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ANALYSIS OF EFFECT OF THE LOAD FORCE FOR A BEVEL GEAR TOOTH HAVING STRAIGHT DIRECTION

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ABSTRACT

Knowing of the geometric designing process of a straight bevel gear we have worked out a computer aided software with which this designing process could be eased. We have designed some bevel gear pairs having concrete geometry in the function of the modification of the number of teeth of the pinion and created the CAD (Computer Aided Designing) models of these gear pairs. After that the TCA (Tooth Contact Analysis) analysis could be followed. The load force have been situated on the top of the tooth edge on the tip circle. The established normal stress, normal elastic strain and normal deformation could be analyzed. Based on the results we can create the necessary diagrams and define the conclusions.

Keywords: bevel gear, tooth, TCA, CAD, normal, pinion

1. INTRODUCTION

The bevel gear pair is widely used in the mechanical constructions. We can use it in the vehicles, robots, working machines, logistics devices, etc. (Figure 1).

Figure 1. Car drivetrain by bevel gear pairs [12]

The main properties of bevel gear is the high load transmission, the changing of shafts' positions and directions [3, 6, 10, 11, 13].
Only one crown wheel is belonged to one geometrical corrected bevel gear pairs [3, 10, 11]. The tooth surface of the crown wheel is created the teeth of the bevel gear by wrapping [3, 10, 11]. One of the bevel gear element is rolled down on one side of the crown wheel and another bevel gear element is rolled down on the other side of the crown wheel. During production the crown wheel is created by the relative motion of the cutting tool in comparison with the bevel gear [3, 6, 7, 10, 11].

2. GEOMETRIC DESIGNING

According to the references [1, 3, 4, 5, 6, 7, 8, 9, 10, 11] we have worked out a computer software with which the geometric parameters of the bevel gears could be determined (Figure 2) [2].

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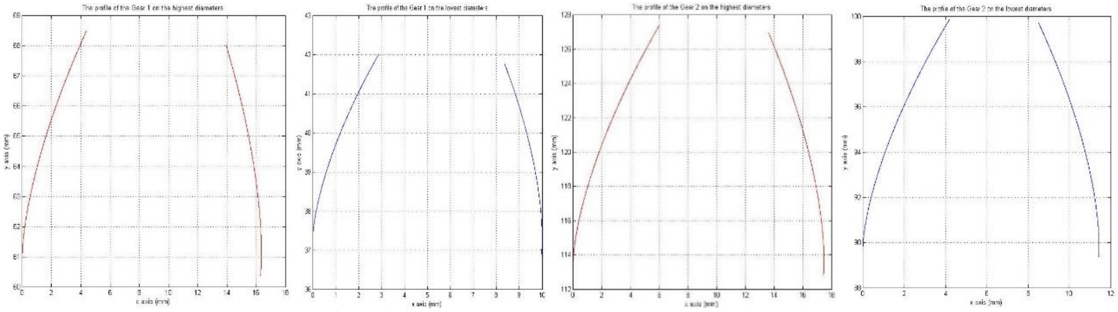

a) tooth profiles of the pinion b) tooth profiles of the driven gear

Figure 2. Determination of the tooth profiles in case of the lowest and the highest diameters (m=10, z1=22, z2=30)

The output parameters of this software are the calculated geometric parameters and the tooth profiles on the lowest and the highest diameters [2]. Knowing of this parameters and the mathematical background the CAD models and the assembly of the gear pairs could be created [2].
We have designed five types of straight bevel gear. We have modified the number of teeth of the pinion. The other parameters are the same. The main input parameters of the designing process could be seen on Table 1. The calculated parameters are contained on the [2] reference.

