IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

# Design and Geometry optimization of spur gear for reduction of stress

**Dakey Suman[1] , Shankar Kumar Singh[2] , Vasu Yarramala[3] ,Sharma Nitish Kumar Uday[4] , Majji Sai[5]**

[1] Assistant Professor, [2,3,4 5]UG Student

[1,2,3,4 5]Department of Mechanical Engineering,

[1,2,3,4 5]Godavari Institute of Engineering and Technology, Rajamundry-533296, Andhra Pradesh, India

***Abstract***:Gear transmission is a major form of power transmission, of which the reliability greatly affects the life of many mechanical devices. Gears have two main failure modes, namely tooth surface pitting and tooth root fracture. Tooth surface pitting is mainly due to excessive contact stress and tooth root fracture is mainly due to excessive bending stress. In spur gears, the maximum bending stress concentration is known to occur in the gear tooth fillet region. This study focuses on the geometric optimization of symmetric involute gears to alleviate stress concentrations near the fillet. Stress relief is achieved by incorporating strategically placed holes in the area between adjacent teeth. The size and location of these features are varied to reduce bending stresses, leading to increased load capacity, extended gear lifetime, reduced manufacturing costs, and minimized noise and vibration. CATIA V5 software are used to model spur gears and ANSYS software are used for geometric optimization process to achieve the desired stress distribution.

KEYWORDS: Spur Gear, Stress, CATIA V5, ANSYS.

## I. INTRODUCTION:

Spur gears are one of the most commonly used types of gears in mechanical systems, known for their simplicity, efficiency, and versatility. These cylindrical gears consist of teeth that are parallel to the gear axis, allowing them to transmit rotation motion and power between parallel shafts. Spur gears are widely employed in a wide range of applications, including machinery, automotive systems, industrial equipment, and even in everyday devices like clocks and printers.

Spur gears are cylindrical gears with teeth that are parallel to the gear axis. They mesh with other spur gears to transmit motion and power between parallel shafts. The teeth of spur gears are straight and extend radially from the gear's cylindrical body. This configuration results in a constant gear ratio and smooth, uniform motion transfer.

There are two principal forms of failure for spur gears in contact with each other: failure by means of bending and failure through contact stress at the gear tooth surface, the contact stress, or pitting stress, between two contacting gears may be calculated by means of the Hertzian contact equation, and is relative to the square root of the applied tooth load (AGMA 2001-D04). The bending stress is estimated by assuming the gear tooth as a cantilevered beam, by a cross section of face width by tooth thickness. The spur gear tooth load is directly proportional to bending stress. Usually, bending failure will happen when the stress on the tooth is superior than or equal to the yield strength of the gear tooth material

Historically, efforts have primarily focused on improving gear geometry, especially the working involute flanks. These have been technically classified and described by various standard accuracy grades based on application type and tolerance limits, such as profile, runout, lead, and pitch variation. The maximum bending stress concentration is known to occur at the gear tooth fillet [4]. However, its profile and accuracy are typically determined by a drawing with a generous root diameter tolerance and, in some cases, the minimum fillet radius, which can be difficult to assess. Improvement in tooth bending strength is typically achieved through gear technology rather than gear geometry.

Two main approaches have been employed to reduce bending stress for a given tooth size. The first involves altering the generating cutter tooth tip, with the most common application being the use of a rack with a full tip radius .The second approach modifies the gear tooth fillet profile from the trochoidal to the circular fillet. Further enhancements for both methods have been based on mathematical functionfitting techniques, where the cutter tip radius or the gear tooth trochoid fillet profile is replaced by a parabola, ellipse, chain curve, or another curve to minimize bending stress.

**Failures can occur in spur gears due to various reasons:**

**Tooth Wear:** Continuous meshing and sliding between gear teeth can lead to wear, affecting the gear profile and causing noise and vibration. This wear can result from insufficient lubrication, improper material selection, or high loads.

**Tooth Breakage:** Excessive loading or shock loads can cause individual gear teeth to fracture or break. This can happen due to material fatigue, inadequate design, or sudden overloads beyond the gear's capacity.

