THE TRANSVERSE CONTACT RATIO OF WORM GEARINGS

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ABSTRACT: *The article presents the description of the method applied to the determination of the mesh duration factor of worm gearings which is rather difficult to define when compared to that of the spur gearings. A numerical method has been used to determine the transverse contact ratio for* **involute worm.** *The above mentioned factor can be used for a dynamic calculation of drives with worm-gear speed reducers.*

Key words: gearings, worm gearings, the transverse contact ratio, involute worm

1. INTRODUCTION

In order to increase the reliability, to extend the life and to increase the loading capacity of machines, we encounter the requirement how to secure the continuity of their operation and to reduce the unfavourable dynamic effects. An optimally designed drive requires the evaluation of its condition and the occurance tendency of resonance areas or their possible restriction to acceptable amount. With the dynamic analysis of drives, which worm gearings are parts of, it is necessary to determine the toughness parameters of its individual components. The transverse contact ratio of gearings determines the way in which the multi-paired teeth meshes alternate that enables the determination of the way of these drive elements compliance fluctuation. The results obtained can be used for designing and manufacturing of gearings with the integral transverse contact ratio which from the point of the dynamic effects minimization inside the drive is the most favourable.

2. MESH FIELD

The geometry of worm gearings is more complicated than with the classical spur gearings and therefore it requires a more complex calculation. The worm gearings teeth profiles are created as envelope areas of individual areas of the tool that is identical with the worm. The geometry of the worm toothing is also created by the envelope area.

In order to specify the mesh field of the worm gearing, it is necessary to determine the contact lines, the intersection points of which, with the axis plane of the worm (or with the areas that are parallel to the axis plane), create the set of points that defines the mesh lines. The determination of the contact lines is a specific issue which leads to the searching for the common points of contact of the two space areas [1, 2].

The work [1] determines the shape and the dimensions of the gearings mesh field with the Archimedean worm by graphical – analytical method. The authors came to the conclusion that the mesh field is under the influence of the module, averaging factor, the number of the worm runs, the number of teeth and the worm gearing rim shape. Based on the previous research [2], the calculation programmes that enable the determination of the contact or mesh lines for various geometries of worms are available.

The mesh field (fig. 1) is then given by the area that is created by a set of points or curves of the mesh and contact lines that are restricted by the following areas:

- a tip cylinder of the worm
- a tip cylinder of the spiral gear
- planes limiting the rim sides of the spiral gear
- rim globoid of the worm wheel

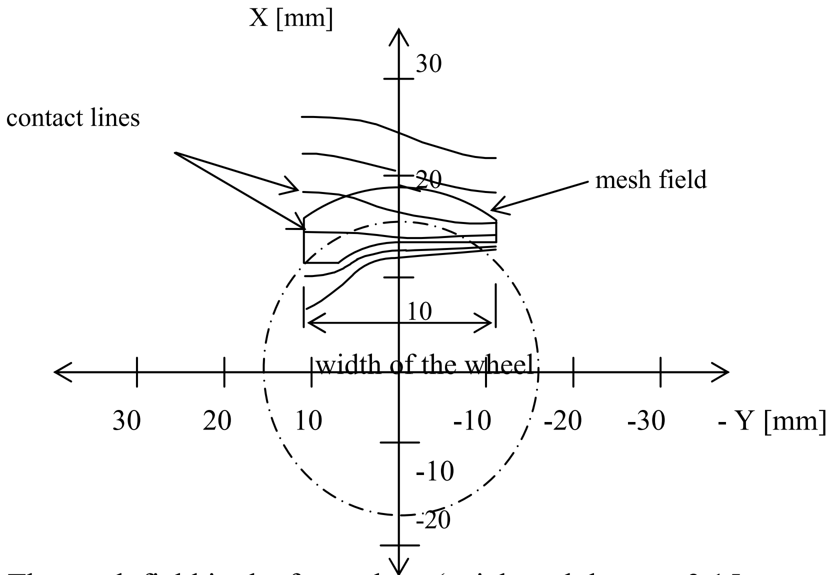

Fig. 1. The mesh field in the front plane (axial module $m_x = 3.15$ mm, number of runs $z_1 = 4$, number of wheel teeth $z_2 = 41$, lead angle $\gamma = 21.801^{o}$, involute worm)

The mesh line for the j-th section that is parallel to the axis plane of the worm is shown in fig. 2, where the points U and Z are the boundaries of the mesh. The points D_i are the points of intersection of the contact lines with the j-th section plane. Fig. 2 shows how the boundaries of the sharp beginning and the end of the mesh can be determined.

If the point D_n of the mesh line satisfies the condition, i.e. lies in the area of the real mesh and the point D_{n-1} lies outside the mesh area, there is an approximation line put down between these points, the step is softened and gradually the beginning of the mesh area Z in the section plane j is searched for by the iteration method. A similar method is used to determine the final point of the mesh line U in the same section plane. The set of points Z_j defines the curve in the space that restricts the beginning of the mesh field and the set of points U_j defines the curve that restricts the end of the mesh field.