Table 1. The input parameters of the designing of bevel gear

The main parameters of the bevel gear pairs	*Gear drive I.*	*Gear drive II.*	*Gear drive III.*	*Gear drive IV.*	*Gear drive V.*
Number of teeth of the pinion (z_1)	20	21	22	23	24
Number of teeth of the driven gear (z_2)	30				
Module (m) [mm]	10				
Bottom clearance (c^*)	0.2				
Pressure angle (α_0)	20				

Figure 3. The CAD model of a designed bevel gear pair (m=10, z1=22, z2=30)

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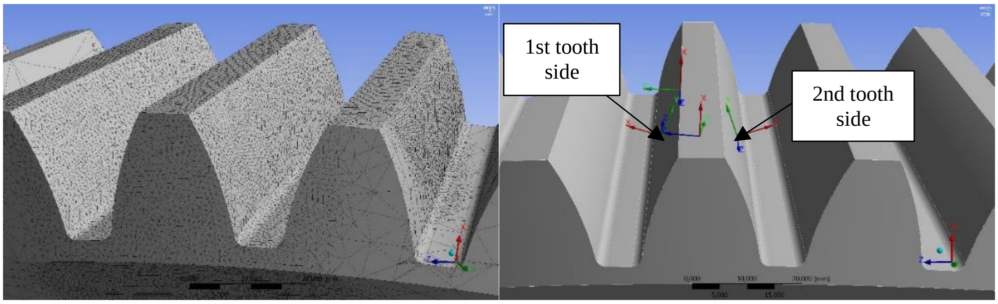
3. TCA OF THE LOADED TOOTH

The aim of the TCA is the analysis of the gear teeth by a finite element software [1, 2, 5, 8, 14]. The production is very expensive that is why many analysis have to be done before the production. Using of the TCA many mechanical parameters (stress, deformation, etc.) could be analyzed because of the goodness of the designed gear pair.

During the analysis the teeth of the driven gear have been loaded and analyzed in the function of the modification of the number of teeth of the pinion. The accuracy of the TCA's calculation is influenced by the accuracy of the finite element mesh. In this analysis the mesh density has been 1 mm around the analyzed tooth. The mesh type is triangular. One coordinate system has been adopted in the center of the tooth. Sphere meshing has been used around the analyzed tooth which center point is the center point of the adopted coordinate system. The sphere radius has been selected for 40 mm (Figure 4.a).

Two coordinate systems have been adopted on the middle of both sides of the tooth surfaces. The x directions have been the normal directions because they have been set perpendicularly to the tooth surfaces (Figure 4.b).Another coordinate system has been adopted on the middle of the edge of the tip circle.



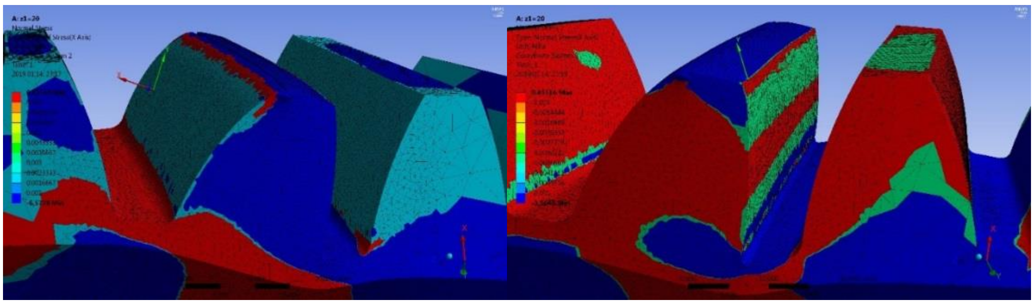
a) b)

Figure 4. The adoption of the finite element mesh and the necessary coordinate systems of the tooth of the driven gear

We have loaded the teeth of every designed driven gears (Table 1) by 100 N, 300 N and 500 N load forces. The direction vector of the loaded force is closed 45° with the vertical y coordinate axis.

The type of the material is structural steel [2].

3.1. Normal stress analysis



a) 1st tooth side b) 2nd tooth side

Figure 5. Normal stress distributions (z1=20) in case of F=100 N load force

The normal stress is analyzed on the two tooth surfaces in case of every driven gears (Figure 5).

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The normal stresses of the 1st tooth side is periodically changed (Figure 6). The lowest stresses have been established in case of 21 number of teeth of the pinion.
The normal stresses of the 2nd tooth side is continuously increased (Figure 7). The lowest stresses have been established in case of 20 number of teeth of the pinion. These values are defined in absolute value.

