advance grinding, as a consequence to the rotating movement of the two gears, there is obtained a gearing comparable to an unsteady gearing, it can still be affirmed that on the left and right flank there take action two resultant forces, Ps and Pd, which are inclined by the angle ρ compared to the gearing line. These two forces are combined in a resultant pressure force A, which has a radial component, Ar (figure 3). Through the entering and exiting of the teeth in and from the gearing zone, forces of different sizes are attributed to the sections in contact. In the rolling point, where there takes place just a pure rolling, without sliding, the angle ρ modifies its direction, and, therefore, the forces that take action on the tooth are jump modified, too.

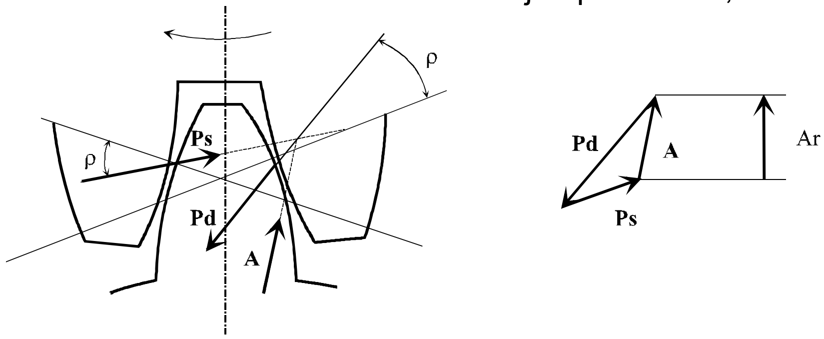

Figure 3. The forces that take action on the flank of a tooth;
Ps and Pd – the force that takes action on the left (right) flank;
Ar – the radial pressure force; ρ - the angle of friction

Figure 4 shows the variation of the forces Ps and Pd, which take action on the flanks of the tooth, and also their mean value, Pm, on a gearing section. Along the gearing line, contact in 2, 3 and 4 contact points has been considered between the flanks. From the figure there can be observed the jump in the gearing pole.

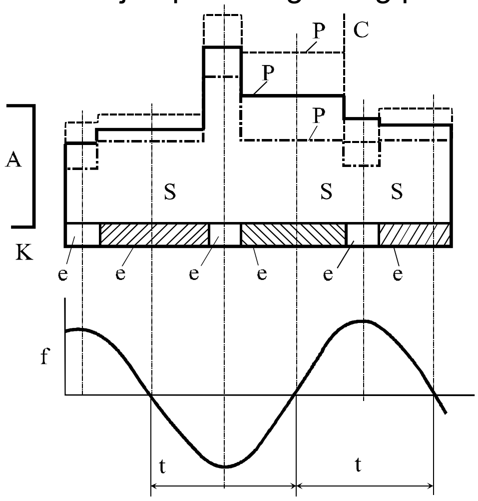

Figure 4. The variation of forces along the gearing line. K – the head on the gearing line;
C – the rolling point; Ps, Pd – the force on the left (right) flank; Pm – the median force;
Ar – the radial force; S – symmetry point; ff – the error on the flank; tg – the base pitch;
e2, e3, e4 – the contact on two, three and four flanks respectively

Following the measurements that have been performed on a large number of grinded pieces, three points have been discovered, for which the profile error is zero. These three points of the right flank have a correspondent, on the gearing line, of three symmetry points s1, s2, s3, decaled by ½ of the base pitch. As it can be seen in figure 4, the mean force Pm has a maximum on one of the three flanks, and two minimums on the other two. It is also found that the profile errors are maximal in the areas where the contact is made in three points. For the diminishing of these error, the avoidal of the areas of contact of flanks with an odd number, and the placement pf the gearing pole on the portion of passing from one zone of contact with an even number to another with an even number also, is pursued. In conclusion, for the avoidal of profile errors, a moving of the grinder's profile and a concordant establishment of the exterior diameter is pursued.

Following the notations in figure 5, an efficient method can be deduced, for determining the optimal gearing angle of grinding and the exterior diameter of the grinder. This method consists in assuring that when a pair of teeth exits the gearing, a new pair of teeth enter the gearing, so that a four-point contact can be established.

