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Design and Stress Analysis of Spur Gear Using Ansys and SolidWorks

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Abstract

Gears are currently the world's most prevalent and widely used mechanical parts. The surface stresses of the spur gear are one of the most significant causes of gear failure in a gear system. This study examined a spur gear pair's contact stresses to determine the maximum pressure on the gear teeth. The Lewis equation is used to compute the maximum allowable stress for Gear, and contact stresses are estimated using the Hertz contact stress equation. These results are compared with Finite Element Analysis (software-based results). Different Gear materials such as copper, Cast Iron (Gray), and aluminum are tested and studied here. The spur gears are designed in Gear Trax software and then imported and meshed in SolidWorks and Ansys software separately, and after that, simulation is performed on the gears in both softwares. The results confirmed that contact stress computed using the analytical approach (Hertz equation) is equable to the FEA results of SolidWorks and Ansys, having a low percentage error value.

Keywords: Spur gear, Hertz Contact Stress, Solid works, Ansys, Gear Trax

Introduction

Power transfer among shafts can be carried out in various methods, including cogs or gears and elastic components such as chain systems and belts. The frictional force transmits the circumferential force in belt and friction wheel drives. Gears are the oldest, most sufficient, powerful, and stab among many methods of transferring mechanical power between two shafts. Gears are now the planet's common and widely used automatic device. Gears are crucial for the heavy equipment of industrial buildings, household appliances, electronic parts, ships, industrial equipment, instruments, clocks, and microdevices [1].

Multiple types of gear are available for industrial use; such as Spur gear, Helical Gear, Bevel Gear, Worm gears, and Rack and pinion, but among all these types, Spur gears are most commonly used due to their simplest design and ease of manufacturing. There is a need for gears with greater load-carrying capacity and expanded fatigue life. To obtain this, analyzers in the gear domain have been working on the evolution of advanced materials, advanced heat analysis processes, designing of the gear with steady teeth, and the process of gear construction to trap the issue of the collapse of gears [2]. Gear design requires considering and analyzing two closely related factors: the geometric-kinematic and strength properties factors. Both problems are extremely complex and interconnected, but they must be resolved concurrently to ensure the effectiveness of assembled drive gear systems [3]. However, the shape or needs of gear are only a small part of the overall system design process. Gear transmission is recognized as the industry's challenging aspect of Stress Analysis [4].

The bigger of the two gears in the pair is known as the gear, while the smaller is known as the pinion. If a pinion is employed as a driver, it induces step down, which increases torque and decreases tangential velocity. Gear reacts as a driver; it boosts the drive, gives an increase in velocity, and correspondingly decreases in torque. These gears change the turning speed and move the turning movement to the other axis [5]. Gearboxes are the most frequently used transportation structure, which provides velocity and torque from a rolling force origin to another machine. Different gears are manufactured to meet different utilization objectives, such as automobile differential gear [6].

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Gears may collapse in many distinct methods. Different kinds of failure are impact crack, wear, and stress fracture; there has been increasing focus on the surface stress and shear stress on gears, which lead to crack development [7]. The finite element process can give statistics on contact and bending stresses in gears, besides transportation inaccuracy, which can be extinct simply in SolidWorks and Ansys software. Previously, gear inspection was accomplished by an analysis approach that required complex calculations. Now with FEA's utilization, the gear tooth's bending stresses can be computed for a given loading in Computer-Aided software like SolidWorks and Ansys [8].

This study used SolidWorks and Ansys software to model and analyze the spur gear set stress analysis. The theoretical technique is used to compute the stress study of the spur gear using the Hertz stress equation. Both software is used for stress analysis to better predicts the failure stress against every material. The result values obtained from SolidWorks and Ansys are compared to the Hertz contact stress calculation result, and the relative error is calculated.

Methodology

Gears Specifications

Two Spur gears are used for stress calculations which are designed on gear Trax software and analyzed using SolidWorks and Ansys separately. The specifications of the gears are shown in Table1.

