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The CAD Modelling Possibilities of Gear Pairs by Two Ways in the Mechanical Engineering Practice

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Abstract. *The geometric design of the gear pairs can happen by unique programs or the GearTeq 2021 software. The second one is a complex gear designer software which is capable to design different types of gears based on the initial geometric parameters. Naturally, the users' competence for the gear theorem and the manufacturing technology is necessary for the design process. Gear design and modelling processes are shown in this publication. The designed gear pairs are usable in different engineering fields (robots, working machines, vehicles, etc.).*

Keywords: GearTeq 2021, gears, design, CAD, model

Introduction

The aim of the study is the geometric modelling by computer way because of the further tooth contact analysis (TCA) and manufacturing design.

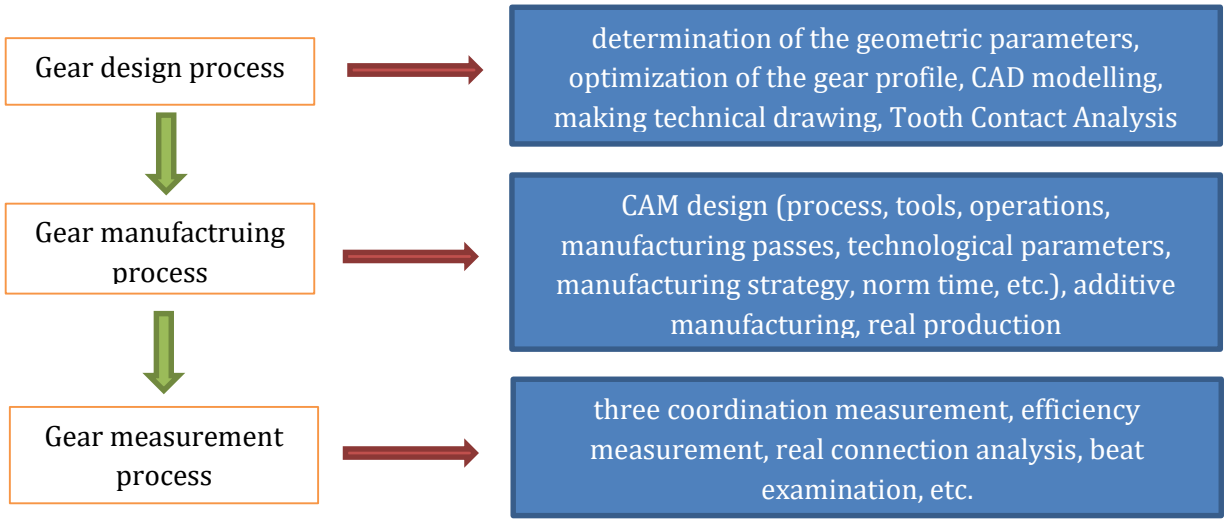

Figure 1. The complex gear generation process

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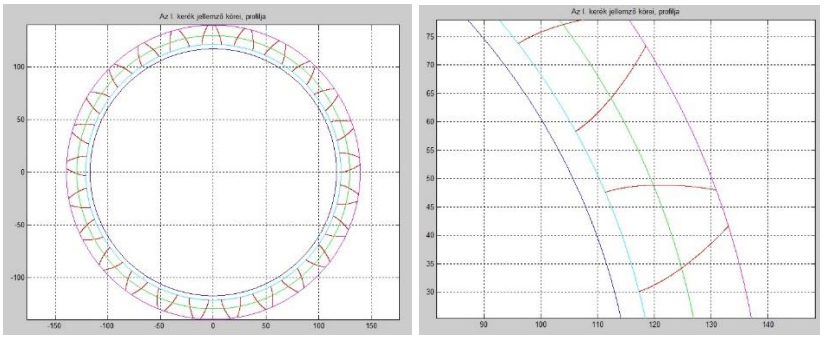
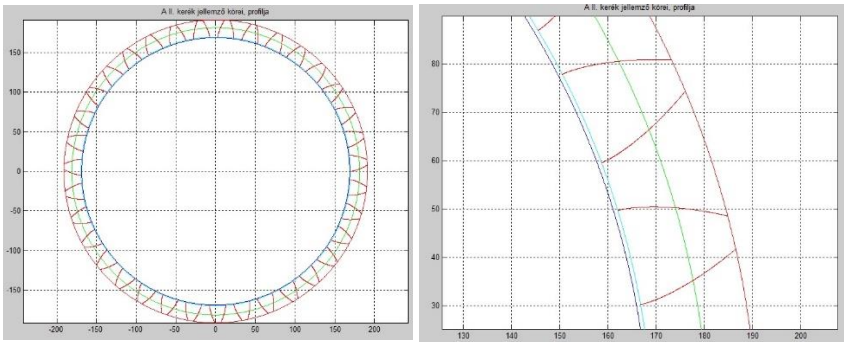
The main steps of the gear generation process can be seen on Figure 1. Originally, three main fields can be created: design, manufacturing and measurement. The aim of the TCA is to analyse the mechanical parameters of the connecting gear pairs for different loads and the optimization of the gear geometry considering the mechanical results.

1. Gear design and modelling by Matlab and SolidWorks software

In case of special gears which have unique geometry making a mathematical software is reasonable to ease the calculation process and to determine to gear profile. The requirements of this software are the calculation of the geometric parameters based on the references [3 - 11] and generation of the gear profile [1 - 4, 6, 8, 10] for the CAD software. Similar unique software was written for spur gears and helical gears (having modified teeth, normal teeth and x-zero type) and bevel gears having straight teeth. After the geometric design and profile drawing by Matlab software the profile points can be saved into txt format for the CAD software (SolidWorks). Interpolation B-spline curve can be inserted for the profile points in the SolidWorks. Considering the calculated geometric parameters the CAD models can be designed. Some existing results can be seen on Figure 2 and 3.



a) pinion



b) gear

X-zero type helical gear pair	Pinion	Gear
Axial module	m= 10 mm	
Number of teeth	z_1=25	z_2=35
Helix angle	β_0=15°	
Lead angle	γ_0=75,923°	
Involute profile angle on the pitch circle in axial section	α_{0h}=20,646°	