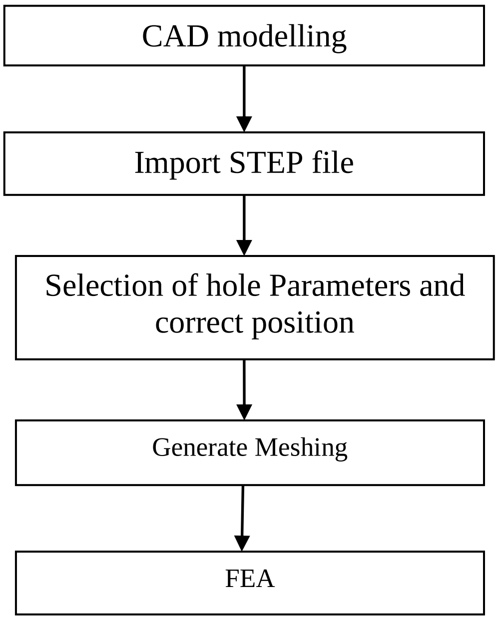
**Pitting:** Pitting is the formation of small craters or pits on the gear tooth surface due to repeated contact stress. It occurs when the contact pressure exceeds the material's capacity to withstand it, leading to surface fatigue and eventual failure.

**Bending Fatigue**: Bending fatigue failure occurs when cyclic loading causes cracks to initiate and propagate from the root of the gear tooth. This type of failure is influenced by factors such as material properties, surface finish, and operational conditions.

**Surface Fatigue**: Surface fatigue, also known as spalling, occurs when surface cracks propagate, and material flakes off due to repeated contact stress. It typically occurs in high-speed applications or under conditions of inadequate lubrication.

**Tooth Deformation:** Excessive loading or improper meshing can cause plastic deformation of gear teeth, leading to changes in tooth profile and increased stress concentrations. This can result in loss of efficiency and premature failure.

## II. METHODOLOGY:




- CATIA V5 software are used for designing of the CAD model of spur gear .
- Then import the step file into the ANSYS software to analysis of spur gear.
- Now select the hole size and the right position to create the hole on the gear and using the different type of the hole configuration for reduction of stress as well as shape optimization.
- Then Generate the meshing which is most important for result, so generating the meshing with proper number of size.
- At the last find out the stress and the total deformation of the gear.

## III. PROBLEM STATEMENT:

The current spur gear design experiences significant stress concentrations during operation, leading to potential reliability issues and reduced lifespan. Addressing these concerns requires a systematic approach to optimize the shape of the gear while minimizing stress levels. The challenge is to utilize ANSYS software to conduct shape optimization, identifying the most effective modifications to the gear's geometry to achieve substantial stress reduction without compromising performance criteria such as load capacity and efficiency. This optimization process aims to enhance the structural integrity of the gear system and ensure its long-term reliability under varying operating conditions.

## III. OBJECTIVE:

The objective is to employ ANSYS software for shape optimization of the current spur gear design to alleviate stress concentrations and enhance structural integrity. By systematically modifying the gear's geometry, the goal is to significantly reduce stress levels while maintaining or improving performance metrics such as load capacity and efficiency. This optimization process aims to ensure the long-term reliability and durability of the spur gear system under diverse operating conditions.

Optimization process:

A).Holes at the center of the tooth: The first step toward reducing the stresses near the fillet is by stress relief holes, the hole is located at the center of the tooth. The analysis is performed by varying the location of the hole along the center of the tooth from the center of the gear, as shown in fig 1.

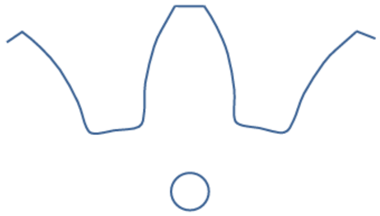


Fig.1

B). Two hole at the center of tooth: For reducing the maximum stresses is by using two holes located at the central distance between center teeth from the center of the gear. The analysis is performed by varying the diameter of the in their specified locations, as shown in Figure 2.

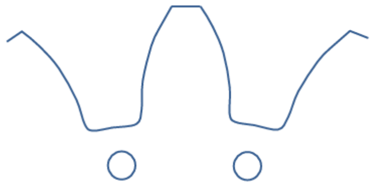


Fig. 2

C). Holes at the mid-space width between two adjacent teeth:

The second step toward reducing the stresses near the fillet is by using stress relief holes located at the central distance of space width between the two adjacent teeth. The analysis is performed by varying the location of the holes from the center of the gear, as shown in Figure 3.

