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CONTROL OPERATION AND ANALYSIS OF THE SPUR GEARS PROFILE

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The theoretic profile of cylindrical gear can be described with an involute curve detected in the front section. The correct formation of the profile assures uniform transmission of the angular velocity from the conducting wheel to the driven one. Profile errors result non-uniform gait, noise and pulsation in the teeth and in bearings. The aim of this paper is the determination of the profile errors using the theoretical profile as reference. The experiment was carried out using a coordinate measuring machine. The real profile is constructed by theoretical equations. The errors are determined comparing these two sets of surfaces, the theoretical and the measured profile. These errors are presented in a graphical user interface (GUI) made by the authors. This GUI is parameterized, so it can be used to evaluate any gear.

Keywords: cylindrical gear, involute profile, profile error, graphical user interface.

Introduction

The profile measurement of the gears are discussed in many papers. The gear manufacturers opinion is that the measurement of these components decelerates the manufacturing process. However, if a wrong gear, without any control processes is installed into a machine, causes loss of time and it is much more expensive. Therefore, the control operations are very important, as the errors are detected before the gears are used. The wrong profile causes unequal meshing, noise and pulsation on the gears teeth and in bearings. The profile measuring consits of the accurate verification of the gear-cutting machines and the gear cutting tools.

The measuring instruments used for the gears profile verification are based on the same principle: the probe tip moves through the profile. The deviation from the nominal involute is shown by a dial gauge or is evaluated by graphical representation in 2D, presented in [1-3]. According to the probe tip movements, these measuring instruments can be divided into two groups. These are the fixed and the moving line methods, as presented in [4]. In [2], there is defined a tolerance range where the measured profile has to allocate. In [5], completely different profile verification methods are presented, using models. These can be: verifying models for the tooth profile gaps and for tooth profile. These control methods are simple, even if, they do not offer a numeric value of errors. As the industrial development rapidly accelerated, the coordinate measuring machines appeared. Using these machines the profile and the tooth direction can be measured. These control machines allow the topographical representation by two slanted perspective planes which gives a three-dimensional impression of the flank presented in [2, 3, 6].

The objective of this paper is to present the differences, the errors, between the theoretical and the measured tooth surfaces of the spur gear. To achieve this paper's goal, the measurements were made using a coordinate measuring machine, DEA Global Performance. Adequate temperature was provided while measuring the gears teeth surfaces. Using mathematical equations the theoretical data were well determined. The errors are presented in a graphical user interface made by the authors and they are also parameterized.

The theoretical involute curve

The involute curve can be created in two ways, which is a relative movement between the base circle of the gear and the tangential line of the base circle, presented in [4]. According to the equation of this curve, which is generated by a given point P fixed on this line, is defined in *Fig. 1*.

The path of the point P is represented in (1), where $X(\varphi_b)$, $Y(\varphi_b)$ are the instantaneous coordinates, r_b is the radius of the base circle and φ_b is the involute curve's running parameter, which is changing all the time.

$$\begin{cases} X(\varphi_b) = r_b \cdot \sin(\varphi_b) - r_b \cdot \varphi_b \cdot \cos(\varphi_b) \\ Y(\varphi_b) = r_b \cdot \cos(\varphi_b) - r_b \cdot \varphi_b \cdot \sin(\varphi_b) \end{cases} \quad (1)$$

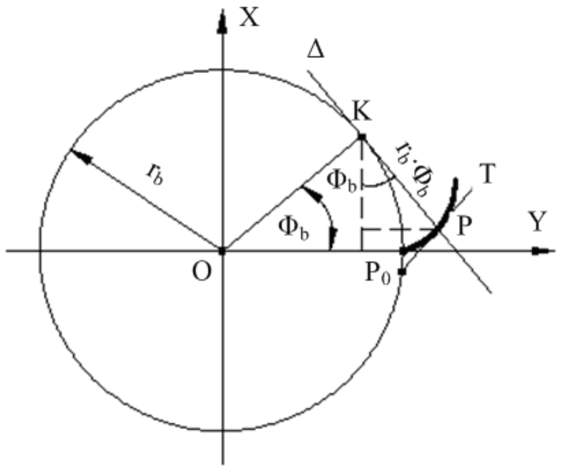

Figure 1: The involute curve of a base circle with r_b radius, [4]

