

Research of the load distribution in the wave kinematic reducer with a modified tooth profile and dependence of the load abilities in proportion to its gear ratio and overall dimensions

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Abstract. Nowadays, there are many types of reducers based on work of gear trains, which transfer torque. The most popular reducers are with such type of gearing as an involute gear, a worm drive and an eccentrically cycloid gear. A new type of the reducer will be represented in this work. It is a wave reducer with the modified profile of the tooth close to the profile of the tooth of Novikov gearing. So such reducers can be widely used in drives of difficult technical mechanisms, for example, in mechatronics, robotics and in drives of exact positioning. In addition, the distribution of loading in gearing of teeth of a reducer was analyzed in this paper. It proves that the modified profile of the tooth allows distributing loading to several teeth in gearing. As a result, an admissible loading ability of a reducer becomes higher. The aim of the research is to define a possibility to reduce overall dimensions of a reducer without changing the gear ratio or to increase the gear ratio without changing overall dimensions. So, the result of this work will be used in further research.

1. Introduction

One of the main priorities of reducer industry development is an increase of permissible load and a gear ratio. The wave kinematic reducer has such characteristics as high permissible load, small dimensions, a high gear ratio, and high positioning accuracy of the output link. This reducer has a wide field of application in precision and lifting actuators.

Properties of this reducer are caused by a tooth profile, close to a profile of the tooth of gearing of Novikov. This profile allows obtaining difference in one tooth between a driven and driver gear. The modified profile of the driven gear has only a tooth top and that of the driver gear has only a leg of the tooth. During the work of a reducer, the convex profile of the tooth of the driven gear engages with a concave profile of the tooth of the driver gear. As a result, the contact area increases, this increase in load capacity improves the contacting pair. In addition, the profile of the tooth of the driven and driver gear allows receiving the minimum dimensions and the high gear ratio of the gear.

2. Features of a design of the wave reducer with the modified shape of the tooth.

Figure 1 illustrates the steps of the kinematic wave reducer. They have the same construction, but the difference makes a gear ratio of each step. The first step of a wave kinematic reducer has an eccentric shaft with an eccentric. The driven gear with the number of teeth equal to z_2 , which is established with the basic bearing on the eccentric shaft. The mechanism of parallel cranks represents the uniform



rotary knot containing two flanges, a gear wheel connected among themselves by fingers, passing through holes in the gear wheels and flanges. Flanges are installed on the driven gear in basic bearings. Basic bearings of an eccentric shaft are placed in the bores of flanges. The eccentricity of an entrance eccentric shaft is equal to the reference center distance of the driven and driver gear.

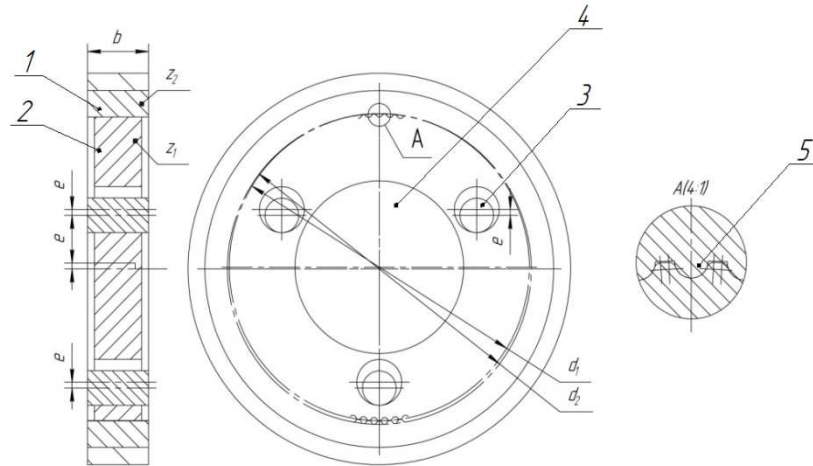


Figure 1. The design of the wave reducer with the modified shape of the tooth. 1 – The driven gear with the number of teeth equal to z_2 ; 2 – The driver gear with the number of teeth equal to z_1 ; 3 – Fingers; 4 – Eccentric shaft. 5 – Tooth shape.

