Analecta Technica Szegedinensia
Vol. 14, No. 1 ISSN 2064-7964 2020

NORMAL DEFORMATION AND STRESS ANALYSIS OF THE TOOTH ROOTS IN CASE OF DIFFERENT WORM GEAR DRIVES

Sándor Bodzás
Ph.D., vice head of department

University of Debrecen, Ótemető str. 2-4., 4028, Debrecen, Hungary
e-mail: bodzassandor@eng.unideb.hu

ABSTRACT

The aim of this study is the comparative finite element analysis of the tooth roots of one tooth on worm-wheels having different geometries. Designing of various cylindrical worm gear drives is essential for the study where all of the input parameters are the same, only the number of thread on the worm is modified. Due to this modification the shape of the worm-wheels is different that is why dissimilar mechanical parameters will be received by the same load force. The creation of the CAD models is also important for the analysis.

Keywords**:** number of thread, worm-wheel, normal deformation, normal stress

1. INTRODUCTION

The Archimedean cylindrical worm gear drives are widely used in different constructions where the bypass axes position and the high transmission ratio is required [3, 4, 5, 7, 8, 9]. The worm could be manufactured by turning and grinding technologies. The heat treatment before the grinding process is important because of the strong load capacity and surface roughness.
The worm-wheel's teeth are generated by direct motion mapping method [3, 5]. It means a special worm-shape cutting tool is needed, which is called hob, which has the same geometry than the worm has. It has grooves around the perimeter because of the chip removal. The tooth thickness and the addendum is higher than the worm has (Figure 1) [3, 10, 11].

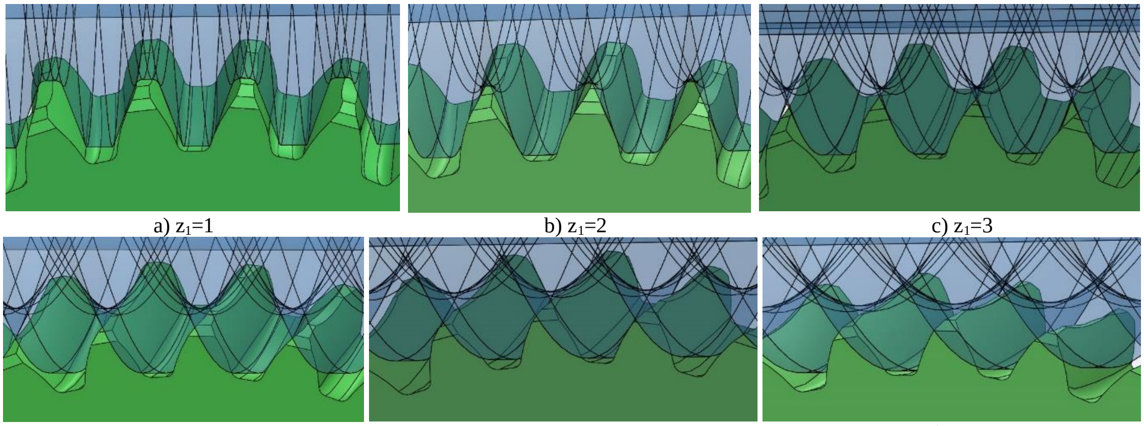

a)

b)

Figure 1. Hob geometry (a) and worm – worm-wheel connection (b) [1, 2]

Six worm gear drives are designed having almost the same input parameters (z_2=30, m_{ax}=5 mm, α_n=20°, r=1.5 mm) [10]. The difference is only the number of threads (z_1=1, 2, …, 6) on the worm surface. The calculated parameters could be seen on [10] publication. The geometric calculations were done by GearTeq software. Knowing of the references' recommendations [3, 5, 7, 8, 9] the user can set the input designing parameters and have the software calculate all of the geometric parameters. After that the CAD (Computer Aided Design) models could be done by SolidWorks software (Figure 2). Finally, TCA (Tooth Contact Analysis) or FEM (Finite Element Method) [6] analysis could be done for the analysis of the connection zone between the elements or the behaviour of the elements by different loads. As a result, the mechanical parameters are received for the evaluations. Graphs could be done for the comparative TCA or FEM analysis so that the appropriate gear geometry could be selected for the given engineering application.

