

ANALYSIS OF THE NORMAL TENSION VALUES IN THE CONTACT ZONE AND ON THE FILLETS OF THE BASIC TOOTHED GEAR PAIRS AS A FUNCTION OF THE CHANGE OF THE MODULE

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In our publication, more than one basic toothed gear pairs have been designed and modelled. Normal tension dispersions – appearing in the contact zone of the drive pair – and their measure on contact tooth surfaces have been analyzed by the effect of a given moment load. During designing the numbers of the teeth of the gear pairs have been chosen equal, but the modules of the pairs have been different. We analyze how normal tension values form on the tooth surfaces of the gears in the contact zone of the tooth and on their root zone as a function of the change of the module in the case of the same meshing method, loads and boundary conditions.

Keywords: basic tooththing, finite element method (FEM), normal tension, module

1. Introduction

A certain computer program was developed for making the CAD models [1–6] of the basic toothed gear pairs. Input values of the program are the number of

teeth (z_1 and z_2) and the module (m) of the driving and driven cog wheels (Fig. 1).

Based on the input parameters, the program calculates the further parameters of the gear pairs and it draws the cog wheels on the screen. It saves the profile points of the cog wheel in .txt file, which can be imported in SolidWorks design software. After all these CAD models of the given gear pairs can be made. Table 1 contains those parameters of the gear pairs which were designed by us.

During designing the numbers of the teeth of the cog wheels on the driving and the driven gears were chosen equal but we enhanced the value of the module (Table 1).

2. Making the mesh of FEM

For the analysis of the contact points, Ansys R18.0 FEM software was used. In the tooth contact zone, 0.15 frictional factor was applied. During the CAD modelling of the cog wheels, between the root circle diameter and the inner diameters of the bore, 15 mm thickness was applied in the case of every cog wheel. The tooth length of the cog wheels was chosen to be 40 mm each.

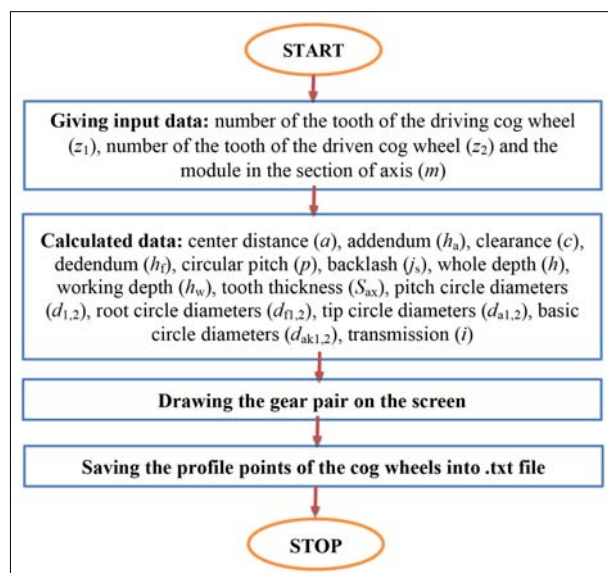


Fig. 1. The principle of the operation of the program

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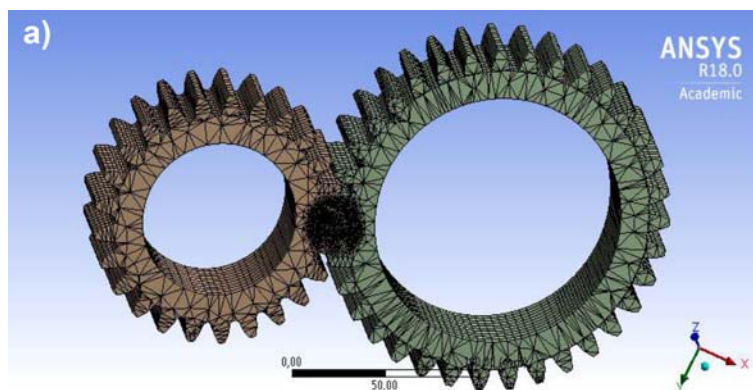
Table 1. The parameters of the designed drive pairs