The reducer works as follows: rotation of entrance eccentric shaft 4 sets the driver gear in motion. Driver gear 2, rolling on fingers 3, makes forward and rotary movements. This complex movement of driver gear 2 transmits torque to driven gear 1, which is attached to the output link [4].

3. Determination of efforts in gearing.

At contact loading, force acts on a small site of a surface; as a result, high local tension is created in a surface layer of the material. This type of loading is encountered at contact of spherical and cylindrical bodies with flat, spherical and cylindrical surfaces.

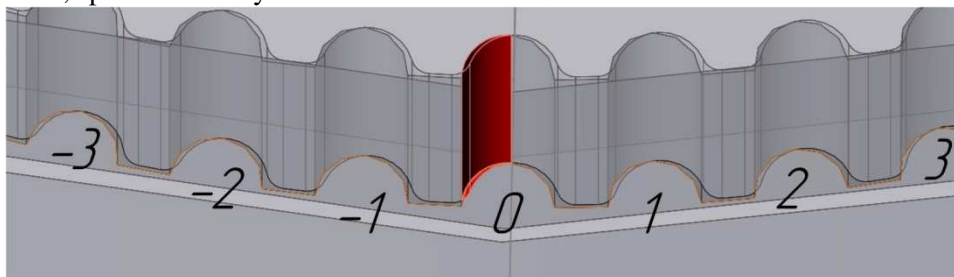


Figure 2. The number of teeth.

For carrying out the strength analysis of a kinematic wave, the reducer with the modified profile of the tooth, the SolidWorks program was used. In this program, we will make the driven gear of the reducer motionless, and we will turn the driver gear through certain small angle. At a small angle of rotation, gear has no interference, and the gear wheel passes the way equal to the value of a side play. If the angle of rotation increases, the interference of the driven and driver gear is higher (fig. 2, the red zone). Based on the obtained data, we will construct the dependence graph of the rotation angle of the driven gear on interference volume in a projection to each involved tooth (fig. 3). The graph shows that the maximum value of an interference is the share of tooth No. 0, and this tooth is more loaded in the investigation of interference. Since the difference between the number of teeth of the driven and driver gear is only one tooth, this loading is also divided into the neighboring teeth. The neighboring

teeth (teeth No. 1, 2, 3,-1,-2,-3) share this loading among themselves, and the loading is perceived symmetrically concerning tooth No. 0 [4,5].