DOI: 10.14232/analecta.2020.1.82-88



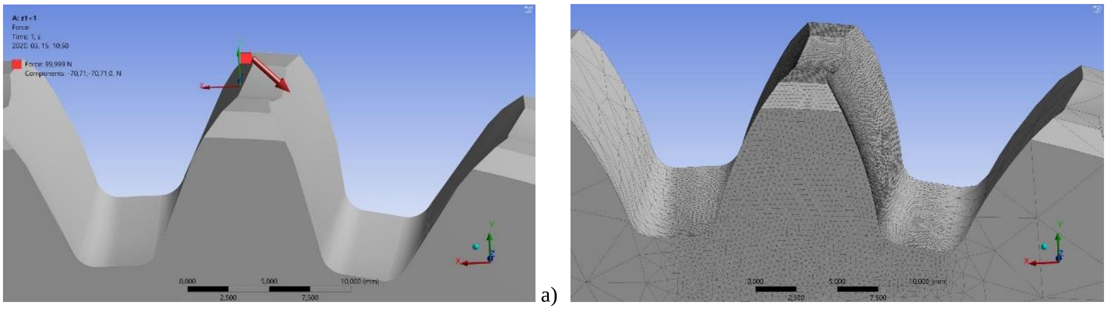
a) z_1=1 b) z_1=2 c) z_1=3

d) z_1=4 e) z_1=5 f) z_1=6

Figure 2. Generation of the worm-wheel surface for different number of threads on the worm

2. MATERIALS AND METHODS

One tooth was loaded by 100 N for each different worm-wheels. The mechanical parameters on tooth roots (left and right) of one tooth are analysed. The force's line of action and the symmetric plane of the worm-wheel is closed 45°. The top edges of the worm-wheels were loaded (Figure 3.a).



a) b)

Figure 3. Load adoption (a) and meshing (b)

The meshing was dense (element size: 0.3 mm, meshing method: tetrahedrons) on the selected tooth. Automatic meshing was applied on the outside areas (Figure 3.b). The number of used elements was 794618. All of the freedom degrees of the worm-wheels were fixed. The type of the material was structured steel (Table 1). Coordinate systems were adopted to the tooth roots.

