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ANALYSIS OF THE EFFECT OF THE ADDENDUM MODIFICATION COEFFICIENT FOR CONTACT SURFACES OF SPUR GEAR

BODZÁS Sándor[1]

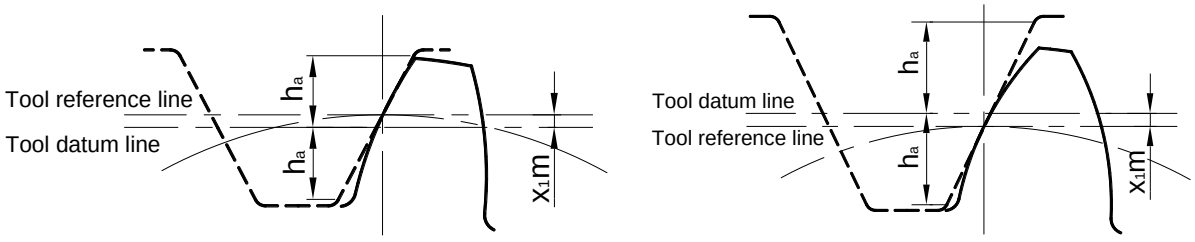
[1]University of Debrecen, Department of Mechanical Engineering, Debrecen Ótemető str. 2-4., Hungary, 4028, e-mail: bodzassandor@eng.unideb.hu

Abstract: The spur gear is widely used in many types of machines and appliances that is why the research of the connection analysis of them (Tooth Contact Analysis, TCA) is very important because of the development of these gears. The TCA analysis is a complex task because the mathematical description, the CAD modelling process, the overall designing process, the manufacturing process of the gears and the definition of the mechanical parameters have to be known. After the gear designing process the gear pairs have to be analysed by TCA method to determine the typical dimension of the mechanical parameters in case of given load. Knowing of the result we can reason for the appropriate gear geometry of the given construction and working conditions.

KEYWORDS: spur gear, TCA, CAD, addendum modification

1 Introduction

The main property of the spur gear pairs having modified straight teeth is addendum modification is applied because of the reach of better mechanical characteristics [3-12, 14 - 21]. The addendum modification is positive if the base profile is shifted outward from the shaft, it is negative when the base profile is shifted towards the shaft (Figure 1) [3 – 12, 14 - 20].



a) negative b) positive

Fig 1. Mating of the tool base profile with the tooth of the gear

The tooth connection is on the pitch circle diameters that is why standard centre distance is applied. The addendum values of the gear pairs [6, 12]:

$$h_{a1} = f_0' \cdot m + x_1 \cdot m \tag{1}$$

$$h_{a2} = f_0' \cdot m - x_1 \cdot m \tag{2}$$

The addition of the addendum modification coefficient is $x_1 + x_2 = 0$, that is $x_1 = -x_2$. If we modify the tooth on one of the gear wheels then with the same value but with different indication you should correct the other gear wheel as well [6, 7, 8, 10, 11, 12, 14 - 20].

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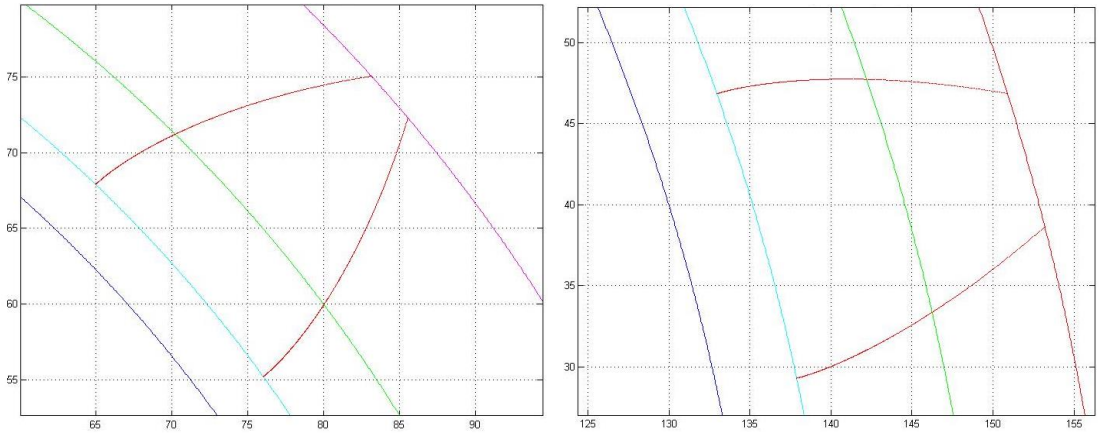
2 Designing of the gear pairs

A computer aided software has been developed to ease the CAD designing process of the gears. The m module is given, z_1, z_2 number of teeth, α_0 base profile angle, f'_0 addendum coefficient, and x_1 addendum modification coefficient [1, 2].

Table 1. The calculated parameters of the gear pairs

The main parameters of the gear pairs	*Gear drive I.*	*Gear drive II.*	*Gear drive III.*	*Gear drive IV.*	*Gear drive V.*
Axial module (mm)	10				
Number of tooth of the driving gear (z_1)	20				
Number of tooth of the driven gear (z_2)	30				
Standard centre distance (a_0) (mm)	250				
Addendum of the driving gear (h_{a1}) [mm]	10	11	12	13	14
Addendum of the driven gear (h_{a2}) [mm]	10	9	8	7	6
Bottom clearance (c) [mm]	2				
Dedendum of the driving gear (h_{f1}) [mm]	12	11	10	9	8
Dedendum of the driven gear (h_{f2}) [mm]	12	13	14	15	16
Circular pitch (t_0) [mm]	31.415				
Backlash (j_s) [mm]	1.507				
Whole depth (h) [mm]	22				
Working depth (h_w) [mm]	20				
Tooth thickness (S_{ax1}) [mm]	14.922				
Pitch circle diameter of the driving gear (d_1) [mm]	200				
Tip circle diameter of the driving gear (d_{a1}) [mm]	220	222	224	226	228
Root circle diameter of the driving gear (d_{f1}) [mm]	176	178	180	182	184
Basic circle diameter of the driving gear (d_{ak1}) [mm]	187.938				
Pitch circle diameter of the driven gear (d_2) [mm]	300				
Tip circle diameter of the driven gear (d_{a2}) [mm]	320	318	316	314	312
Root circle diameter of the driven gear (d_{f2}) [mm]	276	274	272	270	268
Basic circle diameter of the driven gear (d_{ak2}) [mm]	281.907				
The x_1 addendum modification [mm]	0	0.1	0.2	0.3	0.4
The x_2 addendum modification [mm]	0	-0.1	-0.2	-0.3	-0.4
Transmission ratio (i)	1.5				
Base profile angle (α_0) [°]	20				

