# Analysis of the correspondence of the obtained involving surfaces of gears designed with CAD systems with the real surfaces

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***Abstract:*** *The paper addresses the problem of designing 3D models of gears, how well the resulting involute profile corresponds to the real one. Very often are used 3d models of gears to produce various gears through 3d prototyping. Some of the most used CAD systems (Solid Works, Solid Edge or Autodesk Inventor) are used to design the 3D models. The comparative analysis made shows the accuracy of modelling the involute profile of the 3D models from different CAD systems compared to the real profile, what are the deviations and how suitable it is to use them for 3D prototyping of gears. Solutions are presented to obtain realistic gear tooth profiles.*
***Keywords:*** *GEARS, CAD SYSTEM, MACHINE DESIGN, 3D MODELS*

## *1. Introduction*

Due to the widespread use of spur gears in mechanical drives, it is necessary to carefully analyze the new specific capabilities that CAD systems provide for profiling a real involute contour of a spur gear.

With the development of gear manufacturing technologies, in addition to the traditional method of cutting gears using metal-cutting tools removal, new methods are also used. These are the cutting of gears with straight teeth from metal and non-metal from sheet blanks on laser plasma and waterjet cutting machines, as well as the recently highly developed technology of prototyping with 3D printing. The quality of the resulting parts depends not only on the accuracy of the machine and technology, but also on the accurate setting of the involute contour of the cutting teeth when programming the CNC cutting program or 3D model.

## *2. Research into the capabilities of some CAD systems for generating a real involute profile*

The need for the study is due to the fact that 3D CAD systems (SolidWorks, Solid Edge, Autodesk Inventor and others) require that the 3D model of the gears be prepared in advance, after which a 2D contour of the gear is generated from this 3D model. In one of the most used 2D programs Autodesk AutoCAD, the involute curve can be manually profiled, which is a very complex and lengthy process. For this reason, 3D programs are mainly used that automatically generate 3D models of the gears. But to what extent do the generated gears have an involute tooth profile that is as close as possible to the real one?

Some of the most widely used 3D CAD programs, such as SolidWorks and Autodesk Inventor, when generating gear models do not implement a real involute profile of the tooth contour, but only a similar curve to simplify and lighten the file. [2]

The results of the work of the two CAD systems – SolidWorks and Autodesk Inventor are analyzed. Gear profiles are generated with these two systems for different variants of the parameters m - module and z - number of teeth. The goal is to obtain and analyze the generated involute profiles of some of the most produced gear parameters (Table 1).

***Table 1:*** *Gear variants to research.*

| Module | 3 | 5 | 9 |
|---|---|---|---|
| Number of teeth, z1 | 20 | 20 | 20 |
| Number of teeth, z2 | 60 | 60 | 60 |

Using the Autodesk Inventor program, 3D spur gears can be generated from the Design/Spur Gear menu. From the resulting gears, a simplified version (Export to DWG) of the involute curve of the teeth can be generated. The curve thus obtained does not visually correspond to the real curve, and it is used only for visualization and does not burden the software.

For more precise generation of the real involute curve, the command “Export tooth shape” is used. Thus, the involute contour of one interdental space is sequentially saved, and exported to a .dwg file. Then it is necessary to process it further to obtain the contours of all teeth.

The second system used for the comparative analysis and for generating a gear is the CAD program SolidWorks. The 3D models of gears are generated according to the variants in Table 1. After generating the 3D models, the involute contours are exported to a .dwg or .dxf file.

For a more complete analysis, the results of a specialized program AutoCAD .NET API for generating involute profiles, developed by specialists in CAD systems and Engineering Graphics from the University of Ruse, are added to the programs used and studied. [3]

The study presents the work and results of the AutoCAD .NET API application for generating involute profiles of a straight-toothed gear. The result of the application generates the profile of the gear contour in a 2D plane. The application uses the AutoCAD .NET application programming interface (API), which allows manipulating AutoCAD and drawing files through a large set of libraries. The application works with logical functions and geometric objects. The use of logical functions on geometric objects very well resembles the practical method of cutting gears by gear hobbing. The profile is built in such a way that all the requirements and features of the initial tool contour are met. This method of synthesizing an involute profile can be attributed to the geometric profiling methods based on rolling (traversing). The result of the application is a file in .dwg format, on which the contours of both gears are generated.

## *3 Results of the comparative analysis*

To implement the analysis, all generated contours from the used tooth systems and gear profiles are superimposed on each other. All results are generated in .dwg files, which in an AutoCAD environment are superimposed in one file. As a base contour, we take the contour generated by the AutoCAD .NET API application, because this contour was obtained by imitating real gear cutting according to standards and methodologies in the technical literature on Machine Elements and Mechanical Engineering. The analysis compares contours with small, medium and large modules and a small and large number of teeth. The goal is to check whether changing the module and number of teeth affects the accuracy of contour generation in different programs. Table 2 shows the different colors used for the different contours for better visualization.

