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# ADVANCED STRESS ANALYSIS TECHNIQUES FOR GEAR MATING COMPONENTS UTILIZING ANSYS SIMULATION METHOD: A COMPREHENSIVE STUDY

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**Abstract**

*The research aimed to conduct a stress analysis of gears to determine the maximum permissible contact stresses for design purposes and to prevent gear failure resulting from excessive contact stresses. Gears are critical components in mechanical power transmission systems. It is a rotating mechanical element with serrated teeth that interlock with another toothed element to convey torque. The application of gears encompasses a wide range, from diminutive wristwatches to extensive industrial machinery, such as automobiles, the aerospace industry, and marine engines, due to their remarkable durability and compactness. Spur gears feature straight teeth that are oriented parallel to the axis of the wheel. The primary objectives in modern gear design are the bending stress and total deformation of gear teeth. When a pair of spur gear teeth is in use, it usually goes through two types of cyclic stress: contact stress and bending stress. This report shows the contact stress study of a stainless steel spur gear that was done with ANSYS 15.0 Workbench and finite element analysis. Finite element analysis is a method employed to resolve intricate designs by partitioning them into smaller pieces to facilitate the attainment of desired outcomes. This study aims to determine the maximum permissible contact stress and total deformation of a stainless steel spur gear tooth.*

## INTRODUCTION

The ANSYS 15.0 workbench is used to implement contact stress analysis in order to examine the behavior of contact stresses in gears. Contact stresses dominate the gears in automobiles [1-2]. The primary means of power transfer is through gears. It is preferred over other automotive devices due to its compact gear design and power transfer capabilities, which increase engine economy [3–4]. Gears are among the most effective ways to transfer power between the shafts. The primary functions of gears are to transfer torque and angular velocity. The quick growth of sectors including automotive, shipbuilding, and aviation necessitates the sophisticated use of gear technology. Consumers like vehicles with extremely efficient engines [5]. The requirement for quiet power transmission increased as a result. One of the biggest producers of gears is the automotive industry. Given the ongoing desire for lighter cars, more dependability and lighter gears are required to make cars lighter [6]. The development of quieter gear pairs for additional noise reduction is encouraged by the success of engine noise reduction. Reducing the vibration associated with them is the most effective method of reducing gear noise [7]. Since loading conditions are constant everywhere, contact stresses must arise. As a result, most gears break before their estimated or anticipated life. This problem affects the entire performance of heavy machinery and vehicles in addition to the efficiency of the gears. Failure can also be caused by friction, outside pressures, or unanticipated weather conditions. Compression and thermal expansion are also included in the failure category [8].

High contact stress repetition was the main cause of gear failure. This tendency forces the gear to break down before its estimated lifespan [9]. Contact stresses are the most hazardous, even though all failures are fatal and make it difficult for equipment to withstand external loads. Its characteristic of showing up without warning makes it extra harder to get ready for failure and losses [10]. The goal of this study is to identify contact stressors. The finite element method, which divides a big or complex component into a finite number of elements for additional analysis, will be used to do this. In order to do this, contact stress analysis of spur gears was examined using ANSYS work bench, and CAD software (pro Engineer) was used to generate the gear models. More precise contact simulation is useful in identifying the design parameters to improve gear life, and contact stress analysis displays the stress distribution with regard to load. Carbon or alloy steels, stainless steel, and cast iron were the materials employed for this project. The stainless steel spur gear model, which is used in the carried job, demonstrates the excellent strength and resilience of stainless steel to severe loads and strains.



The authors used the ANSYS 15.0 workstation FEA program and the theoretical approach of Hertz equations to analyze the contact stress of stainless steel spur gears. ANSYS Design Modeler is used to sketch and model the spur gear, and Mechanical ANSYS Multiphysics is used to analyze the contact stress. They came to the conclusion that there is a good degree of agreement between the results of the theoretical technique and FEA. Spur gear was employed because of its great efficiency and straightforward design [11]. An analytical method has been used to analyze the contact and bending stress of steel spur gears. The Lewis equation was utilized for bending stress analysis and the Hertzian equation for contact stress analysis. Steel pinions and gears have been employed for both analyses. In order to prolong gear life and prevent deformation, it was determined that spur gear under contact and bending should fall within the safety range [12–13]. Researchers used ANSYS and Pro-E software for design and Hertz equations for theoretical investigation of contact and shear stress in stainless steel spur gears. The ANSYS 15.0 workbench FEA software was used to do finite element analysis. ANSYS design Modeller is used to sketch and model the spur gear, and Mechanical ANSYS Multiphysics is used to analyze contact stress [14–15]. It was determined that by reducing human mistake and conserving time, the software design technique allows the designer to optimize the design process. An investigation of the stress experienced by a pair of mated gears during rotation was conducted. It examined the location of contact stresses at various points using two examples of spur and helical gears. The contact stress at the lowest point of single-tooth contact (LPSTC) and the contact stress equation developed by the American Gear Manufacturers Association (AGMA) are then compared to the variation of the contact stress during rotation. The gear design that takes into account the contact stress in a pair of mating gears was found to be more severe than the AGMA standard [16].