Knowing of this starting parameters the geometric parameters and the profile points are calculated by this software. We have designed five types of gear pairs. The addendum modification coefficients have been changed from 0 to 0.4 . All of other parameters have been constant (Table 1).



a) driving gear b) driven gear

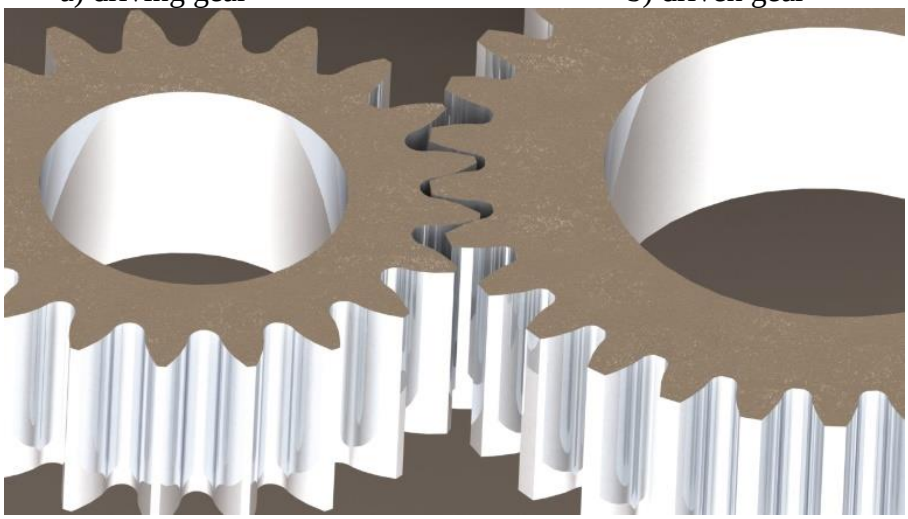
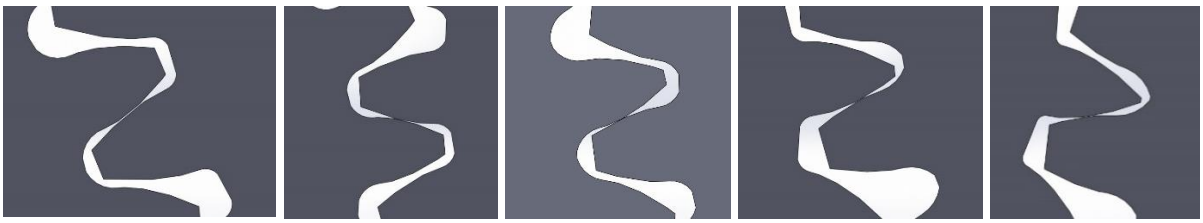


Fig. 2. Generation of the CAD models of the gear pairs



x=0 x=0.1 x=0.2 x=0.3 x=0.4

Fig. 3. The teeth connection of the analysed gear pairs

Based on the calculated parameters and the profile point the CAD models of the gear pairs could be generated (Figure 2).

On Figure 3 the teeth connection of the analysed gear pairs could be seen. In the function of increasing of the addendum modification coefficient the tooth thickness of the driving gears is continuously being attenuated on the tip circle. The tooth thickness of the driven gear is continuously being expanded on the tip circle (Figure 3).

3 TCA analysis of the gear pairs

The appropriate adoption of the necessary coordination systems and the finite element mesh [13, 22, 23] is the main important determining parameters for the TCA analysis [7, 8, 9, 13]. For this analysis three coordination systems have been adopted [9, 10]:

- two coordination systems are situated on the rotation centres of the two gears,
- one coordination system is situated on the contact zone of the gear teeth.

On the contact zone sweep type meshing has been applied [7, 8, 9]. Previously a sphere has been defined on the contact surfaces of the gear pairs. Inside of this sphere dense meshing has been applied having 0.8 mesh element sizes.

The driving gear has been loaded by 700 Nm torque. Five freedom degrees have been fixed only the rotation motion around the axis of rotation has been permitted [7, 8, 9]. The driven gear has been totally fixed.

3.1 Normal stress analysis

Normal stresses (von Mises) have been calculated for the contact zone of the driving gear and the driven gear (Figure 3).