After overlaying all the contours in one file, the following results are obtained (Fig. 1)

Table 2: Curve colors used in comparative analysis.

| CAD system | Color |
|---|---|
| Autodesk Inventor simplified curve | |
| Autodesk Inventor real curve | |
| SolidWorks | |
| AutoCAD .NET API | |

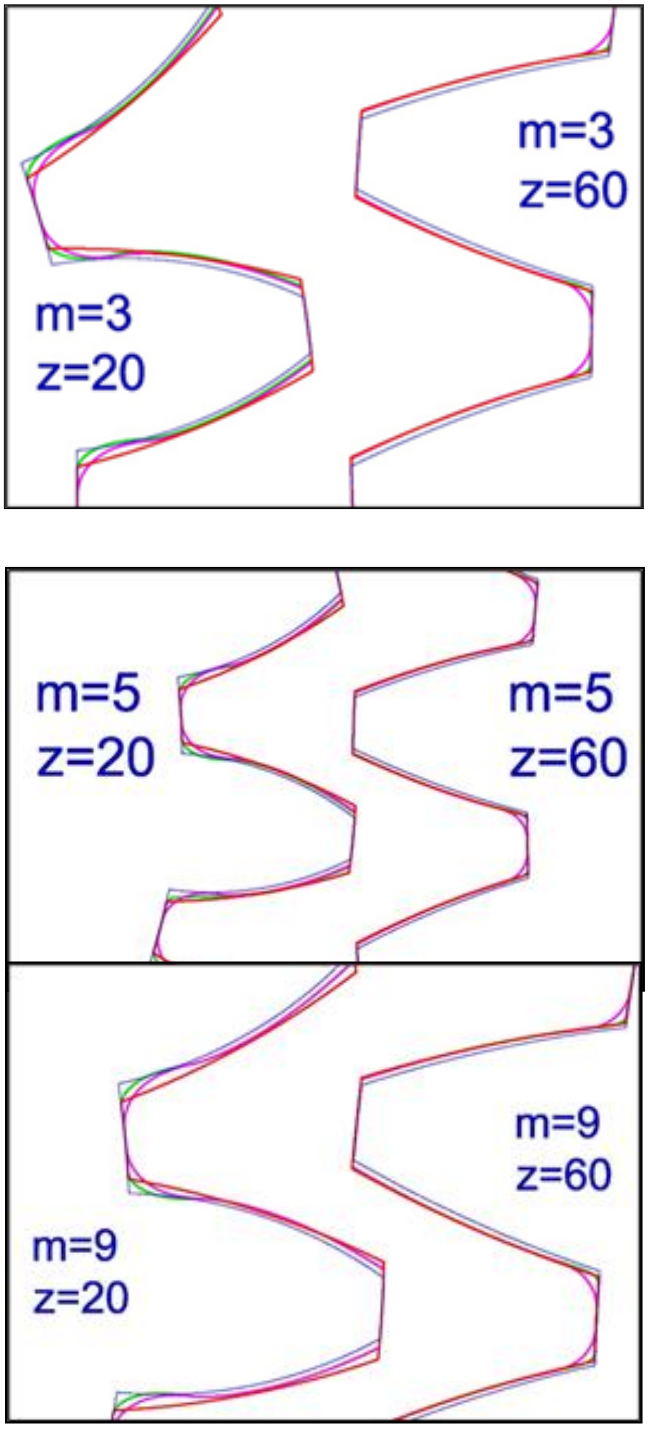


Fig. 1 Comparative analysis of an involute profile obtained using different systems

The gear teeth generated by the SolidWorks program (blue line) differ in smaller thickness for all modules and number of teeth, the difference reaches 0.5mm. The transition curve at the base of the tooth has no radius of curvature, which is unacceptable for a real gear. The diameters correspond to the other curves.

The gear teeth generated by the Autodesk Inventor program as a simplified curve (purple line) for all modules but with a small number of teeth deviate up to 0.5mm from the base contour adopted. For wheels with a large number of teeth, no large deviation is observed. The transition curve at the base of the tooth has no radius of curvature, which is unacceptable for a real gear. The diameters correspond to the other curves.

## *3. Conclusion*

The analysis shows that the SolidWorks program does not provide a real contour of a gear with straight teeth, the generated curves are only for visualization and are not suitable for practical use. The Autodesk Inventor program offers two options for visualization of involute curves - a simplified one to facilitate work with the program and, if necessary, a relatively accurate and real contour. The problem is that the program generates only one inter-tooth gap in the real contour, which means performing more operations to generate the entire contour of the gear. This prolongs and complicates the work. While through the specialized AutoCAD .NET API application, which is significantly easier to use and cheaper than the other programs studied, a real such profile can be created and used very easily and quickly.

Using the AutoCAD application programming interface (.NET API) to solve practical, educational and scientific tasks provides great opportunities for programmers, scientists and engineers from practice. The application offers an easy and quick solution to the task of constructing an accurate profile of an involute gear with straight teeth in the AutoCAD environment. The profile thus obtained can be used to create a 3D model of a gear, which can be subjected to strength and dynamic research in other software systems based on the finite element method. The obtained involute curves of the designed gears using the specified application are very accurate to the real involute, while the involutes constructed using the considered CAD systems in the analysis have deviations.

Such specialized applications can be used to illustrate the learning process when studying involute gearing. It allows to show and simulate the conditions under which undercutting occurs. It is very clearly visible after appropriate magnification the shape of the transition curve and the change even with different bevels and roundings at the tip of the teeth of the comb. From the obtained profiles, various strength simulations can be made or ready-made gears can be cut on laser, plasma or waterjet cutting machines, with sufficient accuracy of the tooth profile.

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