INCREASE OF PERFORMANCE OF GRINDING BY PLATE CIRCLES

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ABSTRACT:

A method is proposed for increasing the grinding efficiency of gear wheels by two disk wheels. The possibility of increasing grinding capacity on machines working in two circles by the method of bending without reducing the accuracy of processing has been revealed. The conditions for increasing the processing capacity are determined when placing the disc wheels in one and two adjacent cavities of the treated wheel.

Keywords: *disc wheels, cross travel, angle of adjustment, machining accuracy*

1. INTRODUCTION.

Grinding with disk circles is used as a finishing operation in the production of gears of heavy loaded high-speed gears, which are usually made of surface hardened alloy steels.

The machining by two disk circles can be carried out according to the schemes with zero and with 15-degree profile grinding angles. The process of grinding is accompanied by the release of a large amount of heat in the cutting zone, resulting in phase and structural changes in the surface layer of the teeth of the wheels being treated, leading to a decrease in operational reliability. The zero-degree method of gear grinding is characterized by a greater thermal stress in conjunction with the 15-degree method. This is explained by the fact that when grinding on the zero scheme, each point of the lateral surface of the tooth is subjected to multiple thermal effects [1 - 6]. Despite the fact that the 15-degree grinding method is less heat-stressed, it is rarely used because of low productivity.

It is proposed in [7 ± 10] to increase the productivity of gear grinding by using circles of cubic boron nitride. The disadvantage of using such circles is the need for expensive modernization of the machines to enable the adjustment of the wheels.

This predetermines the need to search for alternative technical solutions aimed at increasing the productivity of the grinding process with disk circles.

2. MATERIALS AND RESEARCH RESULTS.

Angle of installation of grinding wheels on the gear grinding machine α_i is equal to the sum of the angles (fig. 1, fig. 2):

$$\alpha_i = \alpha_1 + \beta \tag{1}$$

Angle α_1 is determined by the formula:

$$\alpha_1 = \frac{\alpha_{max} + inv\alpha_{max}}{2} - inv\frac{arctga_{max}}{2}; \tag{2}$$

$$\alpha_{max} = arccos\frac{R_{\partial.0} \cdot cos\ \alpha}{R_{\partial.0} + 1{,}2 \cdot m + 2}. \tag{3}$$

Angle β depends on the grinding method and is determined:

– when the grinding wheels are located in the adjacent cavities of the gear wheel (Figure 1) according to the formula:

$$\beta = \frac{\pi}{2 \cdot z} - (inv20° - inv\alpha_1); \tag{4}$$

- when grinding wheels are located in the same hollow of the gear wheel (Fig. 2), using formula:

