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COMPARATIVE TOOTH CONTACT ANALYSIS OF X-ZERO GEAR DRIVES IN THE FUNCTION OF THE MODULE CHANGING

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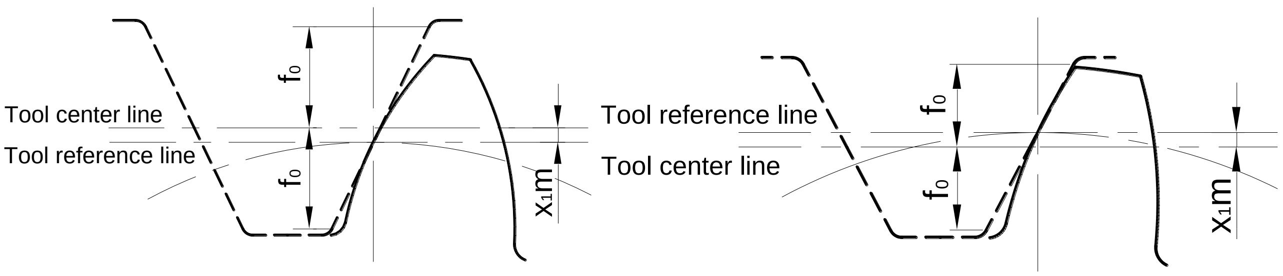
Abstract
In this publication the connection of four gear drives will be analysed beside constant number of teeth in the function of the modul changing. Computer program will be developed for designing of x-zero gear drives. Using this program the x-zero gear drives could be generated with arbitrary numbers and parameters. Based on the connection statements the conclusions will be worked out.

Keywords: modul, toothed gear, finite element, stress

1. INTRODUCTION

The objective of connection analysis and computer modelling is the analysis of the teeth of the gear drive in aspect of stress, strain and total deformation. Before the concrete production and commissioning the dimensions of the connection results for the effect of given loading is defined on the connection tooth surfaces. Based on the received simulation results the tooth geometry could be modifiable because of the better connection properties. After the connection results have been given good results the concrete production of the gear drives could be designed.
In case of toothed gear production the pitch circle diameter is rolled down without slip on the tool reference line. The tool reference line could be different from the tool center line. This effect is called tool stoppage gearing. The produced gear teeth is called a gear having addendum modification (Figure 1) [2, 4, 5, 6].



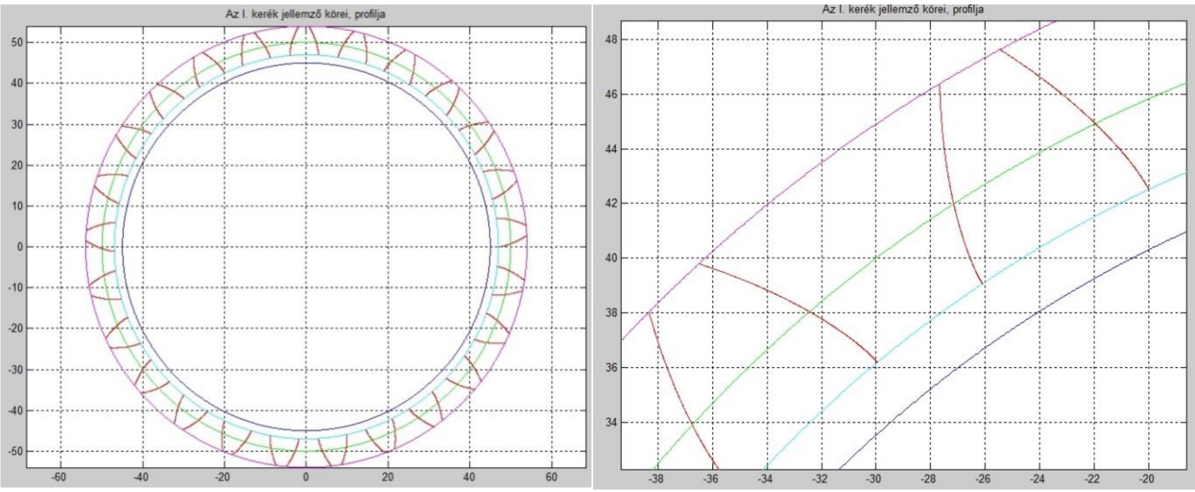
a) positive addendum modification   b) negative addendum modification

