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Determining opposite profile to the flexible wheel the harmonic gear after deformation

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Abstrakt The harmonic toothed gear transmissions undoubtedly are a prospective technology. It is about spur gearing where the meshing is achieved by the flexible deformation of one of the wheels. As a result of this deformation the shape of the flexible wheel changes from its original state resulting in incorrect meshing with the teeth of the opposite profile wheel. The deformation of the shape of the flexible wheel is the result of collision and interference, as well as the contact rate, occurring during the meshing of the flexible wheel with the rigid one. This effects the wearing, and results in an increase in the overall damage and consequently the lifespan of the harmonic gears. That is the reason for the teeth of the rigid wheel to be of an enveloping line of flexible cogs.

Key words harmonic gear, flexible wheel, deformation

1. HARMONIC DRIVE

Fig.1 shows the complete set of harmonic gear, ie flexible toothed wheel, solid sprocket and wave generator.

1 - wave generator
2 - flexible wheel
3 - solid sprocket

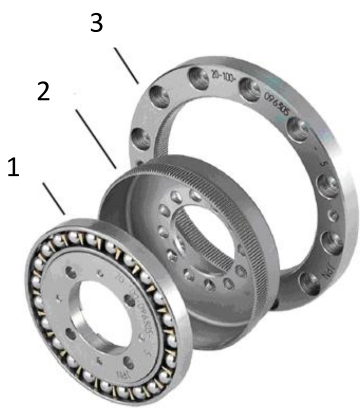
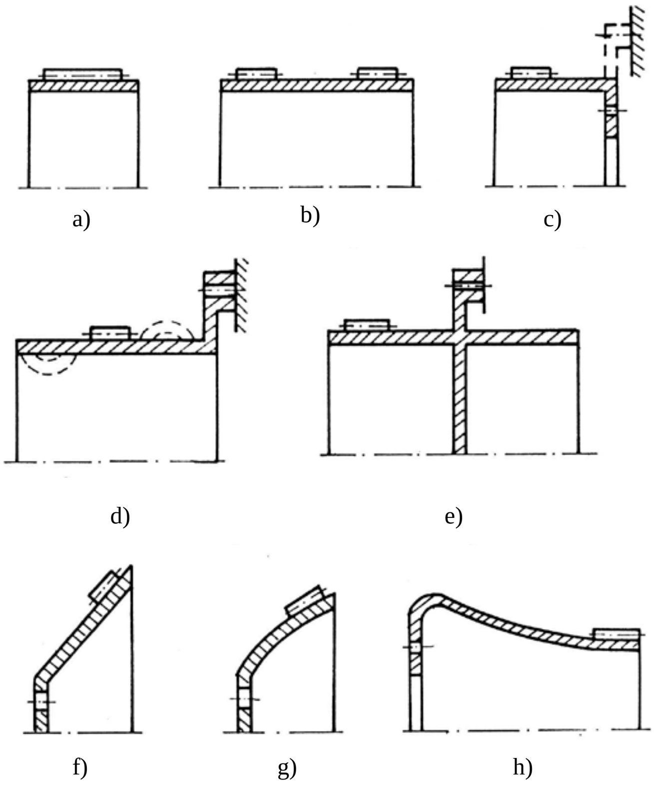


Fig. 1 Harmonic drive

The meshing of a harmonic gear is achieved with the deformation of a flexible wheel (w) under the application of a wave generator (g). There is a very small relative movement between the teeth in the toothed mesh. In reality this relative movement of meshing teeth happens in zones where their loading capacity is small, i.e. on their entrance into the mesh and on their leaving it. This deformation influences the shape of the active walls of the teeth of the flexible wheel. And as a result they do not mesh correctly.

2. THE BASIC TYPES OF ELASTIC ELEMENTS OF HARMONIC GEAR

Schematics basic types of elastic elements harmonic drive are given a (Fig. 2). From a structural and technological point of view, the most complex hermetic elements (Fig. 2 d, e, i) which are also stressed by temperature changes.



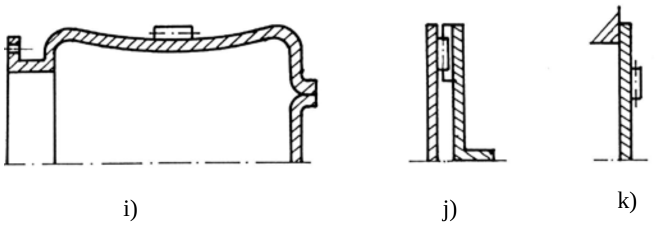


Fig. 2 Schemes basic types of elastic elements of harmonic gear.