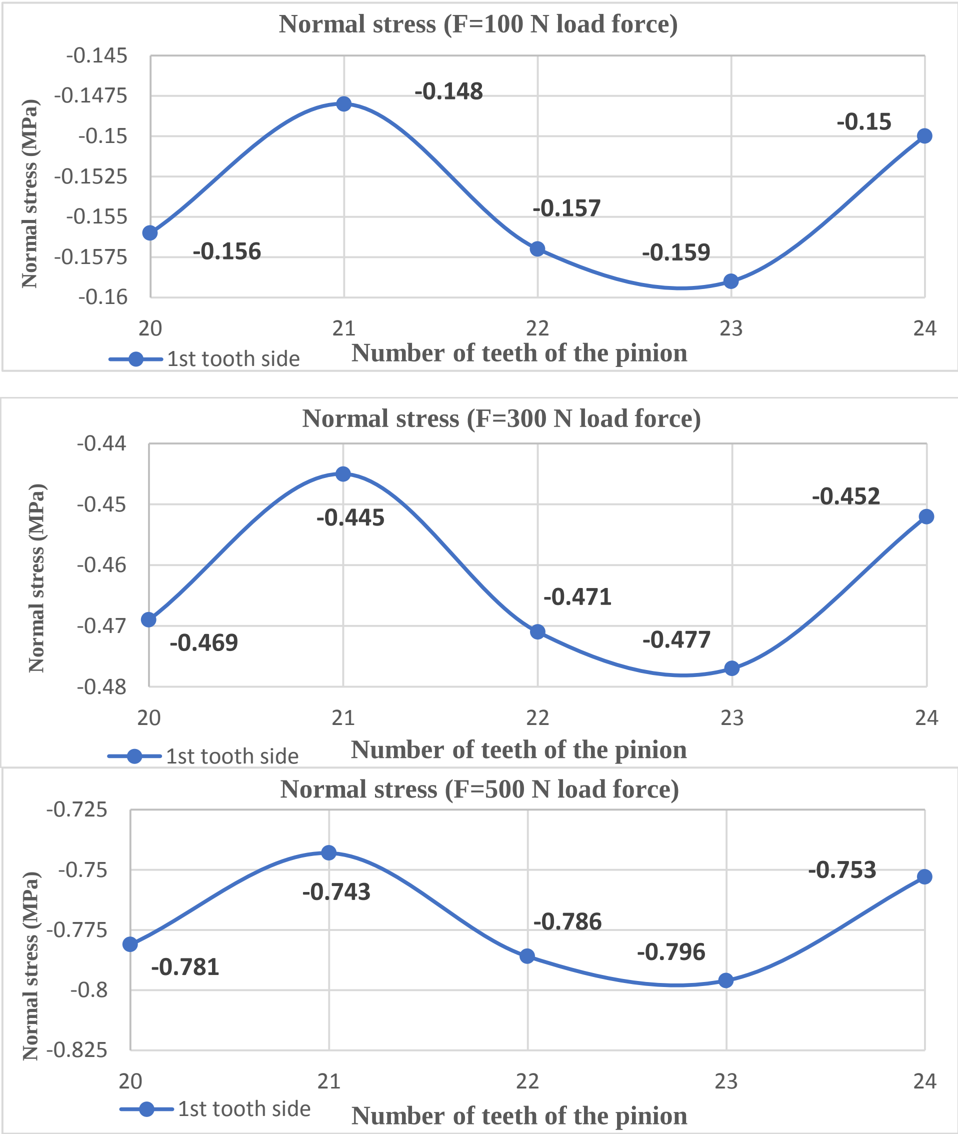

Figure 6. Normal stress results in the function of the number of teeth of the pinion (1st tooth side)