Figure 1 Tool connection with gear tooth

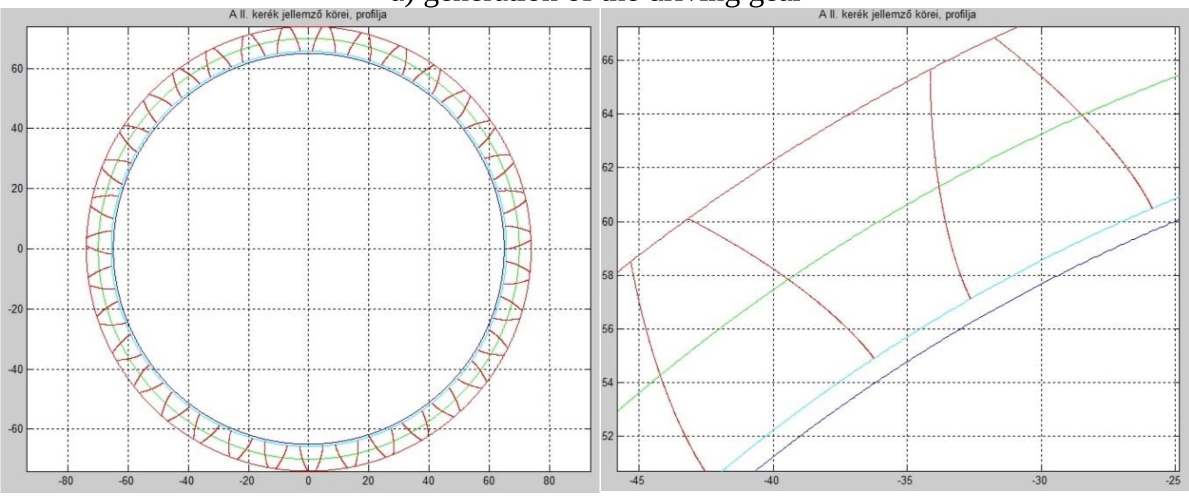
The x-zero gear drive is an extreme case of the x-gear when addendum modification is not used (x_1=0). The tool reference line is the tool center line [2, 4, 5, 6].

2. COMPUTER AIDED MODELLING

A computer program has been worked out for the modelling of x-zero gear drives. The modul and the number of teeth of the gears are asked from the user by the program. Knowing of these three parameters the other parameters of the gear drive are calculated by the program. After the calculations the gears are drown by the software (Figure 2).



a) generation of the driving gear



b) generation of the driven gear

Figure 2 Generation of a concrete geometric X – zero gear drive

The received involute tooth profile points are saved in txt file. The parametric equation of the involute curve is [1, 6]:

$$x_{1F} = \frac{d_{b1}}{2} \cdot (\cos\beta + \beta \cdot \sin\beta)$$
$$y_{1F} = \frac{d_{b1}}{2} \cdot (\sin\beta - \beta \cdot \cos\beta) \qquad (1)$$

Using of the received points the computer models of the gear drives could be designed to the finite element analysis with SolidWorks computer aided designing software.
Four gear drives have been designed [4, 6] and modelled [1] for the finite element analysis. The

number of teeth of the gear drives (z_1, z_2) are the same. Based on the modul standard the modules of the gear drives are changed with 0,5 mm scale [6]. During the analysis the driving gear having lower number of teeth that is why transmission ratio is slower. The calculated parameters of the gear drives could be seen on Table 1.

Table 1 The parameters of the designed gear drives

Parameters	Gear drive I.	Gear drive II.	Gear drive III.	Gear drive IV.
Axial modul (m)	4 mm	4,5 mm	5 mm	5,5 mm
Driving gear number of teeth (z_1)	25	25	25	25
Driven gear number of teeth (z_2)	35	35	35	35
Centre distance (a)	120 mm	135 mm	150 mm	165 mm
Addendum (h_a)	4 mm	4,5 mm	5 mm	5,5 mm
Clearance (c)	1 mm	1,125 mm	1,25 mm	1,375 mm
Dedendum (h_f)	5 mm	5,625 mm	6,25 mm	6,875 mm
Circular pitch (p)	12,566 mm	14,137 mm	15,708 mm	17,278 mm
Backlash (j_s)	0,628 mm	0,706 mm	0,785 mm	0,863 mm
Whole depth (h)	9 mm	10,125 mm	11,25 mm	12,375 mm
Working depth (h_w)	8 mm	9 mm	10 mm	11 mm
Tooth thickness (S_{ax})	5,969 mm	6,715 mm	7,461 mm	8,207 mm
Pitch circle diameter of the driving gear (d_1)	100 mm	112,5 mm	125 mm	137,5 mm
Tip circle diameter of the driving gear (d_{a1})	108 mm	121,5 mm	135 mm	148,5 mm
Root circle diameter of the driving gear (d_{f1})	90 mm	101,25 mm	112,5 mm	123,75 mm
Basic circle diameter of the driving gear (d_{ak1})	93,969 mm	105,715 mm	117,461 mm	129,207 mm
Pitch circle diameter of the driven gear (d_2)	140 mm	157,5 mm	175 mm	192,5 mm
Tip circle diameter of the driven gear (d_{a2})	148 mm	166,5 mm	185 mm	203,5 mm
Root circle diameter of the driven gear (d_{f2})	130 mm	146,25 mm	162,5 mm	178,75 mm
Basic circle diameter of the driven gear (d_{ak2})	131,557 mm	148 mm	164,446 mm	180,89 mm
Transmission ratio (i)	1,4	1,4	1,4	1,4

