Original Article: Double Tooth Contact Effects on Spur and Helical Gears

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ABSTRACT

Since gears are essential in modern mechanical and industrial applications, their research is one of the most demanded areas.
In various design conditions (meshing conditions and geometric sizes), where the gears are used to transmit load and motion, the two teeth of a gear can be in contact simultaneously. In this study, the additional von Mises stress created at the root of one of the teeth by force applied to the other tooth is considered.
For this, the von Mises stress generated in the tooth root is calculated by first applying a force to one tooth, and then the same amount of force is applied to the second tooth, and after that, the von Mises stress in the root of the first tooth is calculated again. After the computation, the difference between the initial and final value is indicated, and the effects created by single and double contact are compared. After that, a calculation is applied to both spur and helical gears with the same geometrical parameters, and it is investigated whether double contact is more desirable for spur or helical gear from the point of view of the structural reliability of the gear tooth. Solidworks Simulation Software models each gear and von Mises stress calculation, and finally, the percentage of effects created by double contact for the helical and the spur gear is calculated.

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Introduction

PUR and HELICAL GEARS

In general, although there are many gear types, spur, and helical gears are the most widely used gears in the industry. Helical gears are spur gears whose teeth are bent at a certain angle (helix angle).

Spur gears... Helical gears are the most similar to spur gears in their geometrical characteristics and shape. Their application areas are very similar and can substitute for each other in many applications. From this point of view, which of these two is more suitable to be used in which application has always been the main topic of the investigations.

Although they are similar to other gears, they have profound performance differences. The performance differences can be understood by considering the advantages and disadvantages of both ([1]; [2]):

Table 1: SPUR GEAR

Advantages	Disadvantages
Efficient and easy to assemble. Straight profile teeth which are easy to align. Minimum power loss according to slippage. Simple design.	Noise at more incredible speeds. Must only be used in parallel axis. Not as durable as other gears.

Table 2: HELICAL GEAR

Advantages	Disadvantages
Smooth operation and low noise. Can be in parallel or crossed axis. Less vibration.	Less efficient than Spur Gears. Power loss according to slippage. Higher manufacturing costs.

A sufficient number of comparisons have been made between them regarding the mentioned performance differences and their comparison in the sample of these gears.

DOUBLE CONTACT

The little-studied "double contact" phenomenon and its degree of influence for each gear are investigated by applying a relatively different approach. Two teeth of the gear may be in contact with two teeth of the other gear simultaneously. This case can happen according to the different gear parameters, such as the gear's number of teeth, its geometry's dimensions, and meshing variations of the gears. Additionally, they can be ultimately the same size or have very different parameters, resulting in different levels of gear ratios. The first objective of this study is to investigate the comparison of double contact with a single contact and to study the effect of double contact on stress reliability in gear teeth. The second and more important objective is to compare the degree of this effect for spur and helical gear and calculate the differences.

ROOT STRESS

Usually, spur and helical gear tooth failure occur in two regions. These regions are the contact regions of the teeth exposed to the most stress (Hertzian contact stress) during rotation motion and the root of each tooth. Although stress values are not very large in these regions, teeth are continuously exposed to these stresses during the continuous rotation of gears, and this situation causes fatigue damage that occurs over time ([3]; [4]). Therefore, optimizing these stress values enables us to reduce fatigue risk by minimizing equivalent stress according to the application. This research considers the tooth's root, and von Mises stress is computed as the equivalent stress. Von Mises is currently considered the most exact computation method for complex geometric shapes among the existing failure theories and principles. The computation results are reliable because they consider the forces in three directions [1].

FINITE ELEMENT ANALYSIS

Model Info

First, the following input parameters are included in the Solidworks program by default, and the helical gear is modeled.