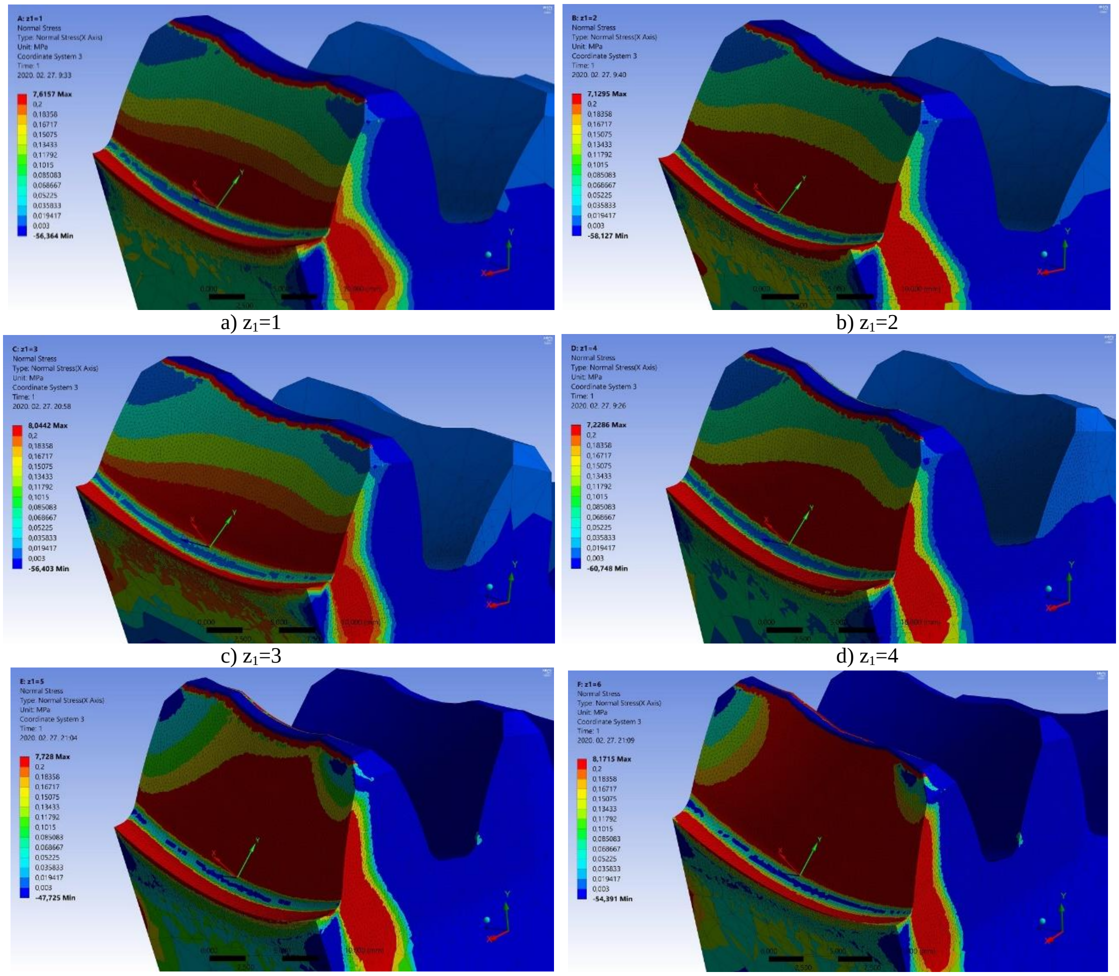
Table 1 Material properties

Material Quality	Structured steel
Density	7850 kg/m^3
Yield stress	250 MPa
Tensile strength	460 MPa
Poisson factor	0,3
Young modulus	200 GPa
Temperature	22 °C

DOI: 10.14232/analecta.2020.1.82-88

2.1. Normal stress analysis

The received normal stress results for the left tooth side could be seen on Figure 4.

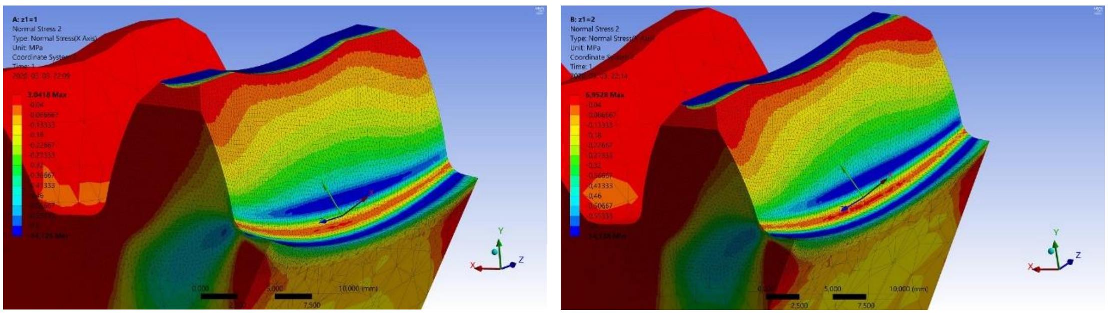


a) $z_1=1$ b) $z_1=2$

c) $z_1=3$ d) $z_1=4$

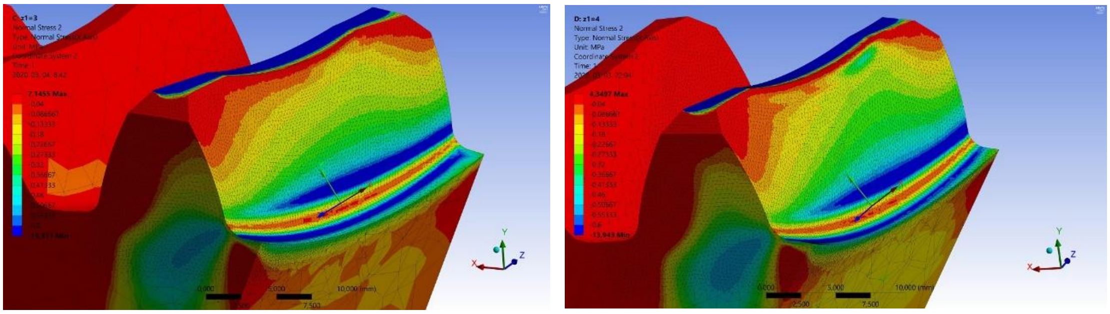
e) $z_1=5$ f) $z_1=6$

Figure 4. Normal stress' distribution on the left tooth side of the worm-wheel's tooth