3. TOOTH CONNECTION ANALYSIS

3.1. Adoption of the finite element mesh

Coefficient of friction having 0,15 value has been set on the connection teeth zone. During the calculations tetrahedron mesh was used. Density of the meshing was automatic in outside of the connection teeth zone [5, 9]. Meshing having 0,6 mm dense has been set on the connection zone (Figure 3).

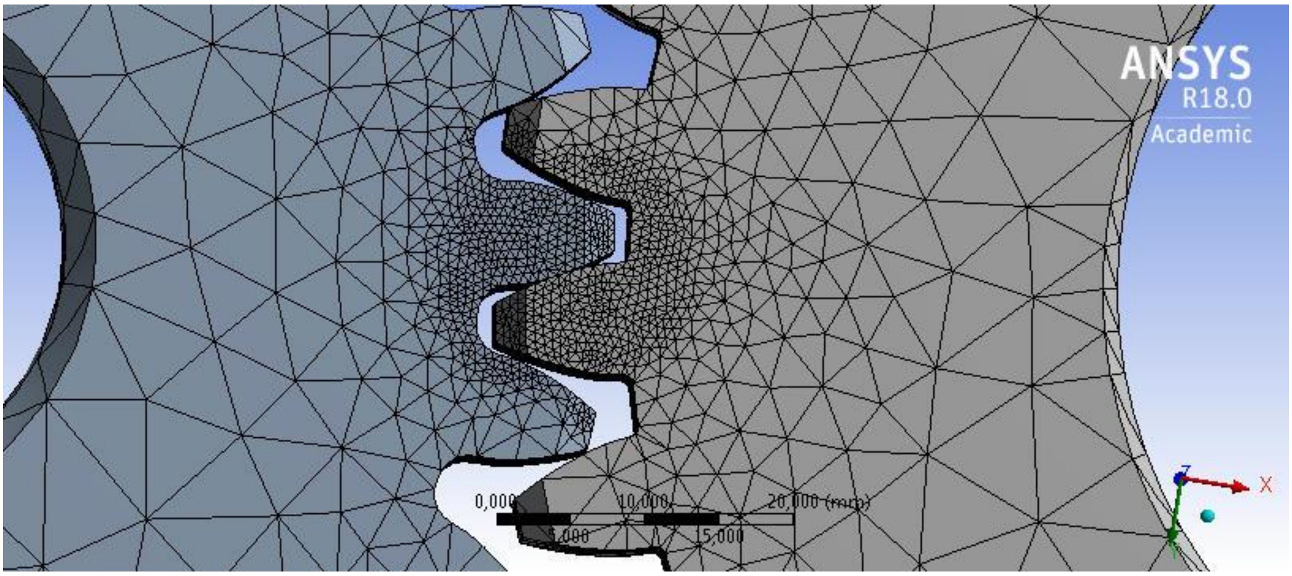


Figure 3 Adoption of finite element mesh

3.2. Setting of loading and boundary conditions

During the analysis the gear drive material is structural steel (Figure 2). The driving gear is loaded with 20 Nm rotation moment (Figure 4).

