Design of a spiral bevel gear acc. to ISO 23509:2006 standards

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Abstract. When the transmitting of power and torque between parts of a machine requires high efficiency, the most appropriate type of gears are the bevel gears. The two main forms of bevel gears are straight and spiral bevel gears. Manufacturing of bevel gears has been implemented using dedicated bevel gear cutting machines. These machines make the production of this type of gears quite costly. This is the main reason that forced many manufacturers start using CNC milling machines for cutting bevel gears. A combination of a 5-axis milling center machine and a modern computer aided manufacturing (CAM) system that supports a vast number of complicated machining procedures, offers the opportunity of machining high quality bevel gears. This paper concerns the presentation of a program written in MATLAB that calculates the basic designing features of a bevel gear pair, as they described by ISO standard. It is also presented the calculated tooth profiling that is used in order to be designed a 3-D model of the gears in a CAD software.

1 Introduction

Gear is one of the few mechanical devices that not only can satisfactorily transmit power between rotating shafts, but can also do so with uniform motion and reliability. Spiral bevel gear is a type of gear that is required to turn the corner from a horizontal engine to the vertical rotor shaft. These gears carry large loads and operate at high rotational speeds. For many decades, information on bevel gear geometry has been developed and published by the gear machine manufacturers. It is clear that the specific formulas for their respective geometries were developed for the mechanical generation methods of their particular machines and tools. In many cases, these formulas could not be used in general for all bevel gear types. This situation changed with the introduction of universal, multiaxis CNC machines, which in principle are able to produce nearly all types of gearing.[1],[2] ,[3] ,[4]
The goal of this paper is to present program that calculates all the geometrical features of a spiral bevel gear. The algorithm of this program is developed in a programming platform, in MATLAB.

2 Method

A complete information on design of bevel gearing is provided by the *American Gear Manufactures Association* (ANSI/AGMA standards) and the *International Organization for Standardization* (ISO 23509:2006 standard). Loading, speed, accuracy requirements and special operating conditions influence the design. In this paper the algorithm for the calculation of geometrical features of a spiral bevel gear pair is developed according to ISO 23509:2006 standard.
A design system is selected to be used in order to produce a spiral bevel gear set. Users should determine the cutting method prior to proceeding.

As it is known bevel gears have tapered elements because they are generated and operate, in theory, on the surface of a sphere, Fig. 2. Pitch diameters of mating bevel gears belong to frusta of cones, Fig. 1. [1],[6]

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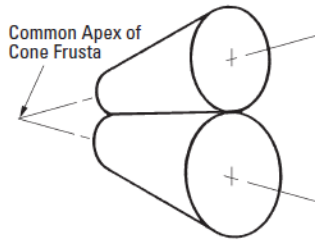

Fig. 1. Pitch cone frusta

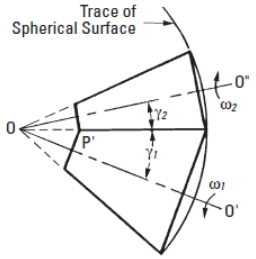

Fig. 2. Pitch cones and the development sphere

Before proceeding design of the geometrical features of each gear of the pair, the pitch cone parameters of the pair should be calculated. One of the recommended procedures of this international standard that is used to begin the calculation of the pitch cone parameters is given in the Table 1. [3]

Table 1. Initial data for the calculation of pitch cone parameters [3]

Symbol	Description	Method 0	Method 1	Method 2	Method 3
Σ	shaft angle	X	X	X	X
a	hypoid offset	0,0	X	X	X
$z_{1,2}$	number of teeth	X	X	X	X
d_{m2}	mean pitch diameter of wheel	—	—	X	—
d_{e2}	outer pitch diameter of wheel	X	X	—	X
b_2	wheel face width	X	X	X	X
β_{m1}	mean spiral angle of pinion	—	X	—	—
β_{m2}	mean spiral angle of wheel	X	—	X	X
r_{c0}	cutter radius	X	X	X	X
z_0	number of blade groups (only face hobbing)	X	X	X	X

