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Technological Problems in Cutting of Wormwheel Teeth

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The criteria of undercutting and crest width of wormwheel teeth are presented in the paper as well as the calculations of influence of pressure angle on occurrence of these phenomena. Elaborated results indicate, that the selection of pressure angle must be related to the tooth addendum modification co-efficient and in a lesser degree, to the lead angle.

Keywords: Worm gear, pressure angle, undercutting, crest width

1. Introduction

In well design and used worm gear, there proceed systematic worm gear abrasive wear. It causes the change of teeth thickness which after some time brings to such a state, that their spalling on the top is possible. This eliminates the gear from use. Simultaneously in some cases during machining the process of tooth undercutting might occur. The undercutting reduces the working surface and might bring to its discharge. What is more such a teeth cause reduction of allowable torque in the gear transmission [1]. Both of these disadvantageous phenomena can be reduced or eliminated by controlling the worm tooth shape in the process of tooth shape design. The most disadvantages situation is the occurrence of undercutting and sharpening simultaneous. Such a gear should not be made because of lack of the basic functional properties.

2. Sharpening of worm teeth

It is assumed that the criterion for sharpening the worm tooth is a ratio quotient of real tooth thickness on the top Sw in the place shown on Fig. 1 and the axial tooth module m_0. This ratio is called sharpening index. So that the sharpening does not occur if the following condition for is satisfied.

$$S_w/m_0 \geq 0,2 \tag{1}$$

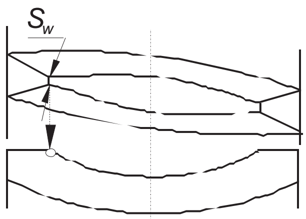

Figure 1 The place of definition of worm gear tooth crest width

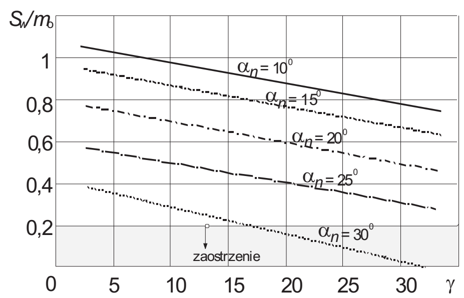

Figure 2 The variation at coefficient of wormwheel S_w/m_0 tooth crest width in the function of lead angle γ for teeth selected values of pressure angle with constant addendum modification coefficient $x = 0$

Bigger values of sharpening index should be when the effects of tooth discharge may cause heavy losses in service. In general it is considered that the crest width cause the acceptation of high value of lead angle α, and also the use of positive indexes of profile displacement. Because of complicated tooth geometry there is no convenient equations which define the values of sharpening index Sw /m0.There remains only the way of defining it on the basis of two sides tooth profile analysis, which is made during tooth machining by top of the tool addendum. Fig. 2 shows the examples of the calculations of crest width obtain by using TESTER program [2].

As it follows from the graph the wormwheel crest width during the use of criterion value $S_w/m_0 = 0.2$, with the constant addendum modification coefficient $x = 0$ and the lead angle for teeth lead angle $\gamma = 30^o$ may occur when the pressure angle is $\alpha_n = 27^o$. For example it comes from the calculations, that when $x = 0.8$, crest width sharpening may occur $\alpha_n = 20^o$.

3. Worm teeth undercutting

The undercutting of worm teeth occurs when, in the worm machining the top of a tool crosses the working profile in the point situated on active tooth flank (W in Fig. 3), so that when the following relation is satisfied:

$$r_w > r_{f2} + 0.2\,\mathrm{m} \tag{2}$$

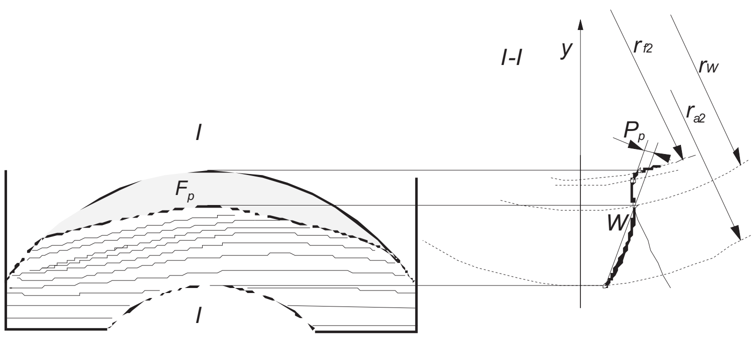

Figure 3 Undercutting of wormwheel tooth (P_p - depth of undercutting)