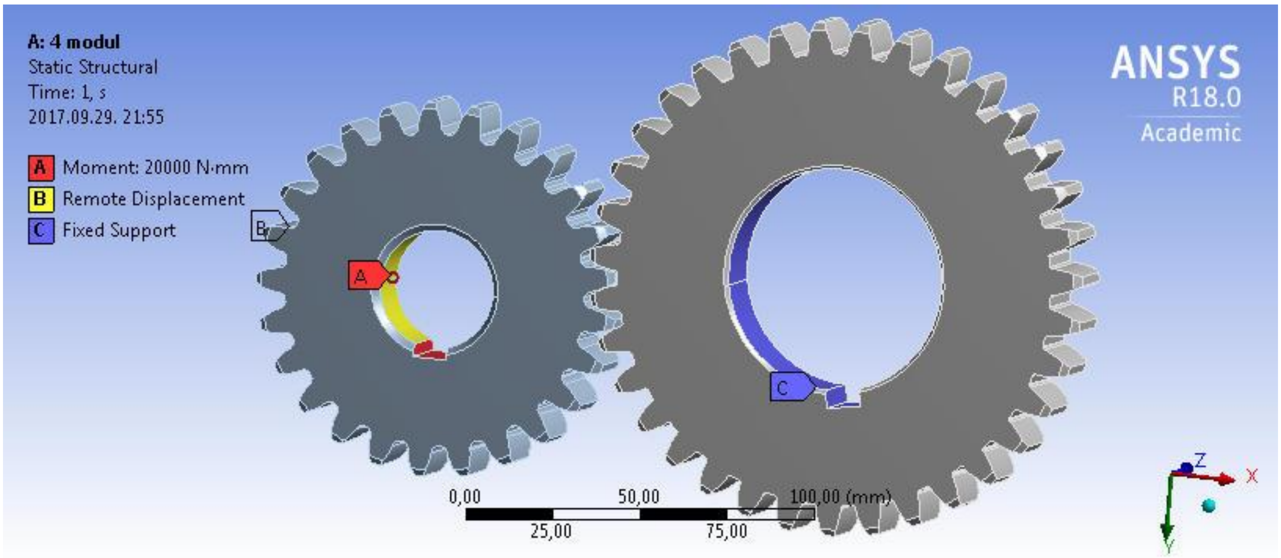


Figure 4 Setting of loading and boundary conditions

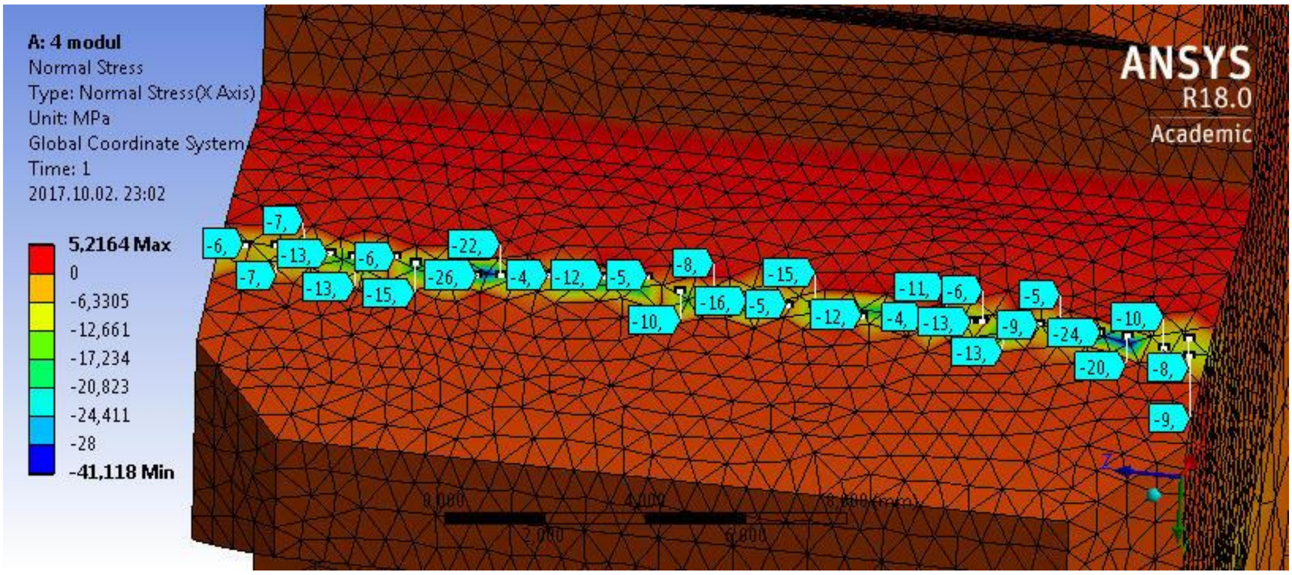
Table 2 Material parameters

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

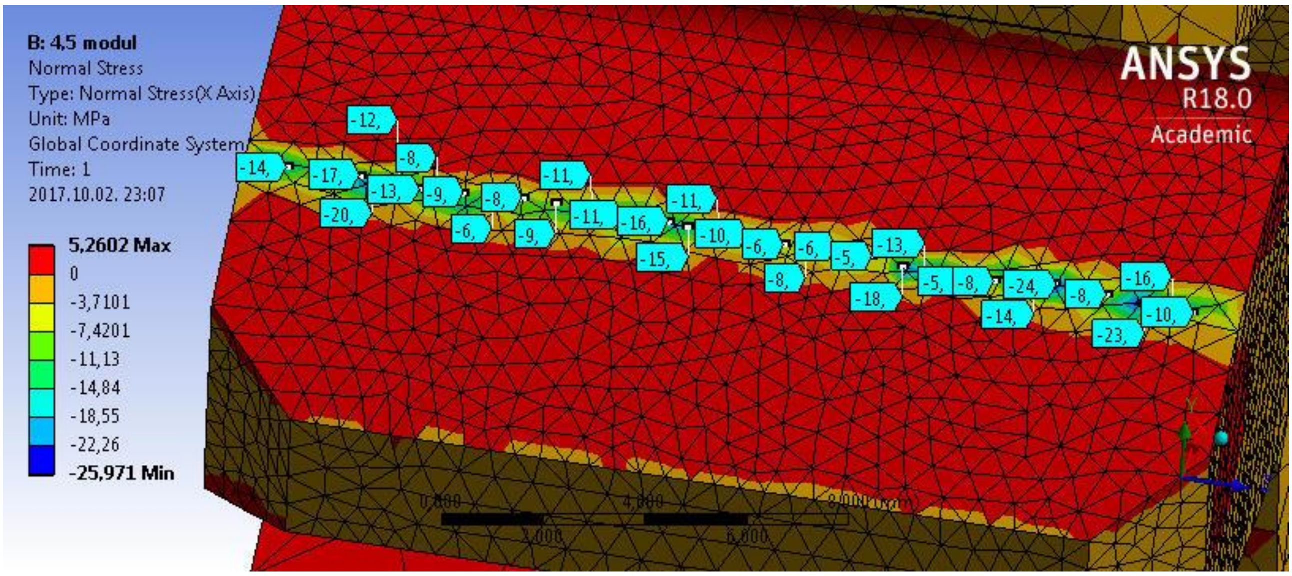
Five freedom degrees of the driving gear have been fixed. Only rotation