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ELASTICITY CHARACTERISTIC OF THE WORM-GEARING TOOTH

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ABSTRACT

The investigation of the elasticity characteristic is very important for the study of an elastic system, such as: gearing, linkage, machine-tool. The introduction of this concept contributes to the completion of the used gearing study and it leads to increase of the gearing tooth rigidity.

1. Introduction

By means of own numerical method, which evaluates the rigidity of the worm-gear-tooth system, the paper presents the elasticity characteristic.

The software, with numerical setting-up and graphic displaying, is an original and special program for determination of the rigidity and it could be adopted for any kind of the worm-gear-tooth system or for the spur gearing and bevel gearing. The developed theory is illustrated with numerical example.

The introduction of this concept contributes to the completion of the used gearing study.

The elasticity characteristic represents the variation of the worm-gear-tooth system rigidity depending on the rolling angle.

So, to determine the rigidity of the worm-gear-tooth system, an original numerical methodology [1, 2] has been developed and it consists of:

1. Geometrical model of the worm;
2.Determination of the worm gear profile and geometry. The profile is obtained numerically by the discreting of helical surface with constant pitch.

The worm gear tooth surface is generated by rolling. The enveloping condition is interpreted in "discrete way" by the "minimum distance method", applied in the case of "discrete representation" of the enveloping profiles.

The "minimum distance method" was devised within the framework of the Machine-Building Technology Department, "Dunarea de Jos" University of Galati [5];

3. Determination of the enveloping profiles;
4. Determination of the contact ratio;
5. Calculus of one pair of elementary teeth rigidity by means of the relation for springs serially connected,

considering the conjugated teeth are two springs (see bases of design).

6. Calculus of elementary gearing tooth rigidity (pinion-rack drive) by means of the relation for springs simultaneously (parallel) connected, considering those springs are materialized by the teeth which there are in the meshing at the same time ("H" rigidity);
7. Calculus of worm-gearing tooth rigidity summing up the rigidities of the all elementary gear-tooth systems ("TOTALE" rigidity).

The software, with numerical setting-up and graphic displaying, is an original and special program for determining of the rigidity and it could be adopted for any kind of the worm-gearing tooth system or for spur gearing and bevel gearing.

The main steps of the calculations are presented in the figure 1.

2. Bases of design

The bases of design are:

a) The worm-gear drive is errors free and it can have deformations;

b) It is taken into consideration only the bending of the teeth produced by the normal force;