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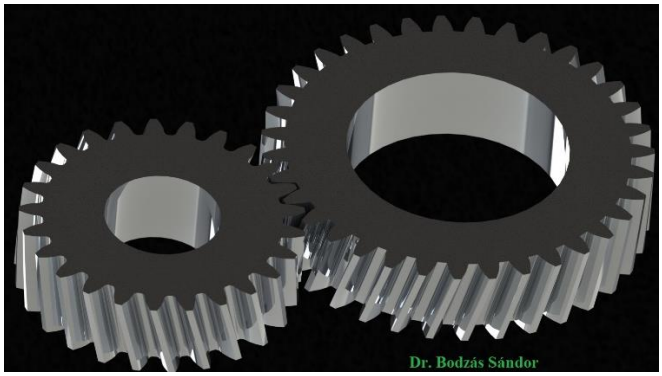
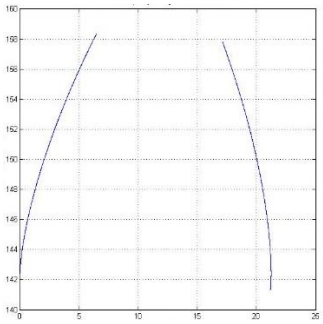
Thread pitch in axial section	t_{oh}=32,524 mm	
Addendum	h_a=10 mm	
Clearence	c=2,5 mm	
Dedendum	h_f=12,5 mm	
Elementary centre distance	a_0=310,582 mm	
Pitch circle diameters	d_1=258,819 mm	d_2=362,346 mm
Outside diameters	d_{a1}=278,819 mm	d_{a2}=382,346mm
Root diameters	d_{f1}=233,819 mm	d_{f2}=337,346 mm
Backlash	j_s=1.6262 mm	
Working depth	h_w= 20 mm	
Tooth thickness	S_{ax}= 15,449 mm	
Base diameters	d_{ak1}= 242,19 mm	d_{ak2}= 339,07mm
Transmission ratio	i=1,4	

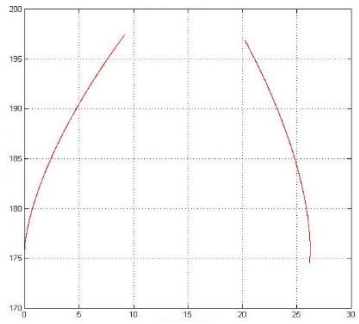
c) The calculated geometric parameters



d) CAD models of the elements

Figure 2. Geometric design of an X-zero type helical gear drive [1]





a) profile on the lowest diameter of the pinion *b) profile on the highest diameter of the pinion*

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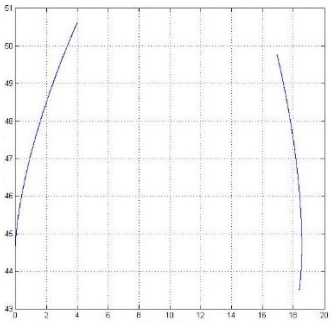
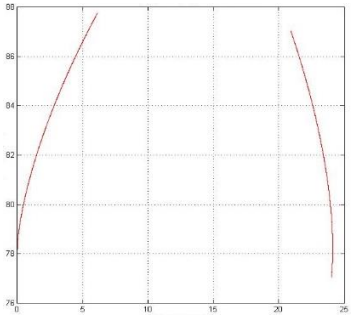


c) profile on the lowest diameter of the gear



d) profile on the highest diameter of the gear

The parameters of a bevel gear pair having straight teeth	**Pinion**	**Gear**
Module	m=15 mm	
Number of teeth	z_1=20	z_2=30
The largest pitch circle diameters	d_{01}=300 mm	d_{02}=450 mm
Half pitch angle of the pitch circle	$\delta_{01} = 56.3°$	$\delta_{02} = 33.69°$
Effective pitch surface radius	R_e=270.416 mm	
Addendum on the largest diameter	f_0=15 mm	
Dedendum on the largest diameter	l_0=18 mm	
The largest outside diameters	d_{f1}=316.64 mm	d_{f2}=474.96 mm
The largest root diameters	d_{a1}=280.03 mm	d_{a2}=420.04 mm
Face width	b=77.26 mm	
Dedendum angle	λ=3.8°	
Tip cone angle	$\delta_{f1} = 60.11°$	$\delta_{f2} = 37.49°$
Root cone angle	$\delta_{l1} = 52.5°$	$\delta_{l2} = 29.88°$
Circular pitch on the largest pitch circle diameter	t=47.123 mm	
Clearance at flank	j_s=2.356 mm	
Pitch circle tooth thickness on the largest diameters	S_{ax}=21.2 mm	
Transmission ratio	i=1.5	

e) The calculated geometric parameters

f) CAD models of the elements

Figure 3. Geometric design of a bevel gear pair having straight teeth [2]

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2. The possibilities of the GearTeq software

A mechanical engineer user has to know the necessary gear theorem and the mathematical and manufacturing skills which can be found in the references [4 - 11] to design connection correct gear pairs. The following gear pairs can be designed among others:

- cylindrical gear drives having straight, helical and spiroid tooth direction,
- bevel gear pairs having straight, circular, spiral tooth direction,
- cylindrical worm gear drives with different worm profiles,
- chain transmissions,
- spline fittings,
- V-belt drives,
- internal gear drives,
- planetary gear drives,
- elliptical gear drives,
- gear pairs having bypass axes.

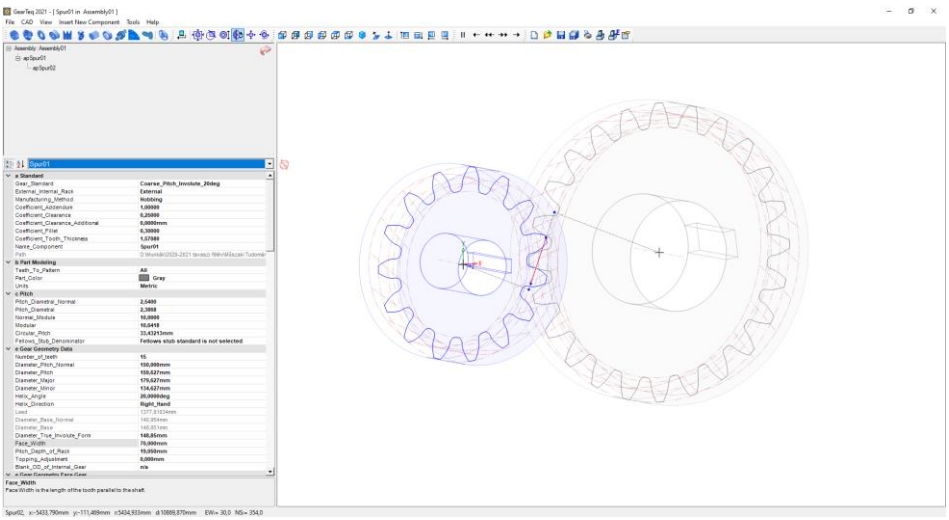
The software can work based on the theorem of double wrapping [4, 6]. It means knowing of the tooth surface of the pinion, the kinematical relations and motion parameters between the pinion and the gear it can determine the tooth surface of the gear by numerical way [4, 6].

The development of the software opened a big choice in the field of tooth design, rapid and connection correct CAD modelling.

Beat examinations and tooth connection analysis can be done on the saved CAD models in the SolidWorks software. There models are usable for different TCA researches.

