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PARAMETRIC MODELING OF GEROTOR PUMP

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Abstract: Gerotor pumps have compact and simple design, good kinematic characteristics, large efficiencies, and many other advantages relative to other rotary pumps. Because of its good characteristics, gerotor pumps have are widely used. Gerotor pumps are used for hydraulics machines, car engines, compressors, and for many other purposes. Basic components of gerotor pumps are inner and outer rotor. During the investigation of gerotor pumps it is very important to get inner and outer rotor easily as for theoretical investigations as for their production. In this investigation, an i-Logic rule with user form is created in Autodesk Inventor CAD software for automatic design of inner and outer rotor. User from input parameters are: teeth number of outer rotor, pump eccentricity, trochoid radius coefficient and outer rotor width. Generating of inner and outer rotor is possible for any combination of parameters, which fulfills geometric and kinematic constraints, which means that a problem of generating of gereotor is, solved in general case. Simultaneously is also created a meshing kinematics of inner and outer rotor. Application of presented results is reflected in fast creating of different profiles combination and its meshing, which makes meshing analyses much easier. In the framework of future research in this area, planned is CFD analysis for specific gerotors and its experimental verification.

Key words: gerotor, gerotor pump, inner rotor, outer rotor, parametric modeling.

1 INTRODUCTION

One of the new types of gearing, which could replace involute gearing in a largely extent is the trochoidalgearing. Implementing a trochoidalgearing in gear technology would have large positive effect on the functional characteristics: required efficiency and service life with minimum mass and overall dimensions. Trochoidal gearing implementing would lead to a reduction in material consumption which would lead to large savings. Another major advantage of the trochoidal gearing is simultaneous contact of all gearing tooth is achieving better load capacity related to the gear pairs with involute gearing.

Because of the advantagestrochoidal gearing there is a great interest of Mechanical Engineers for their implementation into mechanical systems. Applying

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trochoidal gearing is present in a large number of rotary machines which are used in a variety of purposes: rotary pumps, rotary motors, rotary compressors and blowers. A good part of the implementation trochoidal gearing occurs in cycloid drives that belong to a special group of planetary gearboxes. Due to the good characteristics of trochoidal gearing, it is cost effective to work on their development.

One of the most important aspects of analyzing gerotor pump is certainly the analysis of dynamic behavior of pump elements during the its operation. C. F. Heish [1] with this kind analysis came to the useful results which can be further applied into production of gerotors. A very important is aspect of analyzing forces and pressures that occur in gear with inner gearing of gerotor [2]. Also, very important aspect is the kinematic analysis gerotors [3], as well as the determination of pump flow [4]. By observing and taking into account all of these aspects, it can be concluded that the research gerotors could be very accelerated if there were their adaptive parametric CAD model. Some groups of authors are partially managed to implement this kind of model in researching of gerotor [5-7]. In order to make this model usable for practical research and experiments, it is essential to implement technological gaps in the model [8-9].

This paper presents a parameterized model gerotor pump. The parametrized CAD model automatically creates gerotor gears with simultaneous generating of gears kinematic. The parametric model is developed to generate all combinations of gearing parameters that are physically feasible.

2 GEOMETRIC CHARACTERISTICS OF GEROTOR GEARING

In practice, trochoidal profiles are applied most frequently for the inner gearing. In the innertrochoidal gearing profile of one of the gears is generated by trochoid, while the coupled profile is adequate inner or outer envelope. Due to the specific geometry, the entire profile can be applied for the coupling. Trochoids equations can be written in the following general expression:

$$x_t = e_t\left(\cos\varphi + \lambda k_t \cos\frac{\varphi}{k_t}\right), \qquad y_t = e_t\left(\sin\varphi + \lambda k_t \sin\frac{\varphi}{k_t}\right) \tag{1}$$

and the equations of inner and outer envelopes are:

$$x_a = e\left\{\lambda k_t \cos\frac{2\eta}{k_t} - \frac{1}{\lambda}\sin 2\eta \sin\frac{2\eta}{k_t} + w\cos\frac{2\eta}{k_t}\right\}, \qquad y_a = e\left\{\lambda k_t \sin\frac{2\eta}{k_t} + \frac{1}{\lambda}\sin 2\eta \cos\frac{2\eta}{k_t} + w\sin\frac{2\eta}{k_t}\right\} \tag{2}$$

Wherein:

$$w = \pm 2\left[\cos^2\eta - \left(\frac{\sin 2\eta}{2\lambda}\right)^2\right]^{1/2}. \tag{3}$$

In equation (3) the character "+" refers to the outside, a sign "-" on the inner envelope. In order to simplify the performance of parameterization equations (2) are transformed into the following form:

$$\begin{aligned} x &= \left(R_a + R_b\right)\cdot\cos\alpha + e\cdot\cos\left(\alpha+\beta\right) - q\cdot\cos\left(\alpha+\phi\right) \\ y &= \left(R_a + R_b\right)\cdot\sin\alpha + e\cdot\sin\left(\alpha+\beta\right) - q\cdot\sin\left(\alpha+\phi\right) \end{aligned}, \tag{4}$$

Equations (4) are used for a parametric model of trochoidal gear with outergearing, while the gear with inner gearing is done by approximation with circular arcs, [10, 11].

