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IMPROVED ACCURACY GEAR TOOTH CAD MODELLING

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Abstract: The paper deals with a possible improvement of gear tooth profiles by using exact calculations for generating 2D curves instead of approximation processes. This method can be applied in almost all CAD software and gives a far superior result in profile precision.

Keywords: *gear design, CAD modelling, gear optimization*

1. INTRODUCTION

In this days, optimization of different machine parts plays a huge role in the designing process. The optimization process can take place in different stages of the designing process. The necessary changes mostly begin to surface after the first design is ready for testing. All prototype and finished product modelling and the necessary FEM analysis can benefit from a more accurate CAD model so we can make a more realistic simulation and predict the outcome of the final product. Most CAD software manufacturers provide different tools and downloadable modules to improve the ability of their software. Aside from the differences of the user interface all professional CAD system has multiple tool for a given sollution like curve design. These solutions mostly based on the same principles, so a generalised idea can be used on all system without limitations regardless of the manufacturer.
According to the biggest CAD software developers manuals [1–4] all system capable of high precision modelling.

2. CURVE MODELLING IN CAD SYSTEMS

Most of the modern CAD modelling software are capable of making full or partial gear designs from given parameters. This helpful modules greatly reduce the necessary time of making new gear designs as need arise.

The bottleneck of these modules is the precision. Mostly they are adequate for supplying 3D CAD models directly for low or low-mid quality gear production but it is unusable if high precision is needed. In this case there are specialised software capable of making high and ultra high precision gears, but they have a huge cost that makes their usability very limited.

The other more convenient way is to use our already existing CAD software capabilities for this purpose.

We shall show a method in FREECAD 2D-3D software that can make a high precision evolvent to create a gear tooth profile and the differences of the approximation and precision concerning the two methods.

The main method for making an evolvent in CAD system is by making a spline from a few already calculated point [5].

Advantages:
- only a few coordinate point is necessary,
- low end PC-s can handle the graphical needs of the designer,
- fast solution that can be applied with few clics.

Disadvantages:
- limited use only in low and low – mid quality gears can be made by this method,
- spline has inflection points so they can't provide a profile that can be made into a smooth tooth surface (wavy surface),
- not suitable to provide good 3D models for FEM analysis,
- third party software or serious post processing is required to make a high precision model with this method.

It is evident from the above mentioned drawbacks that a better solution may be beneficial if we want to keep the original CAD software useful for gear design purposes.

The other solution is called in a lot of name depending on the software we use, but they are more or less the same procedures that makes curves from exact equations.

Advantages:
- this method is calculating the exact points coordinates,
- precision is adjustable by user via defining the number of calculated points,
- precision is only depend on the capabilities of the hardware and the number of calculated points the user define,
- possible to make higher precision tooth surface that can be manufactured,
- the method can be used with any approximation type for making curves,
- no specialised software or knowledge required.

Disadvantages:
- stronger hardware required for high precision gear designer,
- depending on the CAD software in a few case it can be more time consuming than the approximation method.

After we review the main differences of the two method let's have some thought about the equation driven method. This can be done by supplying a parametric equation of the curve and giving the number of points or steps we needed to calculate. An example can be seen in the next figure.

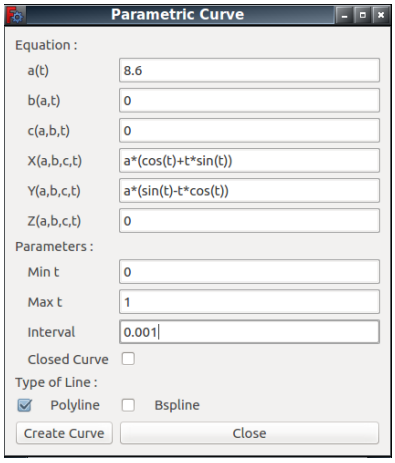


Figure 1. Equations for gear with evolvent profile with tooth number F = 11 and module m = 2

Figure 1 shows the first experimental evolvent equations made by the procedure. The method for making a continuous line is by applying polyline for the calculated points. In this way the inflection points can be avoided entirely. The comparison of the approximation and the equation method can be seen in the next figure.