2.1. The application of the GearTeq software for gear design

We designed some samples by the software where TCA could be done after the geometric design. Based on the geometric parameters and the material selection these gears are advantageously usable for the vehicle industry.



a) Design of a helical gear by GearTeq

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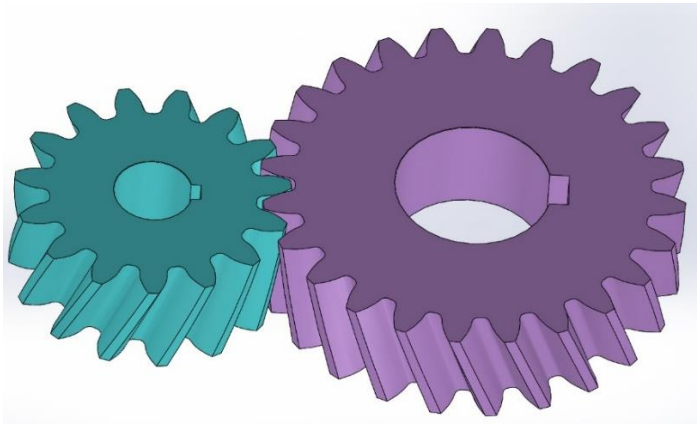

b) The CAD models of the elements

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SYMBOL	VALUE	UNIT	TERM
	Coarse_Pitch_Involute_20deg		Standard
Pdn	2,54		Normal Diametral Pitch
Pd	2,386819		Diametral Pitch
	10		Normal Modular Pitch
m	10,641778		Modular Pitch
øn	20	deg	Normal Pressure Angle
ø	21,173	deg	Pressure Angle
	20	deg	Helix Angle
	Gear Data		Spur01
	Right_Hand		Hand of Helix
	1377,8103	mm	Lead
Np	15		Number of Teeth
Dp	159,627	mm	Pitch Diameter
Dpn	150	mm	Pitch Diameter, Normal
do	179,627	mm	Major Diameter
dr	134,627	mm	Minor Diameter
a	10	mm	Addendum
b	12,5	mm	Dedendum
x	0		Addendum Modification Coefficient
	0	mm	Addendum Modification
db	148,851	mm	Base Diameter
dbn	140,954	mm	Base Diameter, Normal
TIF	148,854	mm	True Involute Form Diameter
ht	22,5	mm	Whole Depth
p	33,432	mm	Circular Pitch
pn	31,416	mm	Circular Pitch, Normal
	3	mm	Fillet Radius
B	0,5	mm	Backlash
t	16,2161	mm	Tooth Thickness
tn	15,2381	mm	Tooth Thickness, Normal
t	14,8611	mm	Tooth Thickness Minimum
F	70	mm	Face Width
			Chordal Tooth Thickness
	15,741		Chordal Tooth Height
	148,854		Chordal Tooth Reference Circle
	16,659		Chordal Tooth Thickness
	16,3099		Chordal Tooth Thickness Minimum
			Size Over Pins
dw	16,256	mm	Pin Diameter
M	177,906	mm	Measurement Over Pins
	176,965	mm	Measurement Over Pins-Minimum
			Span Over Teeth
k	2		Number of Teeth to Span Over
	46,349	mm	Span Measurement
	45,972	mm	Span Measurement Minimum
			Master Gear Test
	0		Master Pitch Diameter
	0	mm	Test Radius (Max. Act.)
	0	mm	Test Radius (Min. Act.)
	AGMA-Q7		AGMA Quality Class
	0,2032	mm	Max Runout
	0,04318	mm	Pitch Variation
	0,06858	mm	Profile Tolerance
	0	mm	Tooth Alignment Tolerance
	0,08128	mm	Tooth to Tooth Composite Tolerance
	0,3048	mm	Total Composite Tolerance
	0,377	mm	Tooth Thickness Tolerance
	0	mm	Hob Protuberance
	38,7	deg	Roll Angle at Major Diameter
	0,37	deg	Roll Angle at TIF Diameter

c) The calculated geometric parameters

Figure 4. Design of a helical gear drive

(m_{ax}=10 mm, β_o=20°)

SYMBOL	VALUE	UNIT	TERM
	Coarse_Pitch_Involute_20deg		Standard
Pdn	2,54		Normal Diametral Pitch
Pd	2,386819		Diametral Pitch
	10		Normal Modular Pitch
m	10,641778		Modular Pitch
øn	20	deg	Normal Pressure Angle
ø	21,173	deg	Pressure Angle
	20	deg	Helix Angle
mg	0,625		Ratio, 1:x
C	207,515	mm	Center Distance
	0	mm	Center Distance Extension
	0	mm	Center Distance Backlash
MA	0	mm	Approach Length
MR	0	mm	Recess Length
mp	1,426		Contact Ratio
	Not Hunting		Hunting Determination
	562,5		Hunting Mesh Cycle
	1, 3		Hunting Common Factors
	4.7cpm		Hunting Tooth Frequency
	37,5		Pinion RPM
	Gear Data		Spur02
	Left_hand		Hand of Helix
	2204,4965	mm	Lead
Np	24		Number of Teeth
Dp	255,403	mm	Pitch Diameter
Dpn	240	mm	Pitch Diameter, Normal
do	275,403	mm	Major Diameter
dr	230,403	mm	Minor Diameter
a	10	mm	Addendum
b	12,5	mm	Dedendum
x	0		Addendum Modification Coefficient
	0	mm	Addendum Modification
db	238,162	mm	Base Diameter
dbn	225,526	mm	Base Diameter, Normal
TIF	240,526	mm	True Involute Form Diameter
ht	22,5	mm	Whole Depth
p	33,432	mm	Circular Pitch
pn	31,416	mm	Circular Pitch, Normal
	3	mm	Fillet Radius
B	0,5	mm	Backlash
t	16,2161	mm	Tooth Thickness
tn	15,2381	mm	Tooth Thickness, Normal
t	14,8611	mm	Tooth Thickness Minimum
F	70	mm	Face Width
			Chordal Tooth Thickness
	17,657		Chordal Tooth Height
	240,526		Chordal Tooth Reference Circle
	18,1428		Chordal Tooth Thickness
	17,7889		Chordal Tooth Thickness Minimum
			Size Over Pins
dw	16,256	mm	Pin Diameter
M	274,629	mm	Measurement Over Pins
	273,653	mm	Measurement Over Pins-Minimum
			Span Over Teeth
k	4		Number of Teeth to Span Over
	106,896	mm	Span Measurement
	106,519	mm	Span Measurement Minimum
			Master Gear Test
	0		Master Pitch Diameter
	0	mm	Test Radius (Max. Act.)
	0	mm	Test Radius (Min. Act.)
	AGMA-Q7		AGMA Quality Class
	0,2286	mm	Max Runout
	0,04572	mm	Pitch Variation
	0,07366	mm	Profile Tolerance
	0	mm	Tooth Alignment Tolerance
	0,07366	mm	Tooth to Tooth Composite Tolerance
	0,3048	mm	Total Composite Tolerance
	0,377	mm	Tooth Thickness Tolerance
	0	mm	Hob Protuberance
	33,27	deg	Roll Angle at Major Diameter
	8,09	deg	Roll Angle at TIF Diameter
	Pinion Data		Spur01
	Right_Hand		Hand of Helix
	1377,8103	mm	Lead
Np	15		Number of Teeth
Dp	159,627	mm	Pitch Diameter
Dpn	150	mm	Pitch Diameter, Normal
do	179,627	mm	Major Diameter
dr	134,627	mm	Minor Diameter
a	10	mm	Addendum
b	12,5	mm	Dedendum
x	0		Addendum Modification Coefficient
	0	mm	Addendum Modification
db	148,851	mm	Base Diameter
dbn	140,954	mm	Base Diameter, Normal
TIF	148,854	mm	True Involute Form Diameter
ht	22,5	mm	Whole Depth
p	33,432	mm	Circular Pitch
pn	31,416	mm	Circular Pitch, Normal
	3	mm	Fillet Radius
B	0,5	mm	Backlash
t	16,2161	mm	Tooth Thickness
tn	15,2381	mm	Tooth Thickness, Normal
F	70	mm	Face Width
			Chordal Tooth Thickness
	15,741		Chordal Tooth Height
	148,854		Chordal Tooth Reference Circle
	16,659		Chordal Tooth Thickness
	16,3099		Chordal Tooth Thickness Minimum
			Size Over Pins
dw	16,256	mm	Pin Diameter
M	177,906	mm	Measurement Over Pins
	176,965	mm	Measurement Over Pins-Minimum
			Span Over Teeth
k	2		Number of Teeth to Span Over
	46,349	mm	Span Measurement
	45,972	mm	Span Measurement Minimum
			Master Gear Test
	0		Master Pitch Diameter
	0	mm	Test Radius (Max. Act.)
	0	mm	Test Radius (Min. Act.)
	AGMA-Q7		AGMA Quality Class
	0,2032	mm	Max Runout
	0,04318	mm	Pitch Variation
	0,06858	mm	Profile Tolerance
	0	mm	Tooth Alignment Tolerance
	0,08128	mm	Tooth to Tooth Composite Tolerance
	0,3048	mm	Total Composite Tolerance
	0,377	mm	Tooth Thickness Tolerance
	0	mm	Hob Protuberance
	38,7	deg	Roll Angle at Major Diameter
	0,37	deg	Roll Angle at TIF Diameter

