

## AUTOMATING THE MODELLING PROCESS OF INVOLUTE SPUR GEARS WITH STRAIGHT TEETH

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### ABSTRACT

In the paper the possibility of using Delphi programming language in the design of the tooth profile was presented. A developed numerical application was used to generate a tooth profile of involute cylindrical gears with modification and without modification. The size of modifications of the tooth root and the addendum was compared with the parameters obtained from the analytical calculations and machining simulation of gears.

**Keywords:** involute cylindrical gears, Delphi programming language, gears modifications.

### INTRODUCTION

In modern design the most commonly used model of gear is a virtual CAD model. It allows to carry out the analysis (including method FEM) without producing the prototype.

Cylindrical gears with straight teeth are suitable for the simplest mechanical gearboxes. To improve the strength parameters of gearing, various modifications of gear are made. Tooth profile can be modified, to ensure optimum dynamic parameters during meshing, by:

- tooth root modification (protuberance) – Fig. 1,
- addendum modification – Fig. 1.

Shape modification in the tooth line correction is a mirror of gear deflection (due to unequal distribution the load on the facewidth of toothed gears). This modification can be obtained by:

- crowning,
- modification of end relief,
- modification of direction of flank line.

It is often necessary, for operational reasons, it is necessary to remove some part of material on the side of the tooth, or to remove material on entire flank of the tooth. This modification is called

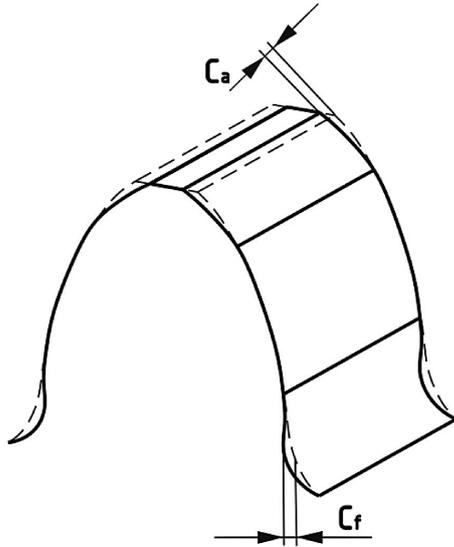
a topological modification (three-dimensional). We can make this modification when the parameters of modification are greater than gear's dimensional deviation.

For involute spur gear mathematical formulas describing the following points on tooth profile were described [1–7]. The cutting edge of the tool (Fig. 2) is divided into sections, for which there are certain formulas defining the tooth profile [2, 7, 8].

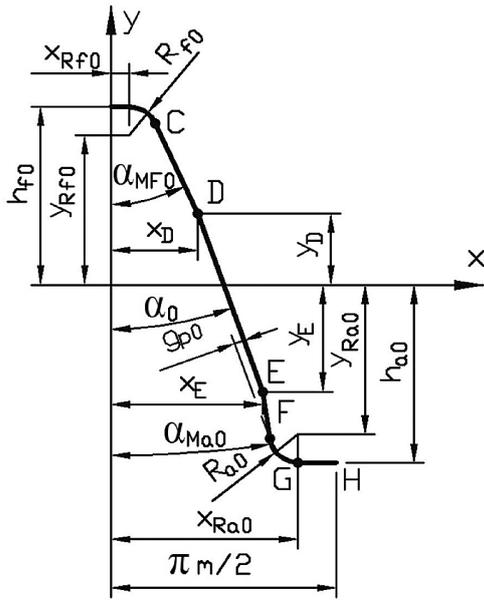
To facilitate the calculation the computer application, developed in Delphi programming language was created. One of the application window is shown in Figure 3.