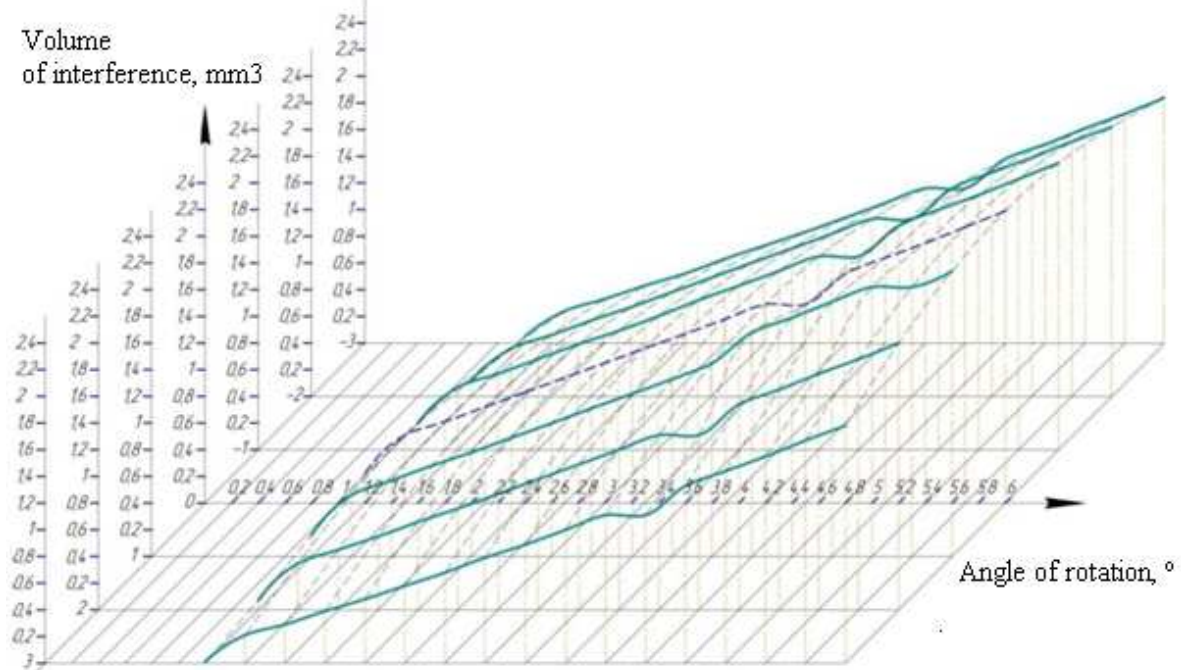


Figure 3. The dependence of the volume of interference on the angle of rotation.

4. Dependences of load capabilities in relation to overall dimensions and a transfer number of a reducer with the modified shape of the tooth.

An increase in the sizes of teeth of the driven gear does not lead to reduction of a load capability, because the distance between the teeth decreases. In this case, the neighboring teeth perceive loading of a greater amount, in comparison with the nominal sizes of a reducer. In case of the increased number of teeth in the driver gear, there is a decrease of the active part of the tooth, which perceives loading. At the same time, the load capability also decreases.

For assessment of the load ability of the reducer with the reduced number of teeth and determination of the optimum value of the number of teeth and loading, we will conduct the next research on gear wheels.

Let the driver gear be a motionless link, loading from the contact with a driven gear is perceived by the contacting area. We will load the driver gear tooth with the 1000 N to 6000 N loading; as a result, we will receive the value of tension. Knowing these data, we will determine the area of perception of loading. The size of the area of perception of loading will depend on size b (width of an active part of the tooth), determined by the number of teeth. If the number of teeth is less, value b is greater, the volume of perception of loading, the moment and the transferred load ability are greater.

If the number of teeth increases, the active part of the tooth decreases; therefore, the end of the tooth is deformed, thereof the area of contact decreases. The landing diameter of the driver gear corresponds to the external diameter of the bearing. The research was conducted in the Solid Works, the steel with a limit of the fluidity of 325 Mpa served as a gear wheel material.

From the received dependences, it is possible to draw a conclusion: loading decreases on average in the range of 1.07 – 1.1 if the number of teeth in the range is by two teeth smaller with small diameters. This implies that it is necessary to apply a reducer with the number of teeth lying in this range. In case of big diameters, loading decreases also in the range of 1.05-1.07 when the number of teeth reduces by 5 teeth. This implies the fact that it is necessary to apply a reducer with the number of teeth of the driver gear lying in this range.

The received dependences (fig. 4) allow defining the value of the maximum load ability depending on the number of teeth. Using a method of extrapolation, it is possible to receive values in points necessary for calculation of the load ability of the reducer with various values of the tooth radius. The obtained data characterize the loading of one tooth.