Number of teeth: 20

Helix angle: 30 degrees (right hand)

Module: 50

Pressure angle: 20 degrees

Face width: 100 mm

Nominal shaft diameter: 200 mm

Details of the analysis:

Material: Gray Cast Iron

Number of nodes: 84205 nodes

Total elements: 54935

Applied tooth load: 600 N.m

Spur gear modeling is carried out by copying all the geometrical parameters of the existing helical gear model. For this, the surface part of the helical gear is copied using the "convert entities" function, and the obtained 2D figure is extended in the direction of the Z coordinate to the same thickness as the helical gear. As a result, two gear models are obtained, which have precisely the same parameters and differ from each other only by the helix angle:

Number of teeth: 20

Module: 50

Pressure angle: 20 degrees

Face width: 100 mm

Nominal shaft diameter: 200 mm

Details of the analysis:

Material: Gray Cast Iron

Number of nodes: 88293 nodes

Total elements: 58025

Applied tooth load: 600 N.m

The inner cylindrical face is chosen as a fixed geometry as a boundary condition in each gear shaft hole. Below are top and front views of gears modeled in Solidworks:

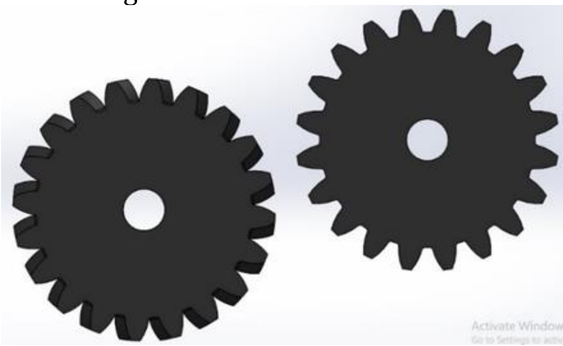

Figure 1: front view of model versions

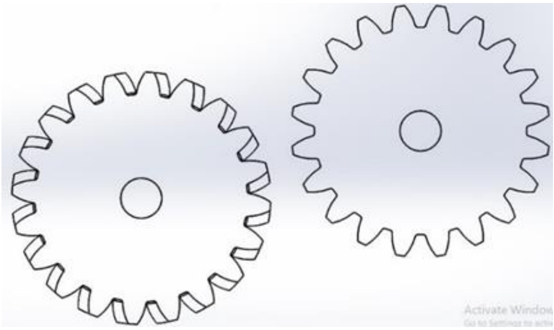

Figure 2: front view of contour versions

Figure 3: top view of model versions

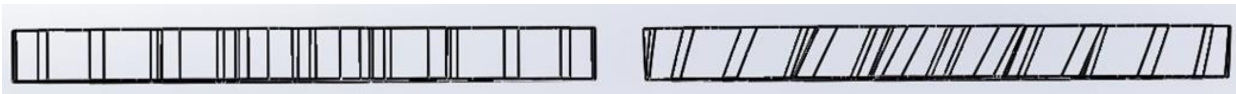

Figure 4: top view of contour versions

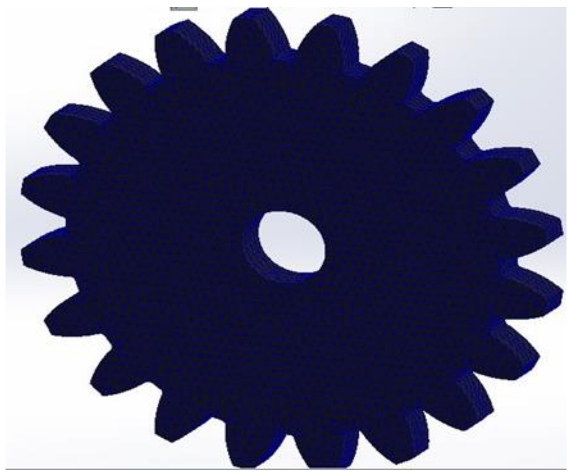

Figure 5: *SPUR GEAR RESULTS*