Parameters	Gear drive I	Gear drive II	Gear drive III	Gear drive III	Gear drive IV
Axial module (m) [mm]	5	8	12	18	25
Number of tooth of the driving gear (z_1)	25	25	25	25	25
Number of tooth of the driven gear (z_2)	35	35	35	35	35
Centre distance (a) [mm]	150	240	360	540	750
Addendum (h_a) [mm]	5	8	12	18	25
Clearance (c) [mm]	1.25	2	3	4.5	6.25
Dedendum (h_f) [mm]	6.25	10	15	22.5	31.25
Circular pitch (p) [mm]	15.708	25.132	37.699	56.548	78.539
Backlash (j_s) [mm]	0.785	1.256	1.885	2.827	3.927
Whole depth (h) [mm]	11.25	18	27	40.5	56.25
Working depth (h_w) [mm]	10	16	24	36	50
Tooth thickness (S_{ax}) [mm]	7.461	11.938	17.907	26.86	37.306
Pitch circle diameter of the driving gear (d_1) [mm]	125	200	300	450	625
Tip circle diameter of the driving gear (d_{a1}) [mm]	135	216	324	486	675
Root circle diameter of the driving gear (d_{f1}) [mm]	112.5	180	270	405	562.5
Basic circle diameter of the driving gear (d_{ak1}) [mm]	117.461	187.938	281.907	422.861	587.307
Pitch circle diameter of the driven gear (d_2) [mm]	175	280	420	630	875
Tip circle diameter of the driven gear (d_{a2}) [mm]	185	296	444	666	925
Root circle diameter of the driven gear (d_{f2}) [mm]	162.5	260	390	585	812.5
Basic circle diameter of the driven gear (d_{ak2}) [mm]	164.446	263.113	394.67	592.006	822.231
Transmission (i)	1.4	1.4	1.4	1.4	1.4

During the calculations tetrahedron meshing was applied on the face surfaces, while tooth lengths were divided into 10 equal parts [5, 9]. The density of the meshing was automatic outside the tooth contact zone [5, 9]. Inside the tooth contact zone 1 mm density meshing was applied (Fig. 2).

3. Setting the loads and boundary conditions

During the analysis, the material of the drive pairs was structural steel (Table 2). The driving cog wheel ($z_1 = 25$) was loaded by 40 Nm torque (Fig. 3).

**Fig. 2.** Application of the mesh of FEM

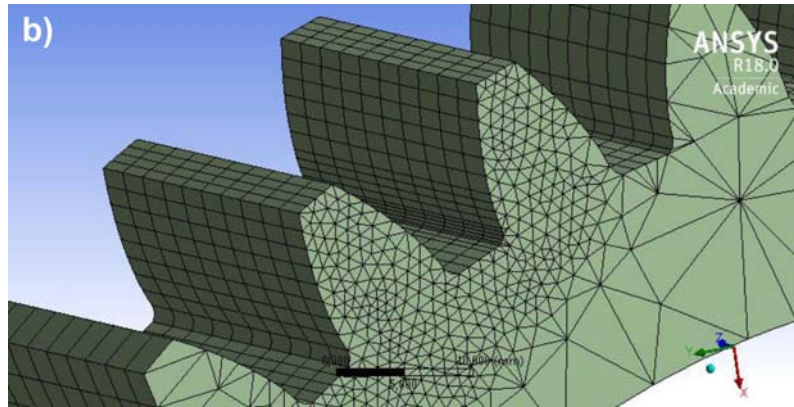


Fig. 2. cont'd

Table 2. Parameters of the material

Density	7850 kg/m ³
Yield limit	250 MPa
Ultimate strength	460 MPa

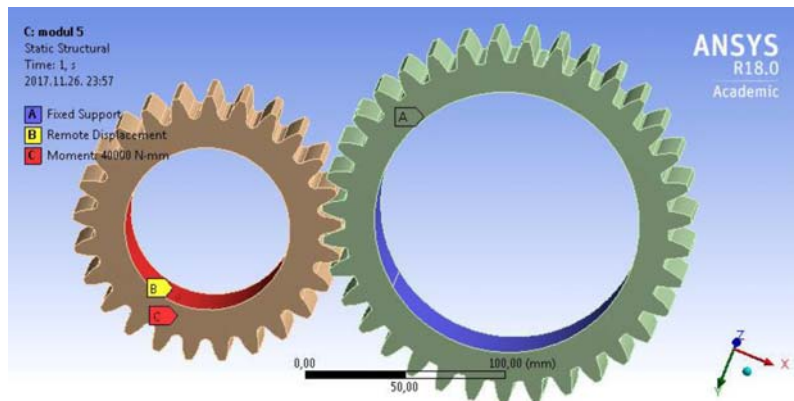


Fig. 3. Setting the loads and boundary conditions

Five degrees of freedom of the driving cog wheel were fixed. Only the rotational movement around the rotational shaft was allowed. In the case of the driven cog wheel fixed support was applied (Fig. 3) [5, 7–9].

