New Siemens applications for designing bevel gears

A M Goanta $^{1,2}$ and P Dumitrache$^{1,2}$

$^1$“Dunarea de Jos” University of Galati, Engineering and Agronomy Faculty of Braila, Calea Calarasilor Street, 810017, Braila, Romania
$^2$Research Centre for Mechanics of the Machines and Technological Equipments, Calea Calarasilor Street, 810017, Braila, Romania

E-mail: goanta_a_m@yahoo.com

Abstract. The current situation in the design of gearings is different from software to software and in some cases requires specialized settings with or without additional costs. There are two ways of generating evolving tooting: one is based on the designer’s solid knowledge of geometry and gearing and the other is based on a series of automation subprograms for 3D modelling of gears. The first method is a general one, applicable to all design software that is based on generating a curve evolving specific to a tooth flank, continued with the construction of the symmetrical flank, the pattern multiplication of circular type around the center of the gear and finally generation of the three-dimensional characteristic of each individual tooth. The second method is much faster and requires only general knowledge about the gear but sufficiently advanced to allow permanent dialogue with the subprogram for generating cone gears. Absolute novelty items are brought about by the new NX design applications that lead to getting gears with curved teeth. In conclusion the paper shows how different variants of bevel gears are generated using various subprograms or performance settings, installed over the SIEMENS NX. An essential component of the paper is highlighting generation capacity of gears and gearing intended for predefined types of gear cutting machines such as those for Gleason and Oerlikon teeth.

1. Real state of the art regarding the software for designing bevel gears

Geometric modelling of cylindrical, bevel or worm gears is a very interesting topic because gears play an important role in the mechanical transmissions that have applicability in all industrial sectors. In general, parametrically CAD modeling ensure its superiority by its quick ability to make changes both at 3D and 2D documentation level. 3D model made so, contains besides geometric type information, information type physical and mechanical properties that are used on the CAE and CAM softwares. As a result of the increased interests for this type of modelling, there are three types of CAD design solutions (computing and generating 3D) that manage more or less efficient generating gear, namely: software for mechanical design 3D CAD, plug-ins designed to increase the performance in the gears (for example those from GWJ Technology GmbH Braunschweig Germany) and last but not least specialized softwares for gears such as those from the company KISSsoft, USA. The plugins are always made separately for each software of general mechanical design such as Inventor, Solid Edge, SolidWorks, Creo, while specialized software are self-contained with a component very well
set on hand calculation and with well-developed 3D modeling component that allows saving the predefined extensions.

Figure 1. Bevel pinion made with Solid Works.

In Figure 1 it is represented the result of generating a bevel pinion spur gear with the help of Solid Works, and in Figure 2 shows the design parameters and also the result of designing a bevel pinion with KISSsoft version 03/2016.

Figure 2. Bevel pinion made with KISSsoft.

2. Theoretical aspects of generating bevel gears flank involute

If I have to begin with a definition, it must be said that bevel gears are machine parts consisting of rotating conical bodies fitted with outer denture /teeth. They enable transmission of torque and rotational movement to a constant transmission ratio [1]. The theory on the graphical representation, sizing computation and reliability is pretty vast and are the central subject of several disciplines. Any
The bevel gear is composed of three main parts, namely: hub, disk, and crown. Two gears having the same module may form an external bevel gear. The design of a mechanical transmission includes all technical-economic operations needed to establish solutions in terms of size and shape in accordance with the design theme, which is usually determined by the customer and must include the scope of application purpose, the operating range, the requirements of size, durability of the product and certain aspects of production [2]. In general, in solving a design theme there are several possible solutions called preliminary variants out of which the best solution shall be selected based on a technical-economic comparison [3]. The special importance attached to gearings led to the development of both three-dimensional software components and a wide range of machine tools for their processing able to communicate through various means with the virtual model made by the designer. Most gears have involute flanks. An involute is a cyclical curve obtained by slipping-free running a straight line on a circle called the base circle [4]. To determine the involute equations it is considered a fixed point on the running straight line, denoted as M, in two successive positions, the first being the initial position tangent to the base circle and the second being any position [5]. The condition of slipping-free running of the generating line onto the base circle it results that the length of the arc T0T, travelled by the tangent point on the base circle, must be equal to the MT segment length, travelled by the same tangent point on the running straight line.

\[ T_0T = r_b (\varphi + \alpha) = MT = r_b \times tg\alpha \] \[ \text{[6],[7]} \] (1)

Legend: \( \varphi \) = expression of the position angle of the current point on the involute \( \alpha \) = pressure angle corresponding to the tangent point between the running straight line and the base circle \( \varphi = tg\alpha - \alpha = \text{involute} \) \[ \text{[8]} \] (2)

This function above is called involute and is represented in Figure 3 on the portion between points \( T_0 \) and M. In Figure 4 shows the forces of the bevel gear.