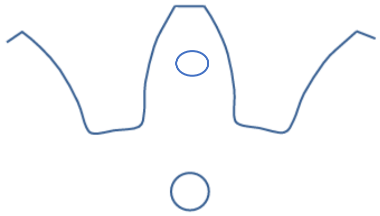


Fig.3

## IV. DESIGN OF SPUR GEAR:

For designing of the spur gear CATIA V5,it developed by Assault Systems, is a powerful computer-aided design (CAD) software widely used in various industries, including automotive, aerospace, manufacturing, and engineering. It provides a comprehensive suite of tools for product design, simulation, manufacturing, and collaboration

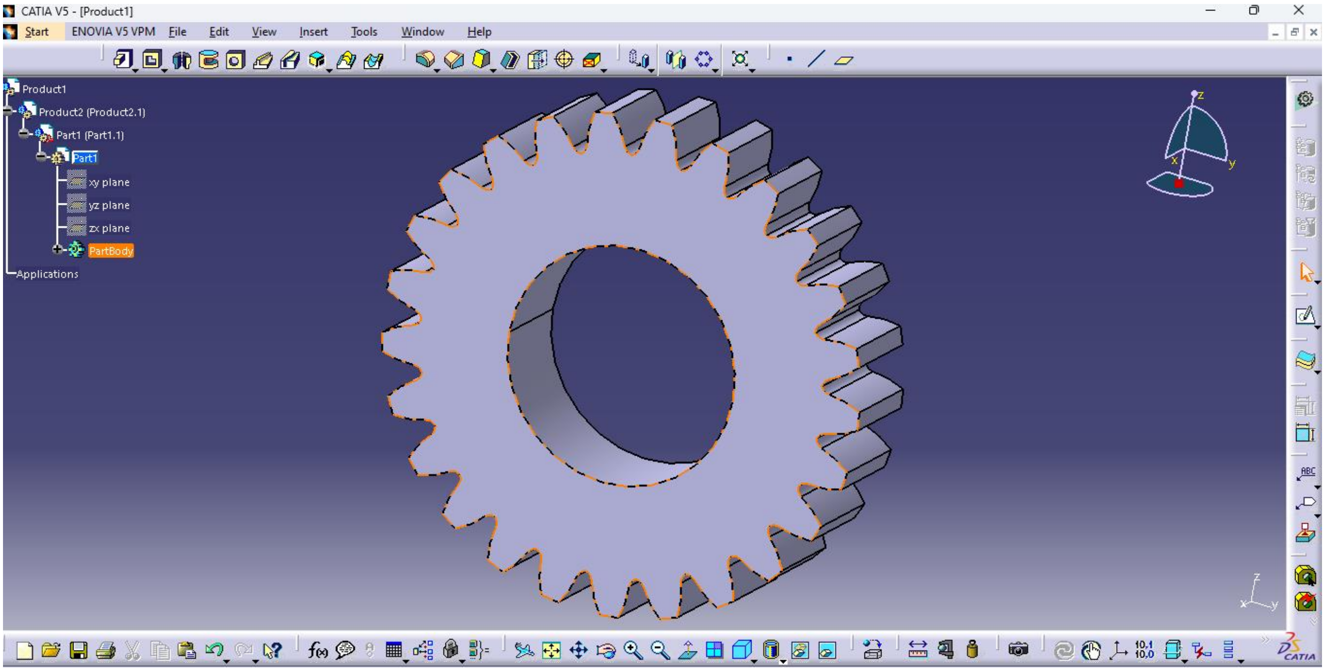



Fig. 4

Teeth Count: The gear has 26 teeth, which refers to the number of protrusions (teeth) around its circumference. The number of teeth affects the gear ratio and determines how the gear meshes with other gears in the system.
Module: The module of the gear is 3. Module is a measure of gear size and represents the ratio of the pitch diameter to the number of teeth. A module of 3 indicates that for every 3 millimeters of pitch diameter, there is one tooth. It influences the size and strength of the gear teeth.
Pressure Angle: The pressure angle of the gear is 20 degrees. The pressure angle is the angle between the line of action (the imaginary line along which the force is transmitted between gears) and the line tangent to the pitch circle. A pressure angle of 20 degrees is a common standard in gear design and affects the load distribution and tooth strength.
Design Considerations: With 26 teeth and a module of 3, this gear configuration is suitable for applications requiring moderate speed and torque transmission. The chosen pressure angle of 20 degrees balances factors such as tooth strength, efficiency, and noise levels.