4. Normal tension analyses in the contact zone

Figure 4 shows normal tension dispersions – on the driving gear contact tooth surfaces – which are the

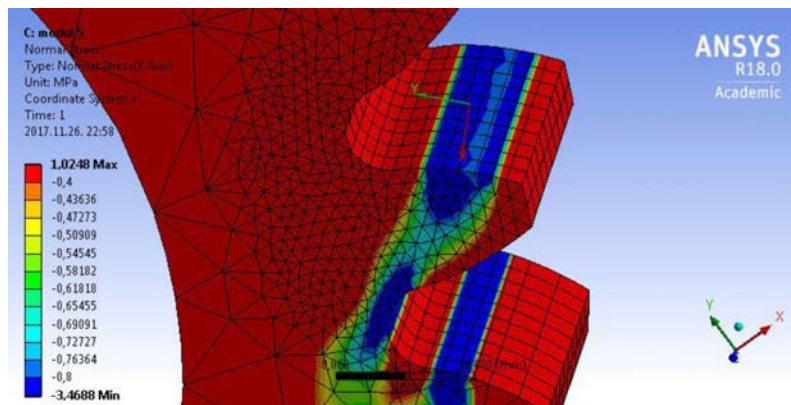


Fig. 4a. In case of 5 mm module (average normal tension on the tooth surface: –1.057 MPa)

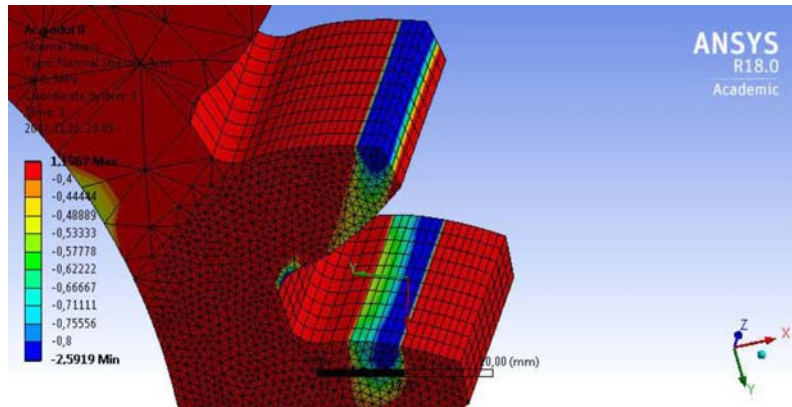


Fig. 4b. In case of 8 mm module (average normal tension on the tooth surface: -0.873 MPa)

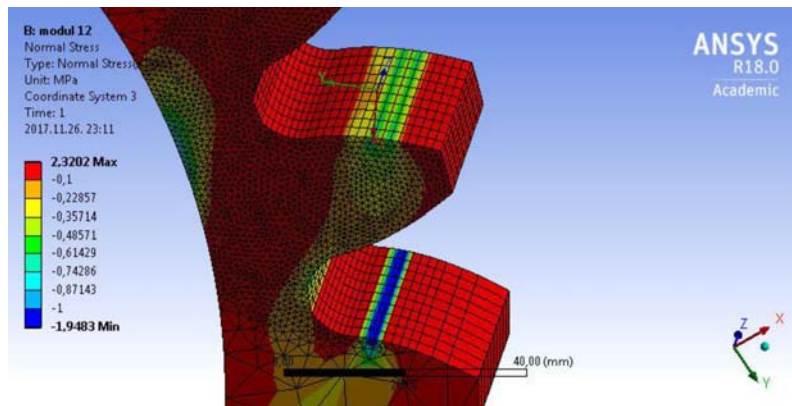


Fig. 4c. In case of 12 mm module (average normal tension on the tooth surface: -0.642 MPa)