Flank topography

Combined measurement tasks can be realized with the coordinate measuring machines. Using coordinate measuring machines the accuracy of the pitch, the lead and the profile track can be measured, presented in [2]. This paper focuses on profile measurement, which realization was made using a coordinate measuring machine, the DEA Global Performance.

All the measuring process begins with the calibration of the probe tip, which is realized with the calibration sphere. After this, a local coordinate system was defined, in which the coordinate points were saved. The origin of the local system is on the gear rotation axis so that the *Z* axis of the local system coincides with the rotation axis *(Fig. 2)*. The gear was fixed on the table of the coordinate measuring machine, without using a rotary table.

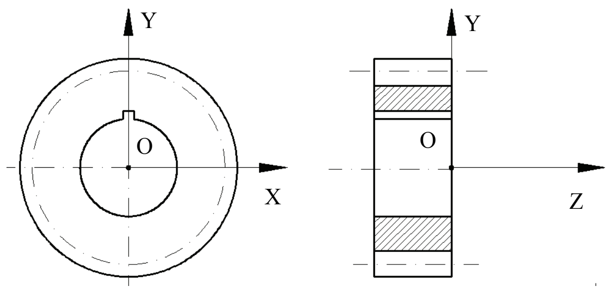

Figure 2: Schematic draw for illustration the local coordinate system

A probe tip with 2 mm diameter was used. Taking into account the papers [7, 8], the probe compensation is turned on and the measuring surface was detected in normal direction *(Fig. 3)*. With these measuring settings the detected points are not calculated in the center of the probe tip, but on the measured surface.

The gear flank measuring was extended in the whole gear width. This measuring process results 671 points on one flank. The measurement was realized in the following way: the coordinate on the Z axis was decreased in small steps while in each step the X and Y coordinates were travelling on the profile (Z – constant for a step while X and Y varies). The limits of these two coordinates, X and Y, were the root and the tip diameter.

Finishing the measurement, these coordinates (X, Y, Z) were saved for post-processing.

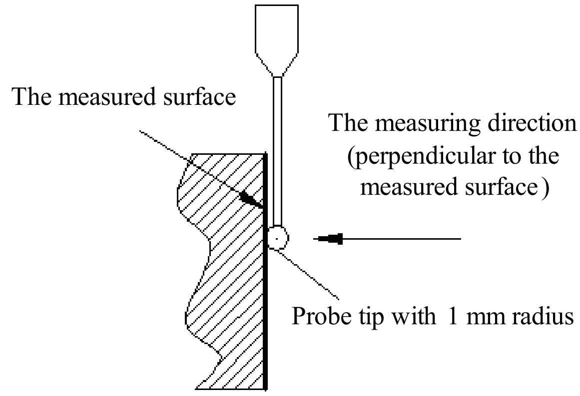

Figure 3: Schematic illustration of the measuring direction, [7, 8]

GUI for cylindrical gears

The post processing of the measured and theoretical data is realized in Matlab software. A graphical user interface, presented in *Fig. 4*, was made by the authors for cylindrical gears. The GUI bases on the interface presented in [9].

This graphical user interface has three parts:

- a part for introducing the theoretical data of the measured cylindrical gear;
- a part for selecting the experimental data of the measured cylindrical gear;
- a part for presenting the theoretical and measured coordinate points and evaluating the mean error.

Introducing the theoretical data

First step is to generate the theoretical flanks surfaces. The initial parameters of the cylindrical wheel are introduced, which are:

- the module;
- the pressure angle;
- the number of teeth.