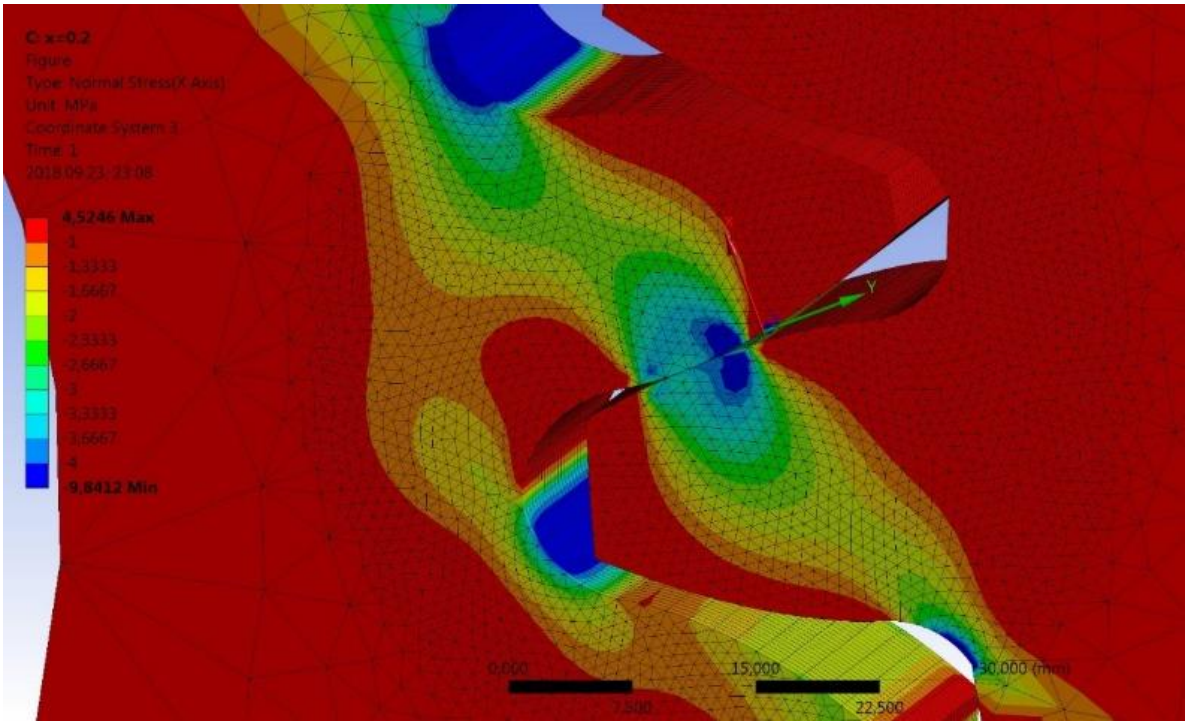


Fig. 3. Normal stress distribution on the tooth contact zone (x=0.2)

The average normal stresses of the contact surfaces are shown in the function of the addendum modification coefficient (Figure 4).

The average normal deformation of the contact surfaces are shown in the function of the addendum modification coefficient (Figure 5).

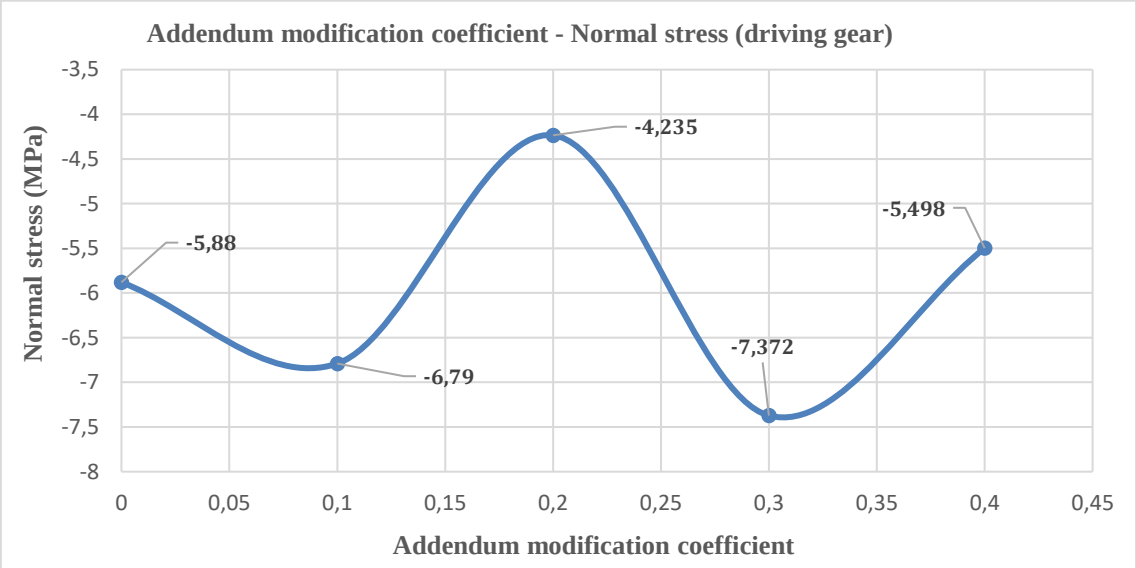
Based on Figure 5 the lowest average normal deformations in absolute value are found in case of 0.2 addendum modification coefficient. The highest dimensions in absolute value are found in the 0 and the 0.4 addendum modification coefficients.

3.3 Normal elastic strain analysis

The calculated average normal elastic strain of the contact surfaces are shown in the function of the addendum modification coefficient (Figure 6).

Based on Figure 6 the lowest average normal elastic strains in absolute value are found in case of 0.2 addendum modification coefficient. The highest values in absolute value are found in the 0 and the 0.4 addendum modification coefficients.

Based on this result it could be determinable that the application of 0.2 addendum modification is the most advantageous because the analysed mechanical parameters (normal stress, deformation and elastic strain) are the lowest in this case. That is why the application of this addendum coefficient is suggested for designing of this gear pair having this geometric parameters.