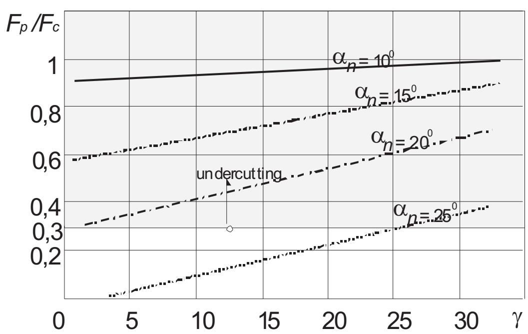

Figure 4 The results of calculations of undercutting coefficient F_p/F_c in the function of lead angle γ for meshing with addendum modification coefficient $x = -0.85$

The information about the undercutting is obtain by crossing out the active and transitory profile, based on formulas given in literature [3, 4]. In worm gears this phenomenon occurs quite often, especially in teeth of meshing with negative addendum modification coefficient. Part of a tooth area (area F_p in Fig. 5) is out of action with all negative effects of this state. It must be emphasized, that undercutting is not so dangerous for gear work as the sharpening is, because of the fact that tooth of gear undergo systematic grinding. This lead to decay of undercutting when the undercutting depth value is small (P_p in Fig. 3).

Determination of undercutting criterion is quite problematic. It seems that the coefficient, with in best way shows the character of this phenomenon is, a percentage used surface which is out of action. This index may be determined with satisfactory accuracy from the figure, in which the contact lines are presented in projection on gear tooth surface. It is shown on the left side of Fig. 5, which is also printed out from the TESTER program. Because of complicated tooth gear shape, there is no relationship between undercutting and tooth braking resistance. Considering the reduction of gear load with undercut profile [1] it can accepted that maximum value of undercutting is in about 30

$$F_p \geq 0.3F_c \tag{3}$$

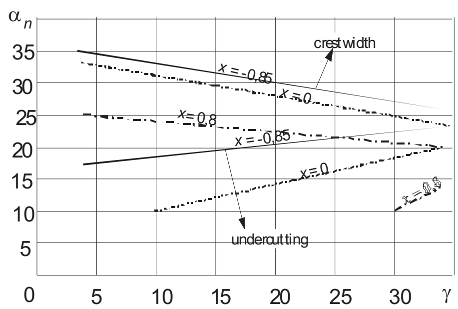

Figure 5 The range of recommended values of pressure angles ?n in the function of lead angle γ for selected values of addendum modification coefficient x (assumed S_w/m_0 and F_p/F_c)

In Fig. 4 the calculation results are presented (obtained by the means of TESTER program) of undercutting index F_p/F_c in the function of lead angle γ for meshing with addendum modification coefficient $x = -0.85$. As it follows from the presented graph the worm teeth undercutting might already occur when the lead angle is $\alpha_n = 21^o$, and if we apply criterion value $F_p = 0.3$ with the addendum modification coefficient $x = -0.15$ and the wormwheel crest width.

4. The influence of pressure angle on undercutting and sharpening of wormwheel teeth

During analysis of the obtained results, it is observed that with given pressure angle the lead angle and addendum modification coefficient have influence on sharpening and undercutting. It is presented In Fig. 5 that for chosen addendum modification coefficient, the influence of crest width on sharpening and undercutting, when the criterion values S_w/S_o and $F_p/F_c = 0.3$. As it comes from the graph, during the lead angle increase leads to the constraint of range of possible to apply values of pressure angle due to sharpening and undercutting. For example for $x = -0,85$

when with lead angle of $\gamma = 5^o$, the proper range of α_n is located between from 17^o and 35^o, then for $\gamma = 35^o$ as a safe we may assume only $\alpha_n = 23^o$ value. Nevertheless it should be remembered that exceeding the sharpening limit is practically unacceptable but exceeding the undercutting limit which arise from accepting the smaller values of pressure angle can accepted.

5. Conclusion

The calculations results obtained for recommended pressure angle show, that precise relations there exist among this angle and of addendum modification coefficient and in a lesser way, of lead angle. Assuming recommended values of pressure angle in accordance with this study it can be obtained the correct design of meshing, if the addendum modification coefficient is known. However it should be remembered that undercutting is much more dangerous for meshing then undercutting, because in many cases undercutting decay after some time at service. In a case when the unification of tools used for wormwheel machining would be required, the pressure angle should be assumed from the range of $17 - 25^o$.

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