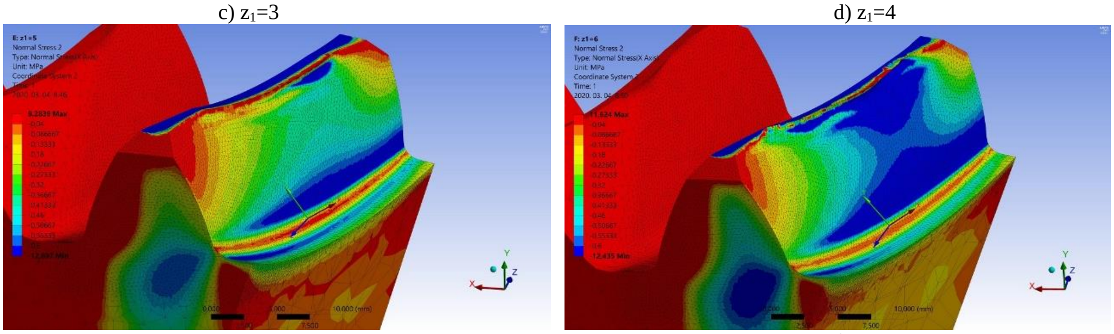


a) $z_1=1$ b) $z_1=2$

DOI: 10.14232/analecta.2020.1.82-88



c) z_1=3 d) z_1=4



e) z_1=3 f) z_1=4

Figure 5. Normal stress' distribution on the right tooth side of the worm-wheel's tooth

The received normal stress results for the right tooth side could be seen on Figure 5.