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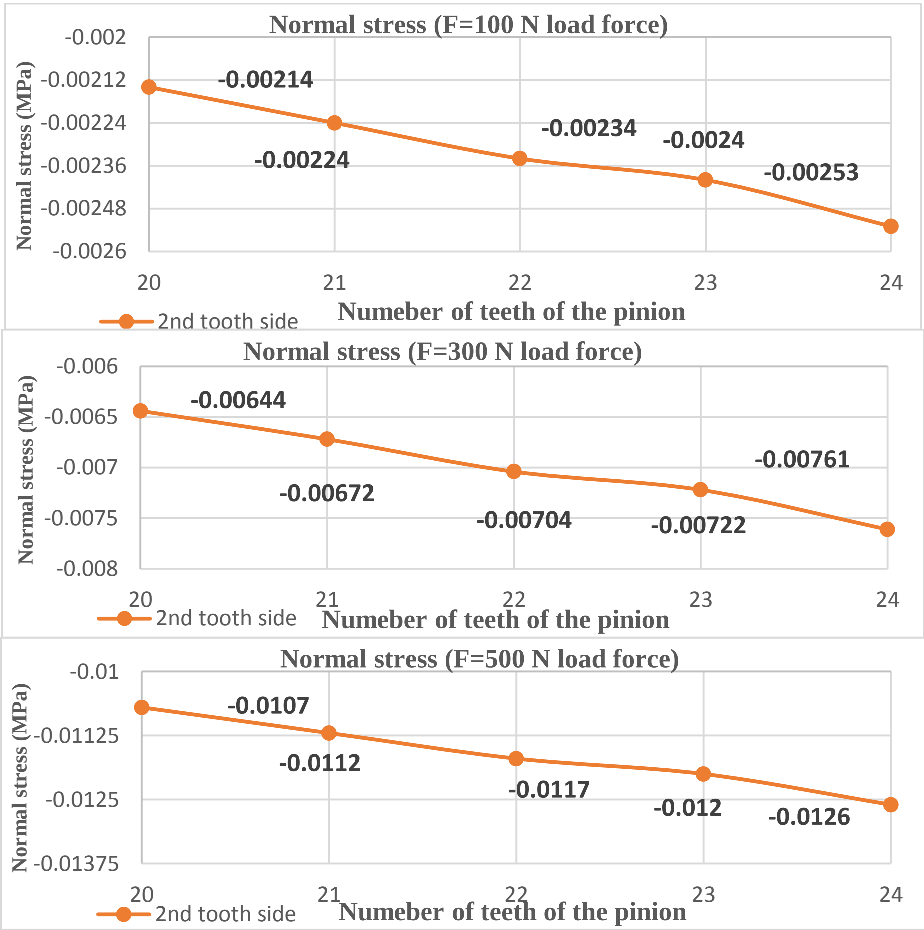
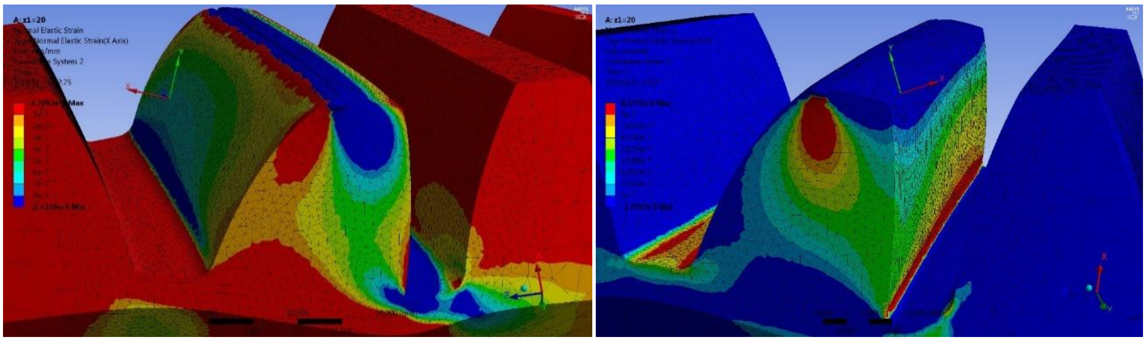


Figure 7. Normal stress results in the function of the number of teeth of the pinion (2nd tooth side)

3.2. Normal elastic strain analysis



a) 1st tooth side b) 2nd tooth side

Figure 8. Normal elastic strain distributions (z1=20) in case of F=100 N load force

The normal elastic strain is analyzed on the two tooth surfaces in case of every driven gears (Figure 8).