around the axis of rotation has been permitted. Fix holding has been used for the driven gear (Figure 4).

3.3. Analysis of normal stress distribution

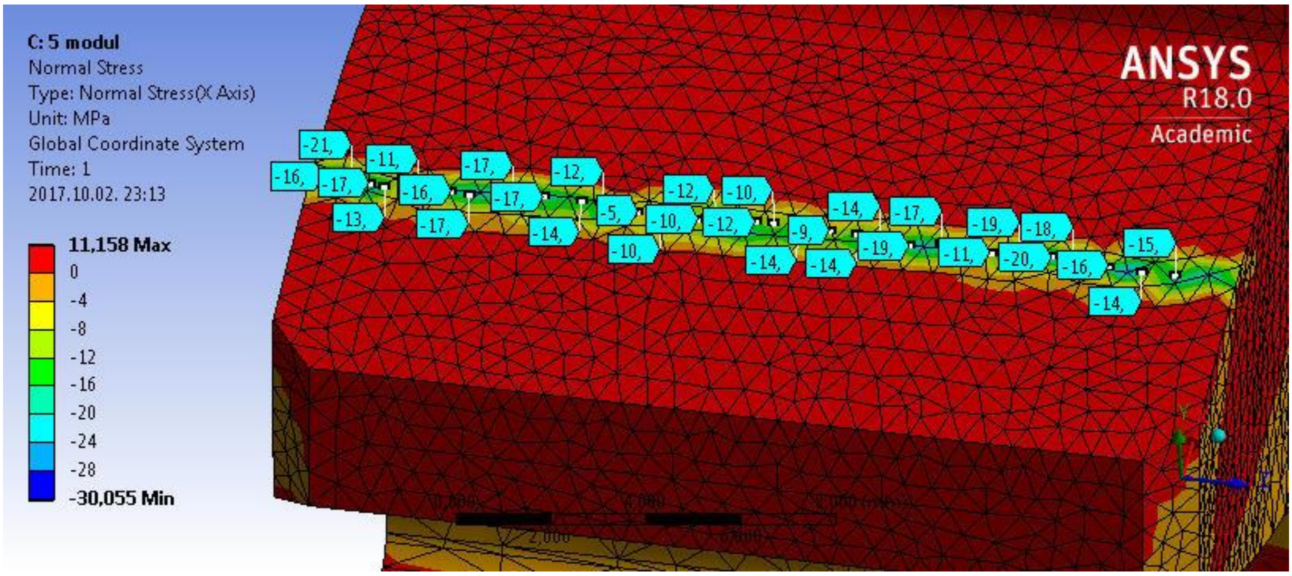
On Figure 5 the normal stress distribution could be seen by the effect of loading moment on the connection tooth surface of the driven gear.