**The goals of this study are listed below.**

- To use ANSYS to calculate the stress distribution through the gear.
- To use Pro-Engineer software to design various gears.
- To use ANSYS to compare the contact stress of several types of mating gears.

## 1.1. Research Procedure

The points for the research process are listed below.

- It was created using CAD/Pro-Engineering software.
- Launch the ANSYS program and select the Static Structural analysis type.
- Set the engineering data and add various material types.
- Following that, the model was imported into the ANSYS workbench analysis.

- Next, the model is meshed to separate it into nodes and elements.
- For the analysis of specific materials, the boundary conditions and material attributes are being used.
- Use an applied torque of 59 KN.mm and an ambient temperature of 22 °C. This work uses a frictionless process.
- At nodes, resolve the unknown parameters.
- Following this, ANSYS was used to run the model for simulation and results.
- The outcomes are examined in light of our goals.

Gears are toothed components that transfer motion or power between shafts without slipping. One of the most important parts of most industrial spinning and heavy machinery, as well as a mechanical power transmission system, is gearing [17–20]. Given their great degree of dependability and compactness, gears may end up being the most efficient power transmission method in machines of the future. Because of their high degree of dependability and compactness, gears will continue to be an essential machine component for power transmission in future machines [21–24]. Furthermore, a sophisticated use of gear technology will be necessary due to the industry's rapid transition from heavy industries like shipbuilding to industries like auto manufacturing and office automation equipment. Different types of gears are made for different purposes. For example, spur gears are used to transmit large amounts of power, helical gears are used to transmit medium amounts of power, and some gears are used to transmit power between shafts that are perpendicular to one another or intersect the axis of shafts. These gears are all-purpose. Certain specialized gears, such worm and bevel gears, are employed in situations requiring higher power transmission [25–26].

Let's use a vehicle as an example to better comprehend it. The engine generates power, and in order to transfer that power to other components and maintain engine efficiency, gears must be installed due to their great efficiency and dependability.

### 1.2. Practical Applications of Gears

- It has dependable service, high efficiency, the ability to transmit enormous power, and a precise velocity ratio.
- It transmits power in a variety of industries and has a small layout.

### Spur Gear

The most well-known and prevalent kind of gears are spur gears. Spur gears are only used to transfer rotary motion between two parallel shafts while preserving constant speed and torque. Their teeth are oriented parallel to the axis. They are utilized for massive power transfer and have a high efficiency and outstanding precision rating. The Alto vehicle's spur gear will be covered in this inquiry.

### Terminologies

The following terms which were mostly used in this section should be clearly understood at this stage. These terms are illustrated in this figure