With these three parameters the theoretical flanks are constructed using (1), *(Fig. 5)*. The base circle, r_b, is calculated by the well known formula, [10]:

$$r_b = \frac{m \cdot z}{2} \cdot \cos(\alpha), \tag{2}$$

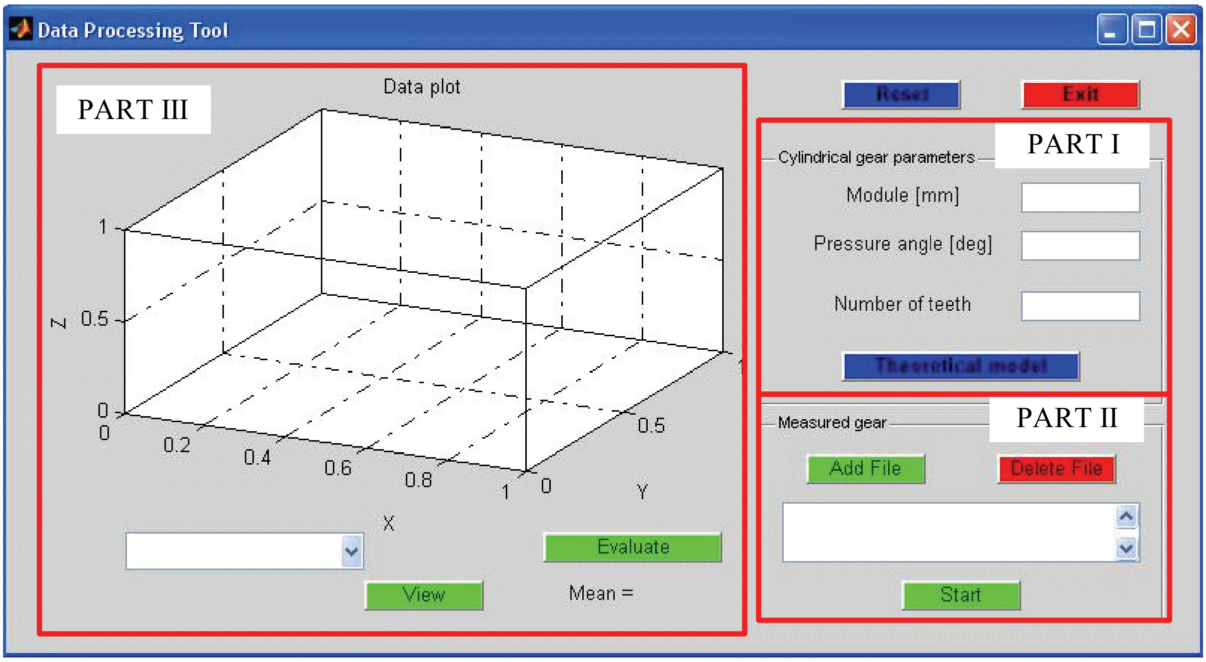

Figure 4: The designed GUI for cylindrical gears

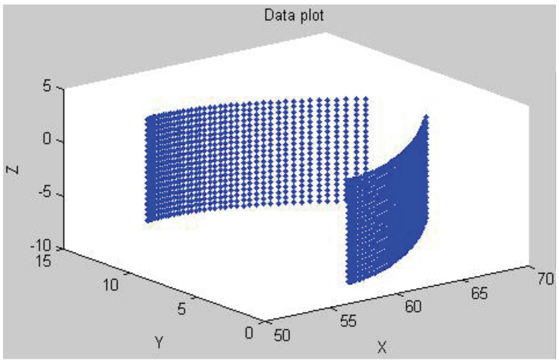

Figure 5: The theoretical surfaces of the measured cylindrical gear

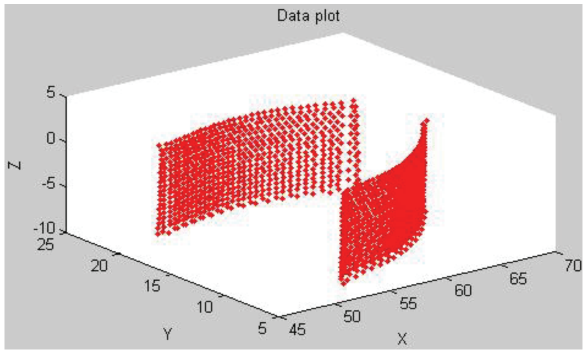

Figure 6: The measured surfaces of the cylindrical gear

Importing the experimental data

The measured gear coordinate points saved previously in a text file, is loaded by the “Add File” pushbutton. In an Open file window the measured data can be selected. This dataset is presented on the graphical part of the GUI *(Fig. 6)*.

The two sets of data are presented on a common figure in the GUI to compare them.

The comparison is realized in the background having two steps: overlaying the two sets of data and calculating the errors between the coordinate points.

The surface overlaying uses the pitch cylinder of the gear. The program determines the intersection points between the measured surface with the pitch cylinder and the theoretical surface with the pitch cylinder. Identifying the intersection points, a supplemental transformation is needed. This is a rotation along the Z axes of the gear. The applied rotation angle is determined between the intersection points *(Fig. 7)*.

