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MODELLING OF THE ASYMMETRIC GEARS USING APPLICATIONS IN MATLAB AND AUTOLISP

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Abstract: The paper present a method of modelling the spur asymmetric gearing. This special gearing, formed by gears with involute asymmetrical teeth, have best performances in relation with the ordinary one. An asymmetric tooth have two different involute profiles with different diameters of the base circles. The software for designing, modelling and analysing the asymmetric spur gears, developed by the paper authors, as aplications in MATLAB, AutoLISP, represent a very efficient instrument which can be easily used by the designing engineer. Also it is a method for reducing the suplimentary costs wich are imposed by a new product.

1 Introduction

The tendencies in present toohted gears research are aimed to obtain best performances of the transmissions by using special gearing with nonstandard parameters [1], [4], [5].

One of the method of optimisation the functional parameters of the involute gears is the utilization of the gears with asymmetrical teeth [7] , [8]

In order to obtain the profile of the asymmetric tooth there are drawn, starting from two different base circles, two involutes, at a certain distance, to create the tooth body. The tooth is no longer symmetrical to the radius passing the intersection point of the two involutes that, for the classic symmetrical tooth, having the same base circle for both profiles, represents the tooth symmetry axis [2].

By choosing a convenient ratio between the diameter of the base circle of the involute inactive profile and the diameter of the base circle of the involute active profile, ratio which is called coefficient of asymmetry, there can obtained optimum performances (load capacity, transmission error, efficiency, weight) for particular aplications [3].

To choose the designing variables, it is very useful modelling the asymmetric gears which can be obtained for different values of these variables, calculating and comparing the functional parameters for a great number of possible solutions.

In order to make the presentation as clear as possible, there are made, from the beginning, a few clarifications on the notations and names used in this paper [3].

- The profile elements with a high gearing angle, called direct profile, are attributed the index “d”.

- The profile elements with a low gearing angle, called inverted profile, are attributed the index “i”.

- The index 1 for the pinion and 2 for the wheel will be used in order to separate the elements referring to pinion and those referring to the wheel.

- In the case of three index notations, the first index represents the position of the profile, the second index indicates pinion or wheel affiliation, and the last index refers to the profile type “d” or “i” (examples: $d_{b1d}, d_{b2d}, \alpha_{a1d}, \alpha_{a1i},$).

2. Parametrical equations of the curves which limit the asymmetric tooth body

The asymmetrical tooth body is limited by the dedendum circle, addendum circle, the involute direct profile, the joint profile for the direct profile, the involute inverted profile and the joint profile for the inverted profile. The first step for define the ecuation of the tooth profiles is to write the parametrical ecuations for the four curves mentioned before in relation with four different reference systems connected with each curve (fig.1). All of these systems reference points are in the center of the gear [2], [6], [8].

For the direct involute profile it is used the reference system x_dOy_d which y_d axes include the point M_o , the point on the base circle, with r_{bd} radius, of the involute direct profile of the tooth.

For the inverted involute profile it is used the reference system x_iOy_i which y_i axes include the point N_o , the point on the base circle, with r_{bi} radius, of the involute inverted profile of the tooth.

To write the parametrical ecuations of the joint profiles there are used the reference systems $x_{2d}Oy_{2d}$ and $x_{2i}Oy_{2i}$ with the axes y_{2d}, y_{2i} including the points I_d, I_i from the dedendum circle (fig.1).