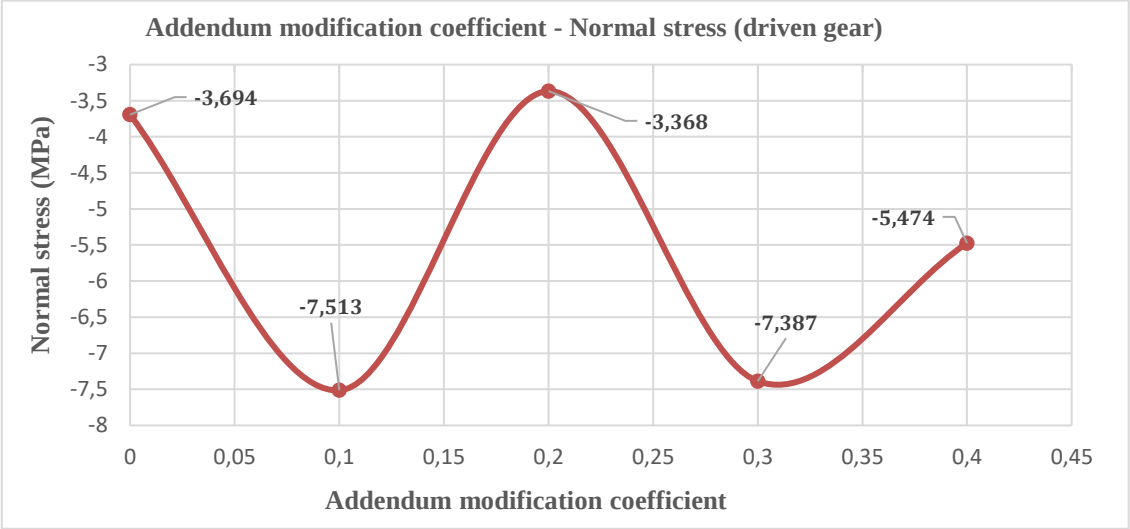
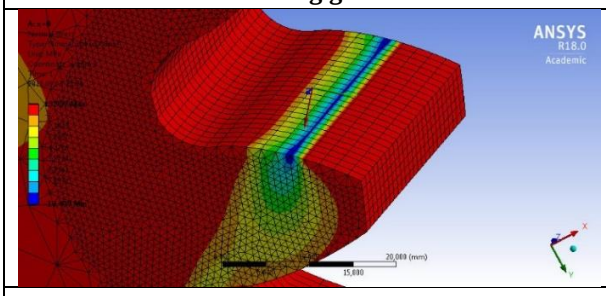
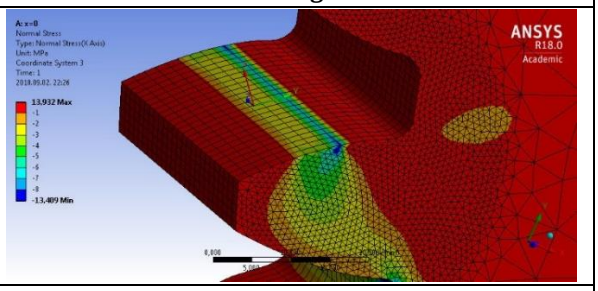


Fig. 4. The average normal stresses in the function of the addendum modification coefficient

Table 2. The calculated normal stress distributions.

