MANUFACTURING AND DESIGN TECHNOLOGY OF COMBINED CORRECTED GEARING AND NON-STANDARD RADIAL CLEARANCE

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Abstract. It is shown that application of combined displacement technology while designing a gear drive makes it possible to expand the region of gearing with non-standard radial clearance. The article describes the influence of parameters of a rake generating profile, as well as the implementation of tangential displacement while cutting the tooth wheels.

1. Introduction

In the field of mechanical engineering the involute gears generated by hob cutters and pitches with standard parameters of generating profiles (PGP) are widely used. To improve both kinematic and strength parameters of such gears, the radial displacement of PGP is applied during the wheel tooth cutting [1]. The tangential displacement of tooth profiles, which is reduced to a change in the calculated thickness and height of teeth, makes it possible to place the gearing in the required interaxal distance, increase the bending strength of teeth and reduce the wear rate by changing geometrical parameters of teeth [2]. Both radial and tangential displacements of tooth profiles, including PGP application with standard initial parameters provide greater opportunities to influence the properties of involute gears. The bended strength of teeth in this case can be increased up to 60% [3]. The gears composed of tooth wheels differ from the regular ones by the quality characteristics with greater freedom in design. More opportunities are provided in case of application of gears with the combined displacement and non-standard radial clearance.

2. Manufacturing technology and a tool for implementing combined displacements

The technology of combined displacement with the help of standard tool implies the cutting of teeth with a typical radial displacement to the full tooth height after which the tool (e.g. a hob cutter) is displaced along the axis by $x_{\tau}m$ and an additional working pass is made along one (any) side of the teeth, thus, implementing a negative tangential displacement. There is no need for an additional passage if a special tool with an unequal step is provided.

The scope of standard tool application can be extended due to the side gaps j_n as a compensator for positive tangential displacement. The maximum total tangential displacement in the gearing will be determined on the basis of the following expression $x_{\tau\Sigma} = j_n/(m\cos\alpha\ )$. In this case it is necessary to adjust to the tapering of teeth caused by tangential displacement to create a backlash in the gearing as it was described above.

In the framework of the existing tooth wheel manufacturing technology a set value of the tangential displacement has to be done by the overdimension reduction during other operations instead of an additional passage during the tooth cutting, for example, when grinding or shaving the teeth. In addition, in the process of tooth wheel manufacturing with the combined displacement, the backlash has to be made not by an additional radial, but by a single tangential displacement of a tool.

When a combined tooth cutting is applied (whether a tangential displacement is performed by hobbing, gear grinding or some other method), initially, the teeth are cut to their full height with zero upper deflection and with a lower deviation within the tolerance for additional displacement of the original profile.

The region of gearing largely depends on the tool used for cutting the tooth wheel. The height of the tooth head of a tool h_a provides the greatest influence on the region. Any changes brought to the region under the influence of this parameter can be compared only with the contact ratio effect. As the h_a decreases, the blocking profile not only sharply decreases in its area, but also shifts to the region of smaller radial displacements with the simultaneous narrowing of the tangential displacements range. This leads to an interval reduction of center distances; however, the minimum value for a given number of gear teeth remains unchanged and stays independent from h_a. The possible achievable values of the radial clearances in gearing vary directly to the variation of the height factor of the head h^*_a due to the corresponding change in the diameters of the tooth space.

With the increase in the height factor of the tooth head, the opposite picture takes place. In case the central distances are equal, the tooth thicknesses remain unchanged regardless of the coefficient h^*_a.

The change in the angle of a tool profile is accompanied by significant changes in the radial displacement values, while the interval of tangential displacements remains unchanged. As the profile angle of rack generating profile (RGP) is increased, the region of gearing undergoes one-sided tension in the direction of negative values of radial displacements.