$$\beta = \frac{3 \cdot \pi}{2 \cdot z} - (inv20° - inv\alpha_1) \tag{5}$$

The length of the transverse stroke of the table depends on the angle of installation of the circles, and the length of the transverse stroke of the table depends on the machine time.
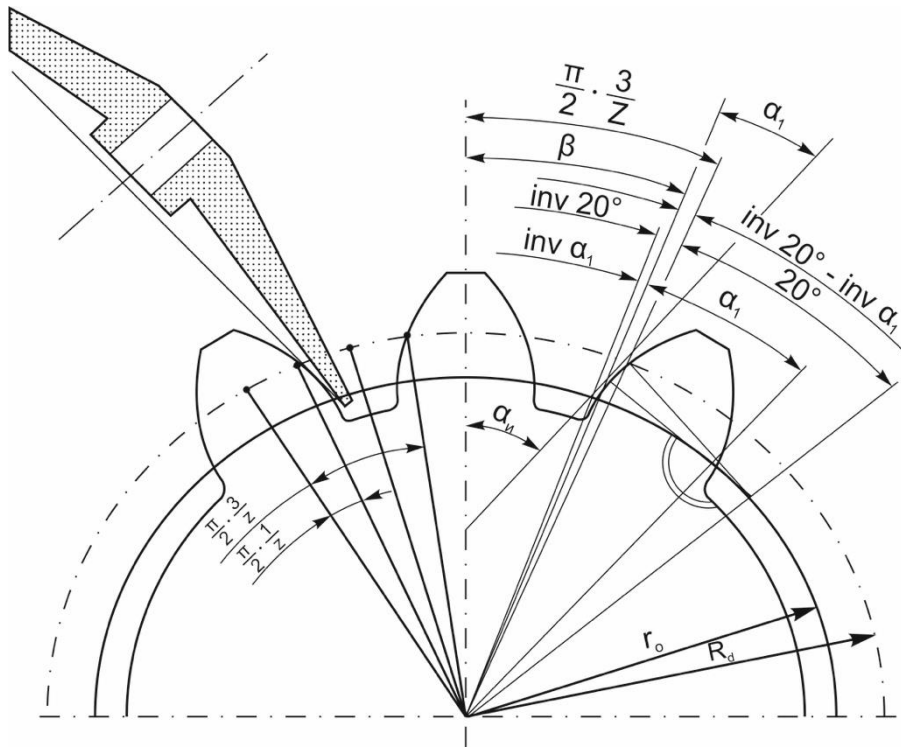
Figure 1 – Scheme of grinding with the arrangement of circles in adjacent cavities of the gear wheel
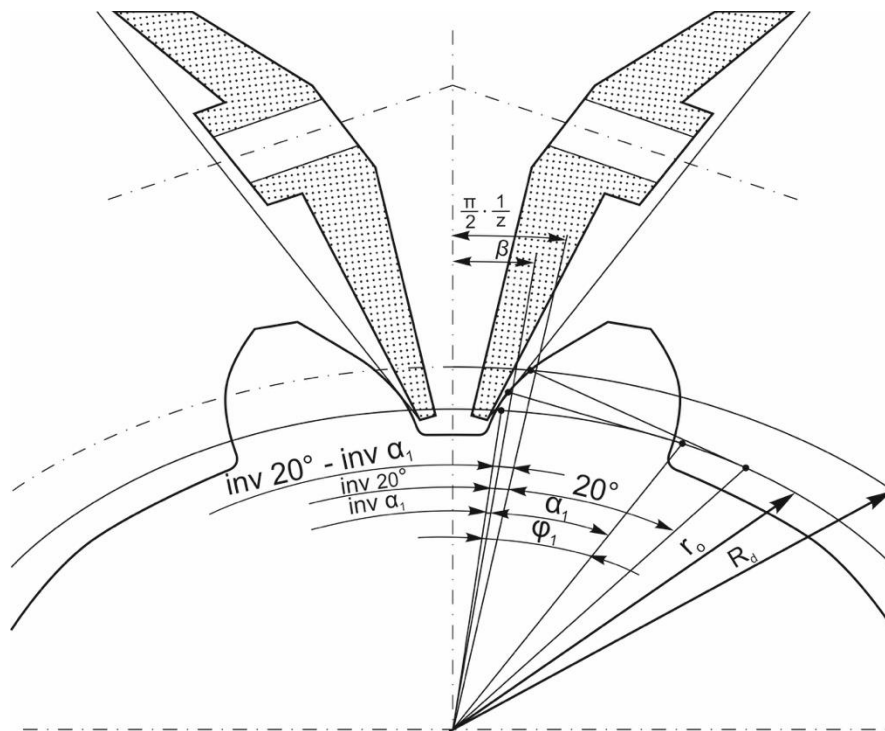

Figure 2 - Scheme of grinding with the arrangement of circles in a single groove in the gear wheel

Analytical dependences are proposed for calculating the length of the transverse course of the table and the angle of installation of the grinding wheels when they are placed in one depression (6) - (8) and in adjacent valleys of the treated gear wheel (9) - (11).

$$l_{x.c.\text{расч}} = 2 \cdot \left(\alpha_{\text{и.расч.}} - \frac{\pi}{2 \cdot z} + inv20^\circ\right) \cdot R_{\partial.0} \cdot \frac{\cos 20^\circ}{\cos \alpha_{\text{и.расч.}}} \; ; \qquad (6)$$

$$l_{x.e(15)} = 2 \cdot \left[\frac{\sqrt{\left(\frac{m \cdot z}{2} + 1{,}2 \cdot m + 2\right)^2 - r_0^2}}{r_0} - \left(\frac{15^\circ}{57{,}32} - \frac{\pi}{2 \cdot z} + inv20^\circ\right)\right] \cdot R_{\partial.0} \cdot \frac{\cos 20^\circ}{\cos 15^\circ} \quad (7)$$

$$\alpha_{\text{и.расч.}} = \frac{\sqrt{\left(\frac{m \cdot z}{2} + 1{,}2 \cdot m + 2\right)^2 - r_0^2}}{2 \cdot r_0} + \frac{\pi}{2 \cdot z} - inv20° \qquad (8)$$

$$l_{x.c.\text{расч}} = 2 \cdot \left(\alpha_{\text{и.расч.}} - \frac{3 \cdot \pi}{2 \cdot z} + inv20°\right) \cdot R_{\partial.0} \cdot \frac{\cos 20°}{\cos \alpha_{\text{и.расч.}}} ; \qquad (9)$$