Driving gear	Driven gear
	
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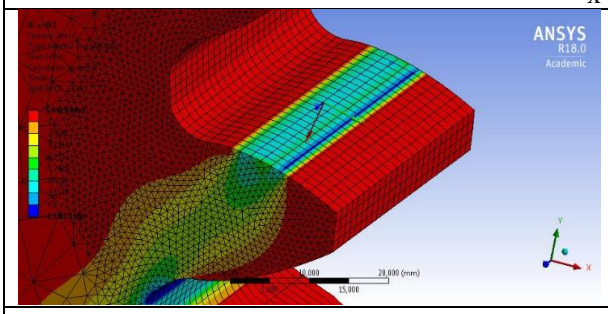	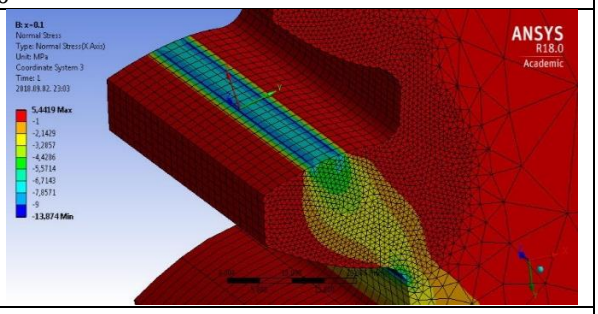
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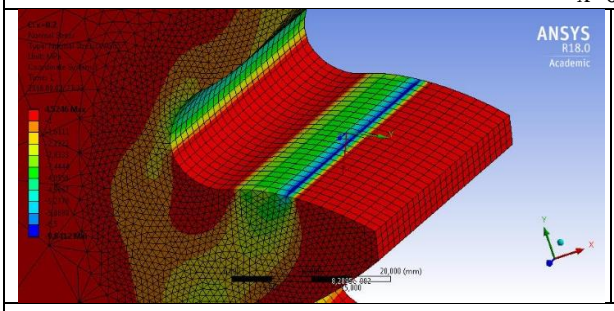	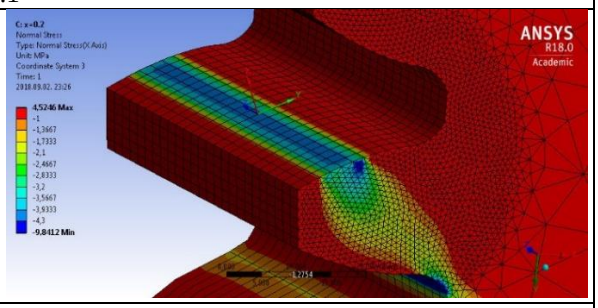
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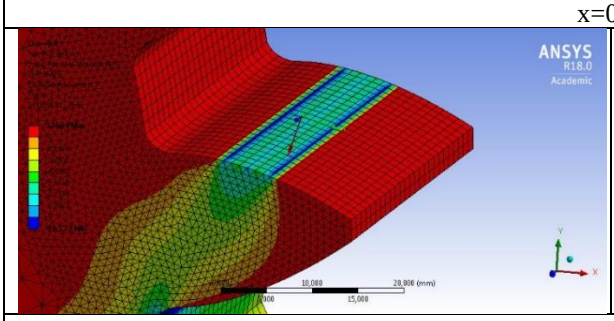	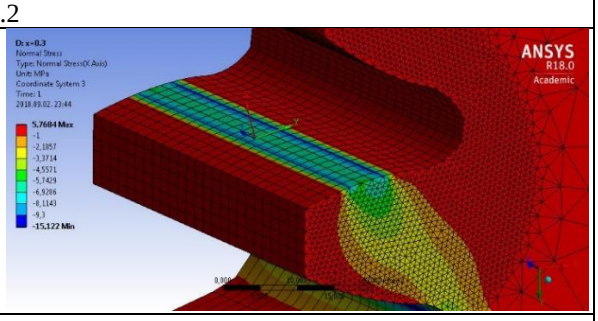
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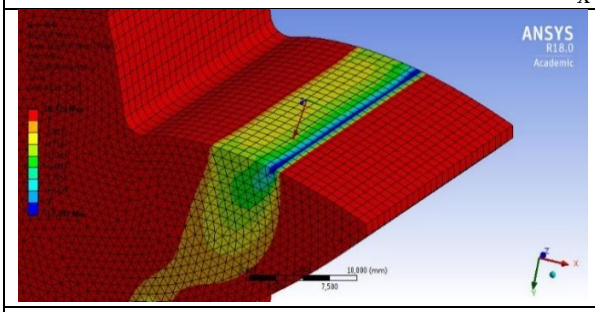
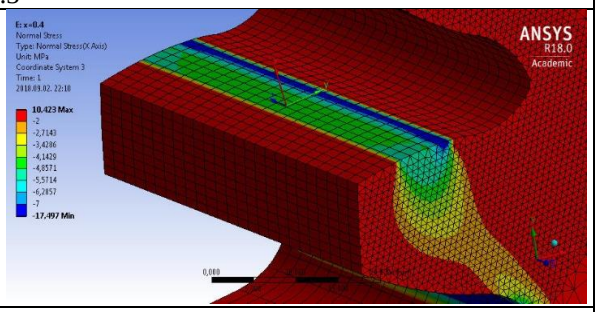
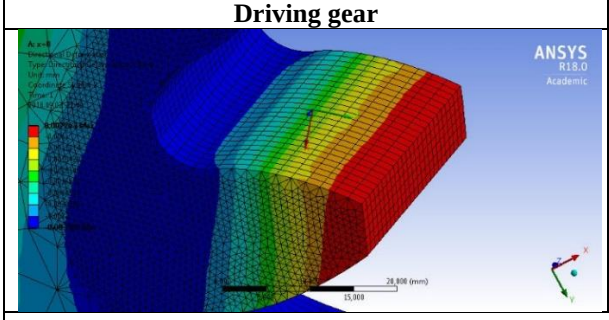
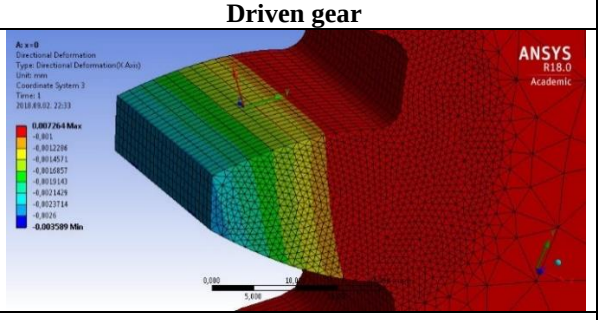
	