The developed application has a many options for determining the parameters. The most important of these are:

- entering parameters and characteristic points on cutting edge tools without modifying the tooth profile, the calculation of the profile points of the gear;
- entering tool parameters without modifying the tooth profile with the possibility of changing the thickness of the tool (tooth thickness of toll is given on the pitch diameter), the calculation of the profile points of the gear;



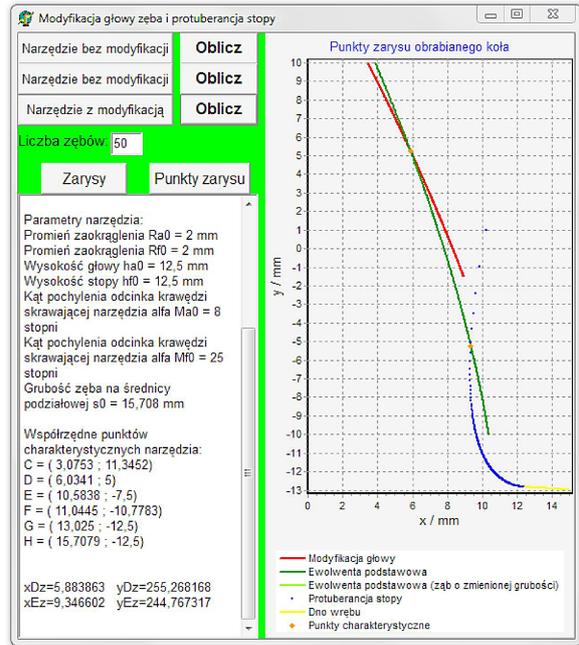
**Fig. 1.** Modification of tooth root and addendum of the gear ( $C_a$  – the depth modification of addendum,  $C_f$  – the depth modification of gear tooth root)



**Fig. 2.** Gear tool with addendum and tooth root modification

- entering parameters and characteristic points on cutting edge tools with tooth root and addendum modification, the calculation of the profile points of the gear;
- graphic representation of tooth profile for whole defined cutting tools;
- display coordinates of point on tooth profile, with possibility of writing them into .txt file.

Tooth profiles generated for example cutting tools are presented in Figure 4.



**Fig. 3.** Window of application for designing the tooth profile

Coordinates of point modification are based on the size of the cutting tool edge division and they are more accurate when the number of divisions is higher. For examples from Figure 4 the number of divisions on the cutting edge was 500.

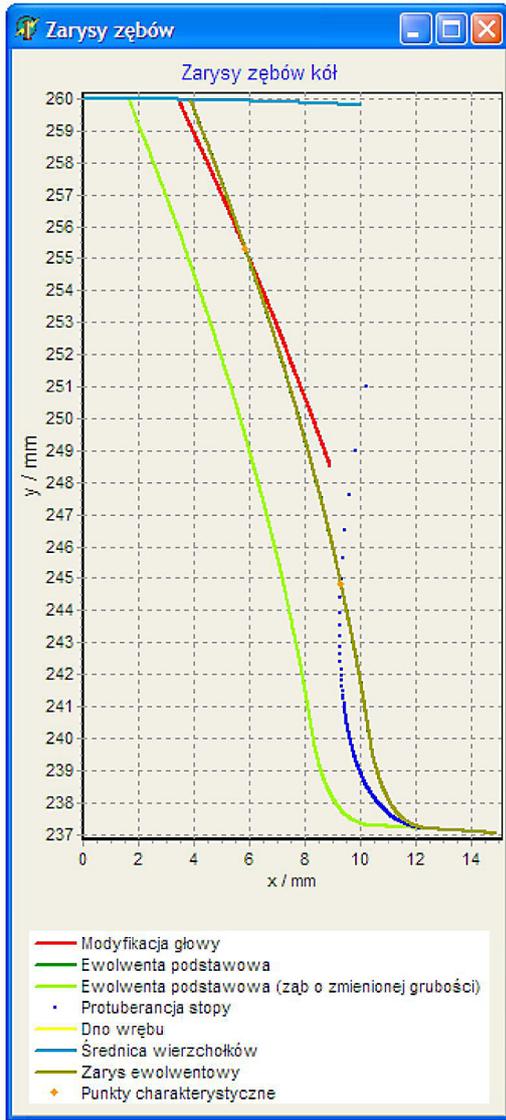
While the division a greater number of profile points is increasing, more accurate tooth profile can be obtained from the outline of the side of the tooth. Unfortunately, in this case, the hardware requirements for smooth operation of the programme were increased.