Table 1: Specification of the Gears

Gear Parameters	Pinion	Gear
Number of Teeth	25	50
Pitch Diameter(mm)	100	200
Base Diameter(mm)	93.696	187.939
Face Width(mm)	20	20
Tooth Thickness(mm)	6.283	6.283
Pressure Angle	20^0	20^0
Circular Pitch(mm)	12.56	12.56

Maximum Allowable Stress for Gear

To get satisfactory results, strength of spur gears and the load bearing capacity of toothed gears is being evaluated by the Lewis equation [5]. Lewis equation is shown as Equation (1).

$$\mathrm{F} = b * y * p_c * \sigma_a \qquad (1)$$

The constant "y"is known as the Lewis form factor. It does not dependent on tooth size butrely only on the total number of teeth which a gear set have. "σ_a"is the Maximum allowable stress for the gear and "p_c" is the Circular

Pitch of the gear and "F" is the tangential load on the gear, and "b" denotes face width of the gear.

The highest value of contact stress of the spur gear is estimated using finite element analysis during the transfer of 300N.m torque with Copper, Cast Iron (Gray), and Aluminum materials. Tangential load is determined using Equation (2).

$$\mathrm{T} = \mathrm{F} \times \mathrm{r} \qquad (2)$$

T=300Nm.

$F=\frac{300}{0.05}=6000N$

$\text{maximum allowable stress} = \sigma_a = 203.14MPa$

The ultimate tensile strength of materials is comparedwith maximum allowable Stress (calculated above) for gear as shown in Table2, which verified that all materials are within safe limits.

Table 2: Maximum Allowable Stress for Gear

Material	Ultimate tensile strength(MPa)	Design	Poisson's ratio	Young's modulus (GPa)
Copper	210 >*203.14*	Safe	0.326	119
Aluminum	310 >*203.14*	Safe	0.211	100
Cast Iron(Gray)	295 >*203.14*	Safe	0.3	71.7

Hertz Contact Stress Equation

Pitting is a surface stress failure due to repeated higher surface stress. Pitting is a typical occurrence on the operational faces of gear teeth, and the root cause is heavy loading, which raises contact stresses over critical limits. This study clearly expresses contact stress using a finite element model. Target and contact components are employed along both ends of the contact pattern formed by this pair of teeth's surfaces [9].

Hertz's theory of contact primarily concerns non-adhesive touch in which no tension force is permitted to develop inside the contact region. To solve Hertzian contact stress problems, the following steps should be followed:

- The strains are minor and remain inside the elastic region.
- Each body may be regarded as an elastic half-space, meaning that the contact region is substantially less than the body's typical radius.
- The layers are non-conforming and constant.
- The bodies make no frictional touch [10].

Power is transferred among gears at the point of contact in the working teethes. The stresses are calculated using Hertz's theory. Equation (3) is the mathematical form Hertz equation.

$$\sigma_c = \sqrt{\frac{F\left(1+\frac{R_1}{R_2}\right)}{R_1 \times L \times \pi\left(\frac{1-\mu_1^2}{E_1}+\frac{1-\mu_2^2}{E_2}\right)\sin \emptyset}} \qquad (3)$$

"σ_c" is the Maximum Value of Contact stress for the gear. "F" is Force pressing the two cylinders (gears) together. *"L"*is the Face Width of the gear. "μ_1" and "μ_2" are the Poisson's ratio of the pinion and the gearconsequently. "E_1" and "E_2" are the Elasticity of pinion and gear respectively.

Table 3: Hertz contact stress for Gear

Material	Hertz Stress (MPa)
Copper	457.06
Cast Iron(Gray)	353.8
Aluminum	405.22

Using equation (3) contact stress is theoretically determined. The Hertz stress values of Copper, Cast Iron (Gray), and Aluminum are shown in Table 3.