The required data of selected method is imported to the algorithm.
Afterwards, one of the two common production methods of spiral bevel gears should be chosen.
In gear industry the production methods are face-milling and face-hobbing, both of them have similar cutting movements. The two different manufacturing methods are shown in Fig. 3 and Fig. 4. [9],[10],[11]

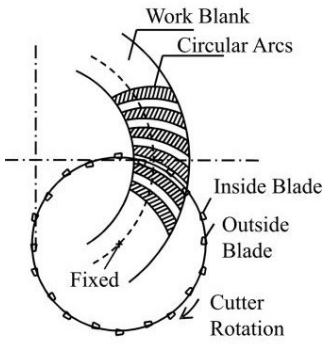

Fig. 3. Face-milling method

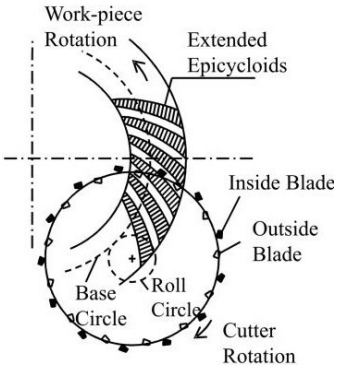

Fig. 4. Face-hobbing method

Continuing, having already been calculated the pitch cone parameters, a set of additional data is now necessary for the calculation of gear dimensions. Table 2. [3]

Table 2. Additional data for gear dimensions [12]

Data type A		Data type B	
Symbol	**Description**	**Symbol**	**Description**
α_{dD}	Nominal design pressure angle, drive side[a]	α_{dD}	Nominal design pressure angle, drive side[a]
α_{dC}	Nominal design pressure angle, coast side[a]	α_{dC}	Nominal design pressure angle, coast side[a]
$f_{\alpha lim}$	Influence factor of limit pressure angle[a]	$f_{\alpha lim}$	Influence factor of limit pressure angle[a]
x_{hm1}	Profile shift coefficient[b]	c_{ham}	Mean addendum factor[b] of wheel
k_{hap}	Basic crown gear addendum factor[b]	k_d	Depth factor [b]
k_{hfp}	Basic crown gear dedendum factor	k_c	Clearance factor [b]
x_{smn}	Thickness modification coefficient [b]	k_t W_{m2}	Thickness factor[b] or Mean slot width of the wheel
	For data types A and B:		
j_{mn}, j_{mt2}, j_{en}, j_{et2}	Backlash (one of four)		
θ_{a2}	Addendum angle, wheel		
θ_{f2}	Dedendum angle, wheel		

When all required data has been imported to the program, the result of the algorithm gives the geometrical features of the tooth profile, Fig. 5.

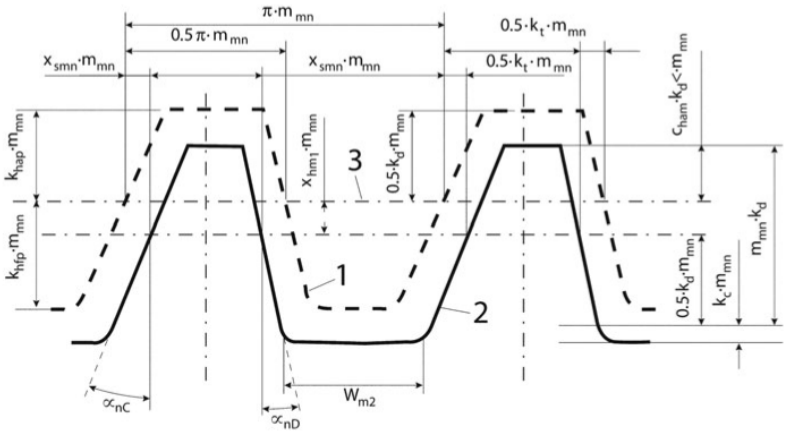

Fig. 5. Basic rack tooth profile of wheel [12]