3. THE ELESTIC DEFORMATION OF THE WHEEL AND ITS IMPACT ON THE GEARING

The existence of a flexible wheel in harmonic gear which deforms at work, needs a personal approach to the investigation in the engaged this transfer. Above all, is needs to express the influence of the deformation elastic of the wheel on the shape of teeth thereon the spaced.

Flexible gear wheel during operation is straining very negative. The following are the main stresses:

- deformity Stress induced by the generator
- stress induced/generated by the transmitted load
- local stresses the from bending the tooth within the tooth gaps.

As a result of the adverse stress the flexible wheel is the limiting part of the load-bearing capacity of the harmonic gears.
The flexible deformation of the harmonic wheel may be twofold:

a) the free deformation at which the harmonic wheel is deformed by means of rollers of a smaller cross-section (Fig.3.a)). Harmonic wheel is deformed an to shape ellipse.
b) Forced deformation, where shape the of harmonic of the wheel is given the shape the generator harmonic deformation (Fig.3. b)).

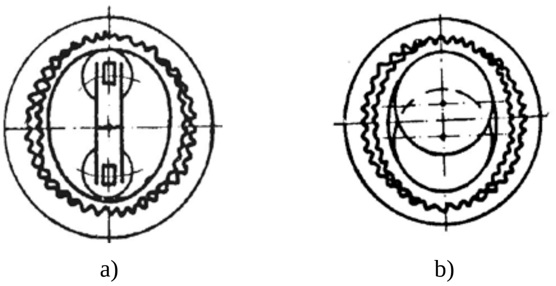


Fig. 3. Deformation of harmonic gear

a) - the loose deformation of harmonic wheel
b) - forced deformation of harmonic wheel

A harmonic gear is able to operate under various shapes and sizes of the flexible wheel deformation. The shape of the flexible wheel ring being deformed under the four forces (Fig.4) is acceptable for harmonic gears for general usage. The disadvantage of this shape is the increased wearing of the flexible bearing by the characteristic forces on the points of stress.

Depending by the angle β vary tension in the flexible wheel. When the value of $\beta \approx 25^{\circ}$ are the 25% less than the $\beta = 0$. Approximate values are recommended:

Gear ratio-i	60 - 100	100 - 130	130
β	25°	30°	35°

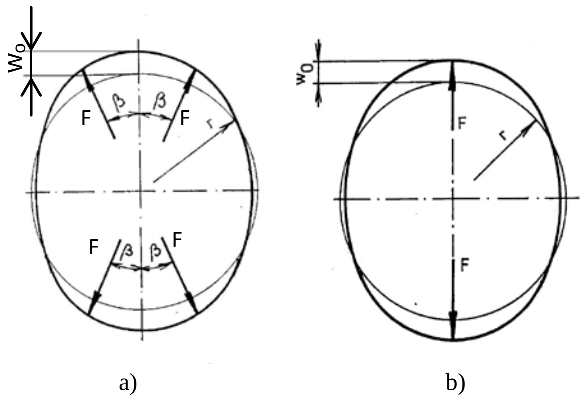


Fig. 4 a) The ring deformed by four forces, b) deformed ring by two forces.

4. DETERMINING THE SHAPE OF THE ACTIVE FLANK OF THE TOOTH AFTER DEFORMANTION

Curve tooth flank must be shaped such to the he ensure:

- increased number of teeth in the synchronic meshing
- correct meshing conditions
- the cheap production and the like.

The shape of the active side of the flexible wheel after deformation is determined by the final elemental method using commands within the programme Cosmos/M where we created a computational geometrical model of the examined example – in this case the ¼ of the flexible wheel of the harmonic gear (Fig. 5).
Most benefit for profile of the tooth flanks have involute curve, which is advantageous in terms of production technology, the provide a suitable tooth flanks. Harmonic transfers have a large number of teeth. In case the number of teeth z > 150 involute is coming to the straight line.

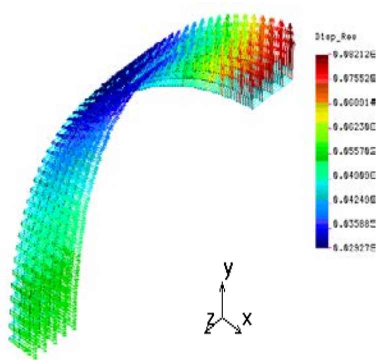
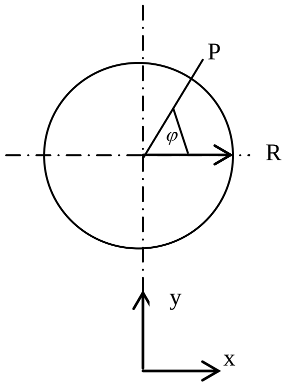


Fig. 5 Vector image of the wheel deformation with the field shift

Inasmuch flanks tooth of a flexible wheel must be envelope curve the tooth flanks of the solid wheel, I decided to create a calculated mathematical model to determine the elastic anti profile wheels.