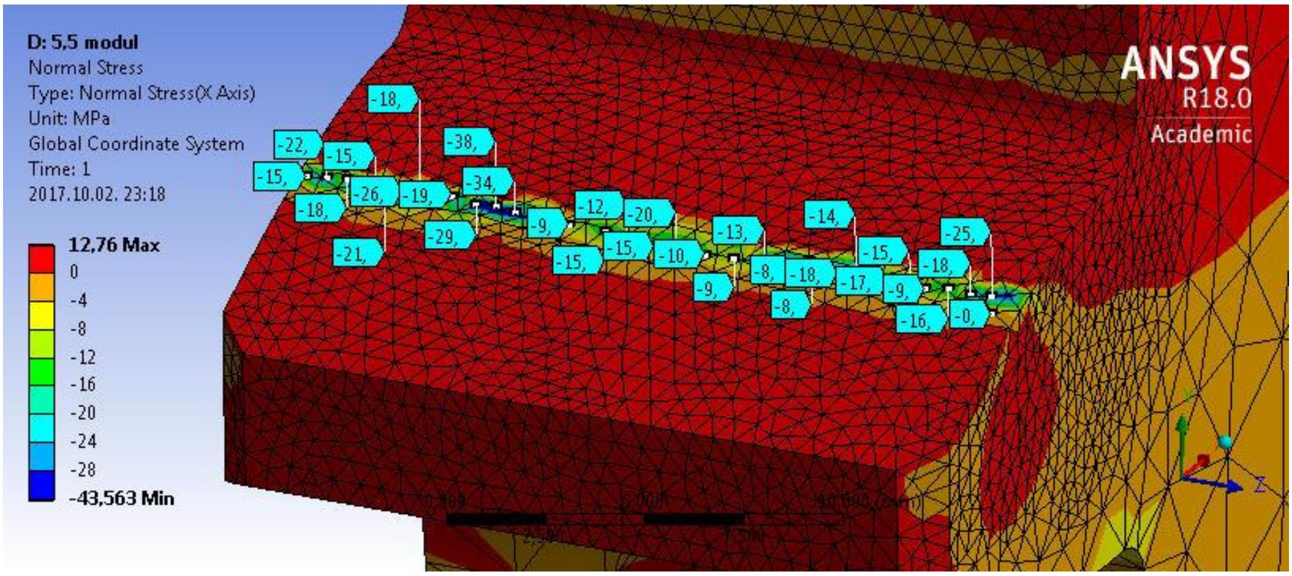
a) in case of 4 mm modul (the average normal stress on the tooth surface: -11,333 MPa)



b) in case of 4,5 mm modul (the average normal stress on the tooth surface: -11,466 MPa)



c) in case of 5 mm modul (the average normal stress on the tooth surface: -14,133 MPa)