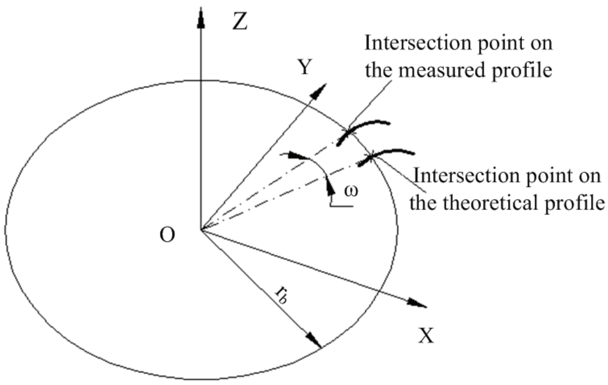

Figure 7: The rotation angle determination

Coordinate points representation and error evaluation

In this part of the GUI are presented the overlapped surfaces and the mean error *(Fig. 8)*.

The errors, the distances are calculated using the formula of Euclidean distance.

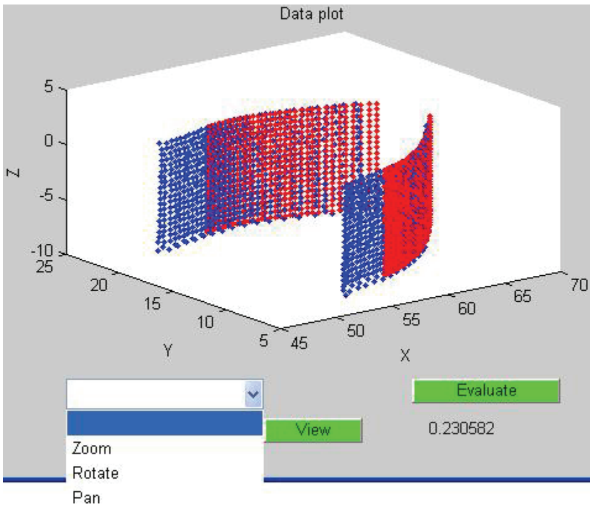

Figure 8: Data evaluation

Having a pop-up menu in the left corner of the GUI the user can move the graphical part (in which the coordinate points are presented). This menu contains three possibilities: Zoom, Rotate, Pan.

Conclusions

The objective of this paper is to present the differences, the errors, between the theoretical and the measured tooth's surfaces of the spur gear. The errors are presented in a parameterized graphical user interface which was realized. The advantage of this GUI is that it is possible to evaluate every measured cylindrical gears flanks surfaces by introducing the correct initial parameters.

It is possible to expand the presented program with angular teething.

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