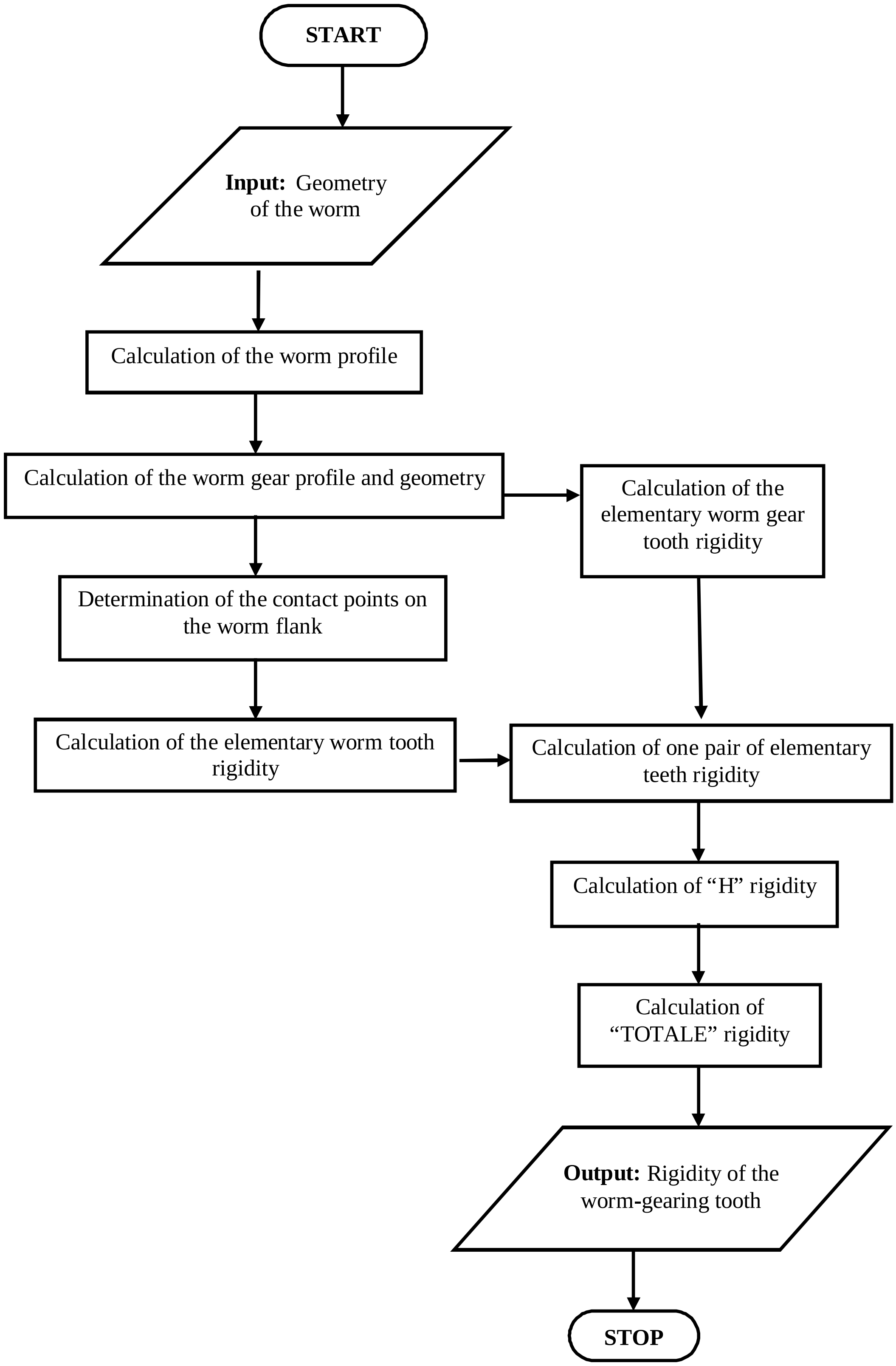


Figure 1. The main steps of the calculations

c) The authors have considered that the worm-gear drive consists of several plane-gear drives (pinion-rack drives), that in fact are cross-sections perpendicular to worm gear axis (figure 2).
d) The elementary tooth is considered to be a beam fixed at one end in the body of gear;
e) The assembly of the plan-gear drives into the worm-gear drive was made on condition that the gear-tooth systems of the elementary gear drives to deform
all together under the action of the same load, so that the worm-gear drive becomes a system of springs serially and parallel connected.

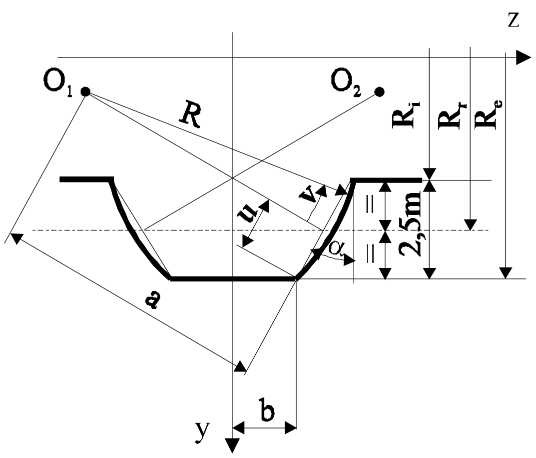


Figure 2. Arch profile of worm in the axial section

3. Numerical results

In this paper it is presented the numerical results performed for a cylindrical worm-gear drive having arch profile with the following parameters:
- number of worm threads: z_1 = 1;
- number of gear teeth: z_2 = 53;
- axial module: m_x= 10 mm;
- diametral quotient: q = 10;
- constructive parameter: a=70 mm;
- angular increment: $\Delta\varphi = \pi/3240$;
- profile angle: $\alpha = 20°$.

Using our computer program (figure 1), the diagram of the worm-gear-tooth system rigidity was obtained, as may be seen in the figure 3, “j” being the rolling angular parameter.