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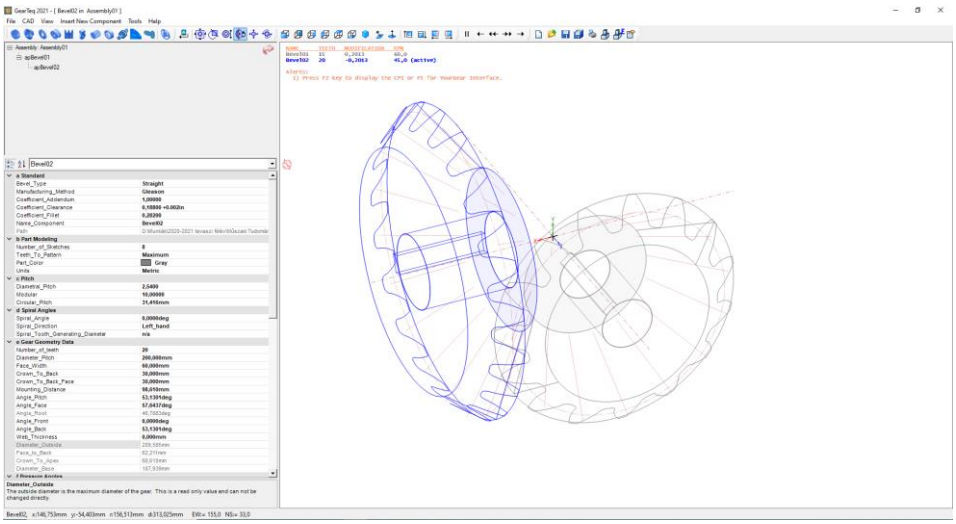

a) Design of a bevel gear having straight tooth by GearTeq

SYMBOL	VALUE	UNIT	TERM
Pd	2,54		Diametral Pitch
m	10		Modular
248	20	deg	Pressure Angle
	0	deg	Spiral Angle
	Right_Hand		Spiral direction
n	15		Number of Teeth
F	60	mm	Face Width
hk	20	mm	Working Depth
ht	21,931	mm	Whole Depth
Dp	150	mm	Pitch Diameter
	36,87	deg	Pitch Angle
AO	125	mm	Cone Distance
p	31,416	mm	Circular Pitch
aP	12,012	mm	Addendum
bP	9,867	mm	Dedendum
c	1,88	mm	Clearance
	4,514	deg	Dedendum Angle
	43,212	deg	Face Angle of Blank
	32,356	deg	Root Angle
do	169,22	mm	Outside Diameter
xo	92,792	mm	Pitch Apex To Crown
t	16,672	mm	Tooth Thickness
B	0,5	mm	Backlash
	1		Addendum Coefficient
	2,012	mm	Addendum Modification
	0,2013		Addendum Modification Coefficient
	2,82	mm	Fillet Radius
	none		AGMA Quality Class
	N/A		Hunting Determination
	N/A		Hunting Mesh Cycle
	1		Hunting Common Factors
	0.0cpm		Hunting Tooth Frequency
	60		Pinion RPM

SYMBOL	VALUE	UNIT	TERM
Pd	2,54		Diametral Pitch
m	10		Modular
248	20	deg	Pressure Angle
	0	deg	Spiral Angle
mg	1,333		Ratio, 1:x
248	90	deg	Shaft Angle
	Left_hand		Spiral direction
n	20		Number of Teeth
F	60	mm	Face Width
hk	20	mm	Working Depth
ht	21,931	mm	Whole Depth
Dp	200	mm	Pitch Diameter
	53,13	deg	Pitch Angle
AO	125	mm	Cone Distance
p	31,416	mm	Circular Pitch
aP	7,987	mm	Addendum
bP	13,892	mm	Dedendum
c	1,88	mm	Clearance
	6,342	deg	Dedendum Angle
	57,644	deg	Face Angle of Blank
	46,788	deg	Root Angle
do	209,585	mm	Outside Diameter
xo	68,61	mm	Pitch Apex To Crown
t	13,744	mm	Tooth Thickness
B	0,5	mm	Backlash
	1		Addendum Coefficient
	-2,012	mm	Addendum Modification
	-0,2013		Addendum Modification Coefficient
	2,82	mm	Fillet Radius
	none		AGMA Quality Class
	Not Hunting		Hunting Determination
	675		Hunting Mesh Cycle
	1, 5		Hunting Common Factors
	11.3cpm		Hunting Tooth Frequency
	45		Pinion RPM