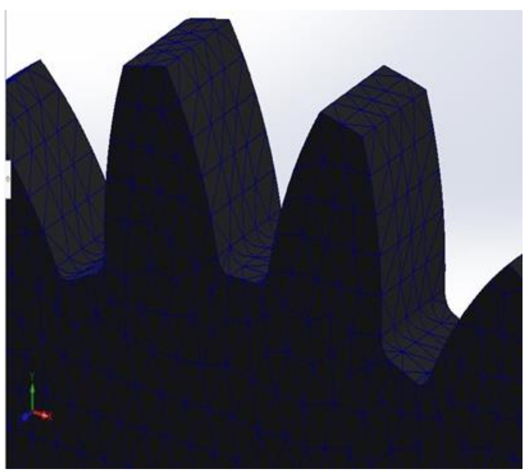

Figure 6: *MESH*

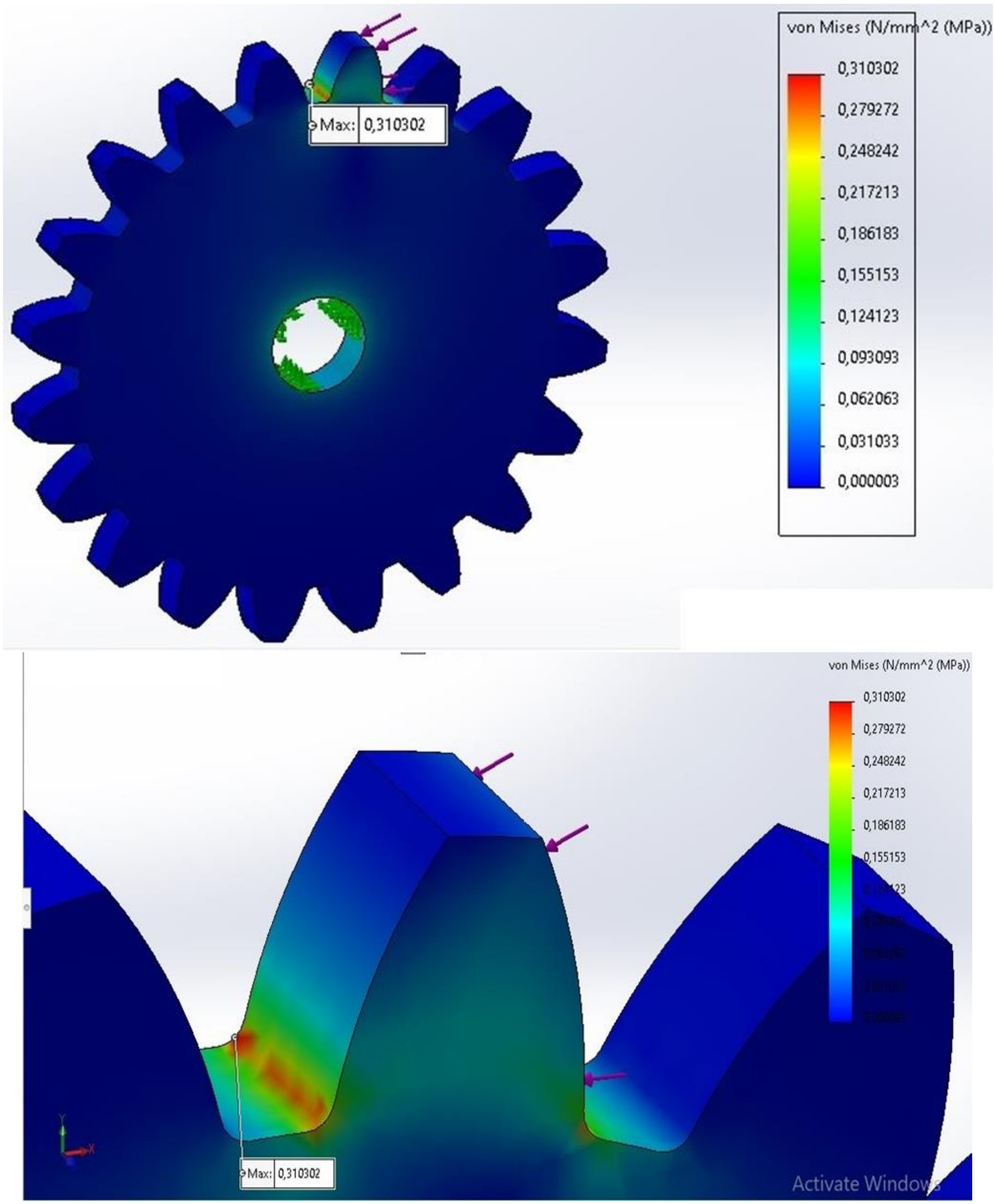

Figure7: Root Von Mises stress *for single load*

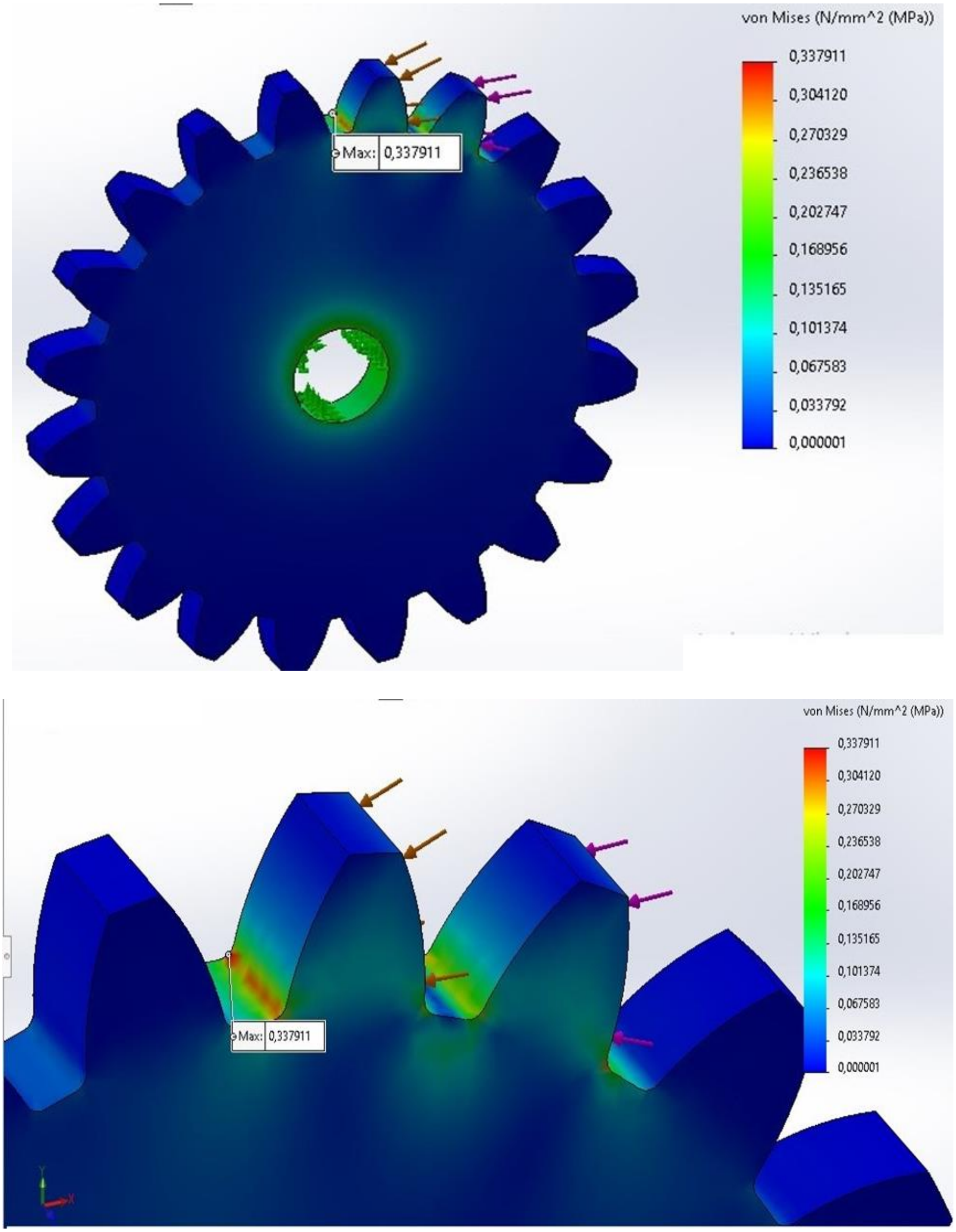

Figure 8: Root Von Mises stress for double load

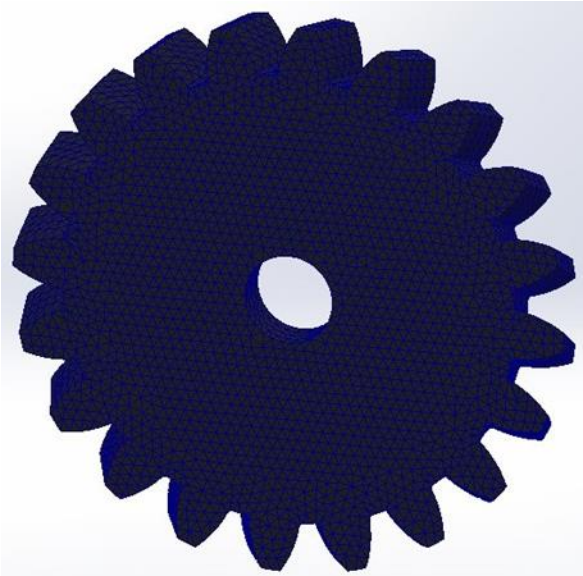

Figure 9: HELICAL GEAR RESULTS

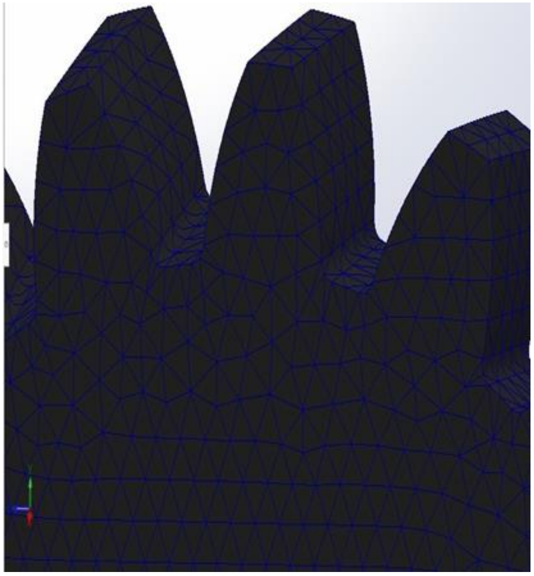

Figure 10: *MESH*

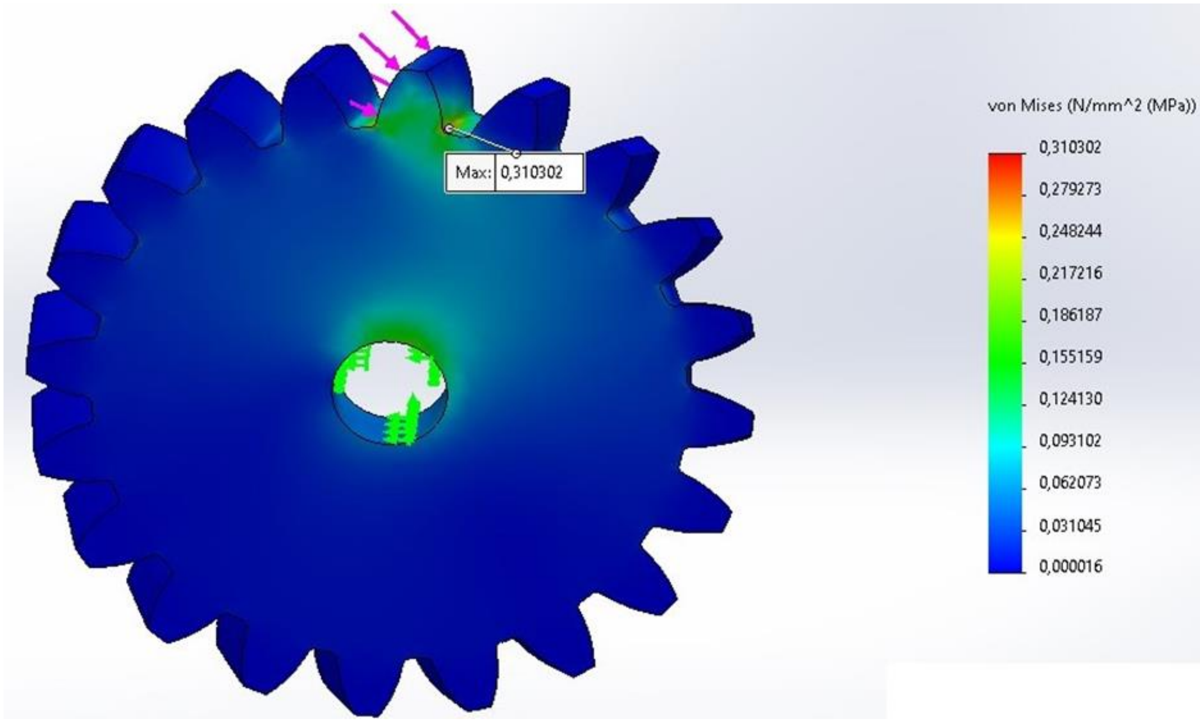

Figure 11: Root Von Mises stress for single load

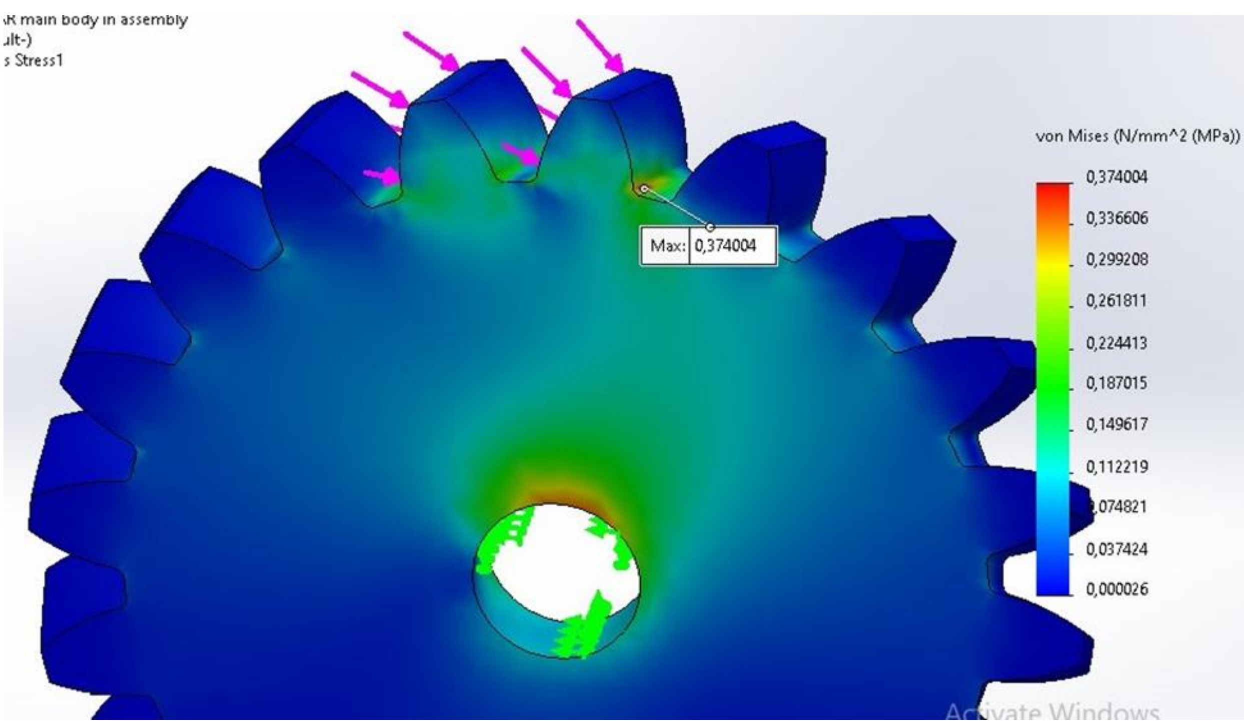

Figure 12: *Root Von Mises stress for double load*

PERCENTAGE DIFFERENCE

According to FEA calculations

Max root von mises stress of spur gear for single load= 0.310302 MPa
Max root von mises stress of spur gear for double load= 0.337911 MPa
Max root von mises stress of helical gear for single load= 0.310302 MPa
Max root von mises stress of helical gear for double load= 0.374004 MPa
SPUR
0.310302 ==> 0.337911 - percentage = 8.897 %
HELICAL
0.310302 ==> 0.374004 - percentage = 20.529 %