4.Elasticity characteristic of worm-gear tooth system

The elasticity characteristic represents the variation of the worm-gear-tooth system rigidity depending on the rolling angle ($j\cdot\Delta\varphi$), where “j” is the rolling angular parameter. It is a cvasisinusoidal curve with the high jumps when a tooth binds or recesses.
The maxim rigidity is 1928.25 KN/mm at j=27, j=149, j=271 and so on (j=122k, k=0,1,2 ..[1]).
The minim rigidity is 1188.626 KN/mm at j=85, j=207 and so on.
The amplitude of the rigidity variation is 739.62 KN/mm, the jump frequency is determined by the j=122k.
In order to perform a complete research on elastic system, for example any kind of the gear drive, the elasticity characteristic must be studied together the static characteristic and frequency characteristic.
It is known that, the static characteristic (figure 4) represents the applied force in function of the deformation.
The information about the dynamic parameters of the elastic system and about the stability ratio is given by the frequency characteristic (figure 5).

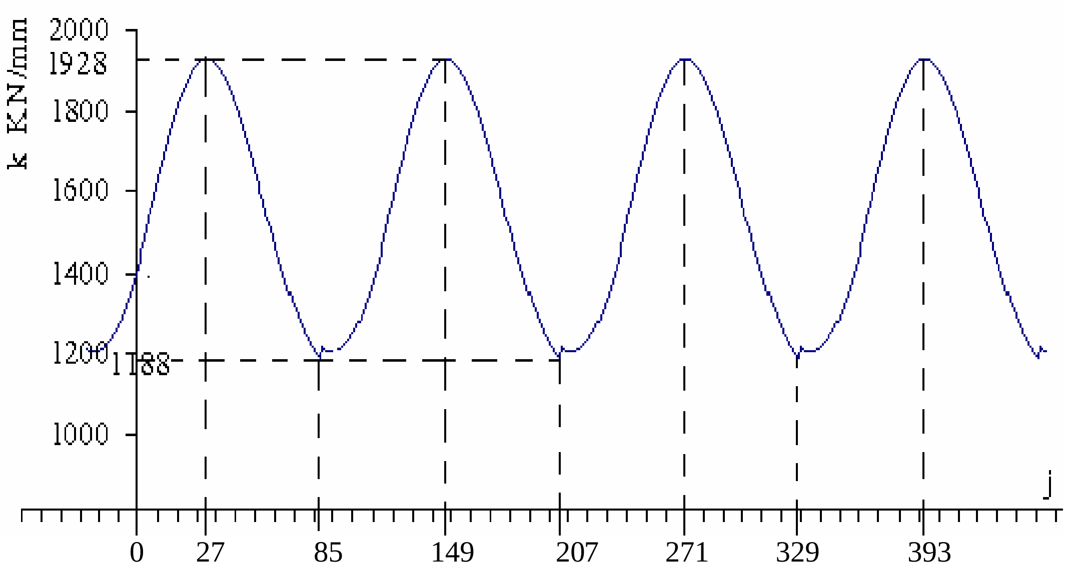


Figure 3. Elasticity characteristic of worm-gear tooth system

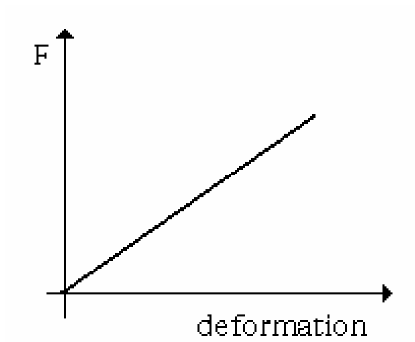
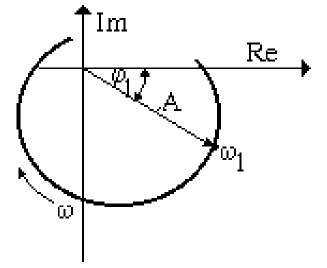


Figure 4. Static characteristic



$$A(\omega) = \sqrt{Re^2(\omega) + Im^2(\omega)};$$
$$\varphi(\omega) = arctg(Im/Re).$$

Figure 5. Frequency characteristic

5. Conclusions

Based on the performed research, the following conclusions might be drawn:

a) The computerized determination of the elasticity characteristic of the worm-gearing tooth for the machine-tools and robots is proposed;

b) The introduction of "elasticity characteristic" concept contributes to the completion of the used gearing study;

c) For a complete research on elastic system, the elasticity characteristic must be studied together the static characteristic and frequency characteristic;

d) The study leads to increase of the gearing tooth rigidity, improving the accuracy of the machine-tool and robot linkages.

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