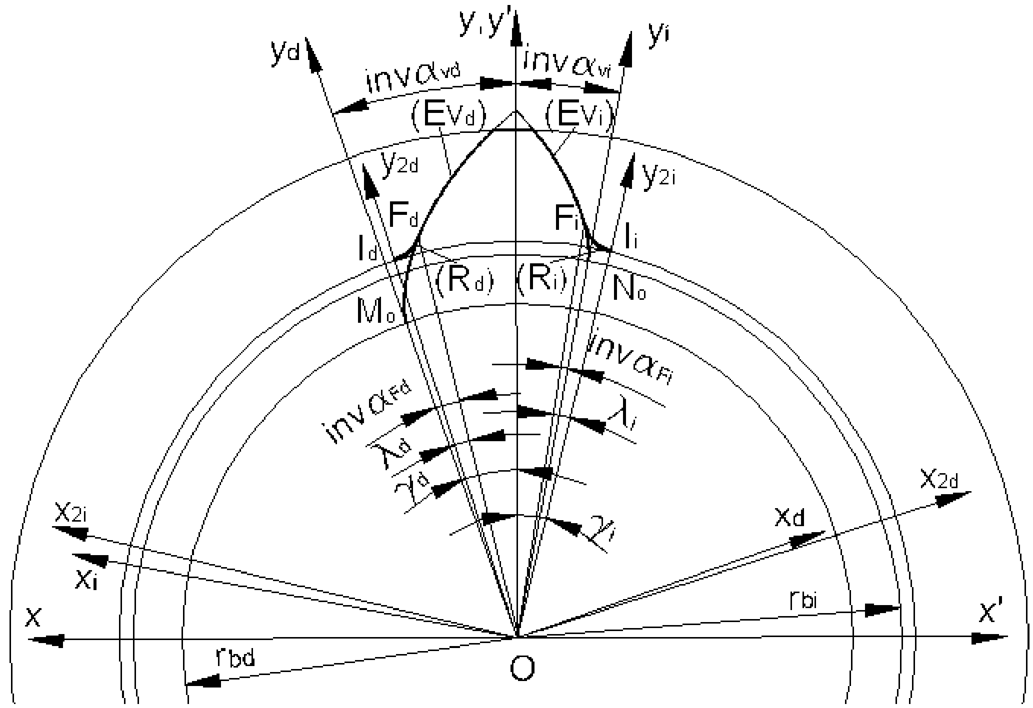
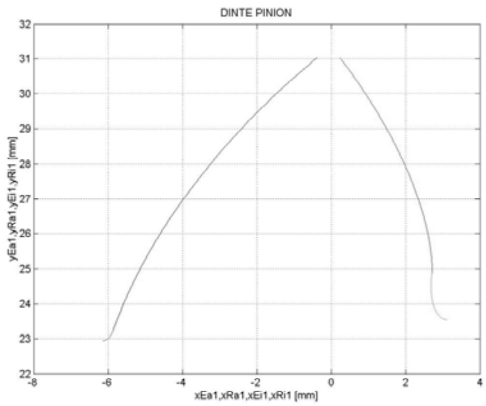
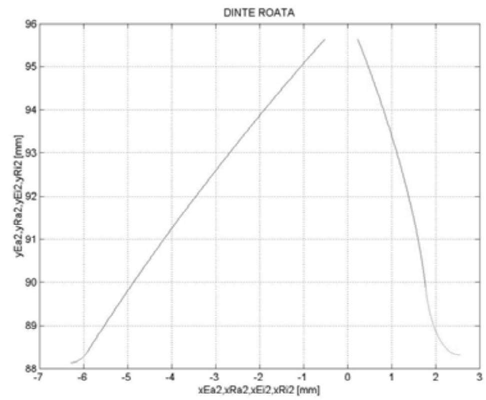
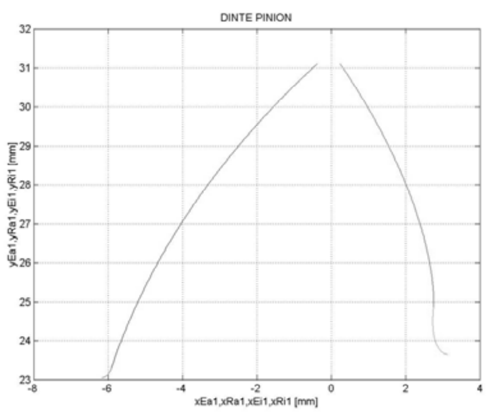
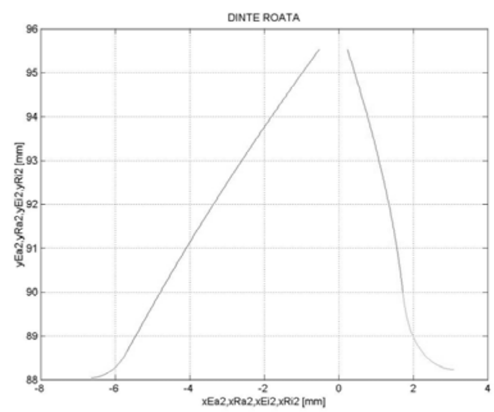
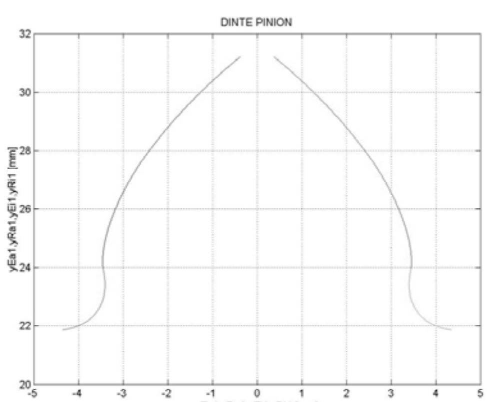
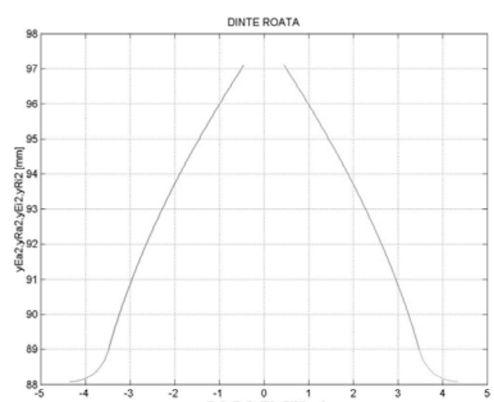