## V. Meshing:

The quality of the mesh directly affects the accuracy of the simulation results. A well-meshed model ensures that the numerical solution closely approximates the behavior of the real-world physical system being simulated. Poor mesh quality can lead to errors and inaccuracies in the results, Proper meshing helps ensure that the numerical solution converges to a stable and accurate solution. Convergence refers to the process where the solution approaches a stable and consistent value with successive iterations. A well-structured and appropriately refined mesh aids in achieving convergence faster and more reliably.
A high-quality mesh contributes to solution stability by reducing numerical oscillations and artifacts in the results. A stable solution is essential for obtaining reliable insights into the behavior of the analyzed system, Efficient meshing practices can significantly reduce computational resources and time required for simulations. Properly optimized meshes with adequate element density in critical areas can achieve accurate results with fewer computational resources.
Meshing accurately represents the geometry and boundary conditions of the model. It ensures that physical boundaries, material interfaces, and contact regions are adequately resolved, allowing for accurate representation of real-world conditions. Meshing influences the sensitivity of the simulation results to changes in input parameters. Sensitivity analysis often involves varying mesh parameters to assess their impact on the results, highlighting the importance of proper meshing practices.

## VI. RESULT:

The number of the teeth used is 26 with a module of 6, the material used was stainless steel with modulus of elasticity of 200 GPa and Poisson’s ratio of 0.3.The first case in the analysis was by using central relief hole at the center of the tooth, the analysis is performed by varying the location of the hole along the center of the tooth by 50-63 mm from the center of the gear, also two-hole diameters are used, viz. 3mm ,6mm and 8 mm as shown in fig 4. The variations affect the stress distributions and the value of the maximum stress or the zone of the stress concentration, these showed that these holes sometimes are beneficial and others are not. Generally, these holes not improving or redistribute the stresses effectively, a try was made by using two holes with different diameter, to find out how this affects the stress contours of the current problem and the result showed a worsen effect of this case.

CASE-1:

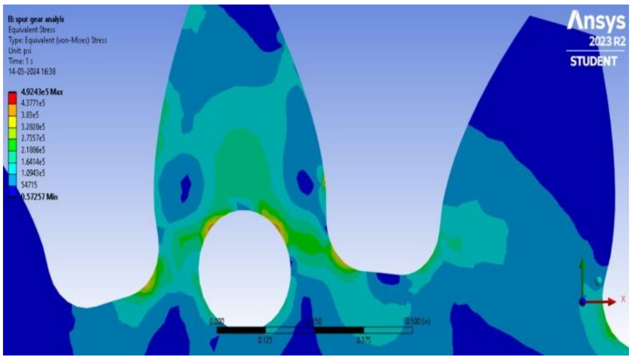



Fig.(a) 6mm hole and 56 distance

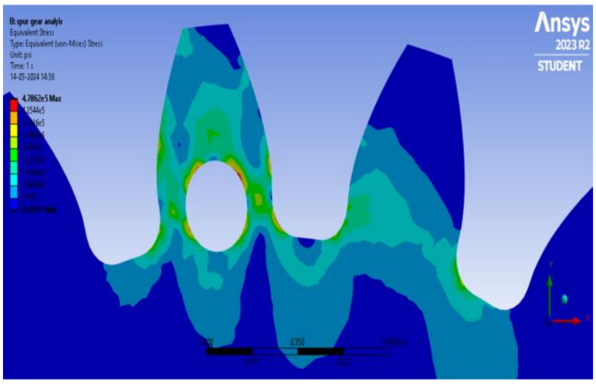



Fig.(b) 6mm hole and 58 distance

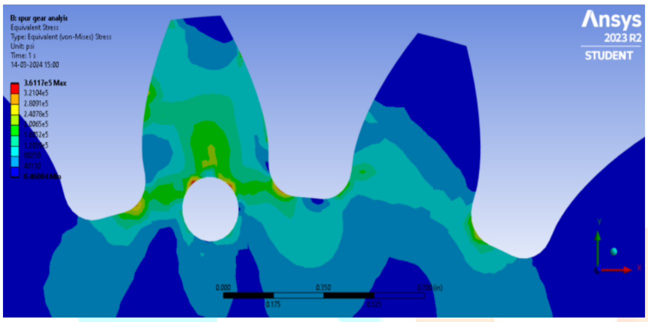



Fig.(c) 5mm hole and 55mm distance

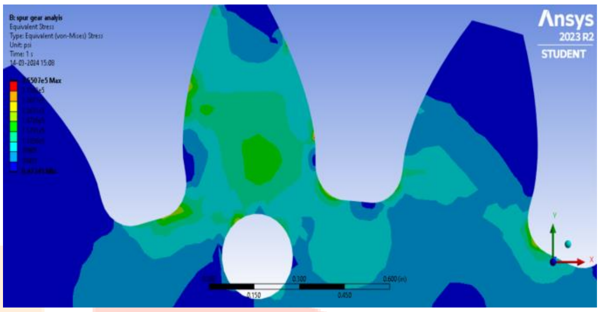



Fig.(d) 6mm hole and 52mm

Fig.5 Effect central holes on the stress values

The results of this case, for the 6 mm hole the worst case at the distance 58 mm from the center of the gear under consideration, while the 5 mm showed almost plateau behavior after a distance of 52 mm low stress with clear behavior of increasing the stress concentration.

Case-2:

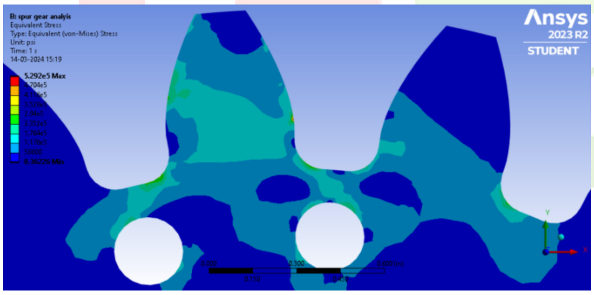



Fig. 5(e) 6mm hole and 50mm distance

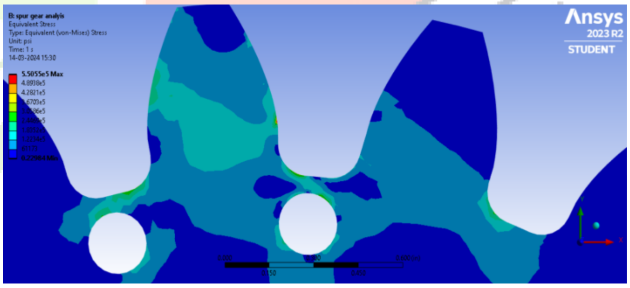
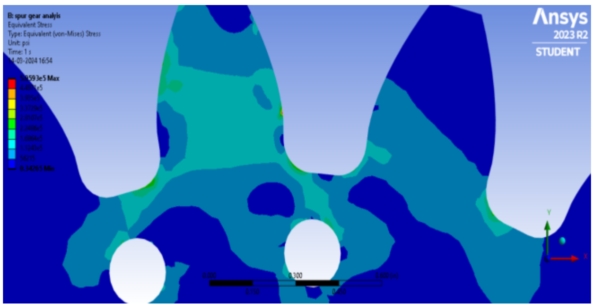