When the angle is decreased, the range of central distances sharply decreases to the zone of their large absolute values. When the values of radial displacements are equal, the teeth of the wheels have a large thickness at smaller values of the angle of RGP profile. Smaller profile angles result in wider application of a tool with an unequal step, raising its boundary to the region of positive tangential displacements. As the angle of RGP profile increases, the boundary decreases and it may reach the region of negative tangential displacements.

3. Gear drive design with the combined displacement

It is very difficult to design gears with the combined displacement when the contact ratio is given since it requires simultaneous consideration of several factors. Usually such calculations are made with the help of computer. To facilitate the solution of this problem, it is possible to determine the tendencies of changing the gearing parameters with the help of blocking profile, however, the standard profiles are designed only for the nominal radial clearance in gearing. Currently, when calculating gear drives, the initial ones are the module, the number of teeth, and the displacement ratio. The contact ration is determined at the end of the calculation when checking the quality of gearing with the view of geometric parameters. As the analysis shows, it is the contact ratio that largely affects not only the losses in gearing and the transmission resource, but also the strength parameters of the gear teeth. Taking into account the experience of using gear teeth in the transmissions of machines, it is expedient to calculate the geometry of gears at a given contact ratio, which ensures trouble-free operation of the transmission.

It is known that the choice of geometrical parameters of a full-scale gearing is significantly limited and represents a line on regular blocking profile in case the radial clearance remains unchanged [4]. The region of gearing can be expanded only if the radial clearance is changed at a given contact ratio. All this allows the designer to extend the framework of regular gearing parameters.

Let us consider the changes in the region of gearing with an alternating radial clearance. For this purpose, let us consider the blocking profile for the numbers of teeth amounting to 10/40. The thick line in Fig. 1 denotes the blocking profile for the standard radial clearance in the gearing amounting to to 0.25 of the module (m).

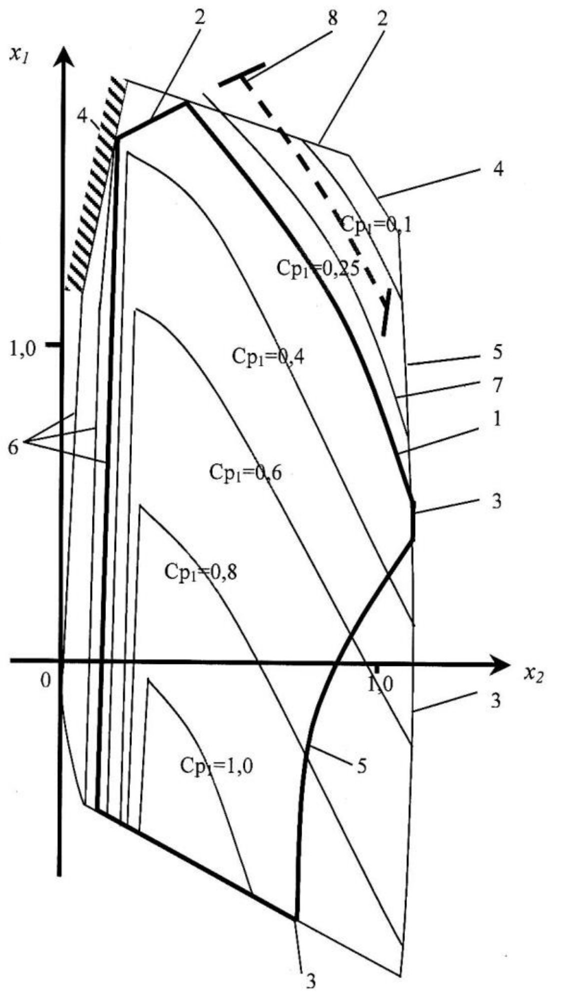

Figure 1. Region of gearing z_1/z_2=10/40

All arguments given below will hold for any contact ratio within the existing gearing. Let us consider the extreme case when the contact ratio is equal to one. The region of gearing will be limited by line 1 of standard blocking profile. The gearings with the higher contact ratio will be located on the same line, but inside the blocking profile