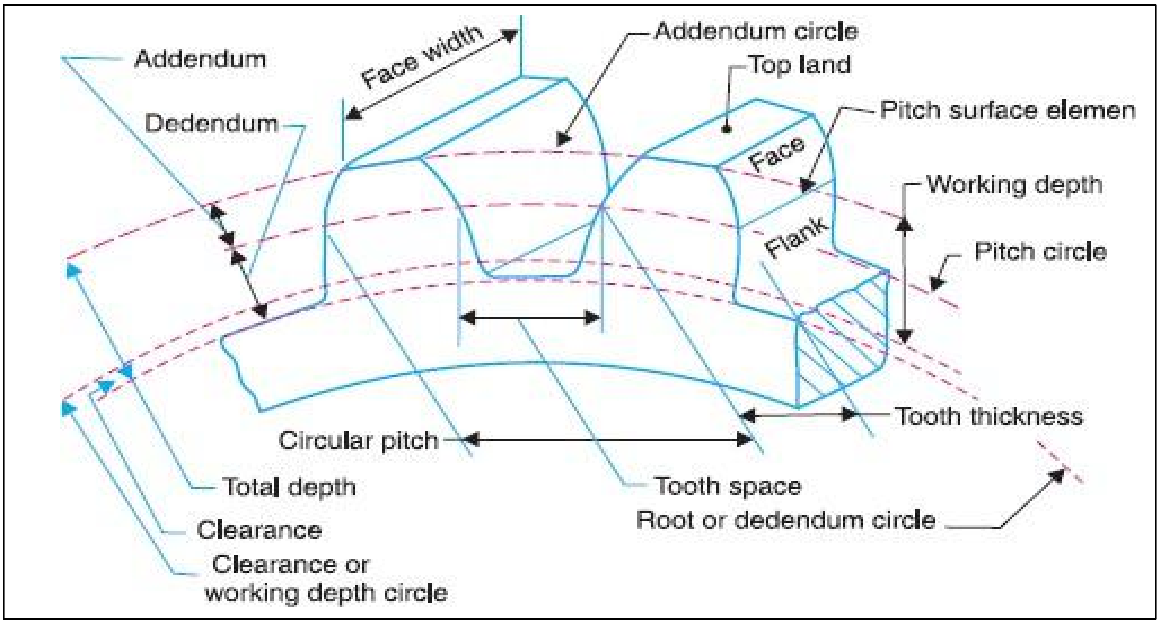


**Figure 1: Gear Terminologies**

### 1.3. Finite Element Analysis (FEA)

A product's response to applied pressure, heat, fluid flow, vibration, and other physical phenomena can be predicted using this automated method. Additionally, it forecasts whether a product will fail, wear out, or function as intended. We call it analysis. Because structure safety is so important in the nuclear and aircraft industries, finite element analysis was initially created for use in these fields [27]. Even the most basic product designs now rely on FEA for design review. It aids in forecasting how a product would behave when subjected to certain physical impacts, such as:

- Mechanical stress
- Motion
- Mechanical vibration
- Fatigue
- Fluid flow
- Heat transfer
- Molding of plastic injection
- Electrostatics

## 2. Devolvement of Finite Element Model

PTC (Parametric Technology Corporation) created the modeling program Pro-Engineer, which is utilized all around the world. It is built on CAD/CAM's 3D capabilities and is intended to significantly cut down on the amount of time you need to spend creating solid models. It provides simple relationships between variables, and model modifications are possible at any time. This software's operation is somewhat similar to the actual production process, which begins with the material of choice and then proceeds via several manufacturing procedures, such as drilling, cutting, and turning. Pro-E offers all the tools and features needed to create a 3D model of the specified part or assembly.

### 2.1. Drawing of both gears in Pro-E

Pro Engineer software was used to create models, establishing appropriate geometry and using a variety of tools to produce the desired model and geometry.

### 2.2. Work in Pro-Engineering

- To create geometry, open the Pro Engineering program and choose Part Modeling.
- Two spur gear geometries are constructed using the dimensions listed in the tables when the front view is chosen for sketching.
- Next, make two spur gear models using the tables' specified dimensions..