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The normal elastic strain of the 1st tooth side is periodically changed (Figure 9). The lowest stresses have been established in case of 21 number of teeth of the pinion.

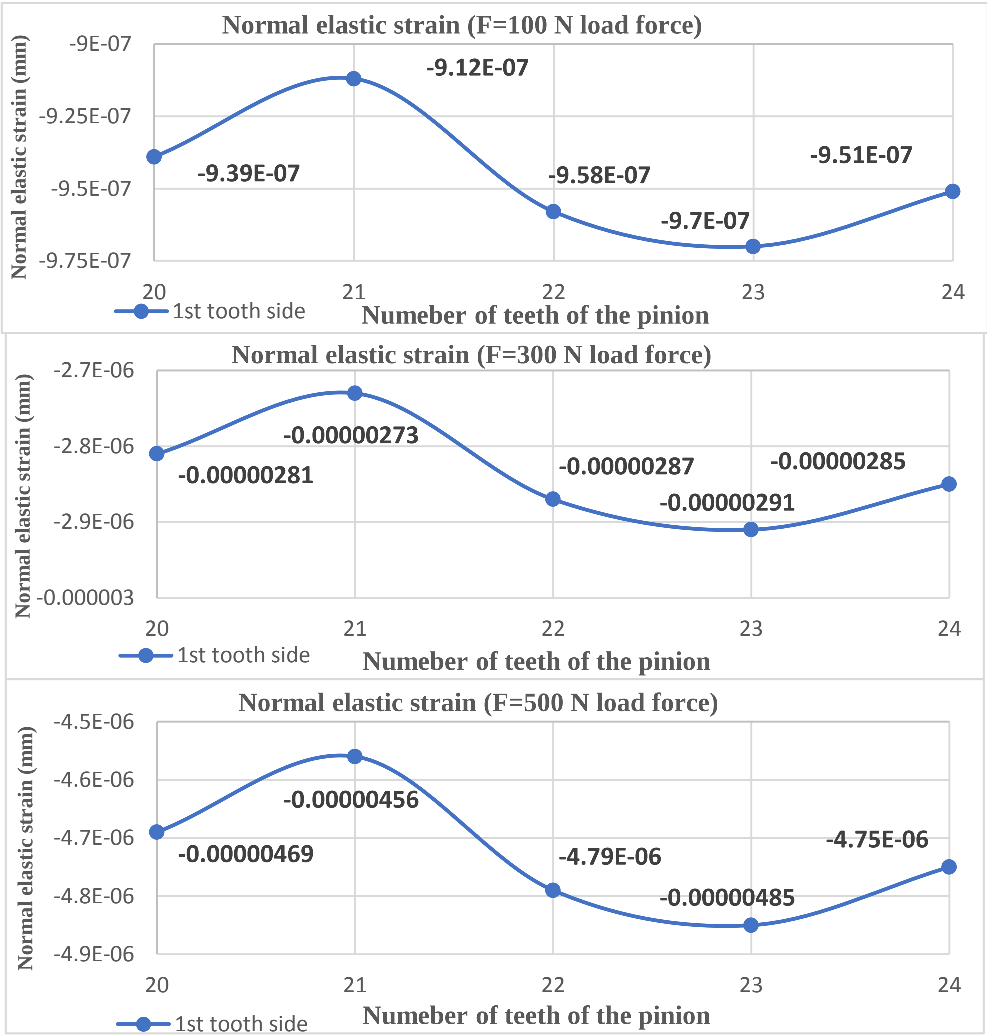

Figure 9. Normal elastic strain in the function of the number of teeth of the pinion (1st tooth side)

The normal elastic strain of the 2nd tooth side is continuously increased (Figure 10). The lowest stresses have been established in case of 20 number of teeth of the pinion. This statement is valid independently from the value of the load force (Figure 10). These values are determinable in absolute value.