b) The calculated geometric parameters

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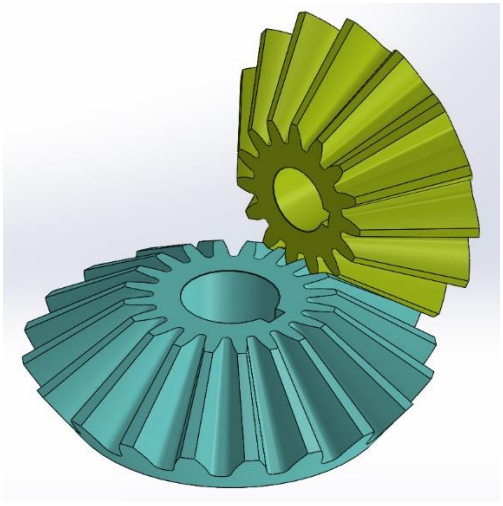
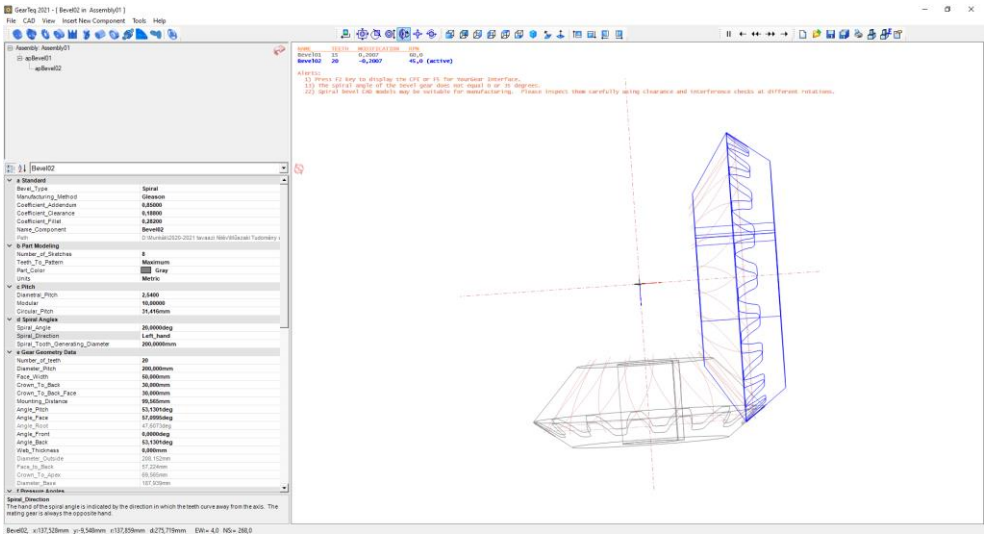
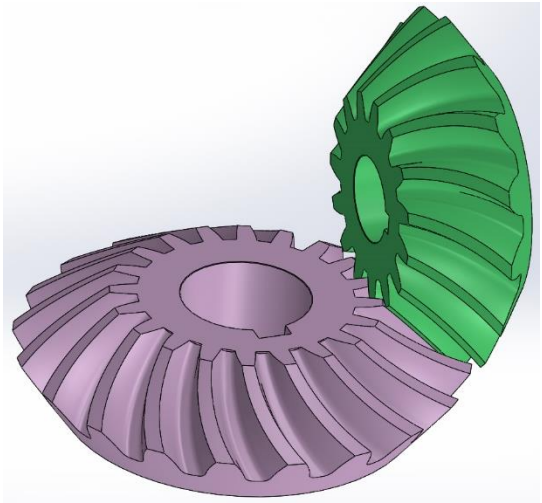


c) The CAD models of the elements

Figure 5. Design of a bevel gear having straight tooth (m_{ax}= 10 mm)



a) Design of a spiral bevel gear by GearTeq



b) The CAD models of the elements

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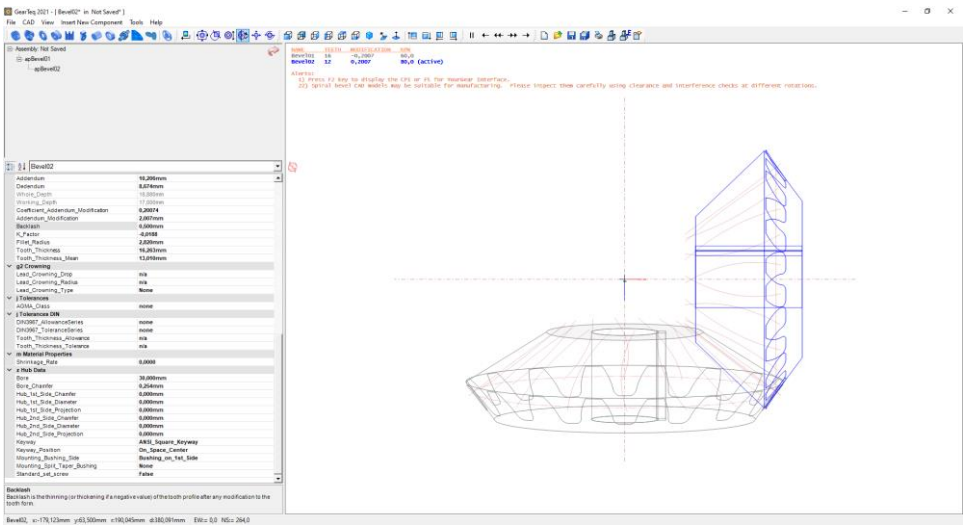
SYMBOL	VALUE	UNIT	TERM
Pd	2,54		Diametral Pitch
m	10		Modular
248	20	deg	Pressure Angle
	20	deg	Spiral Angle
	Right_Hand		Spiral direction
n	15		Number of Teeth
F	50	mm	Face Width
hk	17	mm	Working Depth
ht	18,88	mm	Whole Depth
Dp	150	mm	Pitch Diameter
	36,87	deg	Pitch Angle
AO	125	mm	Cone Distance
p	31,416	mm	Circular Pitch
aP	10,206	mm	Addendum
bP	8,674	mm	Dedendum
c	1,88	mm	Clearance
	3,969	deg	Dedendum Angle
	42,393	deg	Face Angle of Blank
	32,901	deg	Root Angle
do	166,33	mm	Outside Diameter
xo	93,876	mm	Pitch Apex To Crown
t	16,187	mm	Tooth Thickness
B	0,5	mm	Backlash
	0,85		Addendum Coefficient
	2,007	mm	Addendum Modification
	0,2007		Addendum Modification Coefficient
	2,82	mm	Fillet Radius
	none		AGMA Quality Class
	N/A		Hunting Determination
	N/A		Hunting Mesh Cycle
	1		Hunting Common Factors
	0.0cpm		Hunting Tooth Frequency
	60		Pinion RPM

SYMBOL	VALUE	UNIT	TERM
Pd	2,54		Diametral Pitch
m	10		Modular
248	20	deg	Pressure Angle
	20	deg	Spiral Angle
mg	1,333		Ratio, 1:x
248	90	deg	Shaft Angle
	Left_hand		Spiral direction
n	20		Number of Teeth
F	50	mm	Face Width
hk	17	mm	Working Depth
ht	18,88	mm	Whole Depth
Dp	200	mm	Pitch Diameter
	53,13	deg	Pitch Angle
AO	125	mm	Cone Distance
p	31,416	mm	Circular Pitch
aP	6,794	mm	Addendum
bP	12,086	mm	Dedendum
c	1,88	mm	Clearance
	5,523	deg	Dedendum Angle
	57,099	deg	Face Angle of Blank
	47,607	deg	Root Angle
do	208,152	mm	Outside Diameter
xo	69,565	mm	Pitch Apex To Crown
t	14,229	mm	Tooth Thickness
B	0,5	mm	Backlash
	0,85		Addendum Coefficient
	-2,007	mm	Addendum Modification
	-0,2007		Addendum Modification Coefficient
	2,82	mm	Fillet Radius
	none		AGMA Quality Class
	Not Hunting		Hunting Determination
	675		Hunting Mesh Cycle
	1, 5		Hunting Common Factors
	11.3cpm		Hunting Tooth Frequency
	45		Pinion RPM