**Spur Gear First Model**

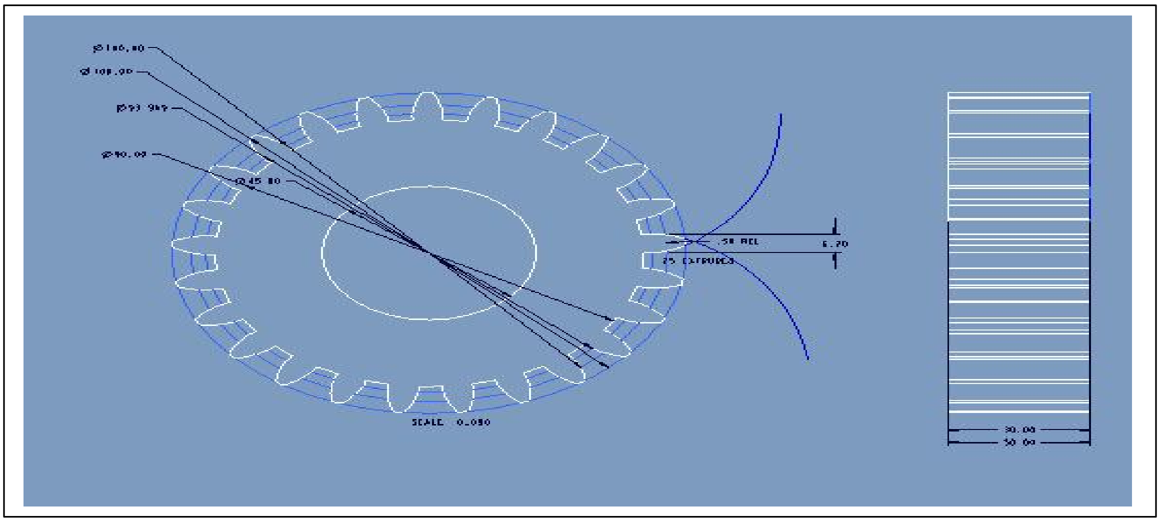

**Figure 2: Drawing Representation of First Spur Gear Model**

Spur Gear Second Model

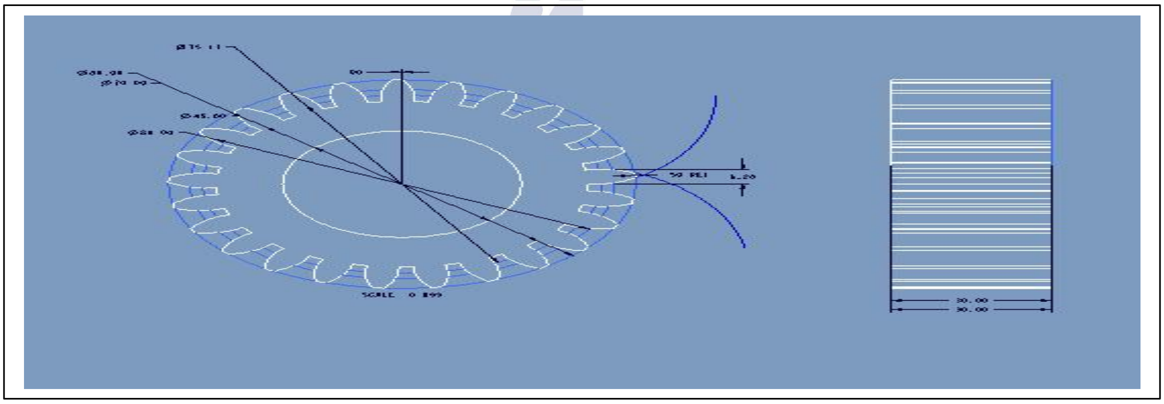

**Figure 3: Drawing Representation of Second Spur Gear Model**

**Tooth Profile Used**

This research employed an involute profile for the construction of spur gear teeth due to the widespread application of involute gear designs in global industries. The primary advantages of utilizing involute gears include their straightforward installation, quiet functioning, and simplicity of production.

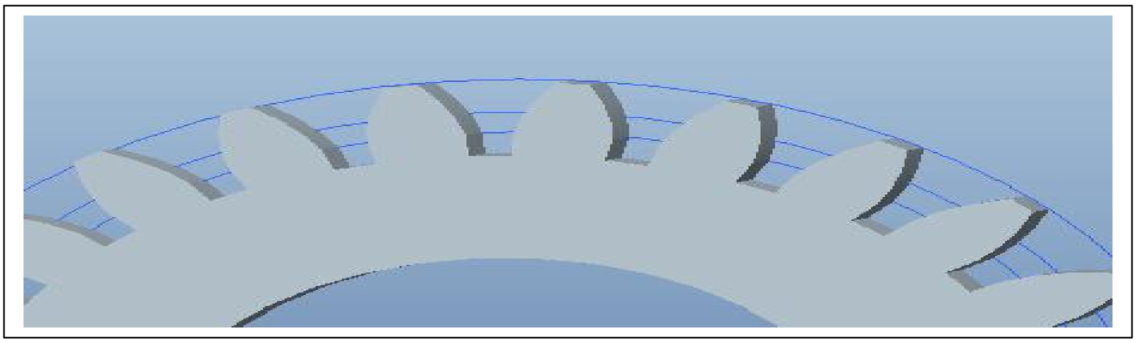

Figure 4: Representation of Spur gear Involute profile

**Setup in ANSYS**

For further analysis, spur gears assembly has been imported to ANSYS 15.0 Workbench.

**Meshing**

Meshing has been done in ANSYS for the purpose of dividing the whole design into small elements to be solved and analyzed easily.

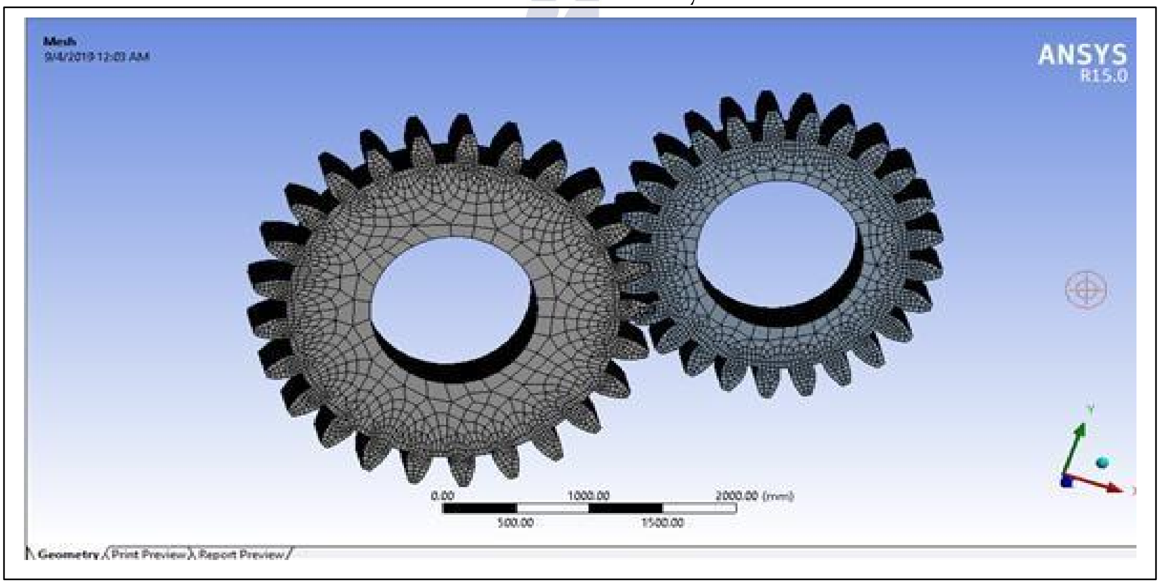


Figure 5: Meshed Spur Gears

**Moment**

In order to obtain the intended findings and to examine the distribution of stresses during static structural analysis, the moment value was entered during analysis.