**Figure 3.** Generation of involute. **Figure 4.** Forces of straight bevel gear teeth.
3. The generating of bevel gears with mechanical design software

In other words, the first method mentioned in the abstract allows for the generation of the flank geometry starting from the mathematical definition of how an involute curve or from the theory of gearing from which is only kept the relevant portion of the gearing zone.

![Figure 5. Profil generator Inventor.](image)

![Figure 6. Design label in Bevel Gears.](image)

Unlike this case, the current trend is to apply more the second method which refers to the use of a specialized command that generate the tooth without doing helpful geometric constructions, as it is much faster. Starting from the same situation, more and more software developers try to solve as many aspects of the gear 3D modelling aspects as possible. Also it should be noted that various design environments such as Mechanical Desktop, Inventor or Solid Edge, contains specialized modules for generating bevel gears.

![Figure 7. Calculation label in Bevel Gears.](image)

![Figure 8. Gear Materials window.](image)
3.1. Generating bevel gears by Mechanical Desktop or Inventor

Mechanical Desktop and Inventor software packages are design software’s produced by the same manufacturer, namely Autodesk Inc. [8]. The first is the older version of the iconic version Inventor 2017 and therefore presents an obvious superiority over its predecessor. Essentially both have a common feature, namely the ability of parametric 3D modelling of both item and assembly, coupled with a variety of modules intended for mechanical design. In the Inventor 2017 assembly-type files saved on the hard disk, bevel gears can be generated by activating Design Accelerator. Figure 5 shows the generating profile of the gap between the two teeth of the cone pinion made with Design Accelerator.

The window in Figure 6 contains a series of parameters that define the design of the two gears forming a bevel gear.

![Figure 5. Generating bevel gears profile.](image)

![Figure 6. Generating profile of the gap.](image)

It must be said that the first step in defining all parameters must have a starting point in selecting the input parameters, namely: Gear Ratio, Number of Teeth, Module and Diametral Pitch, subsequently defining the desired values for the parameters: Face width, Pressure Angle, Helix Angle, Module, Shaft Angle, Unit Correction Guide, etc. In Figure 7 window, the method of calculating the resistance is selected and a number of parameters are set such as power, rotational speed, transmission efficiency and lifetime in hours imposed to the gear.

Also, when ticking the material to apply to each wheel separately, the window in Figure 8 will be opened, where the designer has the opportunity to choose a material from the library or to define a new material not found in the library, whose tabular values to be taken from a particular standard.

Resuming the above data, we must remember the following:

- Designing by Design Accelerator provides the ability to control the outcome both by accurate engineering calculations and by previewing windows.
- Access to modelling tools for the bevel gears is possible only by certain assembly files with the extension *.iam.
- If ordering the generation of the bevel gear is done simultaneously by pressing CTRL, the effect will not take into account the settings from the last application but will be reset to the default "works" values.
All modelling and generation tools are grouped in the Design tab of the ribbon specific to this design software.

Editing any gear or gear subassembly existing in the left browser of the interface can be done by pressing the mouse right button on that item in the browser and choosing "Edit Using Design Accelerator" option.

Figure 11. Generating profile Solide Edge ST 9.

Figure 9 illustrates the window for generating a wedge groove in the hub and Figure 10 shows the result of generating a bevel gear.

3.2. Solution to generate bevel gears by Solid Edge ST9

Solid Edge [9] launched and developed by Intergraph in 1996, acquired by UGS Corp in 1998, has continuously developed and passed from the modelling core ACIS to Parasolid core, at some moment being one of the basic products of Siemens PLM.