c) The calculated geometric parameters

Figure 6. Design of a spiral bevel gear (m_{ax}= 10 mm)



a) Design of a Zerol bevel gear by GearTeq

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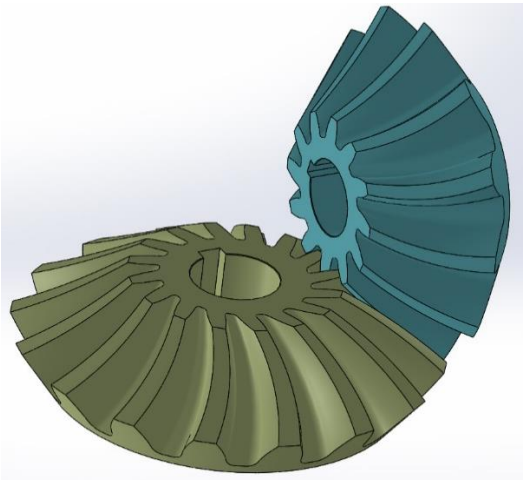

b) The CAD models of the elements

SYMBOL	VALUE	UNIT	TERM
Pd	2,54		Diametral Pitch
m	10		Modular
248	20	deg	Pressure Angle
	0	deg	Spiral Angle
	Right_Hand		Spiral direction
n	16		Number of Teeth
F	50	mm	Face Width
hk	17	mm	Working Depth
ht	18,88	mm	Whole Depth
Dp	160	mm	Pitch Diameter
	53,13	deg	Pitch Angle
AO	100	mm	Cone Distance
p	31,416	mm	Circular Pitch
aP	6,794	mm	Addendum
bP	12,086	mm	Dedendum
c	1,88	mm	Clearance
	6,891	deg	Dedendum Angle
	58,087	deg	Face Angle of Blank
	46,239	deg	Root Angle
do	168,152	mm	Outside Diameter
xo	54,565	mm	Pitch Apex To Crown
t	14,153	mm	Tooth Thickness
B	0,5	mm	Backlash
	0,85		Addendum Coefficient
	-2,007	mm	Addendum Modification
	-0,2007		Addendum Modification Coefficient
	2,82	mm	Fillet Radius
	none		AGMA Quality Class
	N/A		Hunting Determination
	N/A		Hunting Mesh Cycle
	1		Hunting Common Factors
	0.0cpm		Hunting Tooth Frequency
	60		Pinion RPM

SYMBOL	VALUE	UNIT	TERM
Pd	2,54		Diametral Pitch
m	10		Modular
248	20	deg	Pressure Angle
	0	deg	Spiral Angle
mg	0,75		Ratio, 1:x
248	90	deg	Shaft Angle
	Left_hand		Spiral direction
n	12		Number of Teeth
F	50	mm	Face Width
hk	17	mm	Working Depth
ht	18,88	mm	Whole Depth
Dp	120	mm	Pitch Diameter
	36,87	deg	Pitch Angle
AO	100	mm	Cone Distance
p	31,416	mm	Circular Pitch
aP	10,206	mm	Addendum
bP	8,674	mm	Dedendum
c	1,88	mm	Clearance
	4,957	deg	Dedendum Angle
	43,761	deg	Face Angle of Blank
	31,913	deg	Root Angle
do	136,33	mm	Outside Diameter
xo	73,876	mm	Pitch Apex To Crown
t	16,263	mm	Tooth Thickness
B	0,5	mm	Backlash
	0,85		Addendum Coefficient
	2,007	mm	Addendum Modification
	0,2007		Addendum Modification Coefficient
	2,82	mm	Fillet Radius
	none		AGMA Quality Class
	Not Hunting		Hunting Determination
	960		Hunting Mesh Cycle
	1, 2, 4		Hunting Common Factors
	20.0cpm		Hunting Tooth Frequency
	80		Pinion RPM

c) The calculated geometric parameters

Figure 7. Design of a Zerol bevel gear (m_{ax}= 10 mm)

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SYMBOL	VALUE	UNIT	TERM
	Coarse_Pitch_Involute_20deg		Standard
Pdn	2,54		Normal Diametral Pitch
Pd	2,453452		Diametral Pitch
	10		Normal Modular Pitch
m	10,352762		Modular Pitch
øn	20	deg	Normal Pressure Angle
ø	20,647	deg	Pressure Angle
	15	deg	Helix Angle
	Gear Data		Spur01
	Left_hand		Hand of Helix
	2427,6363	mm	Lead
Np	20		Number of Teeth
Dp	207,055	mm	Pitch Diameter
Dpn	200	mm	Pitch Diameter, Normal
do	227,055	mm	Major Diameter
dr	182,055	mm	Minor Diameter
a	10	mm	Addendum
b	12,5	mm	Dedendum
x	0		Addendum Modification Coefficient
	0	mm	Addendum Modification
db	193,756	mm	Base Diameter
dbn	187,939	mm	Base Diameter, Normal
TIF	194,2	mm	True Involute Form Diameter
ht	22,5	mm	Whole Depth
p	32,524	mm	Circular Pitch
pn	31,416	mm	Circular Pitch, Normal
	3	mm	Fillet Radius
B	0,5	mm	Backlash
t	15,7621	mm	Tooth Thickness
tn	15,225	mm	Tooth Thickness, Normal
t	14,848	mm	Tooth Thickness Minimum
F	60	mm	Face Width
			Chordal Tooth Thickness
	10,196		Chordal Tooth Height
	207,185		Chordal Tooth Reference Circle
	15,1725		Chordal Tooth Thickness
	14,7963		Chordal Tooth Thickness Minimum
			Size Over Pins
dw	16,256	mm	Pin Diameter
M	226,219	mm	Measurement Over Pins
	225,258	mm	Measurement Over Pins-Minimum
			Span Over Teeth
k	0		Number of Teeth to Span Over
	-12,122	mm	Span Measurement
	-12,499	mm	Span Measurement Minimum
			Master Gear Test
	0		Master Pitch Diameter
	0	mm	Test Radius (Max. Act.)
	0	mm	Test Radius (Min. Act.)
	AGMA-Q7		AGMA Quality Class
	0,2159	mm	Max Runout
	0,04572	mm	Pitch Variation
	0,07112	mm	Profile Tolerance
	0	mm	Tooth Alignment Tolerance
	0,07366	mm	Tooth to Tooth Composite Tolerance
	0,2794	mm	Total Composite Tolerance
	0,377	mm	Tooth Thickness Tolerance
	0	mm	Hob Protuberance
	35	deg	Roll Angle at Major Diameter
	3,88	deg	Roll Angle at TIF Diameter