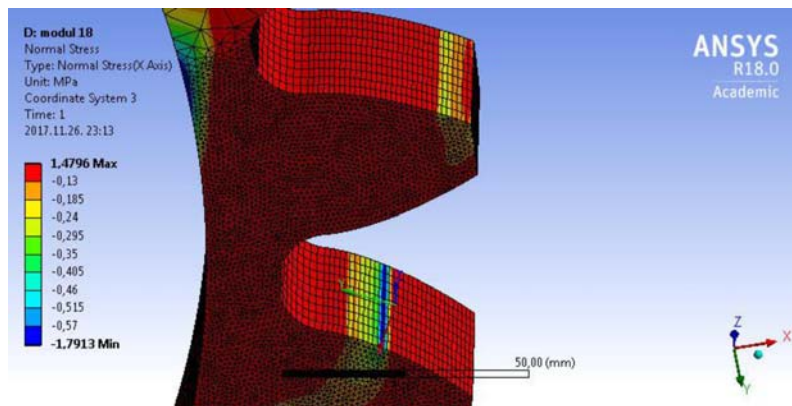


Fig. 4d. In case of 18 mm module (average normal tension on the tooth surface: -0.243 MPa)

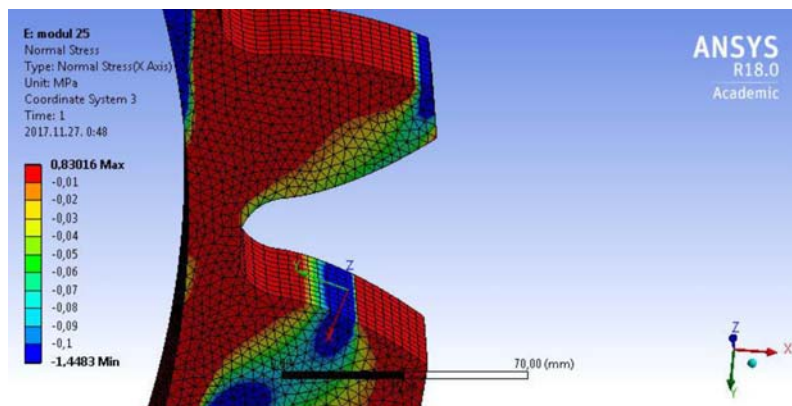


Fig. 4e. In case of 25 mm module (average normal tension on the tooth surface: -0.143 MPa).
Normal tension values on the tooth surfaces of the driving cog wheel

effect of the load of 40 Nm torque. Based on Fig. 4, it can be stated that on the tooth surfaces of the driving cog wheels in the contact zone, perpendicular to the tooth surface, the values of the normal tension decrease as a function of enhancing the value of the module.

Figure 5 shows normal tension dispersions – on the contact tooth surfaces of the driving cog wheels – as an effect of the 40 Nm load of torque. Based on Fig. 5, it can be stated that on the tooth surfaces of the driven cog wheels in the contact zone, perpendicular

to the tooth surface, the values of the normal tension decrease as a function of enhancing the value of the module.

5. Normal tension analyses on the fillet

As an effect of the moment, on the fillet radius of the contact teeth those tension values are formed as shown in Fig. 6. The tension analysis of the fillet (root of the tooth) is important because of the bending stress and of any accidental tooth break.

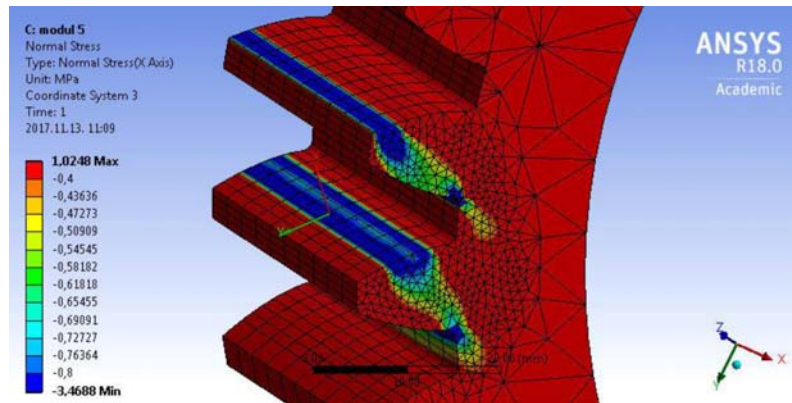


Fig. 5a. In case of 5 mm module (average normal tension on the tooth surface: -1.022 MPa)