Results and discussion

This research used static structural analysis in SolidWorks and Ansys separately. The gear geometry is imported from gear Trax software in SolidWorks and in Ansys as well. Three different materials are selected. Fixed support is given to the gear, and frictionless support is provided to the pinion with a clockwise moment of 300 Nm. After applying the fine mesh, the results of Von mises stresses are carried out. **Fig.1** shows the stress Analysis of Gear with copper material in SolidWorks, presenting the maximum stress value as 4.262×10^8 N/m^2. Similarly, Gear stress analysis with Aluminum and Cast-iron materials are represented in **Fig.2** and **Fig.3**, respectively. Likewise, **Fig.4** displays the result of Gear stress Analysis with Copper material performed in Ansys. **Fig.5** and **Fig.6** show the same results by using Aluminum and Cast-iron materials, respectively.

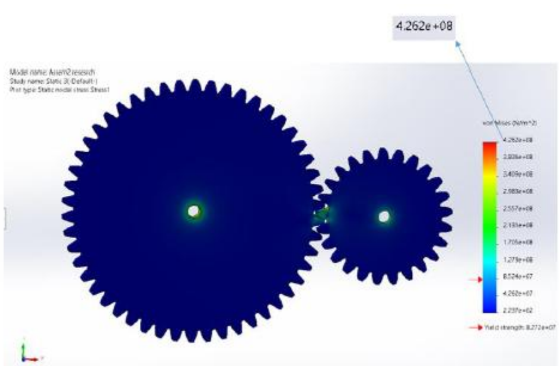

Fig.1. Stress Analysis of Gear having copper material in Solid-works

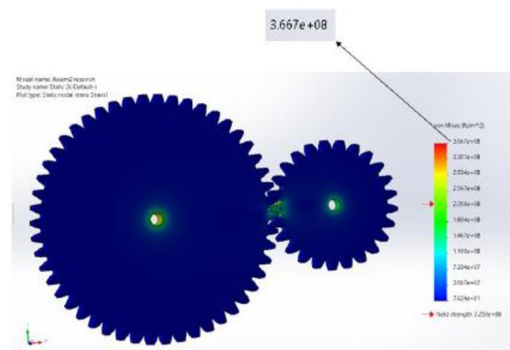

Fig.2. Stress Analysis of Gear having Aluminum material in Solid-works

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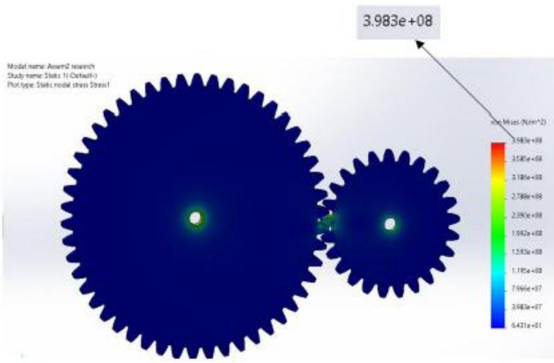