x=0.4	

Table 3. The calculated normal deformation distributions

Driving gear	Driven gear
	
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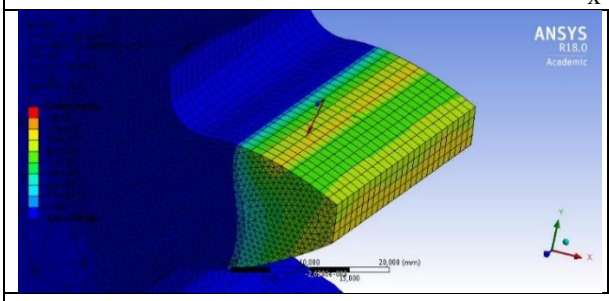	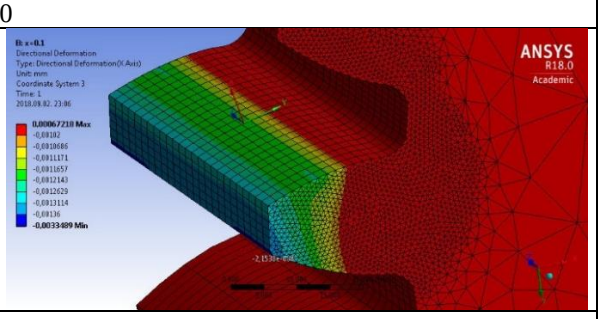
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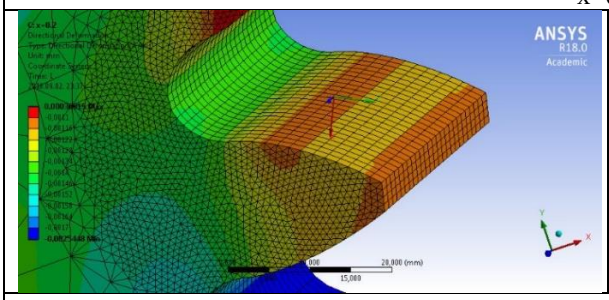	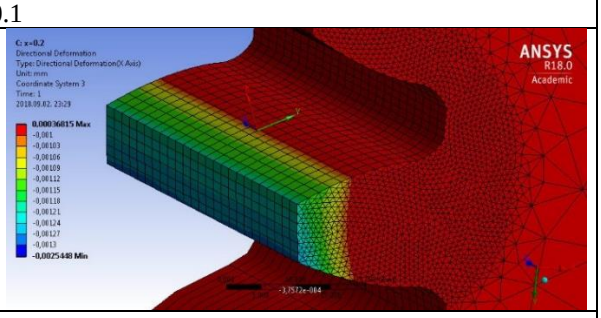
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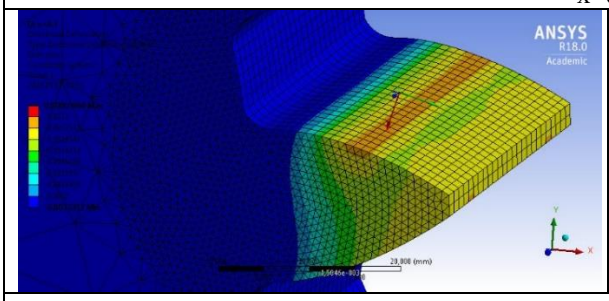	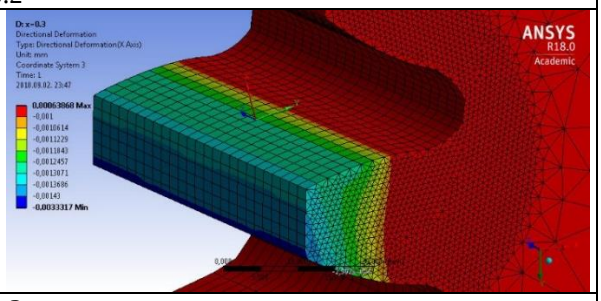
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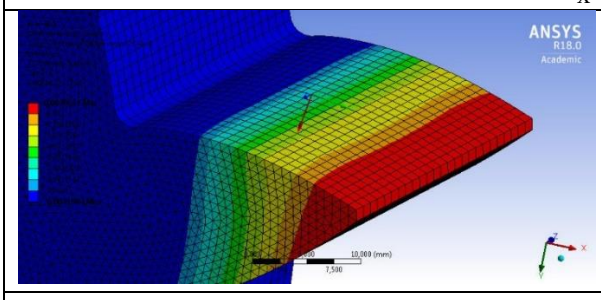	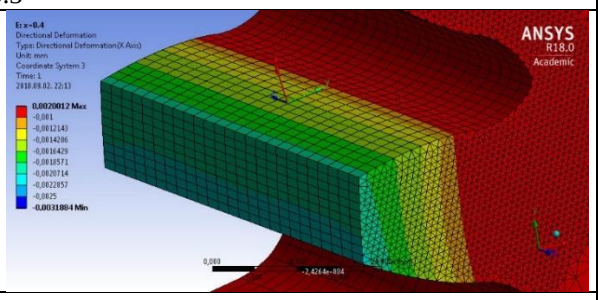
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Table 4. The calculated normal elastic strain distributions