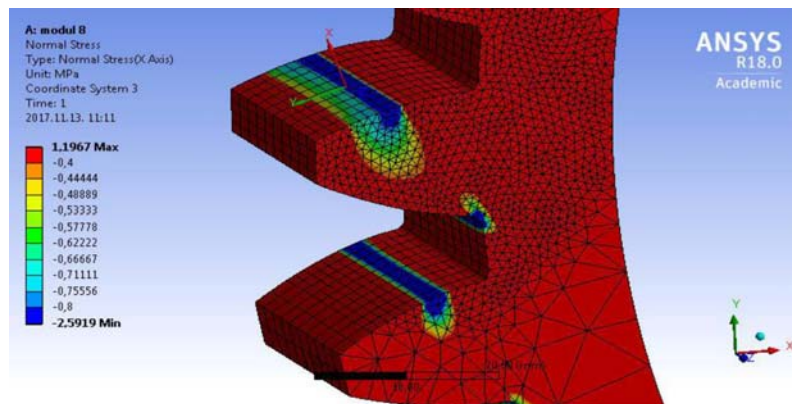


Fig. 5b. In case of 8 mm module (average normal tension on the tooth surface: -0.834 MPa)

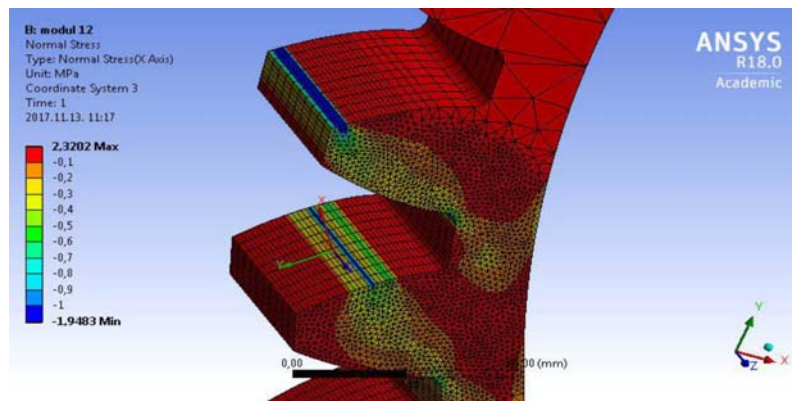


Fig. 5c. In case of 12 mm module (average normal tension on the tooth surface: -0.739 MPa)

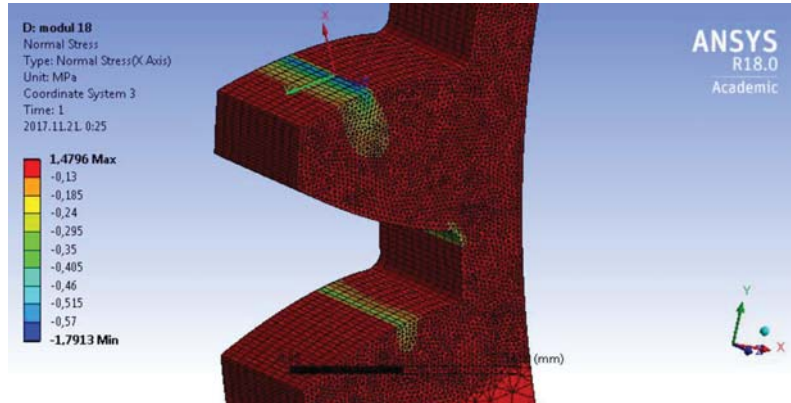


Fig. 5d. In case of 18 mm module (average normal tension on the tooth surface: -0.295 MPa)

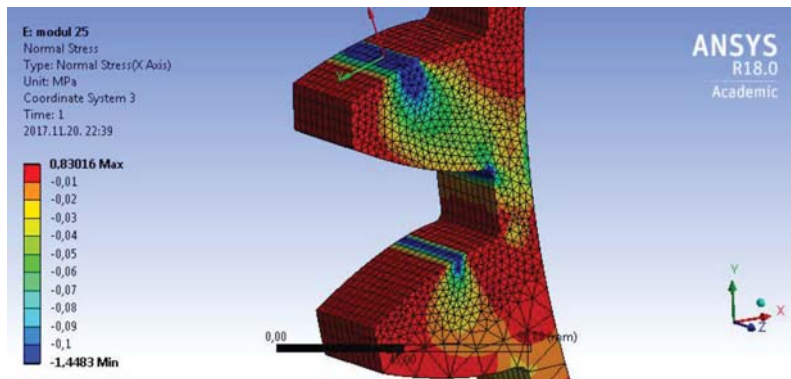


Fig. 5e. In case of 25 mm module (average normal tension on the tooth surface: -0.136 MPa).
Normal tension values on the tooth surfaces of the driven cog wheel