The result of calculations can be transferred to any CAD environment to automate the design process of tooth profile. From the program (Fig. 3) one side of the gear tooth is obtained, which can be used to prepare the whole model of the gear.

More labour-intensive tooth profile modelling method is the simulation of machining in CAD environment. Virtual model (2D or 3D) is obtained by subtracting the mutual reeling and subtraction solid models of basic rack (as tool) and output gear.

To automate the process of virtual machining simulation an application (in Delphi programming language) was created. The program can generate a subsequent commands of simulation:

- copy the gear tool model,
- rotate and move the model of output gear,
- subtract the model of toothed tool from the output model.

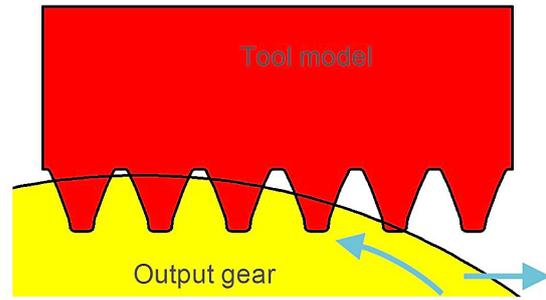


**Fig. 4.** Tooth profile comparison (gear parameters  $m_n = 10$  mm,  $z = 50$ ,  $x_k = 0$ ,  $\alpha = 20^\circ$ ,  $c^* = 0.25$ ): with tooth root and addendum modification, without modification, with tooth width modification

Steps simulation are shown in Figure 5. Movements of models are presented by arrows.

File with simulation command saved in .scr file and can be open in AutoCAD environment. The simulation of the machining process does not have to run for cutting the whole gear. It can be run only for one tooth (one needs to pay attention and check if next step of simulation does not change our selected tooth space).

The sample values of gear modification:  $m_n = 10$  mm,  $z = 50$ ,  $x_k = 0$ ,  $\alpha = 20^\circ$ ,  $c^* = 0.25$  were given in Table 1. Points of tooth profile were designed by using the application (Fig. 3) and by the virtual simulation of machining in CAD environment.

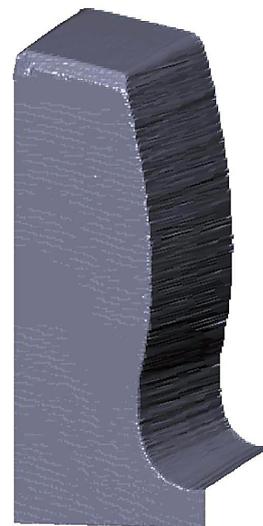


**Fig. 5.** Gear generating simulation

Reverse engineering can be used to reproduce an existing gear and its geometry. The real model is measured by appropriate tools, and so-called point cloud can be obtained. The next step is data processing in CAD system (creating a virtual model of gear). Too small number of measurements can lead to incorrect representation of the original gear. Example of surfaces generated by point cloud measured from cylindrical involute gear are shown in Figure 6. The next operation for that surfaces should be smoothing.

**Table 1.** Value of tooth root and addendum modification for sample gear

Descriptions	Analytic method [mm]	Cutting simulation [mm]
Value of addendum modification $C_a$	0.38407	0.39150
Radius of addendum modification	255.35947	255.28804
Value of tooth root modification $C_r$	0.72547	0.72604
Radius of tooth root modification	244.95065	244.97606



**Fig. 6.** Surfaces of cylindrical involute gear generated from point cloud

## CONCLUSIONS

Computer Aided Design (CAD) allows to calculate a gear tooth form and change modification parameters without the need to manufacture the gear. Programming languages can be used to support the calculations of coordinate points of the designed tooth profile. Created applications allow to create many variants of gear with modification, which will be subjects to analysis (choose the most appropriate).

Parameters of tooth root and addendum modification were calculated with the analytical method (based on the analysis of counterpart gear). According to various studies, these parameters are different because various factors were included in the analysis (e.g. gearing stiffness, meshing ratio, etc.) [5, 7, 9]. The difference between the parameters obtained using the analytical models (depended on counterpart gear) and computer simulation of the machining fits within the numerical rounding errors.

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