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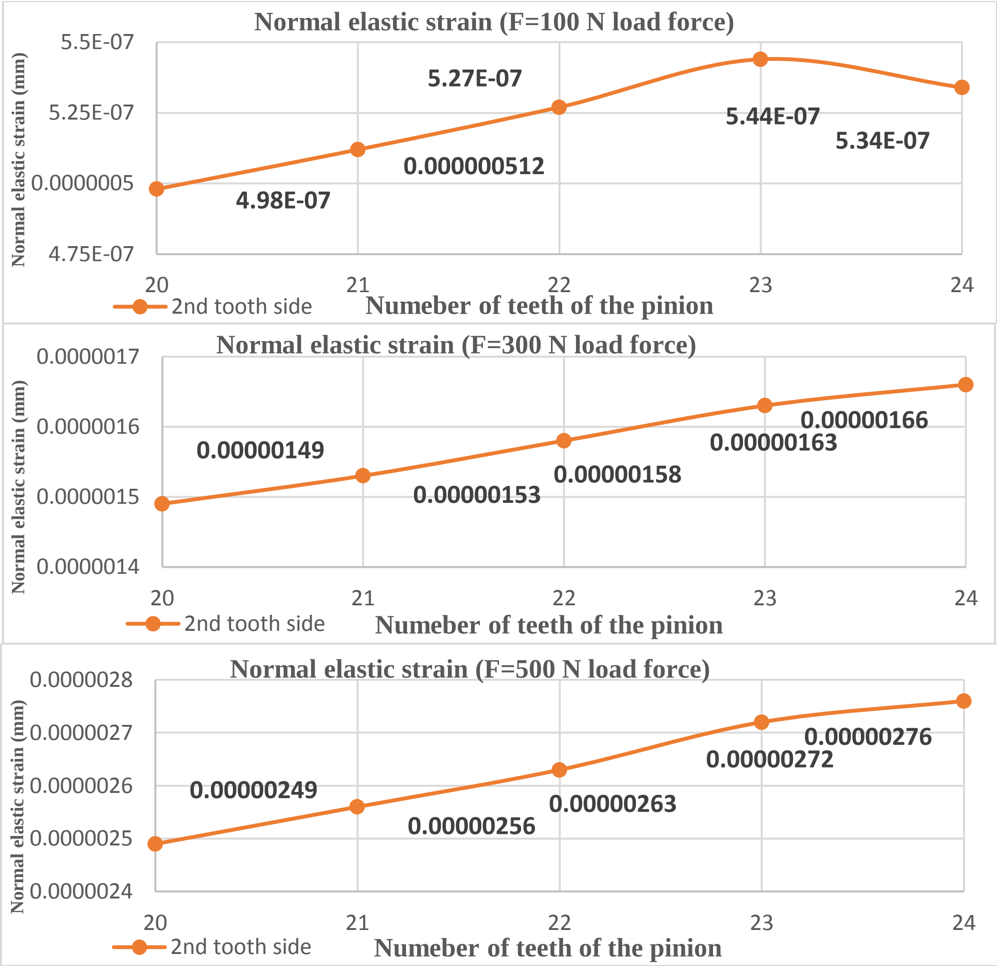
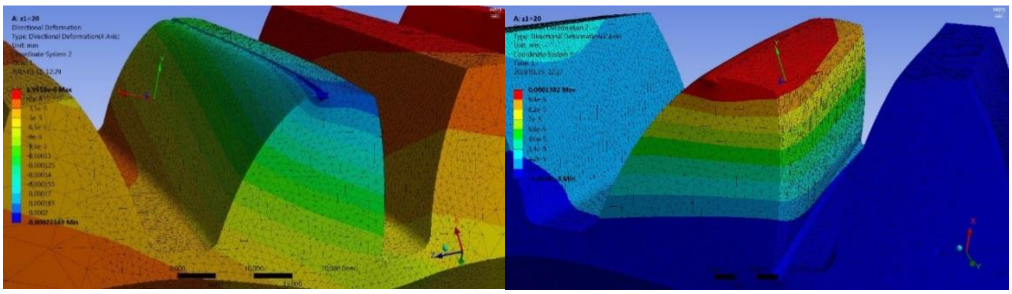


Figure 10. Normal elastic strain in the function of the number of teeth of the pinion (2nd tooth side)

3.3. Normal deformation analysis



a) 1st tooth side b) 2nd tooth side

Figure 11. Normal deformation distributions (z1=20) in case of F=100 N load force

The normal deformation is analyzed on the two tooth surfaces in case of every driven gears (Figure 11).