Fig.3. Stress Analysis of Gear having Cast iron material

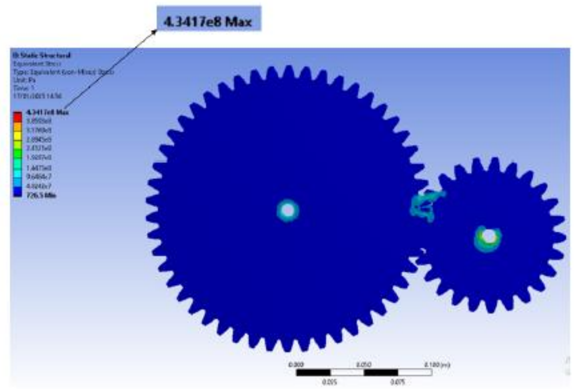

Fig.4. Stress Analysis of Gear having copper material in Ansys

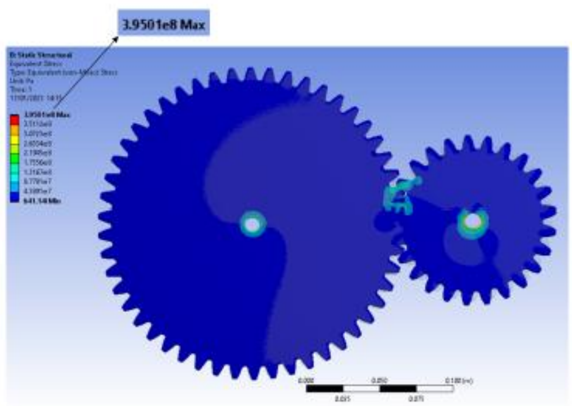

Fig.5. Stress Analysis of Gear having Aluminum material in Ansys

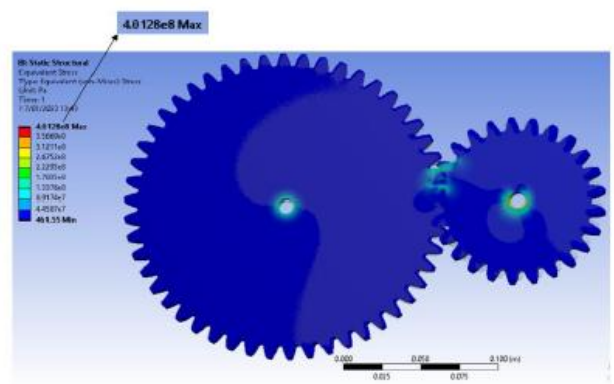

Fig.6. Stress Analysis of Gear having Cast iron material in Ansys

Copper depicted the highest surface stress value while Aluminum represented the least surface stress value for both the software. A comparison of SolidWorks stress and Ansys stress results compared to hertz stress is shown in **Fig. 7**. It is very important to note that the stress values of SolidWorks and Ansys are very close and comparable.

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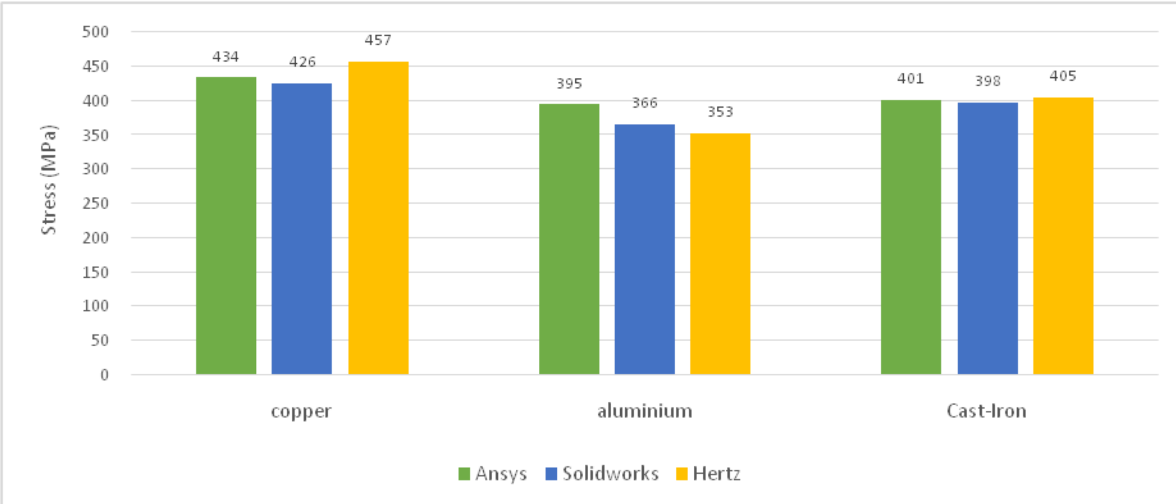

Fig7: Comparison of SolidWorks and Ansys stress with respect to Hertz stress for all 3 materials

Fig. 8 show the comparison of the percentage error of theoretical value and the results obtained from both software for all three materials used here.Maximum error is found for Aluminium which is 11.64% while minimum value is observed for cast iron having a value 0.97%.