Fig. 5(f) 5mm hole and 52.5mm distance




Fig(g) 4mm hole and 50mm distance

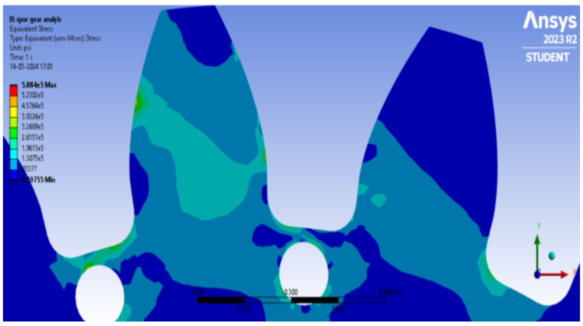



Fig.(h) 4mm hole and 53mm distance

Fig.6 Holes located at mid-space width between two adjacent teeth

The results of this case, for the 6 mm hole the worst case at the distance 53 mm from the center of the gear under consideration, while the 6 mm showed almost plateau behavior after a distance of 50 mm low stress with clear behavior of increasing the stress concentration. the analysis of reducing the stresses near the fillet is by using stress relief holes located at the central distance of space width between the two adjacent teeth. . The distance variations affect the stress distributions with generally accepted to beneficial results, as these holes lowered the maximum values of the stress concentration near the tooth fillet in Figure 6.

Case-3

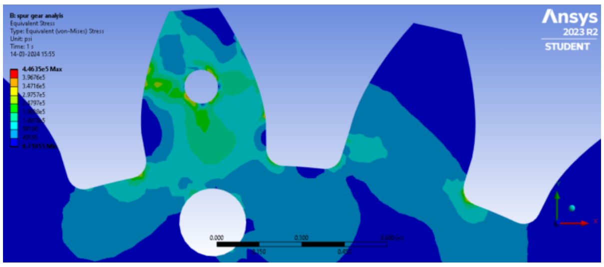



Fig.(a) 6,3mm hole and 51,63mm distance

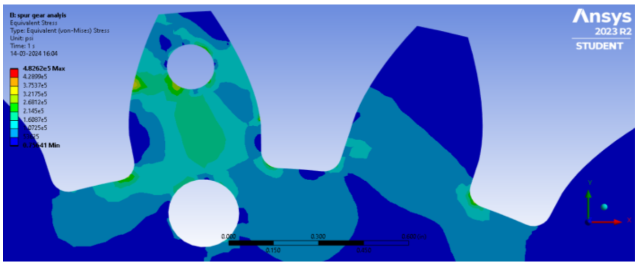



Fig.(b) 6,4mm hole and 50,64mm distance

Fig.7 Effect central two holes on the stress values

The results of this case, for the 6 mm, 4mm hole the worst case at the distance 50 mm, 64mm from the center of the gear under consideration, while the 6 mm,3mm showed almost good behavior at distance of 51 mm,63mm low stress with clear behavior of increasing the stress concentration.

the analysis of reducing the stresses near the fillet is by using stress relief holes located at the central distance of space width between the two adjacent teeth, the diameter of the holes is chosen as 6mm and 3 mm, and its distance are varying from 51cand 63 mm from the center of the gear. The distance variations affect the stress distributions with generally accepted to beneficial results, as these holes lowered the maximum values of the stress concentration near the tooth fillet.

**V. CONCLUSION :**

The current paper proposes a method for reducing the maximum bending stress concentration near the tooth fillet of a symmetric spur gear by focusing solely on geometrical feature aspects. Drilling relief holes, particularly near the fillet, and half circular cuts in the zone between adjacent teeth were used in the optimization procedure. The locations and sizes of these holes or cuts are optimized to change the stress distribution near the fillets, resulting in reduce bending stresses near the fillets. To evaluate the stress distribution and perform geometric optimization, finite element methods were used for formulation and modeling. These gear geometry changes and redistribute the bending stress near the high stress region, resulting in a 25% reduction in stress concentration. As a result, this paper demonstrates that significant reductions in maximum bending stress are possible. This implies relatively small gear dimensions and/or a compact gearing system with low weight and cost.

## VI. REFERENCE

(1). Anant Prakash Agrawal , Shahazad Ali , Sachin Rathore. Finite element stress analysis for shape optimization of spur gear using ANSYS 2022;64(3): 1147-1152 https://doi.org/10.1016/j.matpr.2022.03.404.

(2).Ahmed W. Hussein , Mohammad Q. Abdullah. High-contact ratio spur gears with conformal contact and reduced sliding. June 2022;14: 100412. https://doi.org/10.1016/j.matpr.2022.03.404.