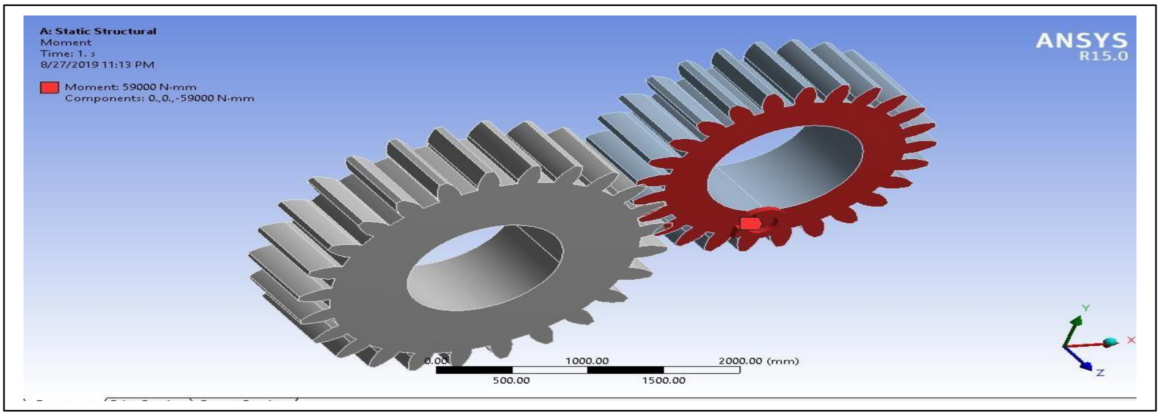


**Figure 6: Representation of Gear Moment**

## 3. Methodology and Tools

Following is the section explaining the methodology followed for this research.

### 3.1. Introduction to Pro-Engineer

The company PTC (Parametric Technology Corporation) made the modeling program Pro-Engineer, which is used all around the world. It uses the 3D features of CAD/CAM and seeks to cut down on the time it takes to make solid models by a lot. It makes it easy to see how different variables are related, and you can change the model at any time. The way this programme works is very similar to the actual production process. It starts with the chosen material and goes through a number of manufacturing methods, such as drilling, cutting, and turning. Pro-E has everything you need to make a 3D model of the part or assembly you want to build. Pro-E has a lot of features that let us make almost any kind of mechanical design. For instance, via numerous processes, a fan or a spring may be manufactured. Furthermore, it possesses the capability to assemble components after they have been constructed autonomously. In our research, we independently constructed two spur gears and subsequently utilized Pro-E to assemble them into the desired configuration.

### 3.2. Pro-Engineer Modeling

This software's operation is somewhat similar to the actual production process, which begins with the material of choice and then proceeds via several manufacturing procedures, such as drilling, cutting, and turning. Pro-E offers all the tools and features needed to create a 3D model of the specified part or assembly.

3.3. Basic Model

**Sketch:** The 2-D cross-section is designed for extrusion, sweeping or other similar processes.

**Part:** Solid model of desired geometry is created for further use of the analysis.

**Assembly:** After solid components are made, they are put together to form a single machine or mechanism. Basic modes are also used in the design of the spur gear's major components. Following this procedure, transferring the assembly to ANSYS for the intended analysis is simple.

The measurements of the stainless steel spur gear models that will be used for analysis in this report are listed below. Using a venire caliper, the measurements of both gear models were obtained from automotive workshop gears.

**Table 1: Dimensions of stainless steel spur gear model 1**

| Gear Type | Spur Gear |
|---|---|
| Module | 4 mm |
| Number of teeth | 25 |
| Pitch circle dia | 100 mm |
| Pressure angle | 20 deg |
| Addendum Circle dia | 108 mm |
| Dedendum Circle dia | 90 mm |
| Tooth thickness | 6.2 mm |
| Base circle dia | 94 mm |
| Thickness | 30 mm |
| Hole dia | 45 mm |



**Table 2: Dimensions of stainless steel spur gear model 2**

| Gear Type | Spur Gear |
|---|---|
| Module | 3 mm |

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| | |
|---|---|
| Number of teeth | 25 |
| Pitch circle dia | 80 mm |
| Pressure angle | 20 deg |
| Addendum Circle dia | 88 mm |
| Dedendum Circle dia | 70 mm |
| Tooth thickness | 6.2 mm |
| Base circle dia | 75 mm |
| Thickness | 30 mm |
| Hole dia | 45 mm |