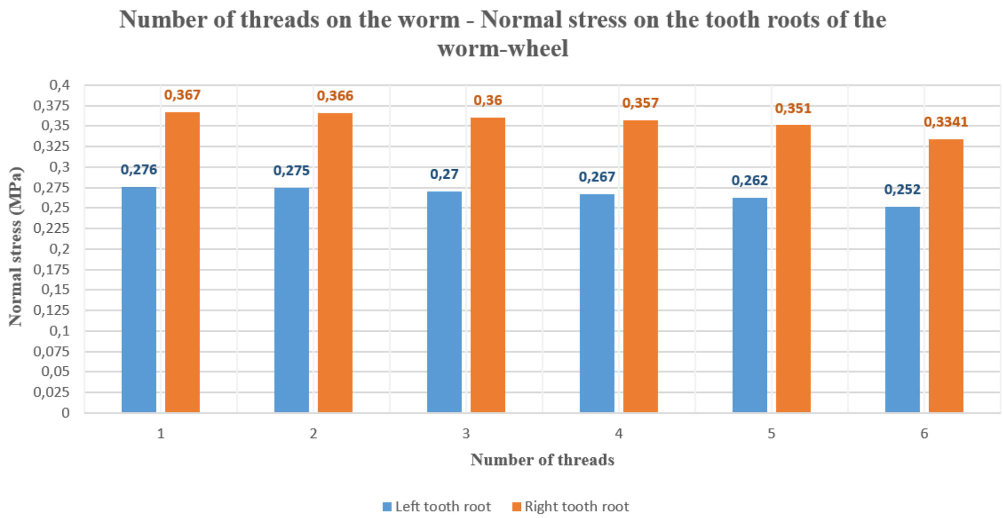
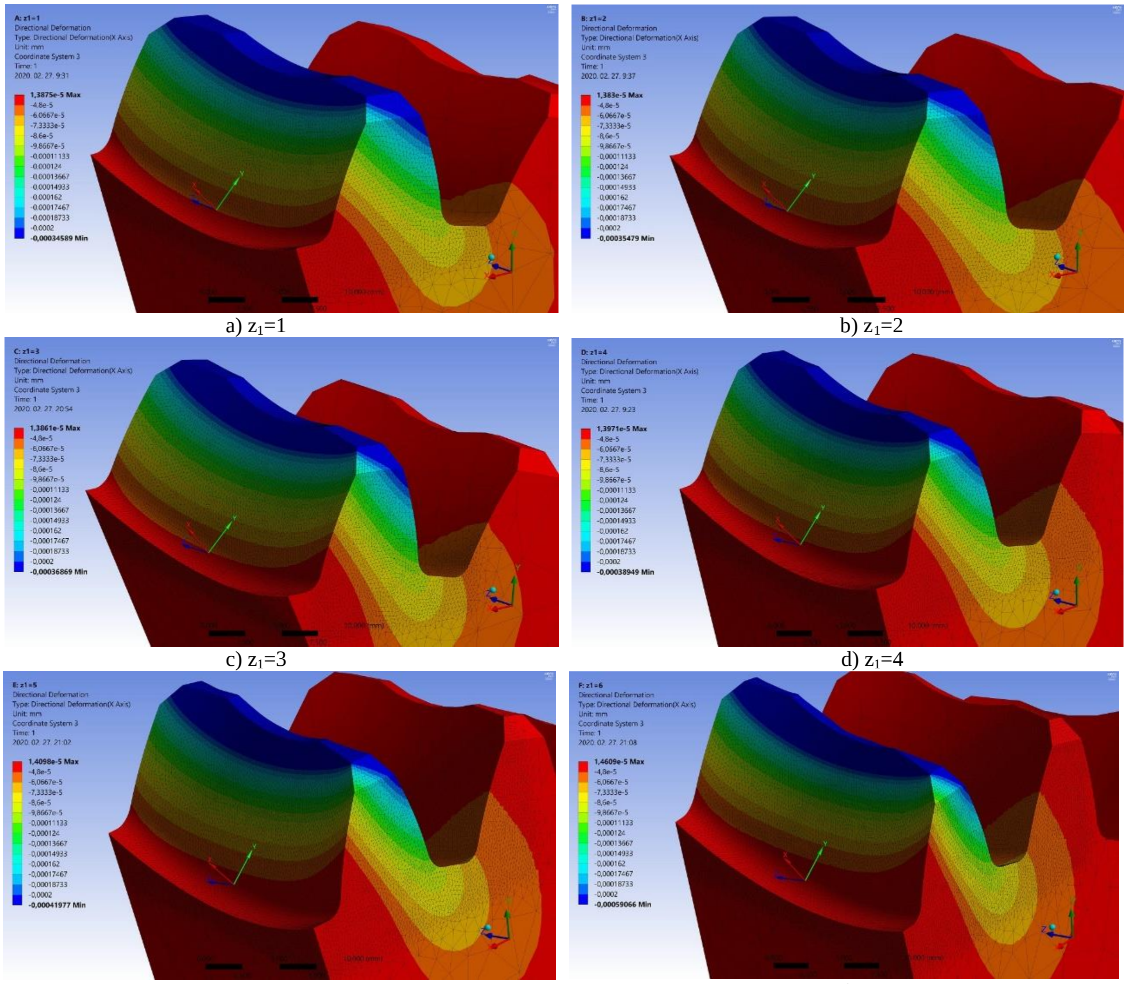


Figure 6. The received average normal stress results on both tooth roots of the worm-wheel

2.2. Normal deformation analysis

The received normal deformation results for the left tooth side could be seen on Figure 7.