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The normal deformation of the 1st tooth side is progressively decreased (Figure 12). The shape of the curve is a half parabola. The lowest deformation have been established in case of 24 number of teeth of the pinion.
The normal deformation of the 2nd tooth side is continuously increased (Figure 13). The lowest stresses have been established in case of 20 number of teeth of the pinion. These values are determinable in absolute values.

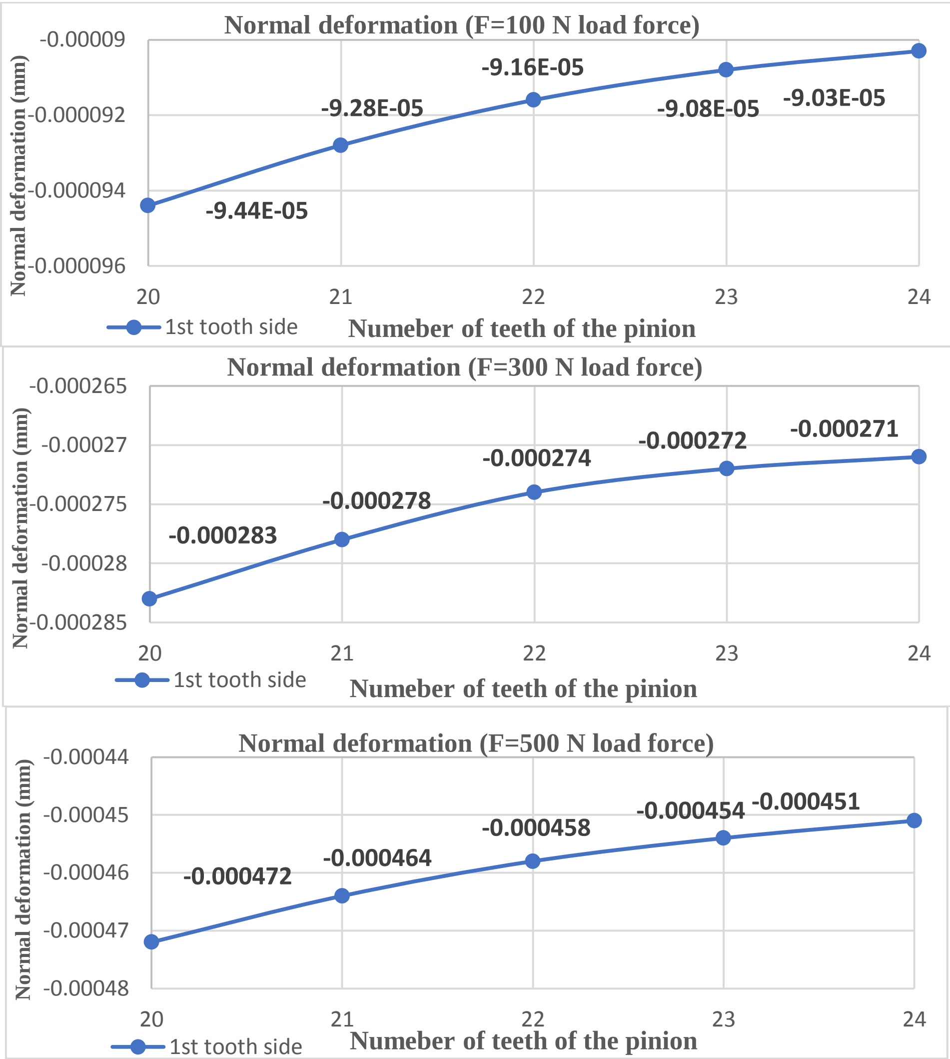

Figure 12. Normal deformation in the function of the number of teeth of the pinion (1st tooth side)