$$l_{x.e(15)} = 2 \cdot \left[\frac{\sqrt{\left(\frac{m \cdot z}{2} + 1{,}2 \cdot m + 2\right)^2 - r_0^2}}{r_0} - \left(\frac{15}{57{,}32} - \frac{3 \cdot \pi}{2 \cdot z} + inv20°\right)\right] \cdot R_{\partial.0} \cdot \frac{\cos 20°}{\cos 15°} \qquad (10)$$

$$\alpha_{\text{и.расч.}} = \frac{\sqrt{\left(\frac{m \cdot z}{2} + 1{,}2 \cdot m + 2\right)^2 - r_0^2}}{2 \cdot r_0} + \frac{3 \cdot \pi}{2 \cdot z} - inv20° \qquad (11)$$

Analysis of these dependencies shows that the length of the transverse stroke of the table depends on the characteristics of the treated gear: the module, the number of teeth, the radius of the dividing circle. With a decrease in the length of the transverse stroke of the table, the inertia of the swinging parts of the machine decreases, the deformation of the lines of the rolling mechanism decreases and, as a consequence, the accuracy of machining of the gear wheel increases.

An analytical formula is proposed for calculating the number of double transverse table moves per minute

$$n_{\text{расч.}} = \sqrt{\frac{l_{xc15°} \cdot n_{15}^2 \cdot R_{r15}^2 \cdot J_{15}}{l_{xcr} \cdot R_{r15}^2 \cdot J_r}} \qquad (12)$$

where l_{xc15} — length of idling; n_{15} — number of table swings, J_{15} — moment of inertia of the swinging parts of the machine; R_{r15} — radius of the rolling roll, corresponding to a 15-degree setting of the machine.

With a decrease in the length of the transverse stroke of the table, the number of strokes per minute increases, and this leads to a decrease in the machine time

$$T_m = \frac{L_x}{n \cdot S} z \cdot K \cdot M \qquad (13)$$

where L_x — length of longitudinal travel of table, m; S — longitudinal feed, mm/min; n – Number of passes; K = 1 with bilateral separation; K = 2 at unilateral separation.
A formula has been derived for calculating the inertia force of the oscillating parts of the machine, the analysis of which shows that by reducing the length of the transverse stroke of the table it is possible to increase the number of its oscillations, while maintaining the inertia of the swinging parts of the machine and the accuracy of processing:

$$P_j = \frac{l_{x.c.} \cdot J}{R_p^2} \cdot \left(\frac{2 \cdot \pi \cdot n}{60}\right)^2 \qquad (14)$$

where $-$ J – moment of inertia of the swinging parts of the machine; n – the number of double transverse table moves per minute; $R_p = \frac{m \cdot Z \cdot \cos 20°}{\cos \alpha_u}$ — radius of the breakout roller.

In Fig. 3 shows the dependence of the length of the transverse stroke of the table (a) and the machine time (b) on the number of teeth and modules of the wheels being machined.