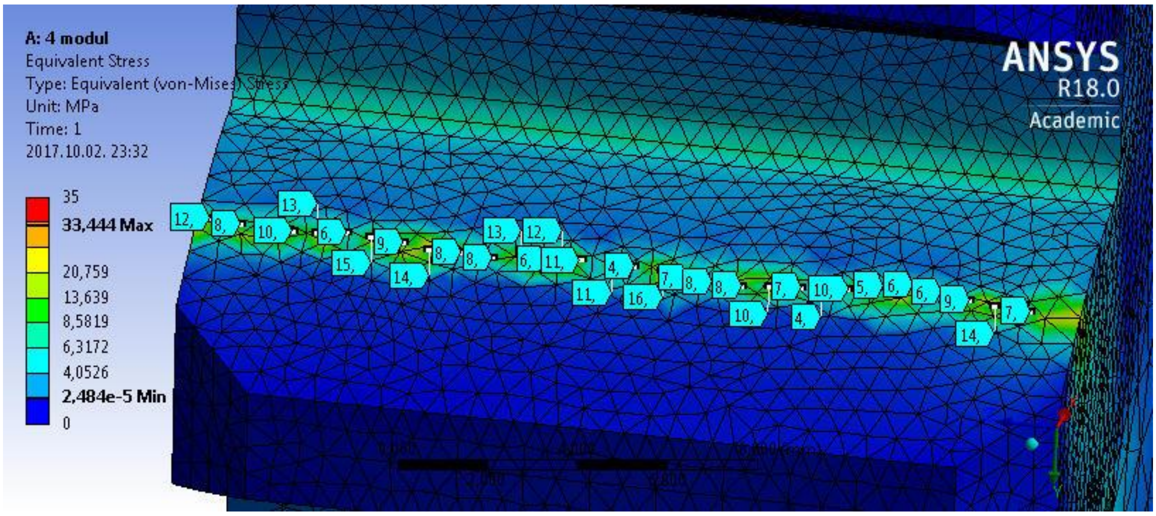


d) in case of 5,5 mm modul (the average normal stress on the tooth surface: -17.366 MPa)
Figure 5 Normal stress distribution on the tooth surface of the driven gear

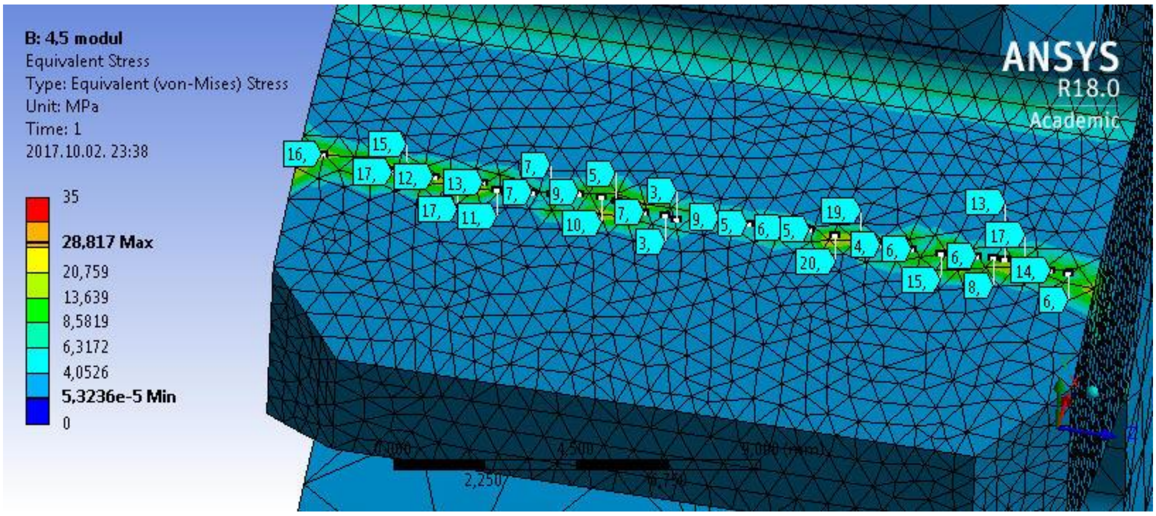
On Figure 3 the normal stress distributions in the function of the modul increase are reduced on the tooth surface of the driven gear on the connection zone. The root has bending and turning stresses.