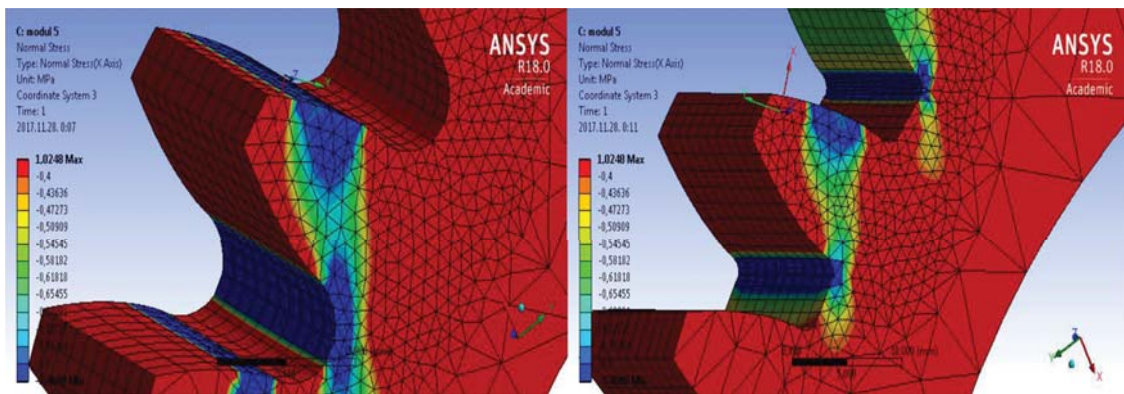


Fig. 6a. In case of 5 mm module, the driving and driven cog wheels

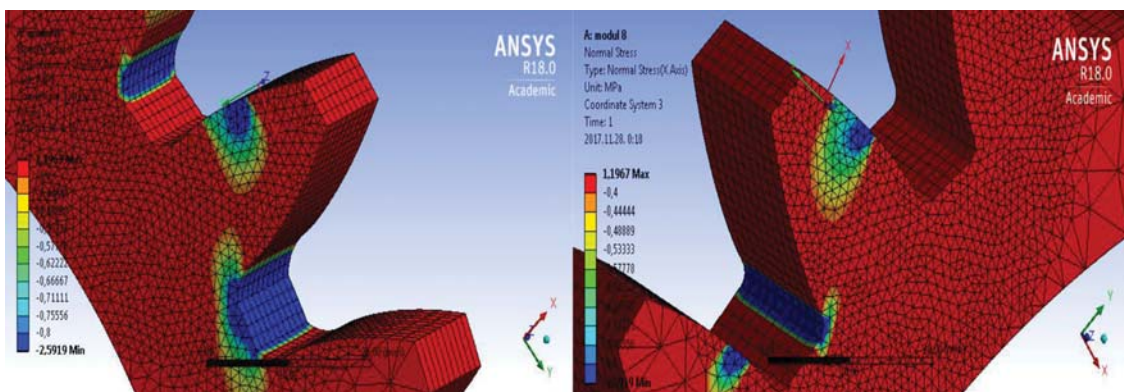


Fig. 6b. In case of 8 mm module, the driving and driven cog wheels

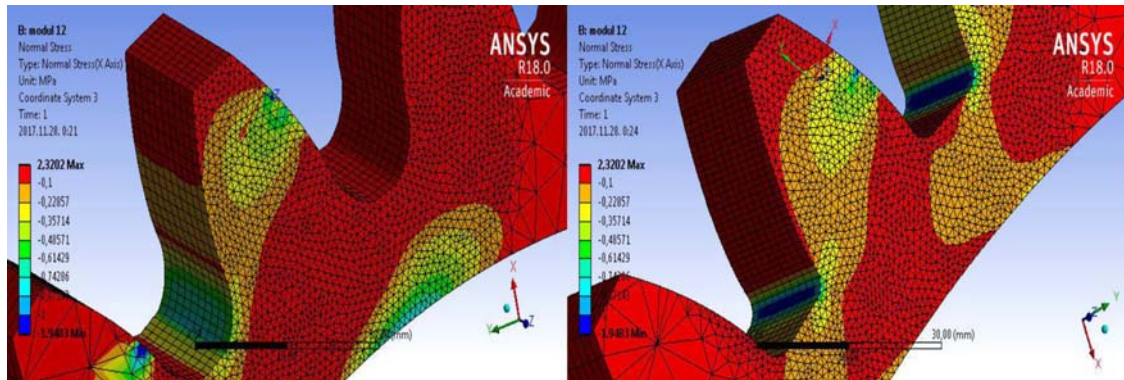


Fig. 6c. In case of 12 mm module, the driving and driven cog wheels

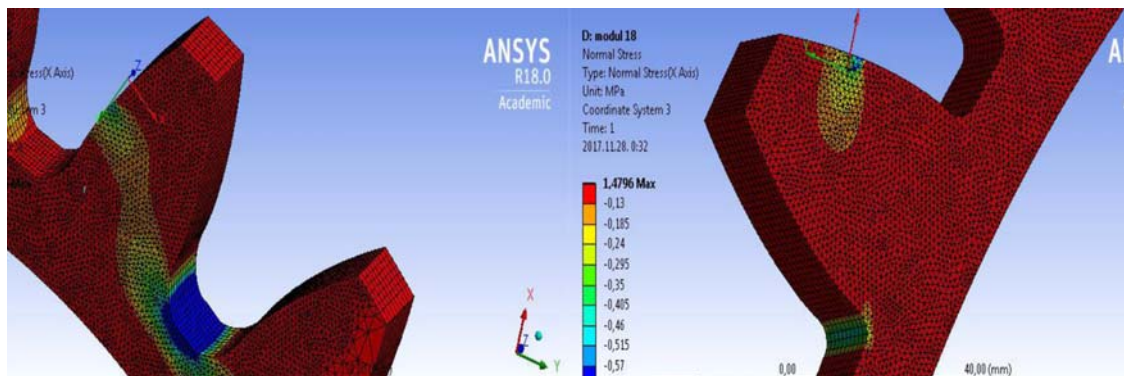


Fig. 6d. In case of 18 mm module, the driving and driven cog wheels

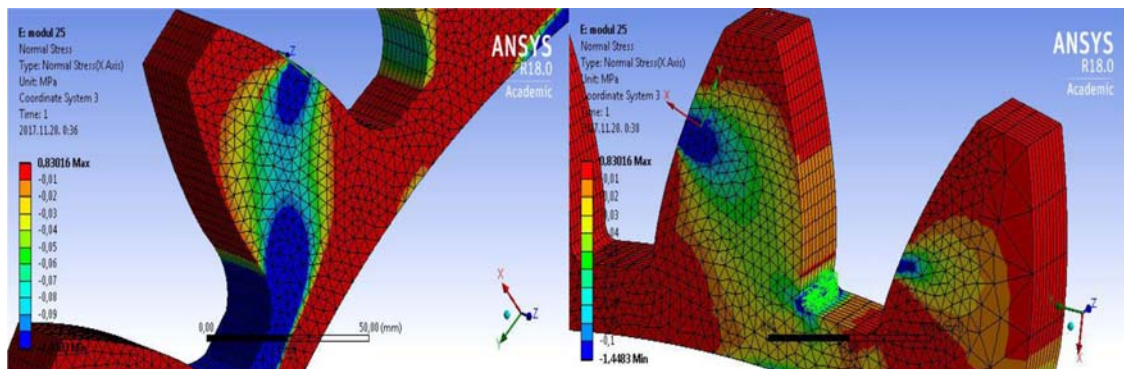


Fig. 6e. In case of 25 mm module, the driving and driven cog wheels.
Normal tension values occurring in the fillet of cog wheels

Figure 6 shows that normal tension values in the fillet of the contact cog pairs decrease in the way perpendicular to the surface, as a function of enhancing the module.

6. Summary

A computer program has been developed to ease the designing and modelling of basic toothed gear pairs. The CAD models of the gear pairs (with equal num-

ber of tooth, but different modules) have been made in Solidworks design software.

The Ansys Finite Element Method (FEM) software has been used to analyze the normal tension values as an effect of the load – on the tooth surfaces of the driving and driven cog wheels. During the analyses, the cog wheels having less number of teeth have been the driving cog wheels. On the face surfaces tetrahedron meshing has been applied, while on the tooth surfaces we applied 10 equally divided mesh – along the tooth length.

After setting the load and the boundary conditions we got the result that as a function of enhancing the module, on the contact tooth surfaces and fillets of the driving and driven gear pairs – in the contact zone – normal tension values perpendicular to the surface decrease.

Acknowledgements

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