Figure 12. Bevel Gear Designer window

Figure 13. Bevel gear SE ST9
With Solid Edge ST 9 (version 2016) similar to the Design Accelerator within Inventor 2017 for generating bevel gears in the assembly files, Bevel Gear Designer application is used within the set of engineering applications called Engineering Reference. Like in the previous case, the tooth flank of the bevel gear with straight teeth, sloping or curved, is not involute flank. Its generation is based on of an arc approximating to a certain extent the theoretical involute. This does not prevent obtaining the execution 2D documentation nor significantly influences the position of the mass centers however, if the file is exported to a manufacturing software, the final result of the manufacturing of the gear in question will no longer meet the quality criteria required by the fact that the gear should ensure a high level of the flank with a low noise level at high speeds. Figure 11 shows the generating profile of the gap between the two teeth of the cone pinion made with Solid Edge Bevel Gear Designer. Figure 12 illustrates the window where parameters are selected to generate a bevel gear, while Figure 13 shows the results for the case of a bevel gear defined by the following parameters: Desire Gear Ratio=4, Pressure Angle=200 Spiral Angle = 180, Shaft Angle=900, Module=3, etc.

4. New Siemens applications for generating bevel gears by NX

Since version NX 7.5, if a new variable of „Environment variables” type is defined under the name "UGII_COUNTRY" to which the value "prc" is assigned, as shown in Figure 14, a new set of instructions will be obtained to allow for modelling bevel gears with tilt or straight teeth, i.e. bevel gears with straight, tilt/sloping teeth of in arches of various curves.

Specifically the additional generating options are: "Spiral Gleason Gear Modelling", "Spiral Oerlikon Gear Modelling", "Gleason Hypoid Gear Modelling" and "Oerlikon Hypoid Gear Modelling". The superiority of this variant of gear generation, specific only to NX as compared to previous versions, is that the generation of the gear flank is based on a spline curve that approximates the involute much better than the alternatives using arcs. Figure 15 shows generating parameters of a Gleason Spiral bevel gear type. It should be noted that these new applications based on "UGII_COUNTRY" variable are not compatible with the NX 11 launched in 2016 but the generated files in one of the earlier versions can be opened and further used for manufacturing purpose using the current version, namely
NX11. Figure 16 shows the generating profile of the gap between the two teeth of the cone pinion and fig. 17 shows the bevel gear in the assembled position made with NX 7.5.

5. Conclusions

Although NX 11 launched in 2016 is software of high range category, unfortunately the package does not include a module for the generation and calculation of gears in general and bevel gears in particular. I don’t not accept any superior facilities offered by the variable "UGII_COUNTRY", as happens in the earlier versions. Making a detailed comparison of the basic package between Inventor 2017, Solid Edge ST9, NX 7.5 and NX 11 v. 2016 the following conclusions can be drawn:

- 3D models of the two bevel gears made with Inventor are automatically positioned in space in such a way that forms a bevel gear unit and the flanks are tangent and meet the gearing theory.
- Formation of 3D unit of the bevel gears made with Solid Edge ST9 requires laborious positioning relative work.
- The highest flanks generation accuracy is achieved by NX.
- Among the 3D models generated with mechanical design softwares, only those made with NX are compatible with the gear cutting machines.

6. References

[1] Haraga G 2007 Proc. of The Int. Conf. on Engineering Graphics and Design, (Galati: Cermi Publishing House) p 289-92
[2] Goanta A M 2015 Comparative study of commands to generate gears from different software design J. Jideg 5 25-28
[3] Popinceanu N and Puiu V 2003 Machine Elements. Design Principles (Iasi: Junimea Publishing House) p 98
[4] Jula A and Lates M 2004 Machine parts (Brasov: TUP) p 362
[5] Moldovean Gh and Velicu D 2002 Cylindrical and bevel gears (Brasov: Lux Libris Publishing House) p 242
[6] Predescu A 2013 Machine parts (Bucharest: EPP Publishing House) p 298
[7] Belcin O, Birleanu C and Pustan M 2015 Machine parts. Design Elements (Cluj: Risoprint Publishing House) p 585
[8] Stancescu C 2014 Adaptive and parametric modelling with Inventor (Bucharest: Fast Publishing House) p 656
[9] Musca G 2008 Solid Edge the complete solution for the projection mechanic (Iasi: PIM Publishing House) p 312