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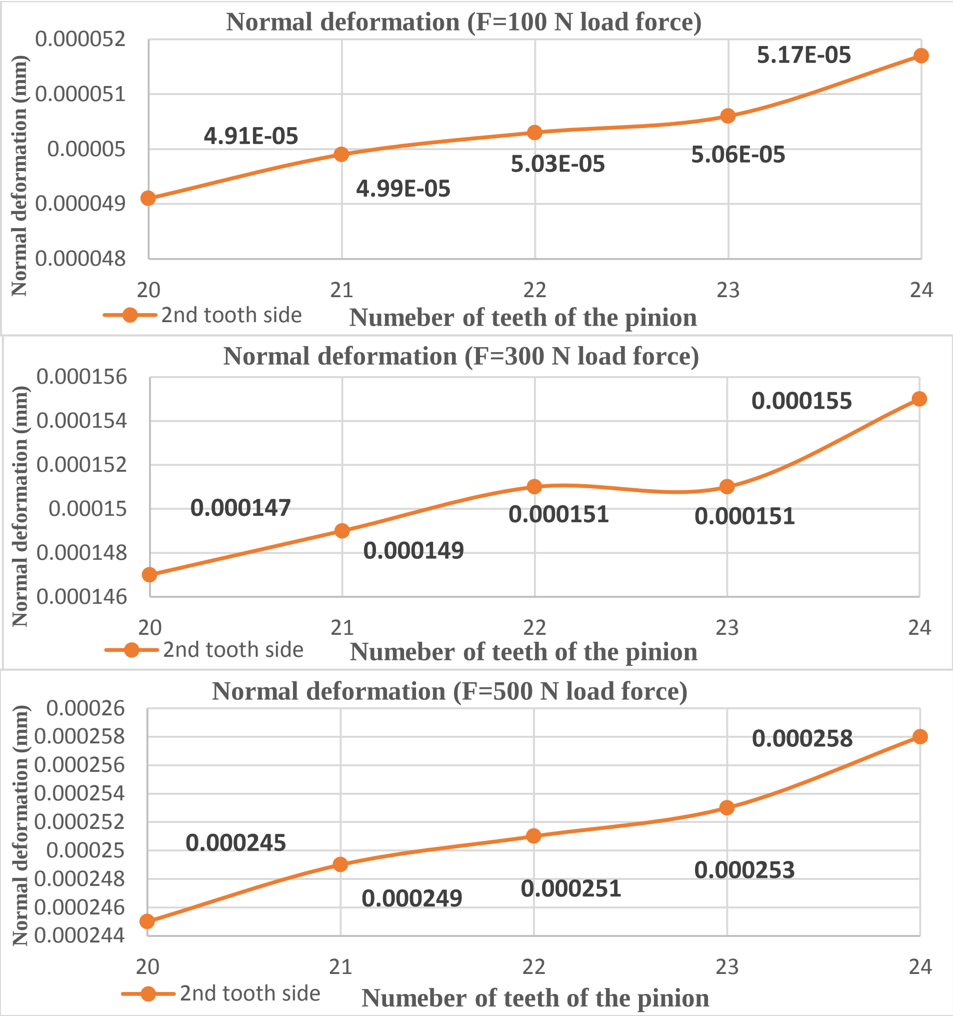

Figure 13. Normal deformation in the function of the number of teeth of the pinion (2nd tooth side)

4. CONCLUSIONS

Knowing of the mathematical calculations and the geometric formulas we have designed five different straight bevel gear pairs in the function of the modification of the number of teeth of the pinion. We used our developed computer aided software for the determination of the geometric parameters and the tooth profiles on the highest and the lowest diameters. After that the CAD models of the gear pairs have been created.

The area of the TCA is a very important research field in the gear research field. The connection and motion analysis of the connecting elements could be realized before the real production. During the analysis if a problem is occurred in the connection zone the gear geometry could be modified that is why the TCA could be started again.

We have loaded the teeth of the driven gear by different load forces. We have analyzed the TCA results in the function of the number of teeth of the pinion and the load force. The appropriate selection of the finite element mesh and the position of the load force are significantly influenced the analyzed process. We have

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created the necessary functions for the evaluations. Knowing of the shapes of the functions we could evaluate the results and define the conclusions. The optimum purpose is depended on the selected TCA parameter which we want to optimize in case of gear designing.

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