3 PARAMETRICMODELLINGOF GEROTOR GEARING

Parametric modeling of gerotorgearingis done in the software named *Autodesk Inventor*. Top-down assembly modeling technique is applied for easier access to all gerotor parameters [11]. All gerotor parameters are defined in assembly file and associated with the individual parts of the gerotor pump (gear with outer gearing, gear with inner gearing and eccentric shaft). Mode of defining parameters is given in Figure 1.

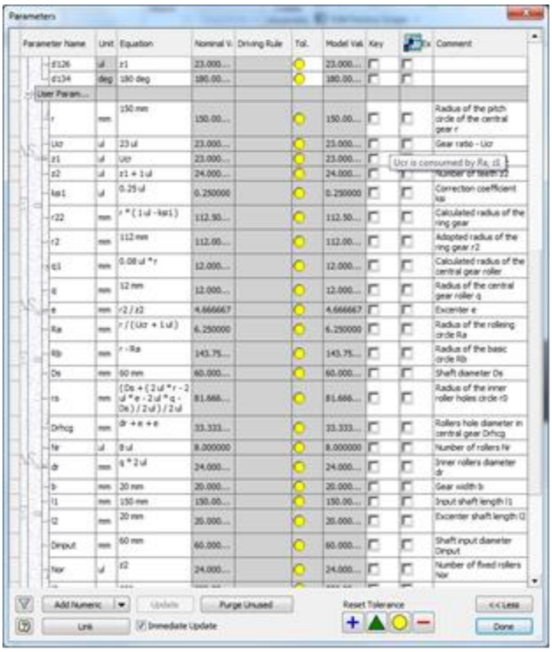

Figure 1. *Parameters definition*

Parameters defining creates all the variables that define the assembly, and all the variables that define the individual parts of the assembly. All mutually dependent parameters are also linked by mathematical relations. After defining the parameters, all of the gerotor files are created: gear with outer gearing, gear with inner gearing and eccentric shaft.

All created individual parts files have the same parameter names as in the assembly file. This operation was necessary in order to write a script which connects parts files and their relations to assembly file with controlling form.

The most difficult part of gerotor in creating its CAD model is certainly a gear with outertrochoidal gearing. The profile of this gear was created using the controls for parametric drawing functions on the adapted equation (4). Creating parametric drawing function for trochoidal tooth profile is given in Figure 2.

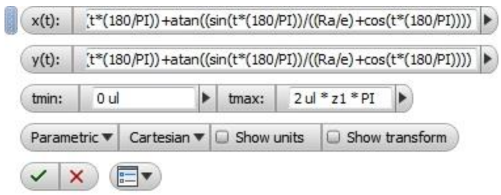

Figure 2. *Trochoid profile generation*

After creating the part files and definition of their parameters, such as the previously defined in assembly file, it is accessed to connecting part files with the assembly file. This step is performed in the environment i-logic. Connecting the parameters of part files and assembly parameters is performed by writing scripts for equalization parameters. Scripts are written by using the command Add rule. Figure 3 shows a code for the connection between part files parameters and previously n assembly file.