## 3.4. Main Parts

**First Model of Spur Gear**

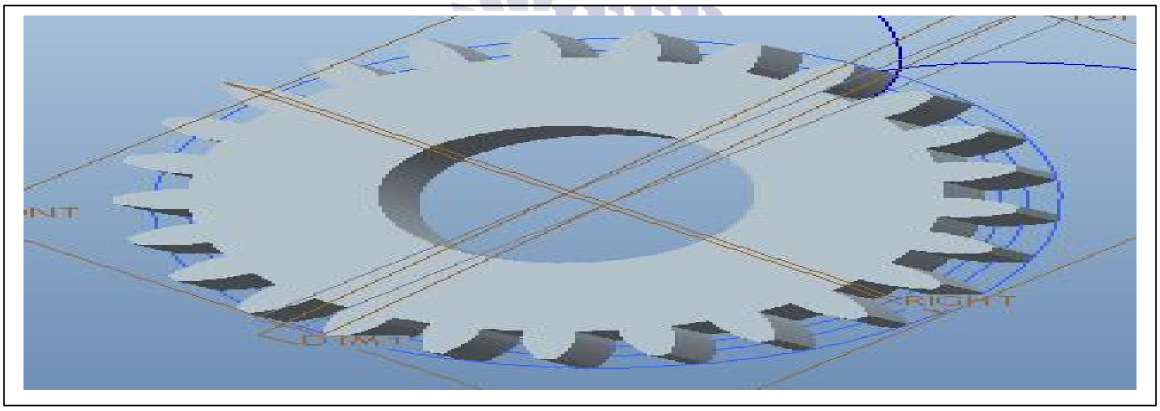


**Figure 7: 3D View of First Spur Gear**

**Second Model of Spur Gear**

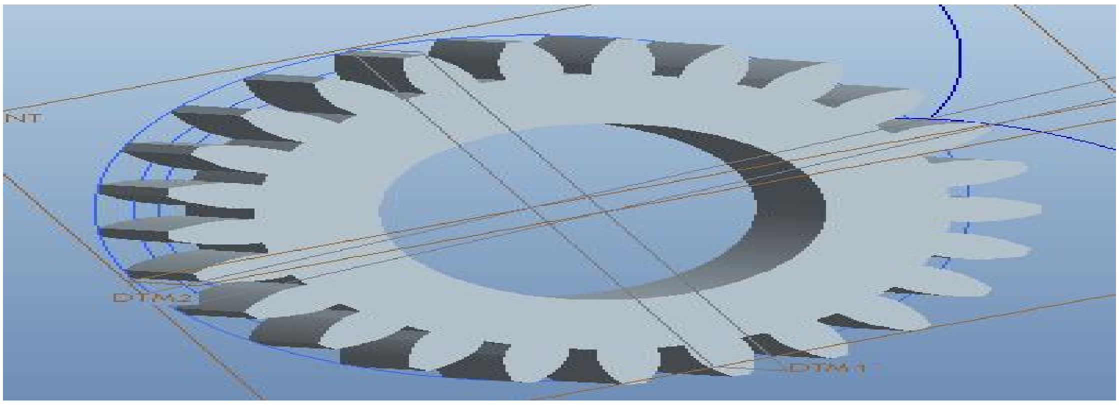


**Figure 8: 3D View of Second Spur Gear**

**Assembly**

This phase merely entails aligning the surfaces, axes, and planes of any geometry or part. The partially limited signal will show up on top if the components are not precisely aligned. If not, a fully constrained signal indicating that the components are correctly aligned will be shown. It is possible to verify the dimensional accuracy here. Any modifications made to a part's geometry will be automatically displayed in the assembled part following the modification.

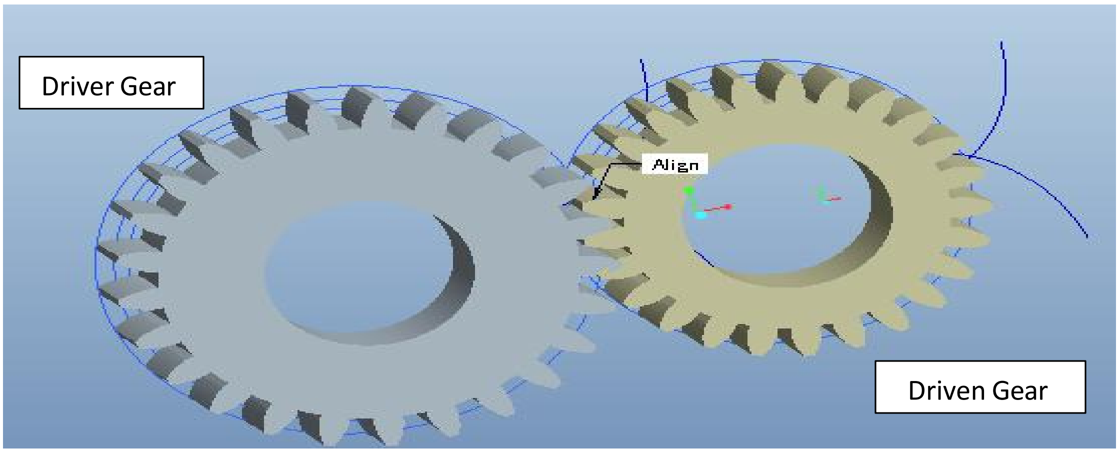


**Figure 9: Assembled view of spur gears**

## 3.5. Generation of other CAD formats

Designers frequently need to transition between programs. Since the portion created here is likely to be utilized in other program for additional research that requires other software to understand it, the format of any file is crucial. The fully completed 3D model of the gear in this study is in.asm format, which prevents the analysis program ANSYS, which is the next stage of the investigation, from reading it. In order to achieve this, it is transformed into the IGES (Initial Graphics Exchange Specification) format, a universal CAD file system that can be used with practically all design and simulation programs.