DOI: 10.14232/analecta.2020.1.82-88



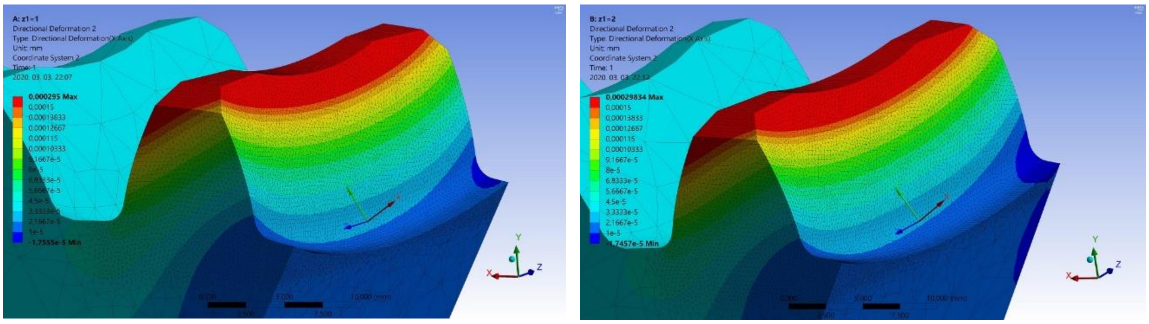
a) z_1=1 b) z_1=2

c) z_1=3 d) z_1=4

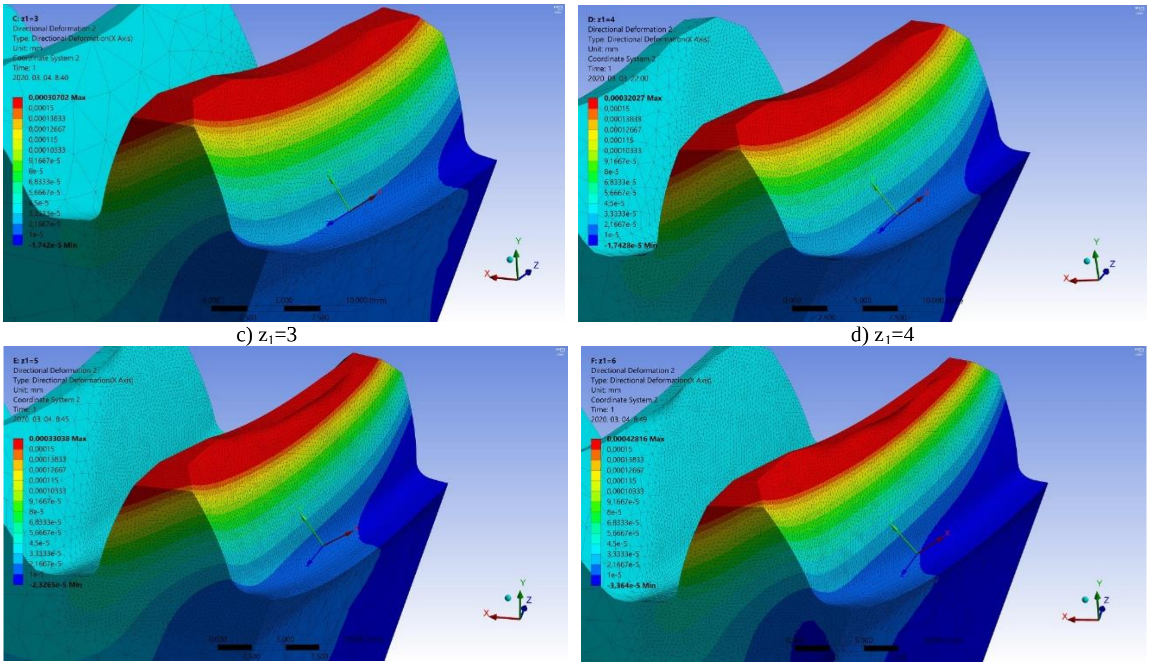
e) z_1=5 f) z_1=6

Figure 7. Normal deformation's distribution on the left tooth side of the worm-wheel's tooth

The received normal deformation results for the right tooth side could be seen on Figure 8.



a) z_1=1 b) z_1=2



c) z_1=3 d) z_1=4

d) z_1=3 e) z_1=4

Figure 8. Normal deformation's distribution on the right tooth side of the worm-wheel's tooth

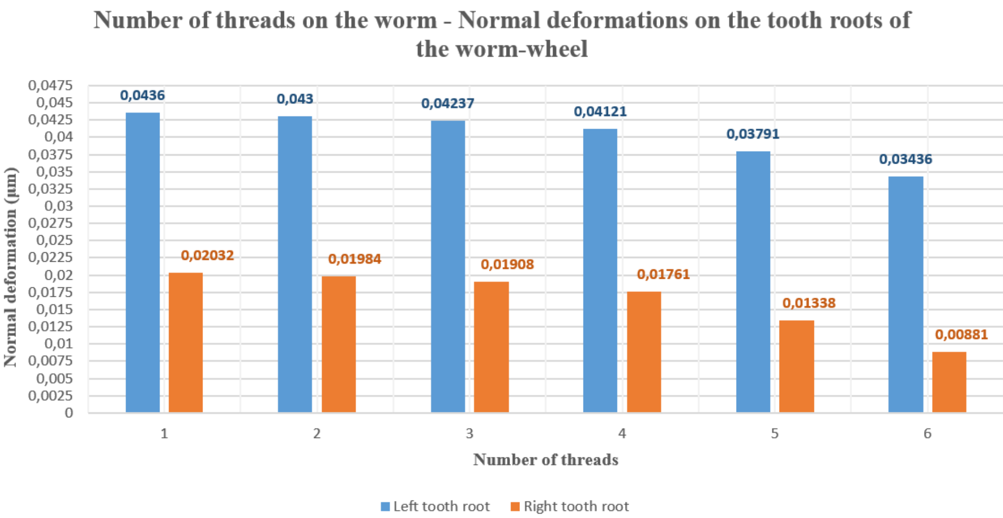


Figure 9. The received average normal deformation results on both tooth roots of the worm-wheel