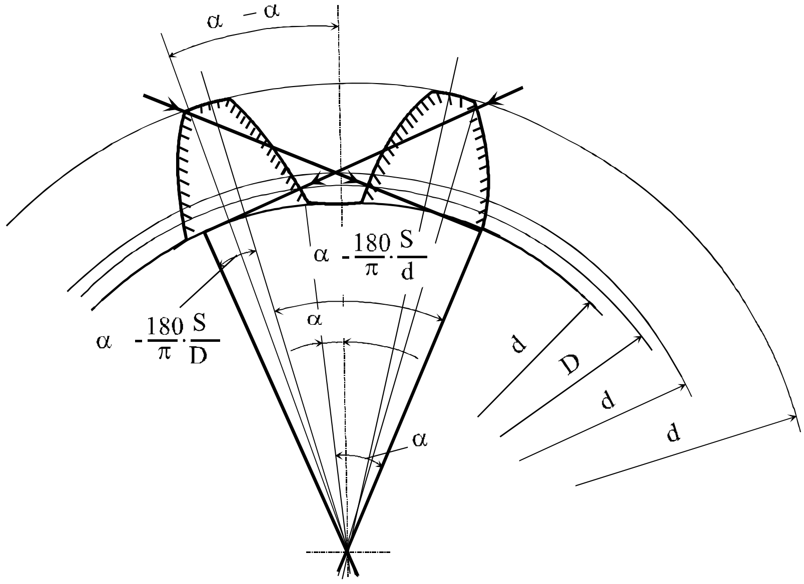

Figure 5. The determination of the optimal gearing angle of grinding

For this, the angle of pressure of the profile on the head of the gear's tooth in frontal plane is determined, as is the thickness of the head of the gear's tooth in frontal plane.

$$\cos\alpha_{e1} = \frac{d_{b1}}{d_{a1}}; \quad s_{e1} = d_{a1} \cdot \left(\frac{s_{d1}}{d_1 \cdot \cos\beta_1} + inv\alpha_t - inv\alpha_{e1} \right) \tag{1}$$

The pressure angle of the gear corresponding to the minimum grinded diameter is determined using the formula:

$$\cos\alpha_{m1} = \frac{d_{b1}}{D_{u1s}} \tag{2}$$

whereas the thickness of the gear's tooth in frontal plane will be:

$$s_{m1} = D_{u1s} \cdot \left(\frac{s_{d1}}{d_1 \cdot \cos\beta_1} + inv\alpha_t - inv\alpha_{m1} \right) \tag{3}$$

With this preliminary data, the gearing angle in frontal plane of the gear can be determined:

$$\alpha_{1f} = \frac{1}{2} \cdot \left[\alpha_{e1} + \alpha_{m1} - \frac{180}{\pi} \cdot \left(\frac{s_{e1}}{d_{a1}} + \frac{s_{m1}}{D_{u1s}} \right) \right] \tag{4}$$

For determining the angle of gearing in normal plane, the gear's rolling cylinder's diameter is established, as is the inclination angle of the gear's teeth on this diameter.

$$D_{1r} = \frac{d_{b1}}{\cos\alpha_{1f}}; \quad tg\beta_{r1} = \frac{D_{1r}}{d_1} \cdot tg\beta_1 \tag{5}$$

The determining of the angle α1s is done by using the formula:

$$tg\alpha_{1s} = tg\alpha_{1f} \cdot \cos\beta_{r1} \tag{6}$$

This angle represents the angle of gearing in normal plane for the gear, while it is processed by the disc-grinder, and is further utilized for the determining of the gearing's and grinder's parameters.

The determining of the angle is done for the new grinder and for the used one, and for the half-used one also, taking into account that it gears with the processing gear by an angle that represents the arithmetic mean of the two. The processing precision of these grinders is high, as they must accomplish the gearing in conditions close to the theoretical analysis of the gearing of the gear with the grinder. This implies an extremely careful processing technology for the grinder, which leads to an increase of costs. Therefore, these grinders are used only for the processing of the gears whose profile error must fit into the high-precision class (5÷3). In the processing of gears, this procedure will be chosen as a last resort, in case the processing with increased precision of the preteething becomes too costly.

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