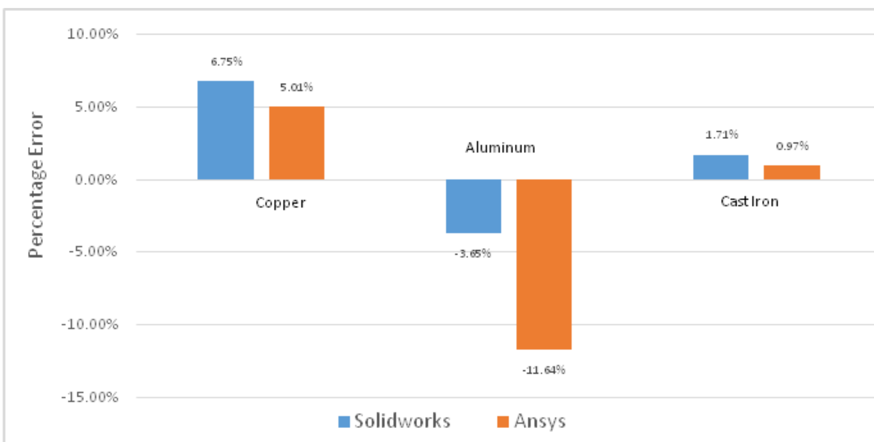

Fig 8: Comparison of % error of theoretical values with SolidWorks and Ansys stress results for all 3 materials

Fig.9 describes the relationship between the number of nodes and Von misses stress for copper material. As the number of nodes increases from 1391320 to 1391420 the value of stress also increases from 4.06×10^8 to $4.28\times10^8$and correspondingly the value of error also reduces.

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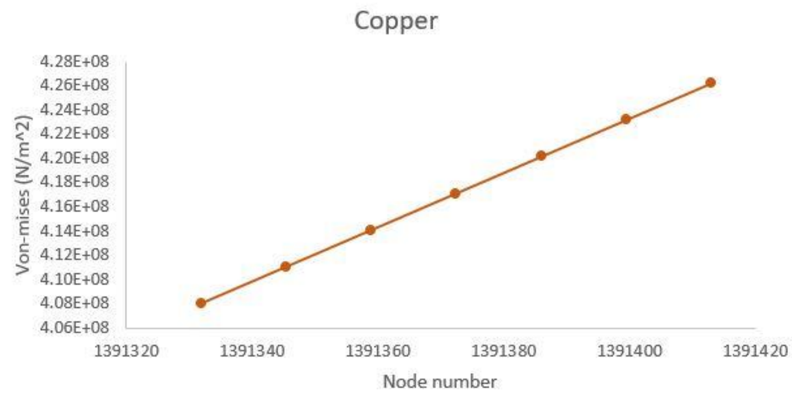

Fig 9: Von mises stress of copper vs Nodes

Fig.10 describes the relationship between the number of nodes and Von misses stress for Aluminum material. As the number of nodes increases from 370000 to 450000 the value of stress also increases from 3.5×10^8 to 3.68×10^8.

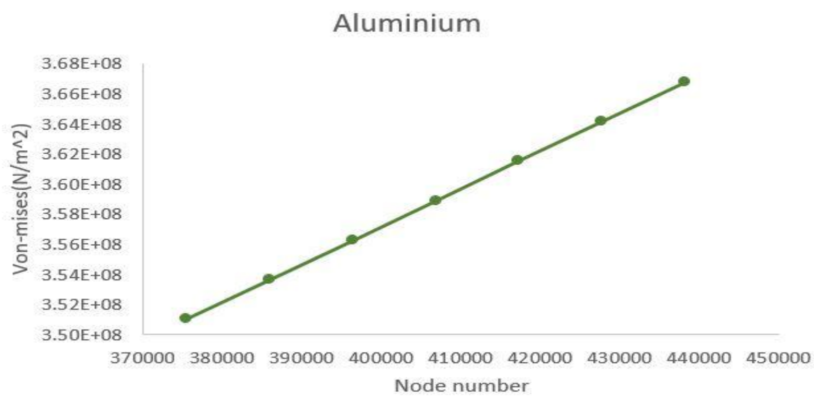

Fig 10: Von mises stress of Aluminum vs Nodes

Fig.11 describes the relationship between the number of nodes and Von misses stress for Cast Iron material. As the number of nodes increases from 1088780 to 1088820 the value of stress also increases from 3.84×10^8 to 4.0×10^8.