Fig. 1 The reference systems used to define the profiles of the asymmetric tooth

In the second step of the study there are determined the ecuations of the direct profile curves in relation with the reference system xoy, and of the inverted profile curves in relation with the reference system $x'Oy'$ (fig.1). Both reference systems have as y respectively y' axis the radius that goes through the tip of the tooth, the alone common point of the two involute profiles.

The parametrical ecuations of the curves Ev_d, Ev_i, R_d, R_i in relation with the reference systems $xoy, x'oy'$ make the exact representation of the tooth body and of the asymmetric spur gear posible. Using the designing and modelling program *Asymmetric_gearing,* developed by the authors of the paper as MATLAB application, one can obtaine the grafcal representation of the four curves for the pinion and also for the gear. In the table 1 are presented some examples for different initial data.

Table 1 Grafical representation of the asymmetric profiles of the tooth (MATLAB)

Tooth of the pinion	Tooth of the gear
$z_1 = 16, z_2 = 57, a = 120, \alpha_{wd} = 40^o, \alpha_{wi} = 18^o, \alpha_{cd} = \alpha_{wd}$, generation with one gear rack	
	
$z_1 = 16, z_2 = 57, a = 120, \alpha_{wd} = 40^o, \alpha_{wi} = 18^o, \alpha_{cd} \neq \alpha_{wd}$, generation with two gear racks	
	
$z_1 = 16, z_2 = 57, a = 120, \alpha_{wd} = 23^o, \alpha_{wi} = 23^o, \alpha_{dc} = 20^o$, generation with one gear rack	
	

3. Grafical representation of the asymmetric gears using a program developed as AutoLISP application

The first aim of obtaining the 2D and 3D models of the asymmetric gears is using these models for the kinematic study and the second one to analyzing the stress and the elastic deflection with the finite element method (figure 5, figure 6). To carry out the representation of the gearing in AUTOCAD there are developed two programs, as applications in AutoLISP, for exact representation of the pinion and of the gear (MDA1, MDA2). In the gearing representation the model of the pinion and the model of the gear have the teeth in contact in the pitch point, on the direct profile. In these programs the representation of the curves that limit the tooth body is performed on the base of the parametrical ecuations of these curves.