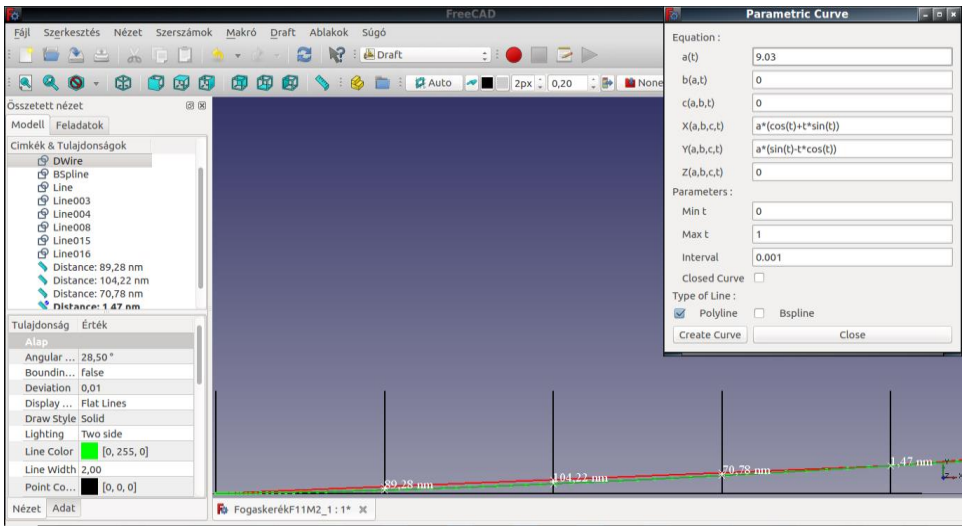


Figure 2. Spline (red) and equation curve (green)

In *Figure 2* the red line is the original spline approximation and the green line represents the equation driven method. The Min t and Max t parameters are the starting and finishing degrees in radian for the calculation of the curve. Interval is the number of steps of number of points we want to have for creating the spline. With numerous trial and error I find that the most practical interval range is between 0.01 and 0.0001. The best result hardware wise was with 0.001. Precision is decreasing as the process approaches the head of the tooth, but it is still much better than the spline version. *Figure 2* clearly shows the inflection point of the spline and the highest deviation from the real curve. The highest deviation is 104.22 nm in this design example. If we make other designs similar to this and only changing the module for a new one the difference is rising between the approximated and equation driven solutions.

Figure 3 is a summary of the degrading accuracy of the spline method compared to the equation driven one. The red line is the spline approximation the green line represents the equation one.

The tooth number F is fixed for 11 and from top to down the module is increasing as follows: 2; 2.1; 2.5.

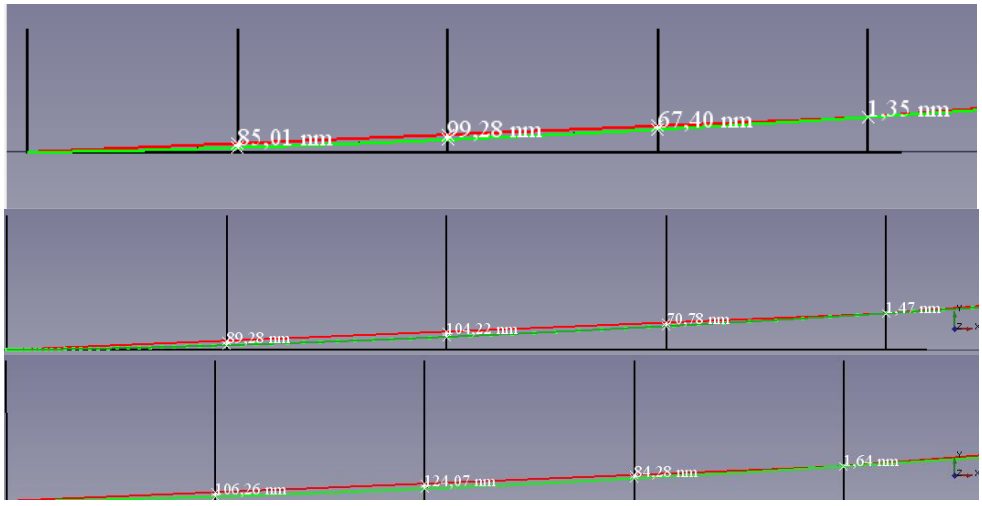


Figure 3. Error increase in the approximation

As it can be seen in *Figure 3* the approximation error is gradually rising with the rise of the module applied.

3. SUMMARY

The equation driven method for making curves has a high potential in industrial use since it allow manufacturers to produce high quality gears without any

specialised software. The method has proven superior in almost any respect compared to the widely used spline approximation method.
Future automation of this method is possible by making program modules based on equations instead of spline approximation.

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