The calculated points determine a tooth profile of the generated gear in a 3-D space. Fig.6**.**

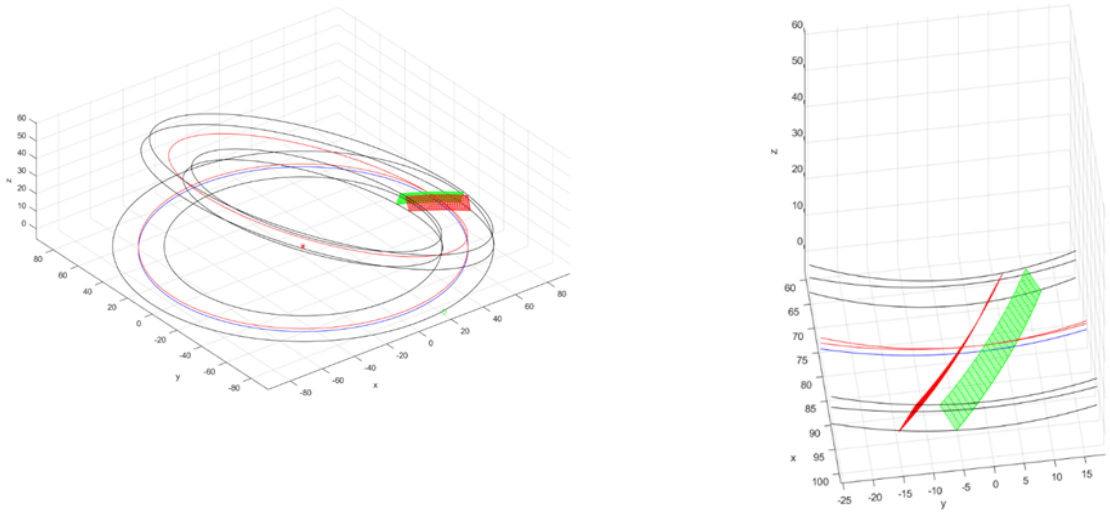

Fig. 6. A tooth profile generating by the program

Commonly, spiral bevel gears are cut with a generating machine that uses a series of cutting blades mounted on a circular tool holder. Instead of a basic rack, a virtual basic crown gear is used, which has straight tooth profile. The generated gear can be flat or take a conical shape. [12]

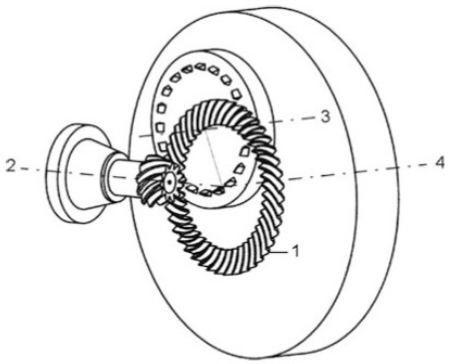

Fig. 7. Virtual crown gear in a bevel gear generator [12]

Fig. 8. Bevel gear pair with associated virtual crown gear [12]