The geometric parameters which are used as input data in the programs MDA1, MDA2 there are obtained with the designing and modelling program *Asymmetric_gearing.*

The following parameters there are necesary to be carry in:

- the numbers of the teeth for the pinion and for the gear z_1 , z_2 ;
- the center distance a ; the pressure angles on the direct and inverted profiles α_{wd} , α_{wi} ;
- the profile angles of the asymmetric gear rack α_{dc} , α_{ic} ;
- the profile angles on the addendum circles, on the direct teeth profiles, for the pinion and for the gear α_{a1d} , α_{a2d} ;
- the tip radius of the gear rack R_1 (or R_1 , R_2 in the case of generation with two different racks) ;
- the rack shift for the pinion X_1 .

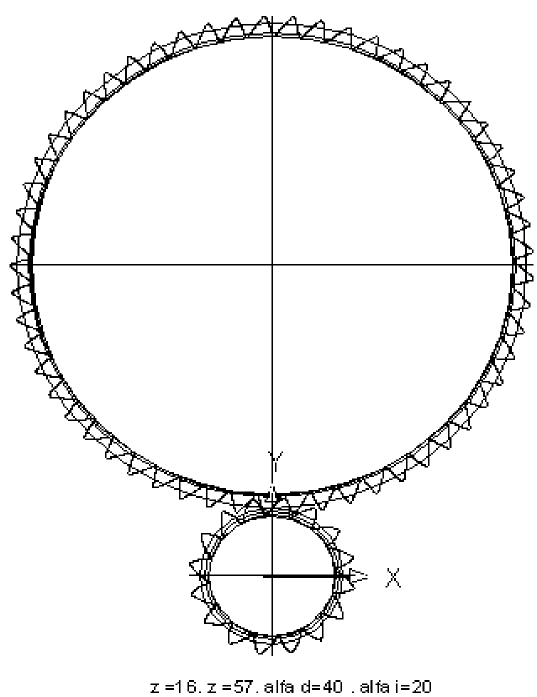


Fig.2 The representation of the asymmetric gear A_as_16_57_120_40_20_0_1 using the programs MDA1, MDA2

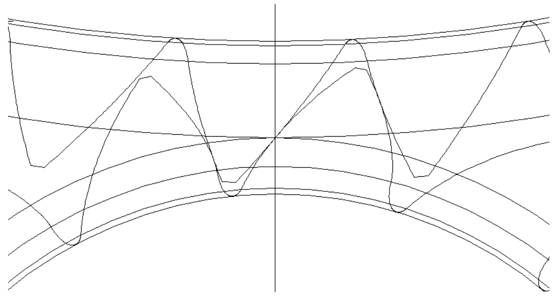


*Fig. 3 The meshing zone – detail of the gearing representa*tion

In the figure 2, 3 and 4 are presented the 2D respectivly 3D models of one asymmetric gear.

To avoid the confusions after obtaining the modells, and to know for each represented gearing which are the initial data, carry in the designing program, it is used a symbol of the gearing that include the initial date.

For example, the symbol:

A_as_16_57_120_40_20_0_1

represent the asymmetric gear with:

$$z_1 = 16,\ z_2 = 57,\ a = 120,\ \alpha_{wd} = 40^o,\ \alpha_{wi} = 20^o,\ \alpha_{cd} = \alpha_{wd}$$

generated with one gear rack.