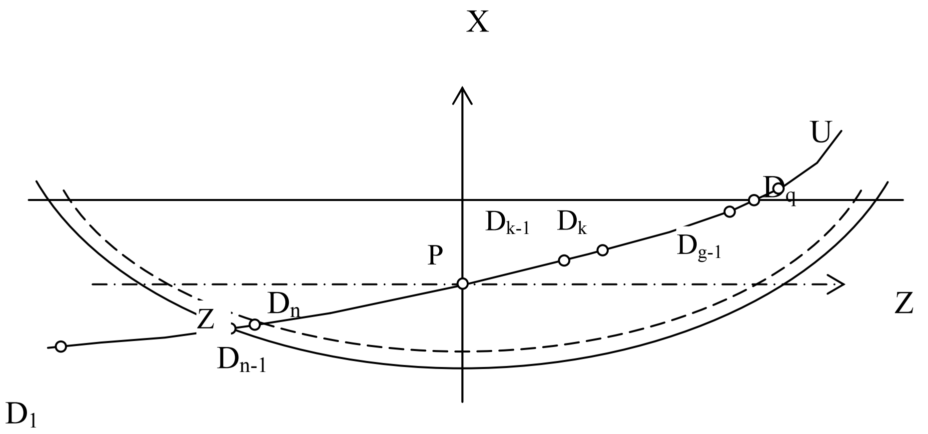

Fig. 2. Section plane j

The top view, i.e. in the direction of the axis – **X**, of the mesh field for the same parameters as in fig. 1 can be seen in fig. 3. The shape of the mesh field corresponds to those that are presented in the literature available [3]. The contact lines correspond to the individual runs (teeth profiles) of the worm.

3. THE TRANSVERSE CONTACT RATIO

The transverse contact ratio is a very important characteristics considering the mesh ratios. The transverse contact ratio of worm gearings has been analysed in the literature rather occasionally. This is due to the difficulties in determinating the mesh lines that are a part of the mesh area of a gearing. Therefore, the presented problem is being considered in a simplified form, i.e. through the replacement of a worm by a rack with oblique teeth [4]. The transverse contact ratio that is considered by this method can be approached to as the preliminary one.

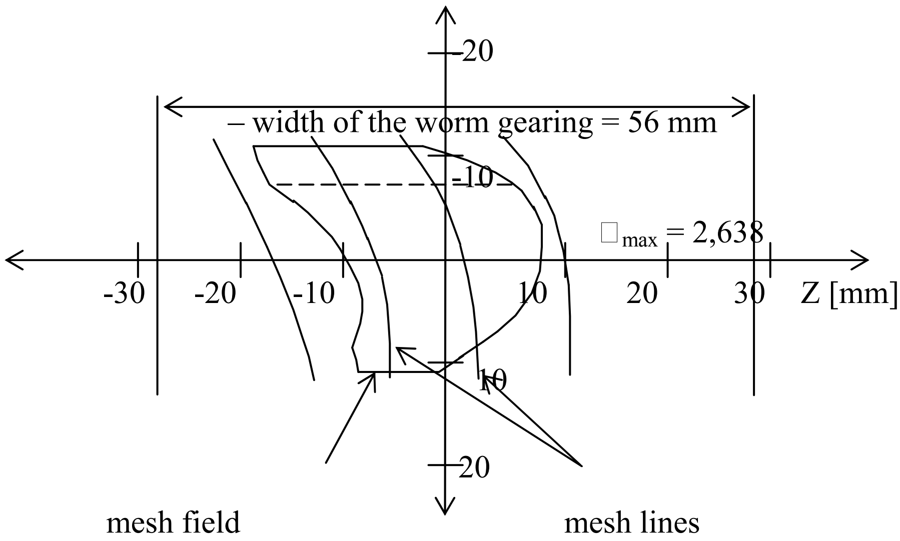

Fig. 3. The top view of the mesh field

In [5] it was proposed that the factor with the maximum value of the individual section planes that are parallel to the axis planes of the worm is considered to be the transverse contact ratio mesh of worm gearings. The transverse contact ratio in the j-th section plane was defined as follows:

$$\varepsilon_j = \frac{l_j}{p_x . cos\alpha_{\Phi j}} \quad (1)$$

where

ε_j – transverse contact ratio in the j-th section plane,

l_j – length of the mesh line in the j-th section plane, $l_j = \overline{ZD_n} + \overline{D_n D_{q-1}} + \overline{D_{q-1}U}$, (2)

p_x – axial worm pitch,

m_x – axial worm module,

$$\overline{D_n D_{q-1}} = \sum_{k=n+1}^{q-1} \sqrt{(X_k - X_{k-1})^2 + (Z_k - Z_{k-1})^2}, \quad (3)$$

$\alpha_{\phi j}$ – average inclination angle of the mesh line in the j-th section plane,

$$\alpha_{\Phi j} = \frac{\alpha_{ZN} + \sum_{k=n+1}^{q-1} \alpha_k + \alpha_{q-1,U}}{q+1-n}, \tag{4}$$

where $$\alpha_k = \operatorname{arcctg} \frac{X_k - X_{k-1}}{Z_k - Z_{k-1}}, \tag{5}$$

Fig. 3 shows the plane with a maximum factor of the transverse contact ratio of the investigated worm gearing.

The aim of the presented article is to design a more accurate and simplified method of how the transverse contact ratio with worm gearings can be determined. Based on the fact that the initial mesh point is the point Z_j having the lowest coordinate value – z and the final point of the contact is the point U_j having the maximum coordinate value – z. It can be seen from fig. 3 that these points will not lie in the same section plane. Since the values of the coordinates – z of the mesh boundary points are obtained from the section planes that are parallel to the axis plane, the determined projection length of the mesh field can be compared to the axial worm pitch.

Then for the transverse contact ratio it is valid

$$\varepsilon = \frac{Z_{U_{j\max}} - Z_{Z_{j\min}}}{p_x}. \tag{6}$$

The proposed solution gives the values of the transverse contact ratio in about 5% higher. Based on this, the alternation of the two-paired, three-paired, or multi-paired teeth meshes can be evaluated.

4. CONCLUSIONS

The presented methodology of the transverse contact ratio of worm gearings determination can also be applied to other types of the worm geometry. The results obtained can be used to determine the toughness parameters of the worm gearing (medium toughness of the gearing required for a dynamic calculation), duration of contact stress along the lines of contact that become the limiting life factor, as well as the optimum worm width.

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