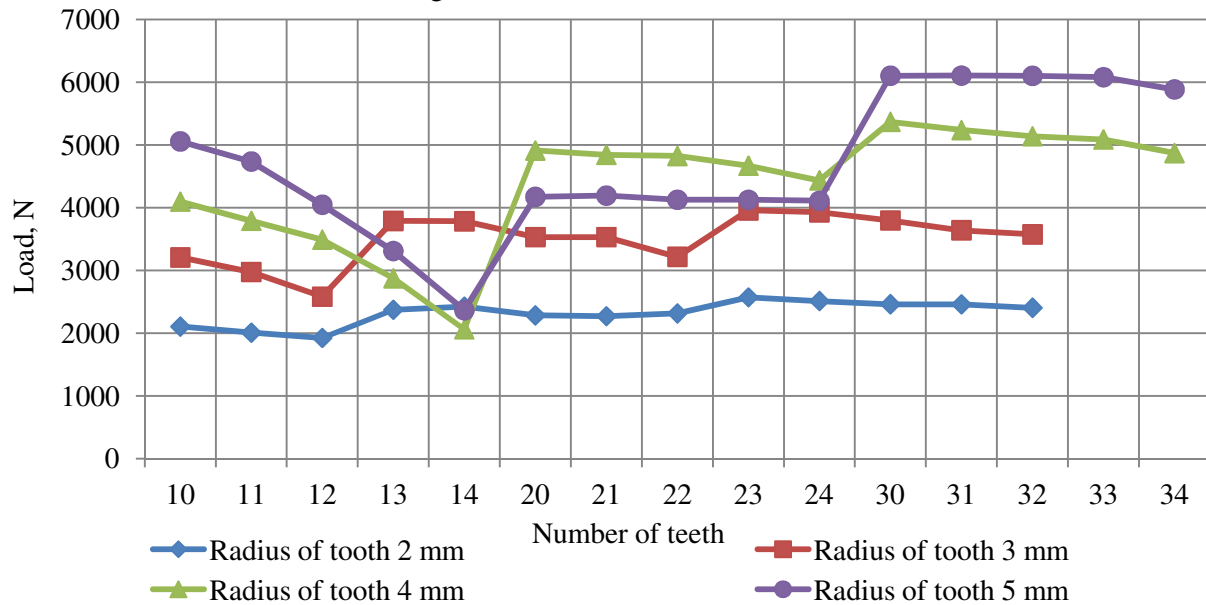


Figure 4. Dependence of the reducer load ability on the number of teeth.

Let us consider an example when the number of teeth of the driver gear remains constant and the diameter of the driver gear changes. The research was conducted in the Solid Works, the steel with a limit of the fluidity of 325 MPa was accepted as a gear wheel material.

Let the driver gear be a motionless link, the loading from the contact with a driven gear is perceived by the contacting area. We will load the driver gear tooth with loading in the range of from 1000 N to 6000 N. As a result, we will receive the value of tension (fig. 5). The size of the area of perception of loading will depend on size b (width of an active part of the tooth), determined in this case by the diameter of a driver gear. The diameter of the driver gear is less, value b is less, and the volume of perception of loading is less, the greater the transferred moment and the load ability (fig. 6).

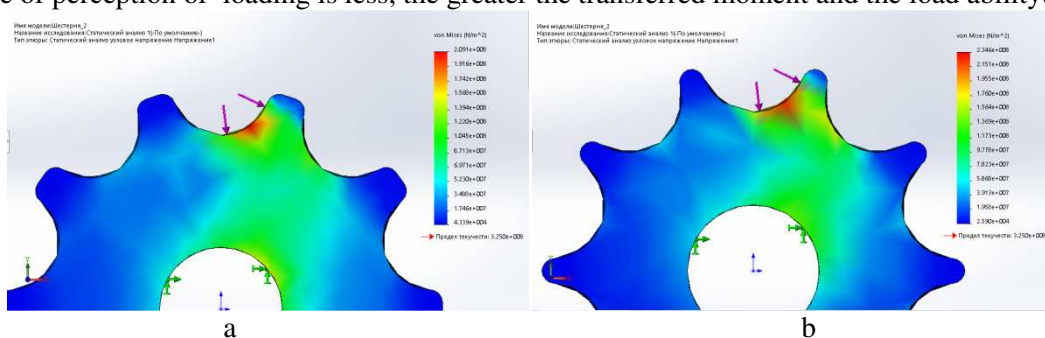


Figure 5. The power picture of the loading driver gear is the following: a – the value of the tooth radius is $r = 2$ mm, the number of teeth is $z_1=10$, the diameter of the driver gear is $d_1=18$ mm, load F is 2000 N; b – the value of the tooth radius is $r=2$ mm, the number of teeth is $z_1=10$, the diameter driver gear is $d_1=16$ mm, the load is $F=2000$ N;