In order to obtain an unambiguous effect of the radial clearance on the region of gearing, only the diameters of the tip of smaller tooth wheel will be changed. The region of gearing with the given contact ratio for different radial clearances obtained by changing the diameter of the gear tips is determined by the interference boundaries: with the transition surface of the wheel - line 2, the gear tips with zero radial clearance - line 3, with the transition surface of the gear - line 4; sharpening point of the gear teeth -line 5, and the boundary of dangerous undercutting of the gear teeth - line 6. The region of gearing when changing the radial clearance is represented as a broken isoline (sometimes broken if the gearing parameters extend beyond the boundaries of the region). In Fig. 1 these isolines are represented by thin lines with corresponding values of radial clearances in the gearing. The break point of these lines corresponds to the coincidence of the lower active and boundary points (r_p = r_l). As is seen from the figure, due to the change of the radial clearance with the given contact ratio it was possible to expand the region of gearing, thus, providing an opportunity for a designer to extend the limits of regular gearing parameters.

Any changes introduced to the radial clearance in the gearing due to the diameter change of the wheel tip will also cause changes in the configuration of the blocking profile. In this case, the changes in the gearing parameters will not be identical to the changes caused by modification of corresponding gear parameters. The difference in the location of isolines with equal changes in the radial clearances in the gearing at the given contact ratio from the regular one is shown in Fig. 2 by isolines 7 (due to the changes of gear parameters) and 8 (for the wheel). The arrangement of isolines 7 and 8 in relation to the line of specified contact ratio of the standard blocking profile is allied. In this case, the left boundary of line 8 coincides with the interference boundary of standard blocking profile 2 and aggravates the gear position, transferring the boundary of tooth sharpening into the region of smaller radial displacements, i.e. the lower boundary of line 8. As for the line 7, there is a similar tendency, however, expressed in favor of the gear.

Thus, it can be said that when the radial clearances are changed due to the changes of the geometrical parameters of one of the wheels, the pairs of the interference regions of the corresponding wheel do not change, however, the state of the twin wheel is aggravated. Fig. 2 (b) shows similar blocking profile for the number of teeth in the pair of 10/10 [5-7].