Conclusion

This study investigated the stress reliability performance of gear teeth in double contact. The effect of the force applied to one tooth of gear on the other tooth located next to it, and the comparison of the effect for helical and spur gear were considered. Solidworks software was used to conduct the research, and spur and helical gear were modeled with high mesh density to get accurate results. It is clear from the calculated von Mises values that the force applied to a tooth affects the von Mises value of the second tooth located next to it. However, this effect is minimal (in this research: 8.897 and 20.529) and cannot seriously affect stress performance. The difference percentage did not change even if the author applied higher forces to the gear teeth, which were not shown in the experiment. However, it should be taken into account that this degree of influence is highly dependent on geometrical dimensions such as helix angle, the distance between teeth, tooth width, and length [5-10]. For this reason, different percentages can be observed in various applications. Subsequently, for helical and spur gears, which have the same geometric parameters, the difference percentage is 8.897 in spur gear, while this percentage is 20.529 in helical gear. Consequently, the helical gear (for helix angle=30) is exposed to approximately 12 percent higher stress increase compared to the spur gear in case of double contact. This can be related to the fact that the teeth in the helical gear are in an inclined position because, as can be seen from the figures of the simulation results, when the teeth are in an inclined position, unlike the spur gear, the stress distribution is uneven. While one linear region of the gear tooth root is entirely stress-free, the other region is exposed to more stress. When the tooth is inclined, the stress created by force applied to the tooth is concentrated only in a part of the root region. In a certain sense, this can be considered stress concentration. As a result, we can say that the effects of double contact are minor, and this small effect is felt more in helical gear than a spur gear. In this research, the author considered stress behavior related to gears for the external gear pump. Both gear types and other factors, such as temperature, were mainly selected according to the external gear pump. Still, since the investigation results are more general, they can be attributed to all applications where gears are used, such as gear reducers and planetary set gears.

References

[1] R.S. Khurmi, J.K. Gupta, *A Textbook of “Machine Design”,* EURASIA PUBLISHING HOUSE 2005 [Google Scholar], [Publisher]
[2] T. Ransegnola, X. Zhao, A. Vacca, *Mechanism and Machine Theory*, **2019**, *142*, 103604. [Crossref], [Google Scholar], [Publisher]
[3] A. Kawalec, J. Wiktor, *Proceedings of the Institution of Mechanical Engineers, Part B Journal of Engineering Manufacture*, **2004**, *218*, 1153-1166. [Crossref], [Google Scholar], [Publisher]
[4] G. Venkateswara Rao, P.Veera Raju, 3T. Jayananda Kumar. “Reducing the Root Fillet Stress in Helical Gear Using Internal Stress Relieving Features”, InternatIonal Journal of research In MechanIcal engineering & technology, **2014**, *4.* [Crossref], [Publisher]
[5] Mr. Sharad J. Chauhan, Mr. Parth K. Patel, Mr. Abhishek Dubey, Mr. Deepkumar K. Patel. “A Review Paper on Design & Development of Helical Gear by using ANSYS & AGMA Standards” *International Journal of Engineering Research & Technology (IJERT),* ISSN: 2278-0181, **2017**, *6.* [Crossref], [Publisher]]
[6] A. Johnson, *Eurasian Journal of Chemical, Medicinal and Petroleum Research*, **2023**, *2*, 1-9. [Google Scholar]

[7] K. Lo Han, *Eurasian Journal of Chemical, Medicinal and Petroleum Research*, **2022**, *1*, 64-70. [Google Scholar]

[8] F. Rebout, *Eurasian Journal of Chemical, Medicinal and Petroleum Research*, **2022**, *1*, 20-32. [Google Scholar]

[9] E. Ghaibi, M.R. Soltani Manesh, H. Jafari Dezfouli, F. Zarif, Z. Jafari, Z. Gilani, *Eurasian Journal of Chemical, Medicinal and Petroleum Research*, **2022**, *1*, 33-39. [Google Scholar]

[10] K. Lo Han, *Eurasian Journal of Chemical, Medicinal and Petroleum Research*, **2022**, *1*, 1-9. [Google Scholar]