**Introduction to ANSYS**

The popular finite element analysis program ANSYS handles a lot of problems by decomposing large problems into smaller ones and then calculating each component separately. With ANSYS, we may conduct a wide range of analyses in a variety of scientific domains, including fluid flow, electrical circuits, mechanical forces, and heat transfer. The finite element analysis method, or FEM, is used to solve all of these. In addition to being helpful in computer-aided processes, this analytical approach is also beneficial economically since it allows one to quickly design and build products based on expected safety factors and product life.

This document will concentrate on contact stress analysis since the goal is being achieved in accordance with contact circumstances. Nearly every facet of engineering, whether static or dynamic, thermal or electrical, fluid, or anything else that needs to be investigated, can be examined using ANSYS's extensive array of analysis choices. All of them can be handled in the context of ANSYS. The ability to immediately modify geometry in ANSYS in the event of a geometry error or the necessity for a modification is a key feature of this program. However, it has certain drawbacks, such as a small number of editing possibilities.

### 3.6. Finite Element Method

Large issues are broken down into smaller, much easier-to-solve components using the finite element method (FEM), sometimes referred to as finite element analysis (FEA). Large engineering issues including fluid flow, heat transfer, and stress analysis are resolved numerically using this method. For analytical purposes, a geometry model is divided into extremely tiny, basic components known as elements that are connected by nodes.

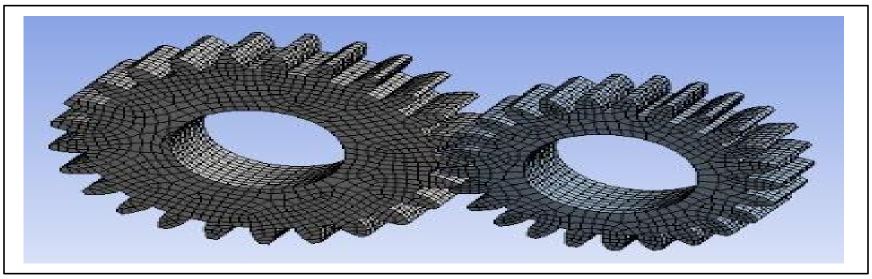

**Figure 10: Finite element meshing of gears**

## 4. Analysis & Results

### 4.1. Static Structural Analysis

The consequences of applying loads to physical structures and their constituent parts are then ascertained. The impact of constant loading conditions on structural stainless steel is computed using a static analysis. Stress, strain, forces, displacement, and fatigue in structures or components brought on by loads are all determined using static analysis. The location of the static structural analysis system is shown in this screenshot. The research schematics illustrate the fundamental elements that must be identified for the stress analysis.

