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ASPECTS CONCERNING FORCES IN THE SCRAPING PROCESS

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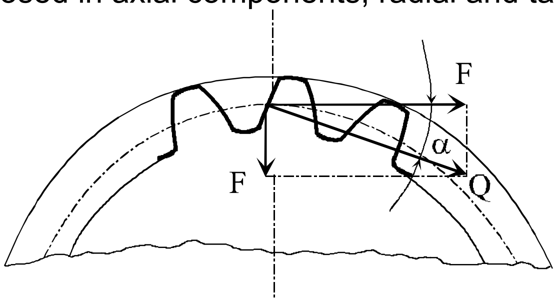
ABSTRACT: Grinding represents the processing of gears of the greatest productivity, the only disadvantage being the fact that the processing tool is extremely expensive, and is only worthwhile in the case of mass production and in large series. One of the specific aspects of this processing procedure are the dynamics of the grinding process.

The grinding process implies the lifting of thin splinters off the flank of the gear to be processed, by the canals on the flanks of the grinder's teeth. This process takes place as a consequence to the existence of a pressure force that is taking action on the gear's tooth, generated by the grinder's tooth and the relative sliding of the conjugated flanks. The pressure force arises either as a consequence to the radial advance between the grinder and the gear, advance accomplished either by the grinding machine by diminishing the distance between the axes of the grinder-gear gearing, or by braking the conducted wheel of the gearing. Following this braking, there arises a resistant moment which must be counteracted, that generates the pressure force necessary for the grinding process.

In both cases the tooth is charged with a Q force, lead by the direction of the gearing line. This force is decomposed in axial components, radial and tangential (see figure 1).



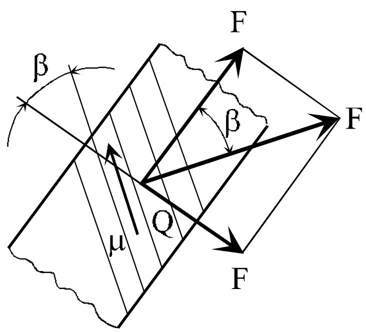


Figure 1. The forces in the grinder-gear gearing

The normal force in the direction of the teeth, Fn, depends on the force Q and the gearing angle in normal plane to the tooth:

$$F_n = Q \cdot \cos\alpha_{1s} \tag{1}$$

This force is itself decomposed on two perpendicular directions, one along the ax of the gear (or grinder), and the other perpendicular on it:

$$F_x = F_n \cdot \sin\beta; \quad F_y = F_n \cdot \cos\beta \tag{2}$$

Since between the gearing flanks there appears a considerable friction force – the gearing functions unoiled and with large specific sliding – this intervenes in a considerable proportion in the calculus of the forces in the gearing. If we consider the sliding friction coefficient μ = tgφ, we obtain the following equations:

– the tangent force:

$$F_t = F_y + \mu \cdot Q \cdot \sin\beta = Q \cdot \frac{\cos\alpha_{1s}}{\cos\varphi} \cdot \cos(\beta - \varphi) \ - \textit{for the moving gear, and} \tag{3}$$

$$F_t = Q \cdot \frac{\cos\alpha_{1s}}{\cos\varphi} \cdot \cos(\beta + \varphi) \ - \textit{for the conducted gear;} \tag{4}$$

– the axial force:

$$F_a = F_x - \mu \cdot Q \cdot \cos\beta = Q \cdot \frac{\cos\alpha_{1s}}{\cos\varphi} \cdot \sin(\beta - \varphi) \ - \textit{for the moving gear, and} \tag{5}$$

$$F_a = Q \cdot \frac{\cos\alpha_{1s}}{\cos\varphi} \cdot \sin(\beta + \varphi) \ - \textit{for the conducted gear;} \tag{6}$$

– the radial force has the same value for both gears, namely:

$$F_r = Q \cdot \sin\alpha_{1s} \tag{7}$$

As a consequence to the division errors and the error of the flank's formation especially for the gear to be processed – in the rolling process there arise transmission errors, which manifest themselves as fluctuations in speed. Through the modification of peripheric speed, because of the moments of inertia of the gear and grinder, their teeth are solicited by a supplementary dynamic force, which is translated into elastic deformations of the teeth. The dynamic force overlaps the force in the gearing, therefore influencing the grinding process. Its fluctuations determine the perturbation of the grinding process and, in consequence, there appears a modification in the thickness of the layer of material taken away by the grinder, fact that leads to errors in the gear's tooth's profile.

Since the grinding is accomplished through the gearing between the gear and the tool with an ax crossing angle, the contact between flanks is established in a single point. In the case of pressing the flanks, the contact point widens into an ellipse spread on the length of the tooth, the size of which is dependant to the size of the curving radiuses of the flanks in contact, the ax crossing angle, the pressure force, as well as the elasticity of the material. Figure 2 shows the shape of the flatting ellipse, and its dimensions are calculated with the formula:

$$L \cong 2 \cdot \frac{\sqrt{2 \cdot b \cdot \left(r_1 \cdot \sec^2\beta_1 + r_s \cdot \sec^2\beta_{ds}\right)}}{\left(tg\beta_1 \pm tg\beta_{ds}\right) \cdot \sqrt{\sin\alpha_{1s}}} \tag{8}$$

In this relation, "b" represents the elastic flatting necessary for the transversal splinting on the longitudinal ax of the ellipse, and is recommended to be equal to 2.5μm. According to Hertz, one can write:

$$\left(\frac{b}{2}\right)^2 = \frac{8 \cdot Q \cdot \rho \cdot \left(1 - \nu^2\right)}{\pi \cdot E \cdot L}; \qquad \frac{1}{\rho} = \frac{1}{\rho_1} + \frac{1}{\rho_s} \tag{9}$$

where the notations are:

Q – the pressure force;

E – the elasticity module;

τ1 and τs – the radiuses of the division circles of the gear and the disc-grinder;

$\rho 1$ and ρs – the curving radiuses of the teeth of the grinder and gear in normal section;

v – Poisson's coefficient = 0.3.

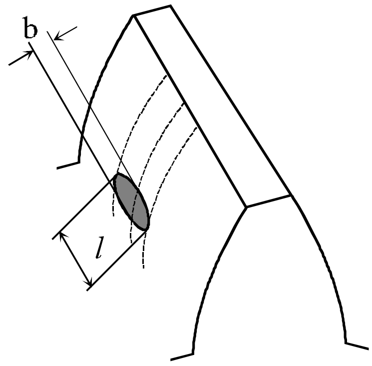


Figure 2. The shape of the flatting ellipse

It can be concluded that, the greater the ax crossing angle, the more the length of the ellipse decreases, and the splintering capacity grows. On the other hand, the guidance of the teeth in gearing grows. The optimal crossing angle of the axes is recommended to be between 10° and 15° for the processing of steel gears, and up to 20° for the processing of gears made of cast, non-ferrous metals and plastic.

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