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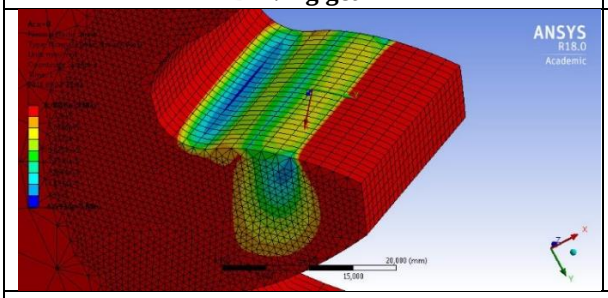	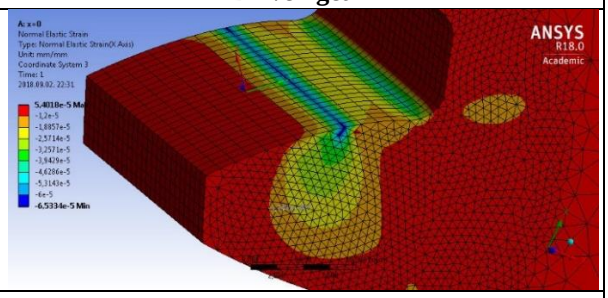
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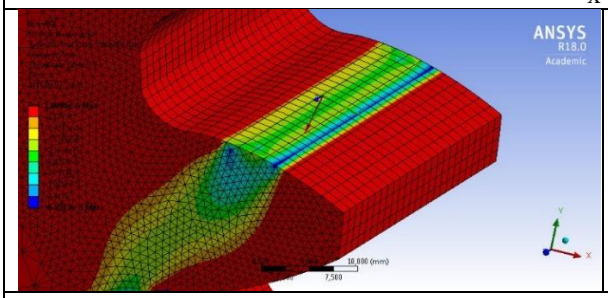	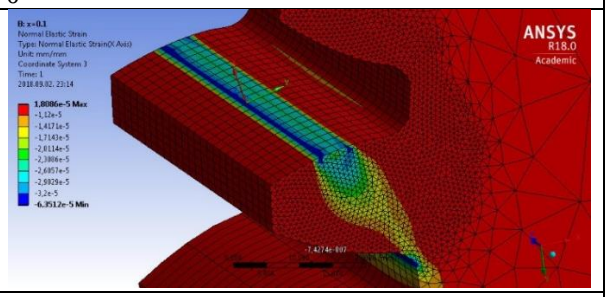
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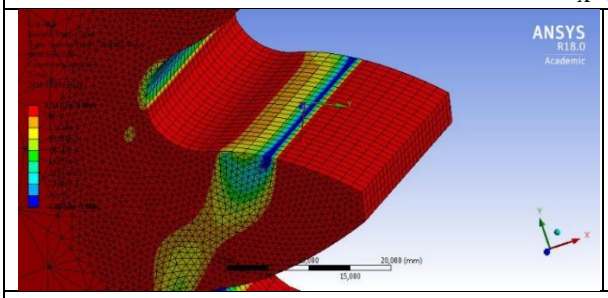	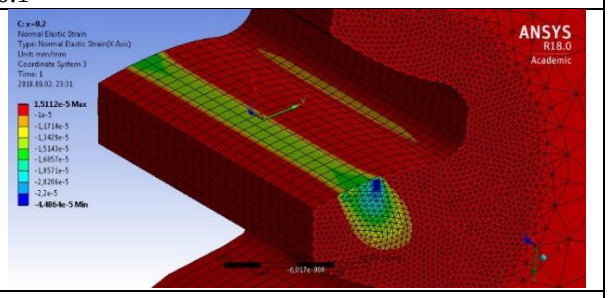
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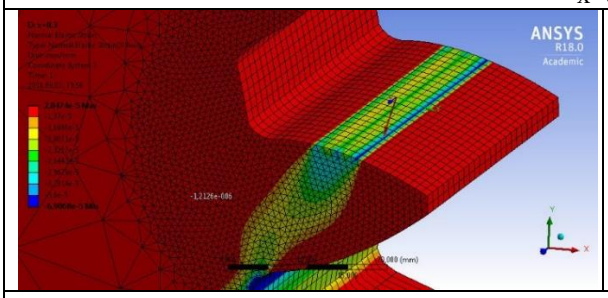	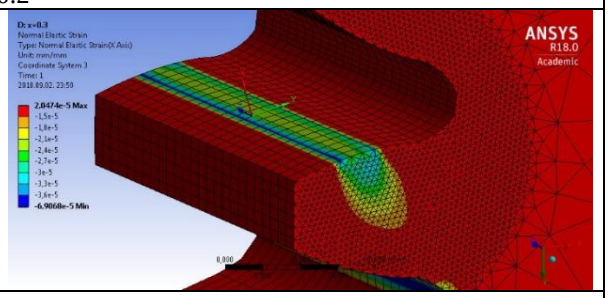
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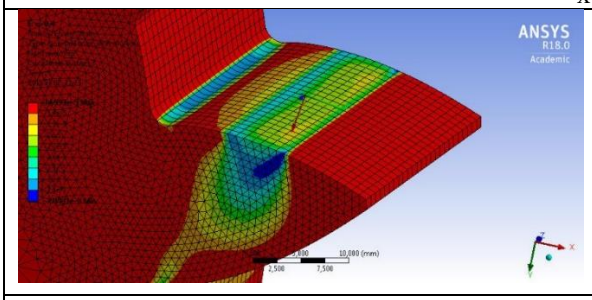	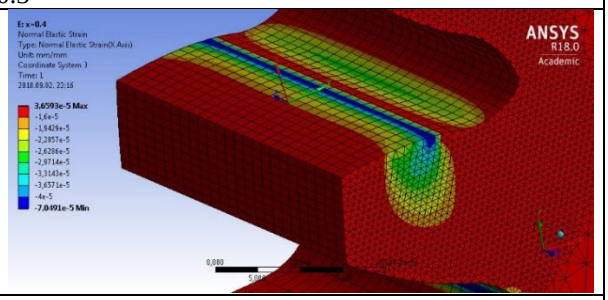
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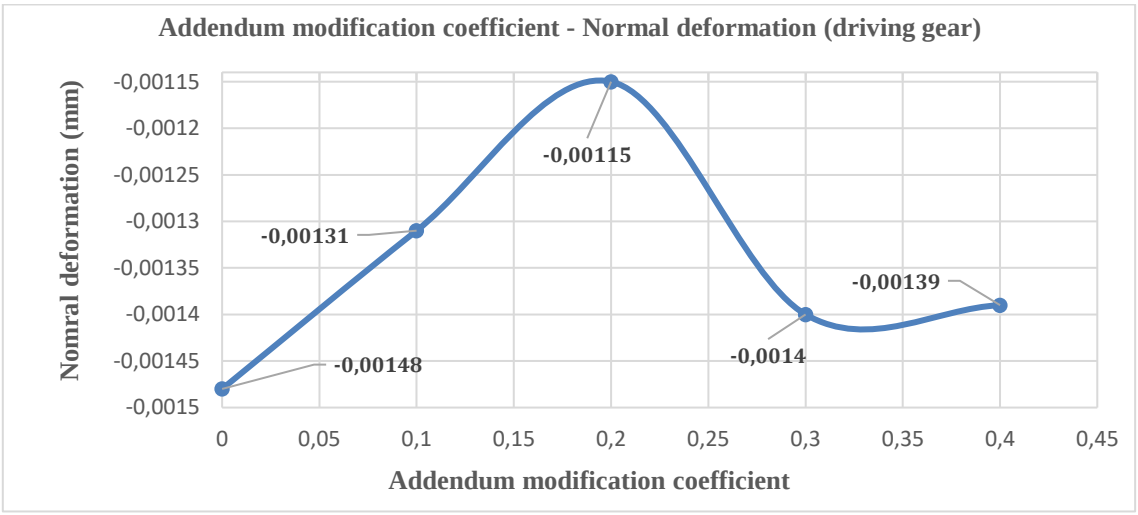