a) The calculated geometric parameters

SYMBOL	VALUE	UNIT	TERM
	Coarse_Pitch_Involute_20deg		Standard
Pdn	2,54		Normal Diametral Pitch
Pd	2,453452		Diametral Pitch
	10		Normal Modular Pitch
m	10,352762		Modular Pitch
øn	20	deg	Normal Pressure Angle
ø	20,647	deg	Pressure Angle
	15	deg	Helix Angle
mg	1		Ratio, 1:x
C	103,528	mm	Center Distance
	0	mm	Center Distance Extension
	0	mm	Center Distance Backlash
MA	0	mm	Approach Length
MR	0	mm	Recess Length
mp	NaN		Contact Ratio
	Not Hunting		Hunting Determination
	1200		Hunting Mesh Cycle
	1, 2, 4, 5, 10, 20		Hunting Common Factors
	60.0cpm		Hunting Tooth Frequency
	60		Pinion RPM
	Rack Data		Spur02
	Left_hand		Hand of Helix
	0	mm	Lead
Np	20		Number of Teeth
Dp	0	mm	Pitch Diameter
Dpn	0	mm	Pitch Diameter, Normal
do	0	mm	Major Diameter
dr	0	mm	Minor Diameter
a	10	mm	Addendum
b	12,5	mm	Dedendum
x	0		Addendum Modification Coefficient
	0	mm	Addendum Modification
db	0	mm	Base Diameter
dbn	0	mm	Base Diameter, Normal
TIF	0	mm	True Involute Form Diameter
ht	22,5	mm	Whole Depth
p	32,524	mm	Circular Pitch
pn	31,416	mm	Circular Pitch, Normal
	3	mm	Fillet Radius
B	0,5	mm	Backlash
t	15,7621	mm	Tooth Thickness
tn	15,225	mm	Tooth Thickness, Normal
t	14,848	mm	Tooth Thickness Minimum
F	60	mm	Face Width
			Chordal Tooth Thickness
	0		Chordal Tooth Height
	0		Chordal Tooth Reference Circle
	NaN		Chordal Tooth Thickness
	0		Chordal Tooth Thickness Minimum
			Size Over Pins
dw	14,63	mm	Pin Diameter
M	35,677	mm	Measurement Over Pins
	35,141	mm	Measurement Over Pins-Minimum
			Span Over Teeth
k	0		Number of Teeth to Span Over
	0	mm	Span Measurement
	0	mm	Span Measurement Minimum
			Master Gear Test
	0		Master Pitch Diameter
	0	mm	Test Radius (Max. Act.)
	0	mm	Test Radius (Min. Act.)
	AGMA-Q7		AGMA Quality Class
	0,2159	mm	Max Runout
	0,04572	mm	Pitch Variation
	0,07112	mm	Profile Tolerance
	0	mm	Tooth Alignment Tolerance
	0,07366	mm	Tooth to Tooth Composite Tolerance
	0,2794	mm	Total Composite Tolerance
	0,377	mm	Tooth Thickness Tolerance
	0	mm	Hob Protuberance
	NaN	deg	Roll Angle at Major Diameter
	NaN	deg	Roll Angle at TIF Diameter
	Pinion Data		Spur01
	Left_hand		Hand of Helix
	2427,6363	mm	Lead
Np	20		Number of Teeth
Dp	207,055	mm	Pitch Diameter
Dpn	200	mm	Pitch Diameter, Normal
do	227,055	mm	Major Diameter
dr	182,055	mm	Minor Diameter
a	10	mm	Addendum
b	12,5	mm	Dedendum
x	0		Addendum Modification Coefficient
	0	mm	Addendum Modification
db	193,756	mm	Base Diameter
dbn	187,939	mm	Base Diameter, Normal
TIF	194,2	mm	True Involute Form Diameter
ht	22,5	mm	Whole Depth
p	32,524	mm	Circular Pitch
pn	31,416	mm	Circular Pitch, Normal
	3	mm	Fillet Radius
B	0,5	mm	Backlash
t	15,7621	mm	Tooth Thickness
tn	15,225	mm	Tooth Thickness, Normal
F	60	mm	Face Width
			Chordal Tooth Thickness
	10,196		Chordal Tooth Height
	207,185		Chordal Tooth Reference Circle
	15,1725		Chordal Tooth Thickness
	14,7963		Chordal Tooth Thickness Minimum
			Size Over Pins
dw	16,256	mm	Pin Diameter
M	226,219	mm	Measurement Over Pins
	225,258	mm	Measurement Over Pins-Minimum
			Span Over Teeth
k	0		Number of Teeth to Span Over
	-12,122	mm	Span Measurement
	-12,499	mm	Span Measurement Minimum
			Master Gear Test
	0		Master Pitch Diameter
	0	mm	Test Radius (Max. Act.)
	0	mm	Test Radius (Min. Act.)
	AGMA-Q7		AGMA Quality Class
	0,2159	mm	Max Runout
	0,04572	mm	Pitch Variation
	0,07112	mm	Profile Tolerance
	0	mm	Tooth Alignment Tolerance
	0,07366	mm	Tooth to Tooth Composite Tolerance
	0,2794	mm	Total Composite Tolerance
	0,377	mm	Tooth Thickness Tolerance
	0	mm	Hob Protuberance
	35	deg	Roll Angle at Major Diameter
	3,88	deg	Roll Angle at TIF Diameter