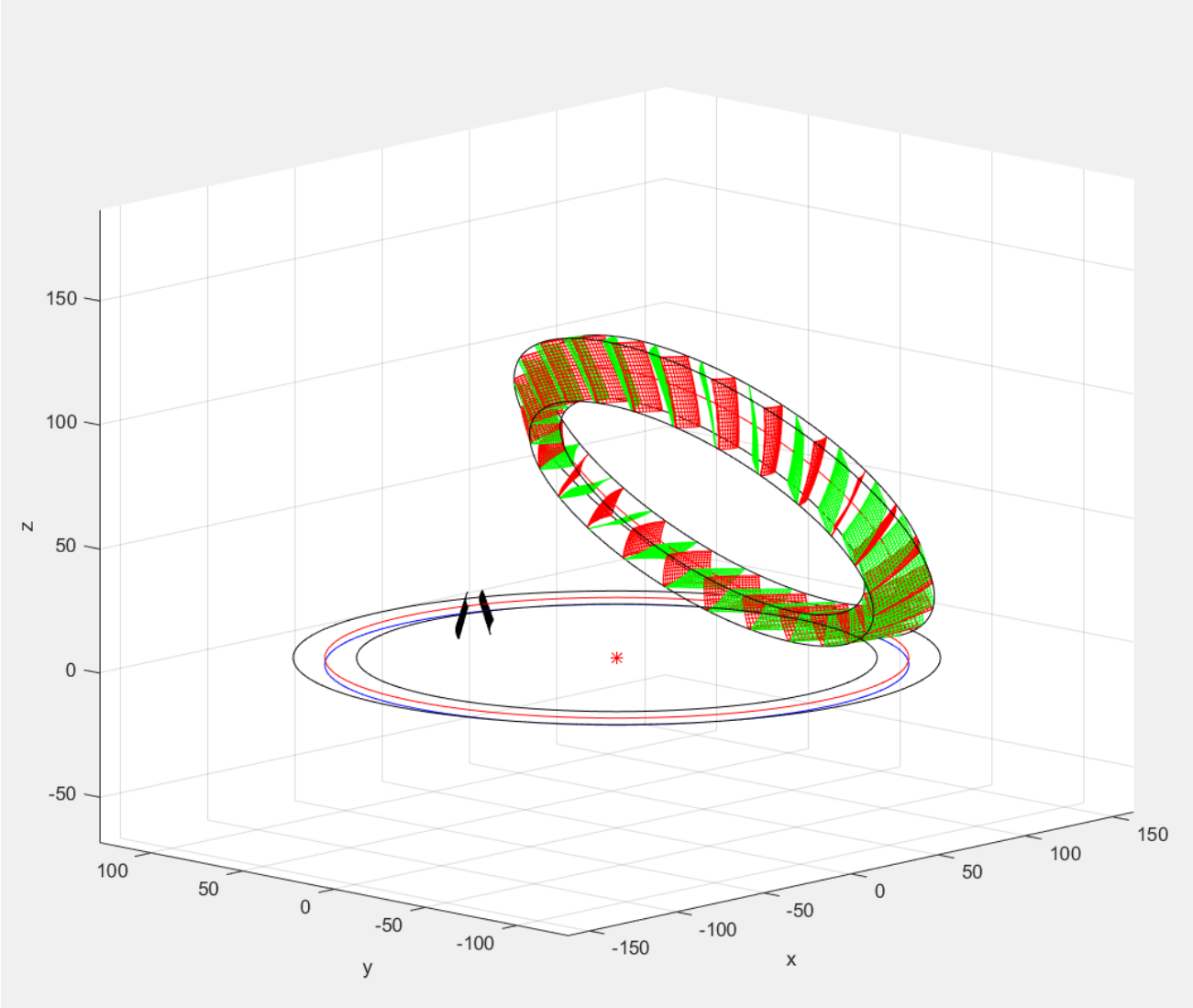

Fig. 9. Calculated generating gear by the program in Matlab

3 Conclusions

The effort to create a program that calculates the basic geometrical features of a tooth profile and generates a virtual gear has come up to a successful procedure.

The spiral bevel gears design remains complex since tooth geometry is affected by the manufacturing process. There are different cutter systems to choose from, depending on the method of producing gears and the supplier of the cutter system. Using the calculated geometrical features of a spiral bevel by the above program, a 3-D CAD model can be created. A 5-axis milling machine center can be used for the machining of the spiral bevel gear. The increased availability of 5-axis milling machine center and the continuous development of modern CAM systems that today support a vast number of complicated machining procedures, offer the opportunity of machining high quality bevel gears avoiding the restrictions that govern the traditional bevel gear manufacturing community.

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