3.4. Analysis of equivalent stress

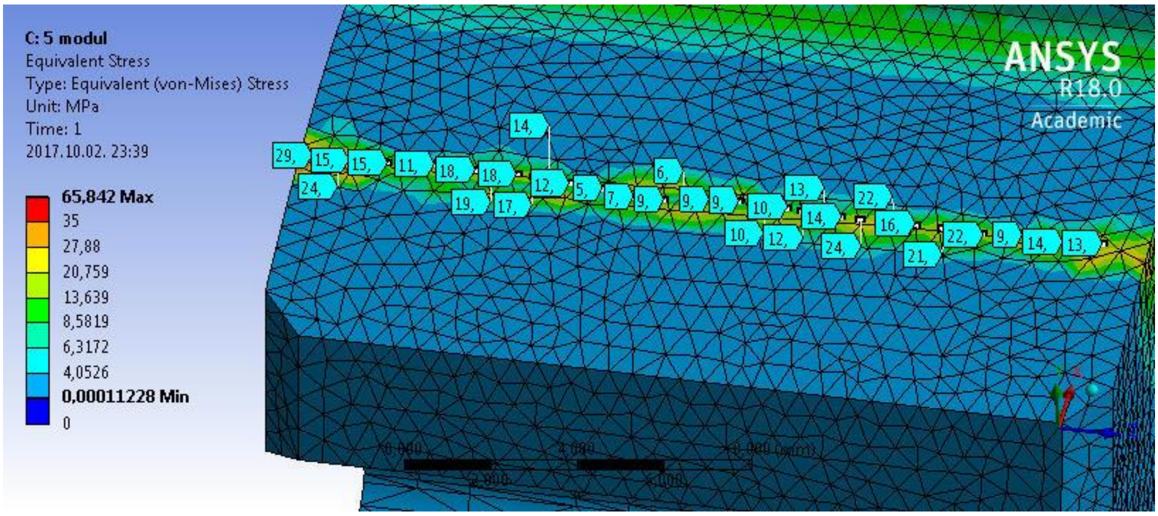
On Figure 6 the equivalent stress distribution could be seen by the effect of loading moment on the connection tooth surface of the driven gear.



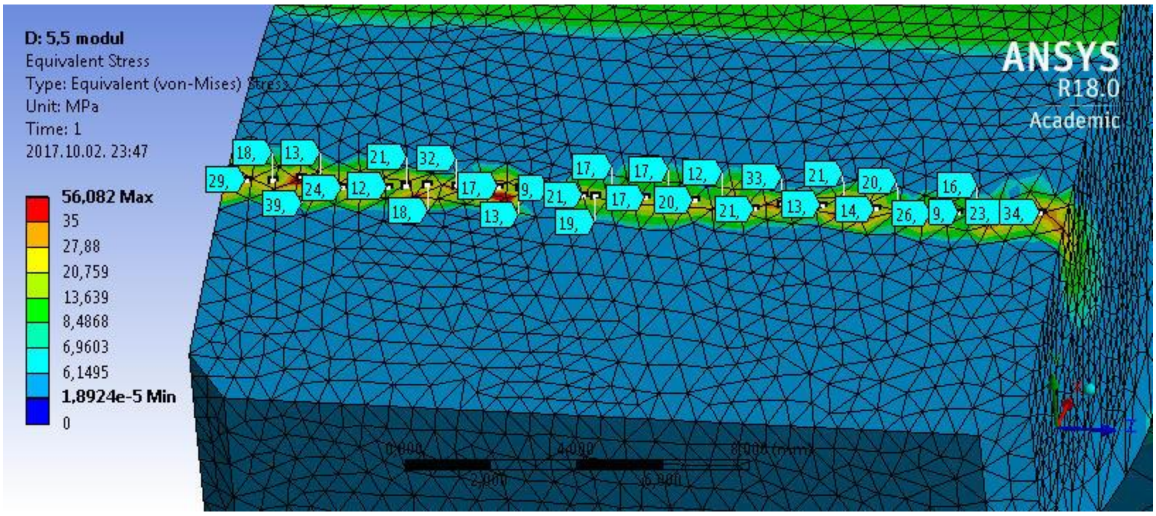
a) in case of 4 mm modul (the average equivalent stress on the tooth surface: 9,833 MPa)



b) in case of 4,5 mm modul (the average equivalent stress on the tooth surface: 10,033 MPa)



c) in case of 5 mm modul (the average equivalent stress on the tooth surface 13,33 MPa)



d) in case of 5,5 mm modul (the average equivalent stress on the tooth surface 22,22 MPa)
Figure 6 Equivalent stress distribution on the tooth surface of the driven gear

On Figure 6 the equivalent stress distributions in the function of the modul increase is increased on the tooth surface of the driven gear on the connection zone. The root has bending and turning stresses.

CONCLUSION

In this publication the x-zero gear drives are designed beside the number of teeth constancy. Based on the standard the modules of the toothed gears have been changed with 0,5 mm step value. Computer software has been worked out for the easement of the designing process. Based on the teeth geometric parameters the CAD models of the gear drives have been worked out by SolidWorks designer software.
Beside similar loading and boundary conditions the evolved normal and equivalent stress dispositions have been analysed [7, 8, 10, 11] on the tooth surfaces of the driven gear by Ansys finite element software. As a result the effect of the modul increasing the normal stress values are decreased and the equivalent stress values are increased on the tooth surface of the driven gear on the connection zone.

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