(3).Gaurav Mehta, Mayank Somani, T. Narendiranath Babu, Tushit Watts. Contact Stress Analysis on Composite Spur Gear using Finite Element Method.https://doi.org/10.1016/j.matpr.2018.02.354

(4).Natali, C., Battarra, M., Dalpiaz, G., Mucchi, E. (2021). A critical review on FE-based methods for mesh stiffness estimation in spur gears. Mechanism and Machine Theory, 161: 104319. https://doi.org/10.1016/j.mechmachtheory.2021.104319.

(5). Dhakshain Balaji V , Varun Gopalakrishnan , Ajay C , Muthuveerappan AL , Bhaskara Rao Lokavarapu , Srinivasa Gupta G. Stress analysis of symmetric and asymmetric spur gears made of ceramic reinforced stainless steel matrix composites. 2022;50(5): 2111-2118 https://doi.org/10.1016/j.matpr.2021.09.431

(6).Qi Wen , Qungui Du , Xiaochen Zhai. Analytical calculation of the tooth surface contact stress of spur gear pairs with misalignment errors in multiple degrees of freedom.2020; 149: 103823https://doi.org/10.1016/j.mechmachtheory.2020.103823.

(7). Qi Wena ,Qungui Dua, Xiaochen Zhai. An analytical method for calculating the tooth surface contact stress of spur gears with tip relief. 2019. 155;170-180 https://doi.org/10.1016/j.ijmecsci.2018.11.007

(8). Sánchez, M.B., Pleguezuelos, M., Pedrero, J.I. (2019). Influence of profile modifications on meshing stiffness, load sharing, and transmission error of involute spur gears. Mechanism and Machine Theory, 139: 506-525. https://doi.org/10.1016/j.mechmachtheory.2019.05.014

(9). Chavadaki, S., Kumar, K.N., Rajesh, M.N. (2021). Finite element analysis of spur gear to find out the optimum root radius. Materials Today: Proceedings, 46: 10672 10675. https://doi.org/10.1016/j.matpr.2021.01.422

(10). Chavadaki, S., Kumar, K.N., Rajesh, M.N. (2021). Finite element analysis of spur gear to find out the optimum root radius. Materials Today: Proceedings, 46: 10672 10675. https://doi.org/10.1016/j.matpr.2021.01.422

(11). Liu, P., Zhu, L., Gou, X., Shi, J., Jin, G. (2021). Modeling and analyzing of nonlinear dynamics for spur gear pair with pitch deviation under multi-state meshing. Mechanism and Machine Theory, 163: 104378. https://doi.org/10.1016/j.mechmachtheory.2021.104378

(12). Zhang, C., Dong, H., Wang, D., Dong, B. (2022). A new effective mesh stiffness calculation method with accurate contact deformation model for spur and helical gear pairs. Mechanism and Machine Theory, 171: 104762. https://doi.org/10.1016/j.mechmachtheory.2022.104762

(13). Kalay, O.C., Doğan, O., Yılmaz, T.G., Yüce, C., Karpat, F. (2021). A comparative experimental study on the impact strength of standard and asymmetric involute spur gears. Measurement, 172: 108950. https://doi.org/10.1016/j.measurement.2020.108950

(14) Dong, P., Zuo, S., Tenberge, P., Uelpenich, R., Xu, X., Liu, Y., Wang, S., Lai, J. (2022). Rapid hob tip corner optimization of spur gears for increasing bending strength. International Journal of Mechanical Sciences, 224: 107322. https://doi.org/10.1016/j.ijmecsci.2022.107322

(15). Kulangara, A.J., Rao, C.S.P., Bose, P.S.C. (2018). Generation and optimization of lattice structure on a spur gear. Materials Today: Proceedings, 5(2): 5068-5073. https://doi.org/10.1016/j.matpr.2017.12.085

(16). Zou, T., Shaker, M., Angeles, J., Morozov, A. (2017). An innovative tooth root profile for spur gears and its effect on service life. Meccanica, 52(8): 1825-1841. https://doi.org/10.1007/s11012-016-0519-7

(17).Zhang, C., Dong, H., Wang, D., Dong, B. (2022). A new effective mesh stiffness calculation method with accurate contact deformation model for spur and helical gear pairs. Mechanism and Machine Theory, 171: 104762. https://doi.org/10.1016/j.mechmachtheory.2022.104762