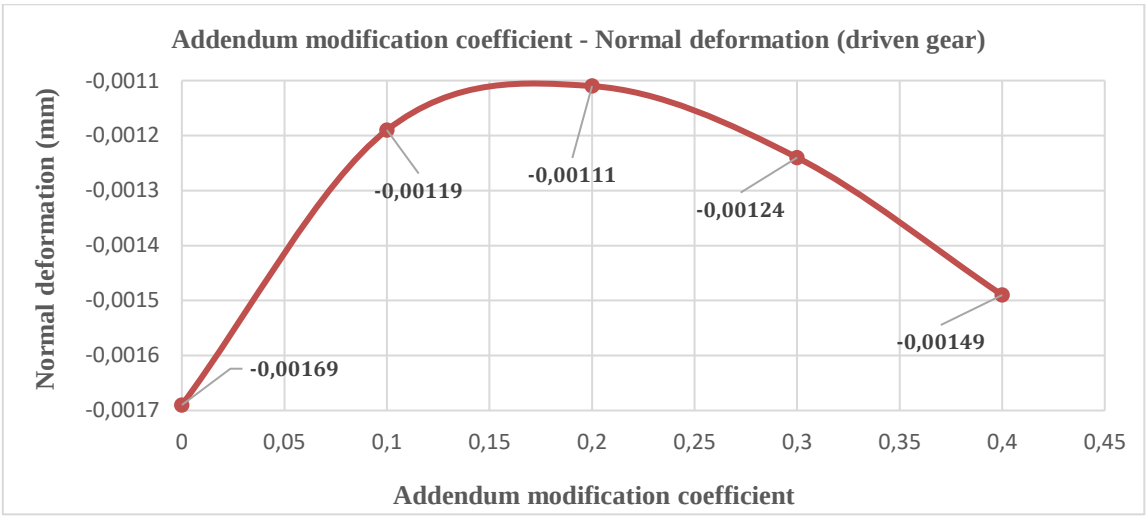

Fig. 5. The average normal deformations in the function of the addendum modification coefficient

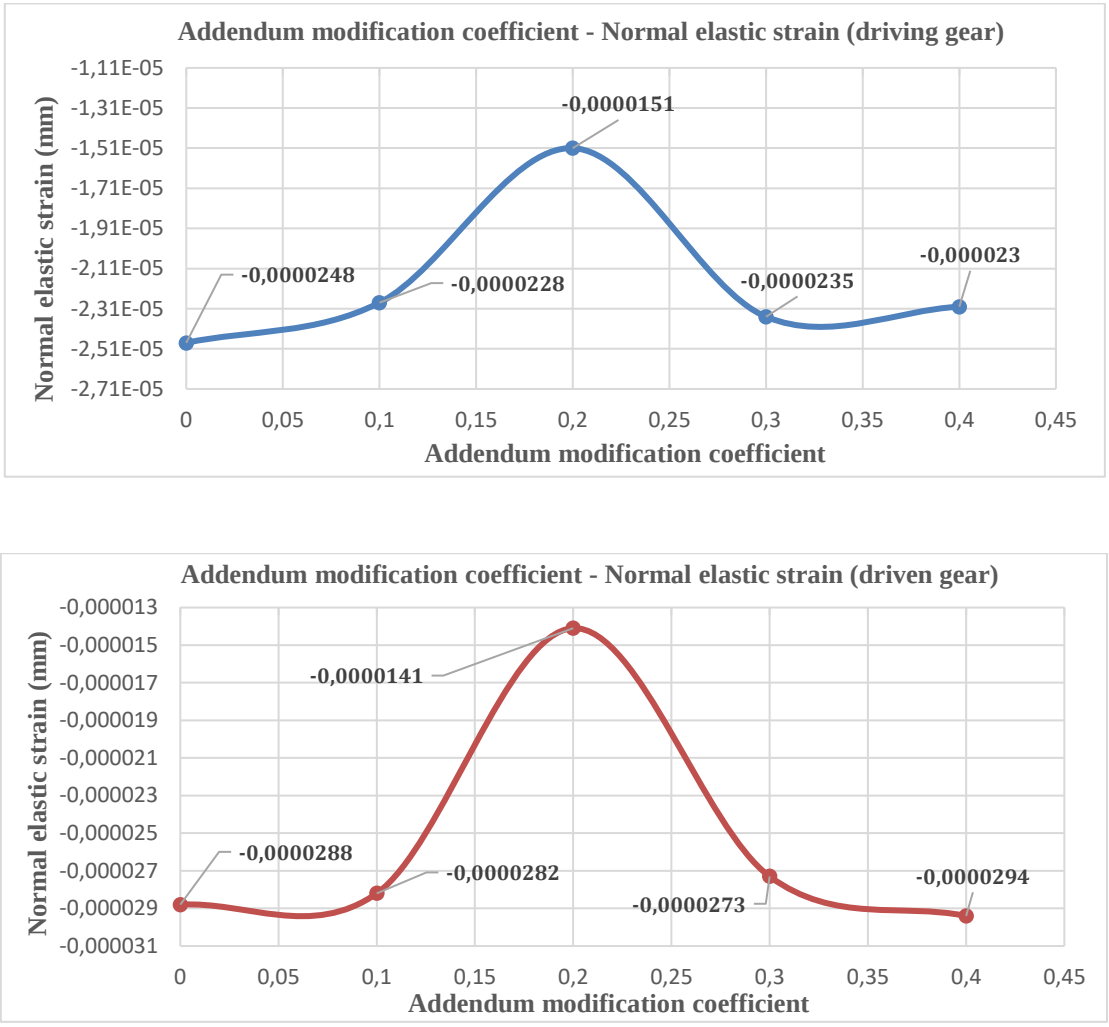

Fig. 6. The average normal elastic strain in the function of the addendum modification coefficient

CONCLUSION

The aim of this research is the analysis of the effect of the addendum modification coefficient for TCA parameters (normal stress, normal deformation and normal elastic strain) of gear pairs. Firstly the creation of the CAD models of the gear pairs is necessary. It means that the designing of the gear pairs, determination of the profile curves and the computer aided designing od the modells. Five types of gear pairs have been designed with the same geometry. The difference of these gears is only the deviation of the addendum modification coefficient.

After the adoption of the finite element mesh and the setting of the load and boundary conditions TCA analyses have been done. Our purpose has been the determination of relation between the changing of the addendum modification coefficient and the selected TCA parameters. After the finite element calculations the functions of the TCA parameters have been determined and the consequences has been composed.

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