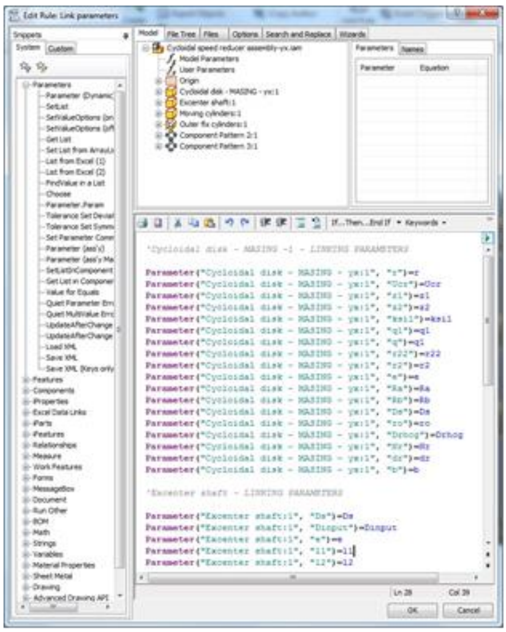

Figure 3. *Linking parameter rule*

This approach is used for creation of general gerotor CAD model with all kinematics parameters. Obtaining the desired dimensions of gerotor is possible by changing the values of independent parameters showed in dialogue in Figure 1. However, in order to speed up this process, a form with independent parameters is made. The advantage of introducing forms consists in the fact that it cannot make mistakes when entering input data. Gerotor CAD model is generating by changing the values in dialog box showed in Figure 1. In preparing the form data entry fields were made with explanations and parameter designations (Figure 4).

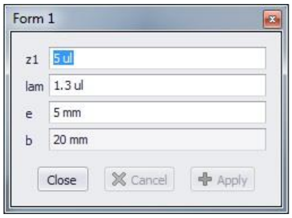

Figure 4. *Communication form*

The form for communication with the parametric model of gerotorhas been filled the following parameters:

Table 1. *Parameters used for gerotor generation*

Parameter name	**Designation**	**Value**	**Unit**
Eccentricity	*e*	5	mm
Trochoid coefficient	λ	1,5	-
Tooth number of inner gear	z_1	5	-
Gear width	*b*	20	mm

Other gerotor parameters has been obtained by mathematical relations using the parameters given in Table 1.

4 GEROTOR TECHNOLOGICAL GAP DETERMINATING

To make installation and operation of gerotor possible, it is necessary to make the gearing with the technological gap. This gap can be calculated, [8,9] or adopt according to recommendations from the literature. Model developed in this paper allows the user to measure the technological gap in a few iterations. This is achieved by using the collision option in kinematics simulation, Figure 5.

Figure 5. *Clearance determination*

The quickest obtaining of technological gap is done by determine some initial value and then bisect interval until it reaches the tooth interference. When it comes to interference with bisection of the interval, value returns to the previous where interference not exist. For example, given in Figure 5, technological gap is determined by the in 6 iterations and it amounts 0.02701 mm.

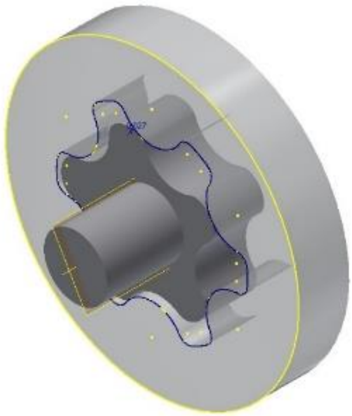

Figure 5. *Parametric model with technological clearance*

5 CONCLUSION

This paper represents parameterization of gerotor gears with eccentric shaft. Investigation is showing a modern approach to CAD modeling, which significantly reduces the time spent on the design of gerotors. In this modeling approach can be very easily integrated optimization method and set of objective function depending on the desired optimization criteria.

Solving of this problem any combination of feasible gerotor parameters is possible for creation in CAD environment. Generation of CAD model also shows simultaneously generated kinematics of movement gerotor elements, no matter what the number of teeth and the dimensions of the pump are concerned. In this paper the particular model of gerotor is concerned. Model parameters are given in table 1 is used in communication form, and model is generated. According to thoseparameters, model couldn't work, so the technological gap had to be included. Technological gap is determinated by collision detection. Technological gap for this particular model needs to be at least 0.0271 mm, so model can be practically feasible.

A further step in the research on this topic will be the creation of an algorithm which will automatically determinate the technological gap. Using this approach, to monitor and conduct analysis of any gerotor size with any parameters of gearing it is possible.

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NOMENCLATURE

Variables:

b gear width, mm

e eccentricity, mm

k_t $z=z_1+1$,-

R_a rolling circle radius, mm

$R_b$stationary circle radius, mm

w distance between the circular gear tooth profile and the real trochoidal profile, mm

x_a abscissa, mm

y_a ordinate, mm

z_1 tooth number of inner gear, -

Greek symbols

α angle between the starting and current position of the contact point of the basic and rolling curve relevant to the center of the base curve, rad

β auxiliary angle, used to simplify the calculation, rad

ϕ auxiliary angle, used to simplify the calculation, rad

φ rotation angle of the reference line, which connects the center of the kinematic circles and passes through the kinematic pole for generating trochoids, rad

η angle of the epicycloid, rad

λ trochoid coefficient, -

Subscripts and superscripts

a envelope
a rolling circle radius index, eq. (4)
b stationary circle radius index, eq. (4)
t trochoid

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