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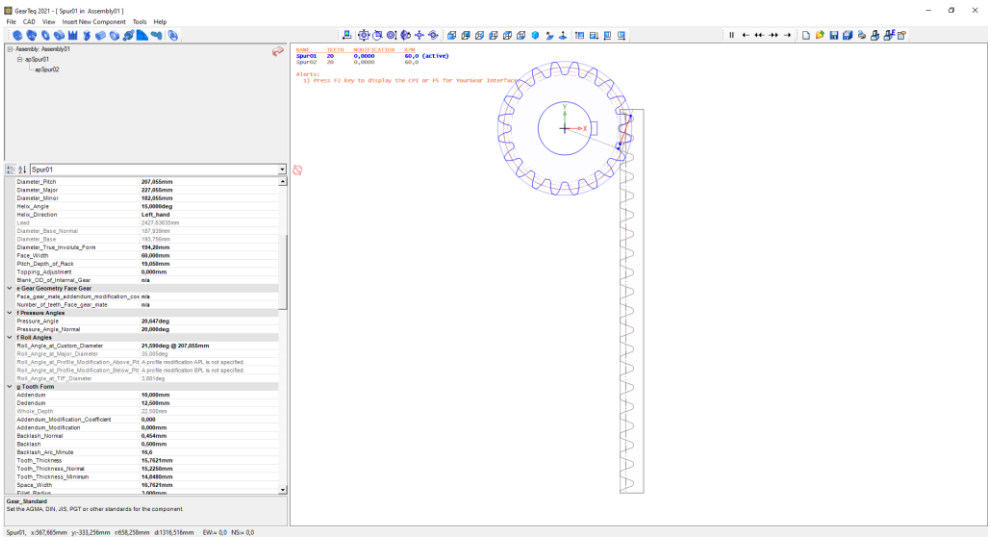
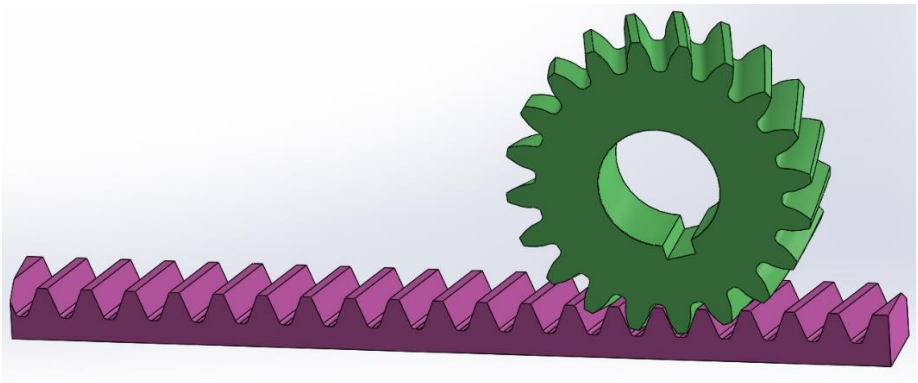
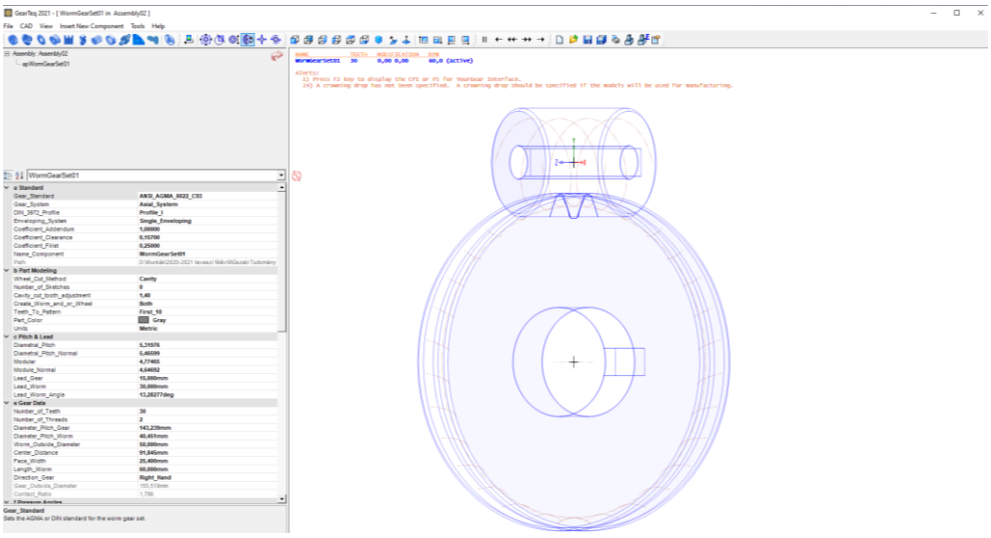


b) Design of a helical gear – gear rack connection by GearTeq



c) The CAD models of the elements

Figure 8. Design of a helical gear – gear rack connection (m_{ax}=10 mm, β_0=15°)



a) Design of a cylindrical worm gear drive by GearTeq

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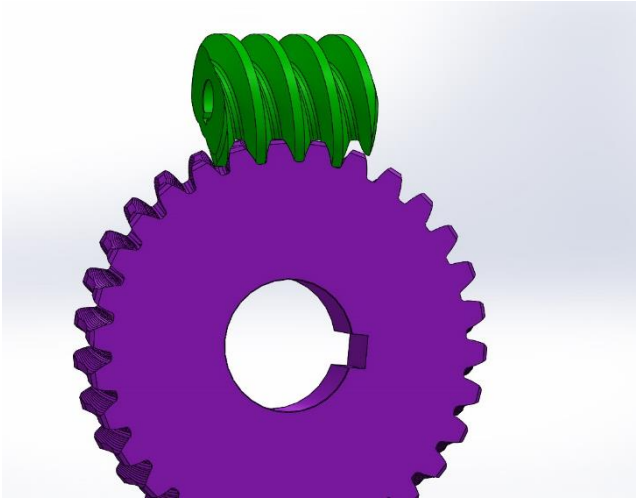
SYMBOL	VALUE	UNIT	TERM
	ANSI AGMA 6022 C93		Standard
	5,31976		Diametral Pitch
	5,46599		Diametral Pitch, Normal
	4,77465	mm	Module
	4,64692	mm	Module, Normal
	15	mm	Lead, Wheel
	30	mm	Lead, Worm
	13,283	deg	Lead Angle, Worm
	1		Coefficient, Addendum
	0,157		Coefficient, Clearance
	0,25		Coefficient, Fillet
N	2		Number of Worm Threads
N	30		Number of Teeth
	Right Hand		Direction of Wheel
	143,239	mm	Pitch Diameter, Wheel
	40,451	mm	Pitch Diameter, Worm
	50	mm	Outside Diameter, Worm
	91,845	mm	Center Distance
	25,4	mm	Face Width, Wheel
	60	mm	Length, Worm
	155,519	mm	Outside Diameter, Wheel
	1,786	mm	Contact Ratio
	20,505	deg	Pressure Angle
	20	deg	Pressure Angle, Normal
	0	mm	Addendum Mod. Coef., Wheel
	0	mm	Addendum Mod. Coef., Worm
	0	mm	Addendum Mod., Wheel
	0	mm	Addendum Mod., Worm
	0,1	mm	Backlash, Wheel
	0,097	mm	Backlash, Wheel Normal
	0,1	mm	Backlash, Worm
aP	4,775	mm	Addendum, Wheel
aP	4,775	mm	Addendum, Worm
	0,097	mm	Backlash, Worm Normal
bP	5,524	mm	Dedendum, Wheel
bP	5,524	mm	Dedendum, Worm
	7,4	mm	Tooth Thickness, Wheel
	7,4	mm	Tooth Thickness, Worm
	1,194	mm	Fillet Radius
	8,007	mm	Pin and Ball Diameter
	51,498	mm	Worm Measurement Over 3 Pins
	154,14	mm	Wheel Measurement Over 2 Balls

b) The calculated geometric parameters



c) The CAD models of the elements

Figure 9. Design of a cylindrical worm gear drive (m_{ax}=4.77 mm)

Conclusion

The aim of this study is to show the design possibilities of different types of gears in classical (unique program) and automatic ways (usage of GearTeq). Unique program is needed for the determination of the mechanical parameters including the geometric and numerical equations in case of classical way. This program can save the calculated parameters and the profile curve into a *txt* file. This file is readable for the SolidWorks software to build up the CAD models of the elements. On the second hand knowing the manufacturing, gear and mathematical theorem the gears can be designed by GearTeq software (automatic way). This program can tightly cooperate with the SolidWorks. After the geometric design the gear parameters can be saved into MS Excel. The CAD

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models can be imported into the SolidWorks. We showed the modelling processes in both cases and some applications. The designed gears can be usable for other researches (TCA). This overall gear design process is usable for solutions of different engineering constructions where the application of gears is needed.

Acknowledgement

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