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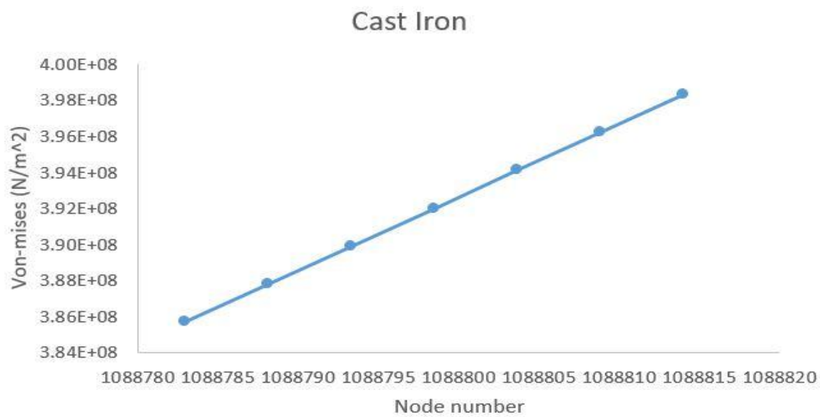

Fig 11: Von mises stress of Cast Iron vs Nodes

The overall result describes that as the number of nodes in the Analysis increases, the accuracy of the results of stresses also increases.

Conclusion

In this study, SolidWorks and Ansys software are used to investigate the performance of the Spur gear pair by comparing these simulation results with the theoretical one. The main goal of the current research was gear stress analysis and checking the reliability of software-based results. The variation between the theoretical stress values of the spur gear drive and the software results is minimal. As, the mesh size in finite element analysis decreases, correspondingly, the accuracy of the result increases. Noticeably, the stress in the Copper material is higher than in Aluminum and Cast Iron (Gray). The value of surface stresses is important in selecting materials for many applications as gears fail mainly due to these types of stresses.

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References

1. Petrescu, R. V. V.; Aversa, R.; Akash, B.; Bucinell, R. B.; Corchado, J. M.; Apicella, A.; Petrescu, F. I. T. Gears-Part I. *American Journal of Engineering and Applied Sciences* **2017**, *10* (2), 457–472. https://doi.org/10.3844/ajeassp.2017.457.472.

2. Rao, P. S.; Sriraj, N.; Farookh, M. Contact Stress Analysis of Spur Gear for Different Materials Using ANSYS and Hertz Equation. *International Journal of Modern Studies in Mechanical Engineering* **2015**, *1* (1), 45–52.

3. Sankar, S.; Raj, M. S.; Nataraj, M. Profile Modification for Increasing the Tooth Strength in Spur Gear Using CAD. *Engineering* **2010**, *02* (09), 740–749. https://doi.org/10.4236/eng.2010.29096.

4. Vullo V. Gears. New York, NY, USA: Springer International Publishing; 2020.
5. Bhavi, Iresh. (2016). COMPARISON OF ANALYTICAL & FEA OF CONTACT ANALYSIS OF SPUR GEAR DRIVE. international research journal of engineering and Technology. 3. 620.

6. Liang, X.; Zhang, H.; Zuo, M. J.; Qin, Y. Three New Models for Evaluation of Standard Involute Spur Gear Mesh Stiffness. *Mechanical Systems and Signal Processing* **2018**, *101*, 424–434. https://doi.org/10.1016/j.ymssp.2017.09.005.
7. M. Fattahi, A.; Gh. Khosroshah, M. Three Dimensional Stress Analysis of a Helical Gear Drive with Finite Element Method. *Mechanics* **2017**, *23* (5). https://doi.org/10.5755/j01.mech.23.5.14884.
8. Panda, S. K.; Mishra, P. K.; Patra, B.; Panda, S. K. Static and Dynamic Analysis of Spur Gear. *International Journal of Hydromechatronics* **2020**, *3* (3), 268. https://doi.org/10.1504/ijhm.2020.109916.
9. Zhu X. Tutorial on hertz contact stress. InOpti 2012 Dec 1 (Vol. 521, pp. 1-8).
10. J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.