3. RESULTS AND DISCUSSION

The fillet radiuses on the tooth roots are the same (r=1.5 mm) for every worm-wheels [10].
Based on Figure 6 the average normal stresses on the right tooth root is higher than on the left tooth root. These results are continuously decreasing in the function of the enhancement of the number of threads on

DOI: 10.14232/analecta.2020.1.82-88

the worm. The decreasing interval is quite low between the prisms. Consequently, the lowest normal stress results are received in case of z_1=6 number of threads.

Based on Figure 9 the normal deformations on the right tooth root is higher than on the left tooth root. These results are continuously decreasing in the function of the enhancement of the number of thread on the worm. The decreasing interval is quite low between the prisms. Consequently, the lowest normal stress results are received in case of z_1=6 number of threads.

As a result, the higher the number of threads on the worm is, the lower normal stress and deformation results on the tooth roots of the worm-wheel's tooth are.

4. CONCLUSIONS

The purpose of this study is the determination of the correlations between the mechanical parameters on the tooth roots of the worm-wheel's tooth and the number of threads on the worm. Six pieces of cylindrical worm gear drives were designed with different number of threads on the worm. Due to this changing the tooth shape of the worm-wheel is also different after the generation. The geometric designing was done by GearTeq software considering the references' recmmendations. Knowing of the geometric parameters the CAD models could be generated by SolidWorks software. After that the one tooth of the worm-wheels is loaded by the same load force. The stiffness and the flexibility of one tooth were analysed by Ansys FEM software. It means we analysed the behaviour of the tooth roots on both tooth sides. Based on the results graphs could be made for the determination of the consequences. We received if we increase the number of threads around the worm the mechanical parameters on the tooth root of the worm-wheel will be decreased.

ACKNOWLEDGEMENT

This research was supported by the **János Bolyai Research Scholarship of the Hungarian Academy of Sciences.**

REFERENCES

[1] https://www.spn-drive.de/en/spn-drive-solutions/gear-components-to-the-spn-standard/worm-drives.html
[2] https://www.star-su.com/cutting-tools/gear-cutting-tools/hobs/involute/worm-gear-hobs/
[3] I. Dudás, The Theory and Practice of Worm Gear Drives, Penton Press, London, 2000, ISBN 1877180295
[4] L. Dudás, Modelling and simulation of a new worm gear drive having point-like contact, Engineering with Computers, Engineering with Computers: Volume 29, Issue 3, 2013., pp. 251-272, ISSN 0177-0667
[5] F. L. Litvin, A. Fuentes, Gear Geometry and Applied Theory, Cambridge University Press, 2004, ISBN 978 0 521 81517 8
[6] S. Moaveni, Finite Element Analysis, Theory and Application with ANSYS, Pearson Education Limited, 2015, ISBN 10: 0-273-77430-1, p. 928
[7] Z. Terplán, Gépelemek IV., Kézirat, Tankönyvkiadó, Budapest, 1975., p. 220.
[8] S. P. Radzevich, Dudley's Handbook of Practical Gear Design and Manufacture, Third edition, CRC Press, p. 656, ISBN 9781498753104
[9] T. Nieszporek, R. Gołębski, L. Soos, Analysis of the worm-wheel toothing accuracy, 2017, Technical Gazette, 24(4), 993-1000., https://doi.org/10.17559/TV-20160422094400
[10] S. Bodzás, Tooth contact analyis of Archimedean worm gear drives for the modification of the number of threads on the worm helical surface, Facta Universitatis, Series: Mechanical Engineering, 2020, ISSN 0354-2025 (during publication)
[11] S. Bodzás, I. Dudás, Designing and modelling of worm gear hob, Doktoranduszok Fóruma 2011, Miskolci Egyetem Innovációs és Technológia Transzfer Centrum, Miskolc, 2011, pp. 12-17.