5. THE COMPUTATIONAL MODUL

We know that the shape of the elastic deformation of the wheel is a circle. Let us choose a on the circle arbitrary point on the P (Fig. 6).



Are the original coordinates of the point P = [x,y]. After deformation the wheel when that it changes his shape, changed to abscissa the point P*=[x*, y*].

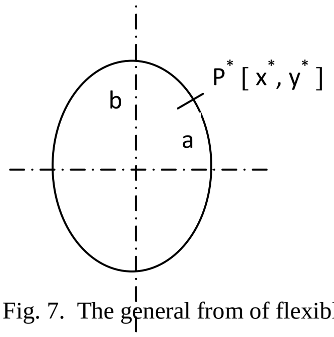
Fig. 6 Starting general shape of the elastic wheel with any.

Coordinate X and Y of point P is given by the equation:

$$x = R.\cos\varphi \qquad (1)$$

$$y = R.\sin\varphi \qquad (2)$$

R – radius
φ – oriented angle from own half axis o_x , the selected point in the interval
$\varphi \in \langle 0, 2\pi \rangle$



Coordinates x*, y* for to the point P*, which is onto the deformed to wheel (Fig.7), we can be described by the equation.

$$x^* = a.\cos\varphi \qquad (3)$$

$$y^* = b.\sin\varphi$$

Fig. 7. The general from of flexible wheel after deformation.

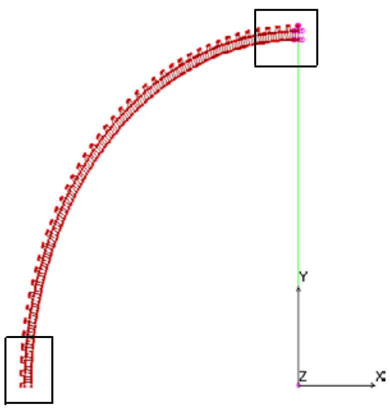


Fig.8. Places readings of the nodes needed to determine a and b

Where *a* and *b* are half axis ellipse that forms the flexible wheel after deformation. After analyzing the tasks have been using computer technology using the least squares method from the measured designation semi axis *a* and *b*.

Value nodes subtraction on the inside of the ring flexible wheel in places that are marked on (Fig. 8).

$$a = 49{,}93853872 \ mm$$
$$b = 50{,}07489444 \ mm$$

From equations (1), (2), expresses the relation:

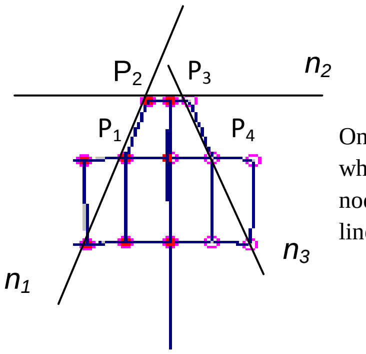
$$\frac{y}{x} = \frac{\sin\varphi}{\cos\varphi} = tg\varphi \qquad (5)$$

$$\varphi = arctg\frac{y}{x} \qquad (6)$$

Position of point P = [x ,y] after deformation

$$x^* = a.\cos\left(arctg\frac{y}{x}\right) \qquad (7)$$

$$y^* = b.\sin\left(arctg\frac{y}{x}\right) \qquad (8)$$



On (Fig. 9) is flexible tooth wheel on which are indicated nodes and stored to be straight line n_1, n_2, n_3.

Fig.9. Meant a straight line.

Then equation anti the profile of the tooth answers a straight line n_1 which is the most important the meshing.

$$x = x_{P_1} + \left(x_{P_2} - x_{P_1}\right).t \qquad (9)$$

$$y = y_{P_1} + \left(y_{P_2} - x_{P_3}\right).t \qquad (10)$$

parameter $t \in \langle 0,1 \rangle$

Equation of the line n2, n3 are not essential for my case, because they are not of the active side in the mesh.

Relations (7), (8), is possible to determine the equation and hence position anti profile tooth after deformation.

6. CONCLUSION

The harmonic toothed gear transmissions undoubtedly are a prospective technology. Its uniqueness is in using a higher number of teeth in mesh and consequently also in conveyance. Within the harmonic gear, the existence of the flexible wheel being deformed while being used requires an individual approach to the mesh examination for this gear. Primarily it is important to define the effect of the flexible wheel deformation on the tooth shape. Since the tooth flanks of the wheel must be flexible envelope curves of the tooth flanks of solid wheel, therefore I created a calculated mathematical model to determine the elastic the anti profile wheel. In the future, I want to deal with setting the calculation of the mathematical model which would apply not only to a straight tooth profile, but I for a circular involute profiles.

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