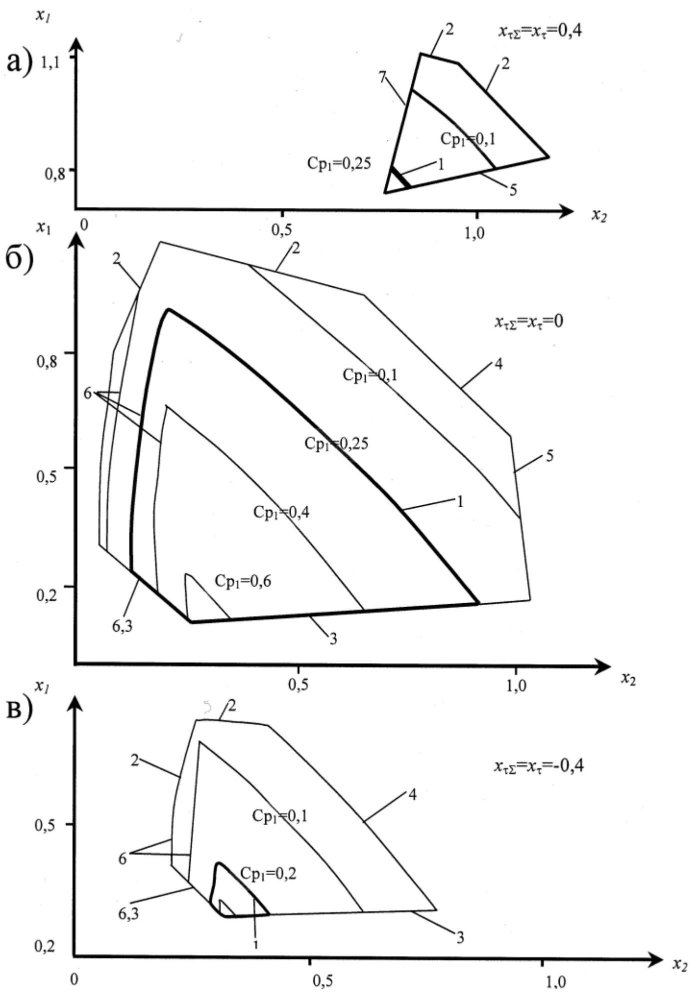

Figure 2. Region of gearing z_1/z_2=10/10

The rules for obtaining the regions of gearing remained the same, that is, the radial clearance was changed only by one of the wheels. Despite the equal number of teeth during the change of radial clearance, the closed profile or contour of isolines of a given contact ratio is not symmetric, except that it forms the profile defining the gearing with standard radial clearance $C_p = 0{,}25m$.

As it can be seen from the comparison of figures 1 and 2 (b), the changing tendencies of gearing profiles are similar. There is a slight difference in the quantitative manifestation of certain trends.

The outer profile which corresponds to the zero radial clearance in the gearing determines the gearing boundaries and consists of the lines representing the boundaries: interference with the transition surface of the wheel - line 2, the gear tip with zero radial clearance - line 3, interference with the transition surface of the gear - line 4; sharpening of the gear teeth - line 5, as well as dangerous cutting of the gear teeth and the wheels - lines 6 and 3, respectively

As shown in the previous case, the standard blocking profile is marked by the bold line, and 1 denotes the isoline of the gearing with the contact ratio equal to 1. A change in the radial clearance leads to the change in the location of profile in the coordinates of radial displacements and to the change in its dimensions, while in general the profile shape remains unchanged if the gearing parameters do not exceed the boundaries of existence limited by the outer contour or profile.

The effect on the region of gearing of tangential dislocation can be shown in figures 2 (a, c) for the coefficients of tangential displacements ($x_{\tau\Sigma} = x_{\tau 1}$) equal to +0.4 and -0.4, respectively. In this case, the entire value of the tangential displacements is referred to the gear.

The application of positive tangential displacement shifts the region of existence into the range of increased radial displacements of the gear and the wheel. In this case, the region of gearing is primarily limited by the boundaries of sharpening of the gear teeth and the wheel, i.e. lines 5 and 7, respectively.

The application of negative tangential displacement allows us to avoid tooth sharpening, i.e. Fig. 2 (c).

4. Conclusion

As it can be seen from the presented materials, the combined displacement application significantly extends the region of gearing of tooth wheels.

In conclusion, it should be noted that the tangential displacement distribution between the tooth wheels will only affect their thickness, which enhances the optimization possibilities when designing the tooth gears. Tooth wheel cutting with a tangential displacement is done with the help of a tool with standard PGP parameters.

The change of the gearing region with variable radial clearance makes it possible to expand this region. The gearing region with a given contact ratio and with different radial clearances obtained by changing the diameter of the tip of gear is determined by the interference boundaries: with the transition surface of the wheel, tips of the gear at zero radial clearance, with the transition surface of the gear, point of gear tooth sharpening and the boundary of dangerous cutter interference of the gear. When the radial clearance is changed, the gearing region is presented in the form of a broken line (sometimes broken if the linkage parameters go beyond the boundaries of the region of existence).

The influence of tangential displacement on the gearing region makes it possible to change from the planar region of gearing to the volumetric one within three coordinates: the radial displacements of the wheel and the gear (as in the conventional blocking profile) and a total tangential displacement. The application of positive tangential displacement shifts the region into the range of increased radial displacements of the gear and the wheel. In this case the region of gearing is primarily limited by the boundaries of tooth sharpening of the gear and the wheel. The use of negative tangential displacement allows us to avoid tooth sharpening.

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