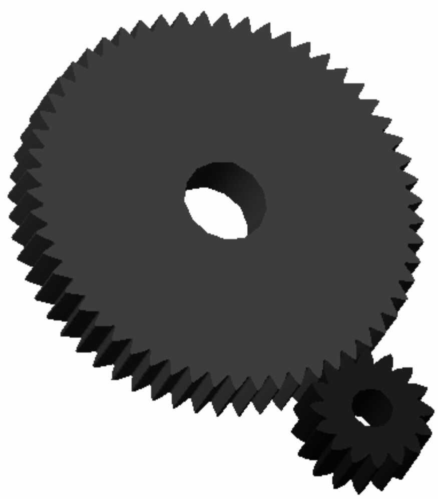


Fig.4 The 3D model of the asymmetric gear A_as_16_57_120_40_20_0_1

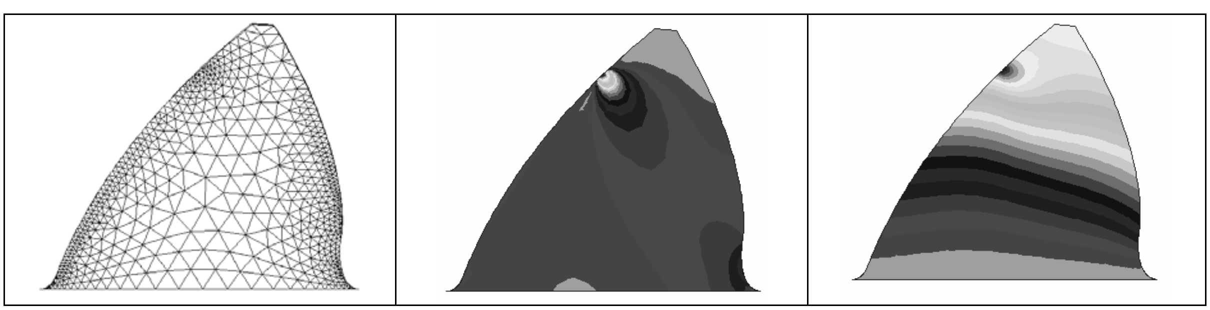


Fig.5 The pinion tooth stress and displacements (FEA)

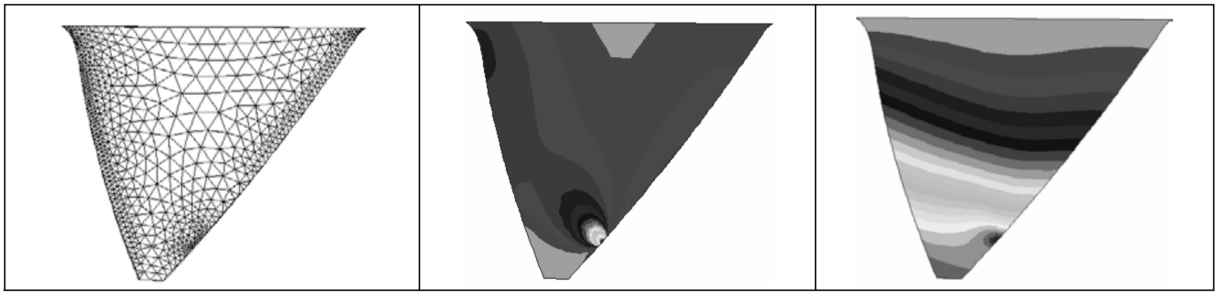


Fig.6 The gear tooth stress and displacements (FEA)

4. Conclusions

The first step in order to obtaining the 2D and 3D models of the asymmetric gear is the mathematical model of the involute tooth with asymmetric profiles. The representation of the two involute curves and two joint curves, that are limiting the tooth body, it is performed on the base of the parametrical ecuations of these curves.

The parametrical ecuations of the asymmetric profile and the geometric parameters, obtained with the first routine of the developed designing program *Asymmetric_gear,* ofer the complete geometry of the asymmetric gearing. Than, with the programs MDA1 and MDA2, one can obtain the 2D and 3D models of the gearing.

The modeling programs of the asymmetric gears can be used to determine the functional parameters like transmission errors, eficiency, bending stress and contact stress, elastic deflection for the tooth of the pinion and also for the gear, for a great number of posible designing variant, for the same initial date. So the designing engineer can obtain the information necesary to choose the best solution for a particular transmission.

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