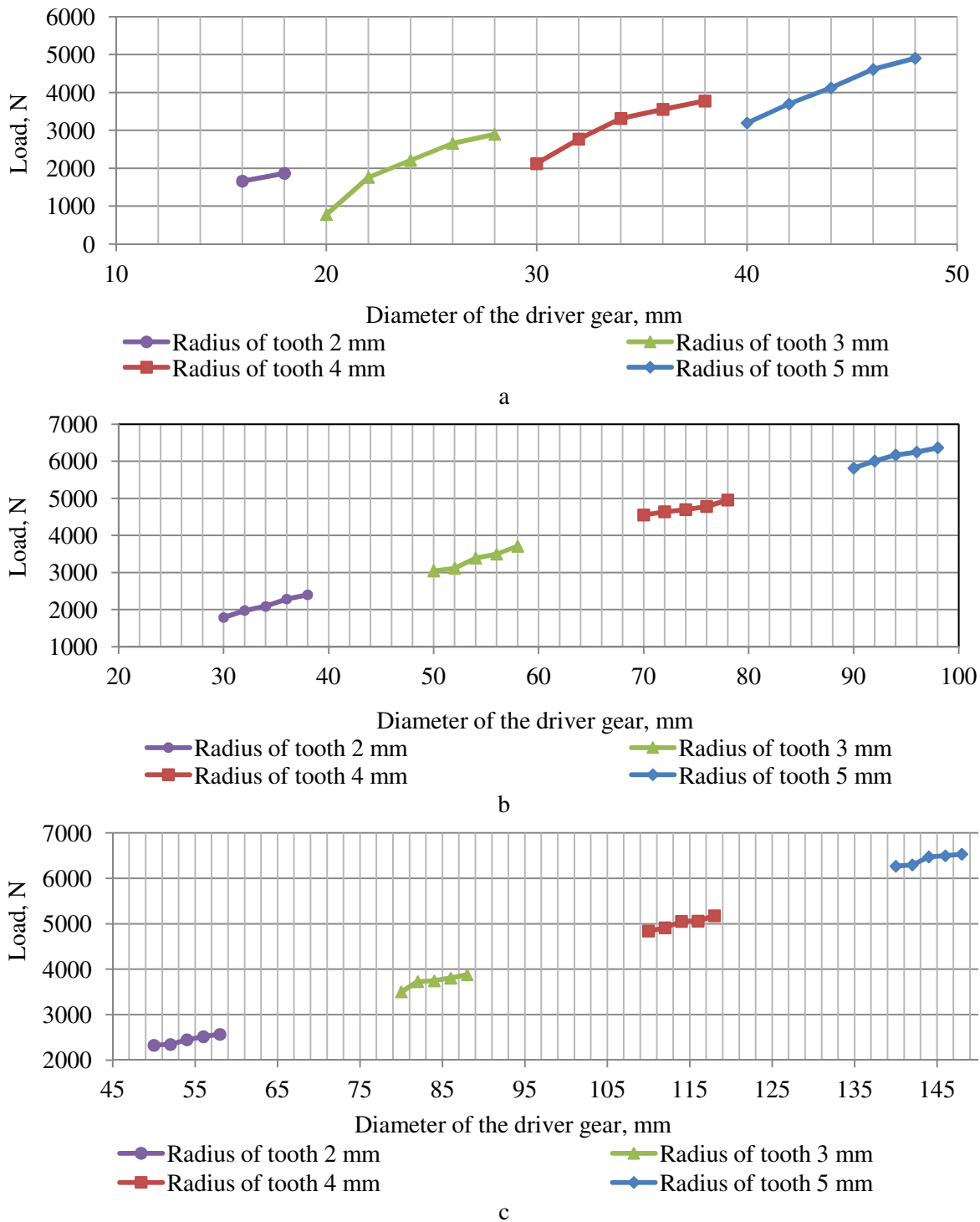


Figure 6. Dependence of a load capability on the diameter of the driver gear in case of: a – 10 teeth; b – 20 teeth; c – 30 teeth;

5. Conclusion

The carried out research shows that the load distribution of the work of the reducer occurs not on one tooth, but on several teeth. Thanks to such load distribution, this reducer corresponds to the parameters of load-carrying capacity in case of rather small dimensions.

Using an extrapolation method on the basis of the received dependences of loading on the number of teeth, and the diameter of the driver gear, it is possible to receive values in points necessary for calculation of a load capability of the reducer in case of various values of the radius of the tooth. For example, it is possible if we draw a straight line through points and then parallel to them to receive other graphics for similar parameters and for various executions. The received values of a load capability need to be used with an inventory coefficient. The received dependences and values show that the load capability of the kinematic wave reducer is much higher than that of reducers with involute gearing.

References

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