Analysis of these dependencies shows that the length of the transverse table travel and machine time on machines with a 15-degree circle setting is greater than on machines configured for the design angle of the producing strip. On average, the optimization of the setting angle of the wheels reduces the machine time by 20%. If we take into account that the total processing time is 6 - 7 hours, then the reduction of machine time by 20% reaches 40 minutes.
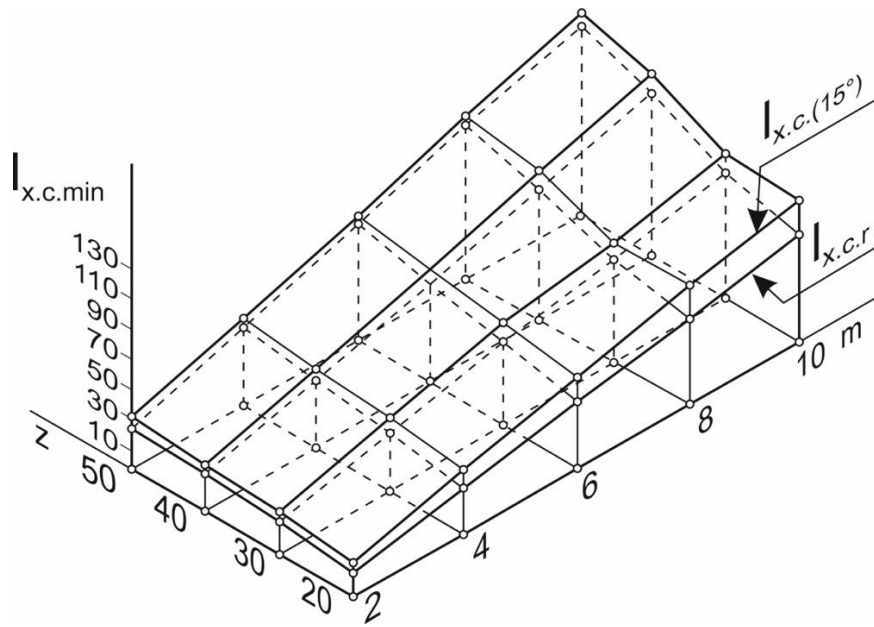
a)
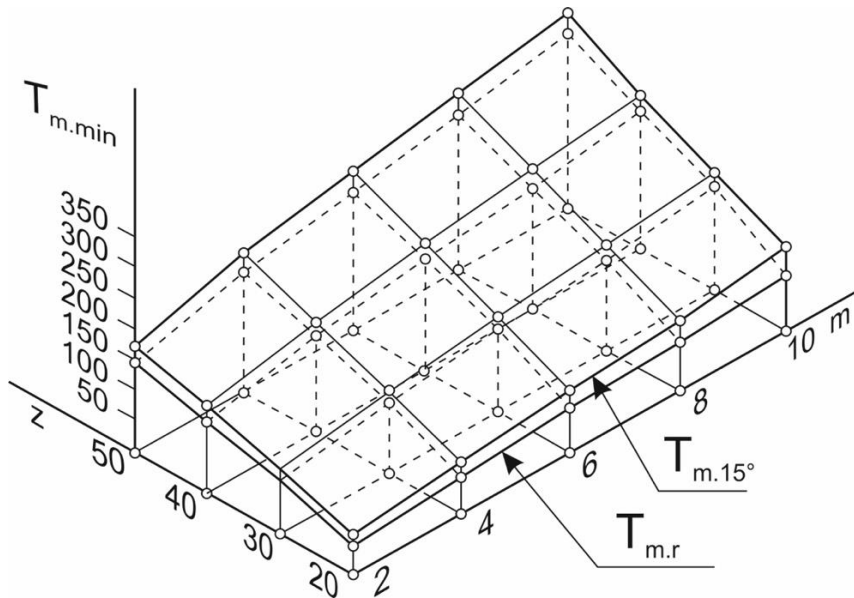
b)

Figure 3 - Dependence of the length of the transverse stroke of the machine table (a) and machine time (b) on the number of teeth and the machined wheel module

It can be seen from the nomogram (Fig. 4) that if the gears differ in a different combination of numbers of teeth and modules, then for each of them there is an optimum angle for setting the circles corresponding to the minimum length of the transverse stroke of the table. With the help of the developed nomogram, it is possible to select the optimal angle of adjustment of the disc wheels for any wheel, in which the machine operating time of the gear grinding will be minimal.
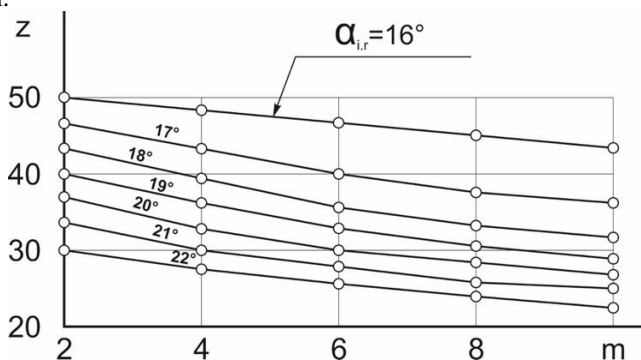
Figure 4 - Nomogram for selecting the angle of installation of disk circles $\alpha_{ir.}$ on the machine (circles are located in one cavity), at which the machine operation time will be minimal

3. CONCLUSION

1. The possibility of increasing the productivity of gear grinding on the machines working with two disk abrasive wheels by the method of bending around the 15-20-degree scheme without reducing the accuracy of processing by increasing the number of swings of the table and turning of the grinding wheels to the calculated angle at which the inertia of the swinging parts of the machine decreases, as a result, the deformation of the rolls of the rolling mechanism decreases.

2. A nomogram was developed with the help of which it is possible to select for each wheel the optimal adjustment angle of the disk wheels, in which the machine operating time of the gear grinding will be minimal

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