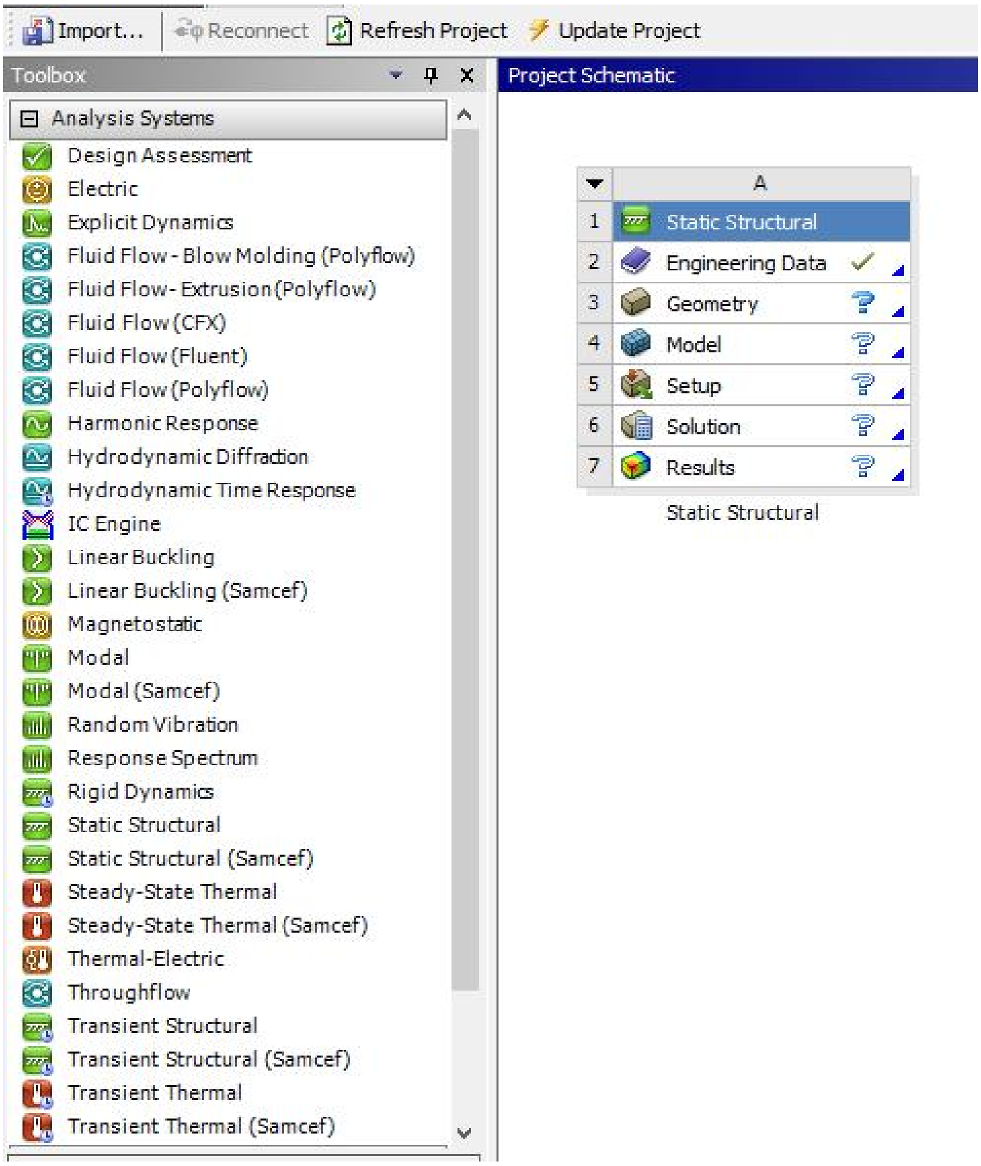


**Figure 11: Selection of static system**

**4.2. Basic Steps of Static Structural Analysis Static structural is completed after the accomplishment of following steps.**

**Modeling**

As stated in this section, the first step before moving on to the spur gear analysis geometry is to design the two stainless steel pieces (Gear) independently in Pro-E and then combine them to create a single geometry. After that, ANSYS imports this geometry for additional analysis.

**Engineering data**

Since our software addresses real-world issues, the data must be as authentic as possible. For this reason, the material is essential to any kind of study. We can choose the material of our part under observation from a variety of materials that are available to us through this ANSYS option. If the material is not accessible in the extensive list of materials, however, there is a way to specify the material and create the needed material.

**Geometry, Model and Meshing**

Importing the geometry is the next step after choosing the material. Although ANSYS itself can also be used to generate the geometry, most of the time it is preferable to use another 3D modeling program because of the limited possibilities available. The next crucial phase in the analytic process is meshing, which must be done carefully because it affects both the accuracy of the results and the time needed to obtain the intended outcome. The accuracy of the output rises with the number of nodes and elements. However, the time it takes to produce results also increases because of the amount of processing the software must perform. A meshing panel that allows for the setting of meshing preferences also shows when the meshing process begins. Tetrahedron is the element type employed in this study. Here, it is also possible to regulate the amount of nodes and elements. Since there are more nodes and elements in this instance, the meshing's relevance center is medium. There are 134406 elements and 616288 nodes created.

| Details of "Mesh" | |
|---|---|
| **Defaults** | |
| Physics Preference | Mechanical |
| Relevance | 0 |
| **Sizing** | |
| Use Advanced Size Function | On: Proximity and Curvature |
| Relevance Center | Medium |
| Initial Size Seed | Active Assembly |
| Smoothing | Medium |
| Transition | Fast |
| Span Angle Center | Coarse |
| Curvature Normal Angle | Default (70.3950 °) |
| Num Cells Across Gap | Default (3) |
| Min Size | Default (1.43920 mm) |
| Proximity Min Size | Default (1.43920 mm) |
| Max Face Size | Default (143.920 mm) |
| P Max Size | Default (287.840 mm) |
| Growth Rate | Default (1.850 ) |
| Minimum Edge Length | 50.4060 mm |
| **Inflation** | |
| **Patch Conforming Options** | |
| **Patch Independent Options** | |
| **Advanced** | |
| **Defeaturing** | |
| **Statistics** | |
| Nodes | 618288 |
| Elements | 134406 |
| Mesh Metric | None |

**Figure 12: Details of Mesh Table**

4.3. Setup and Solution Control

**Applying Boundary condition**

Setting boundary conditions is crucial for all types of analyses. It confines the issue to specific parameters. A solid model, whether it be a vertex, edge, face, body, or node, can be intellectually connected to a point in space (defined by location) via remote points. Applying a boundary condition from outside of your design is simple with remote points.

In this instance, the driven gear, which is positioned on two separate shafts, is larger than the driver gear.

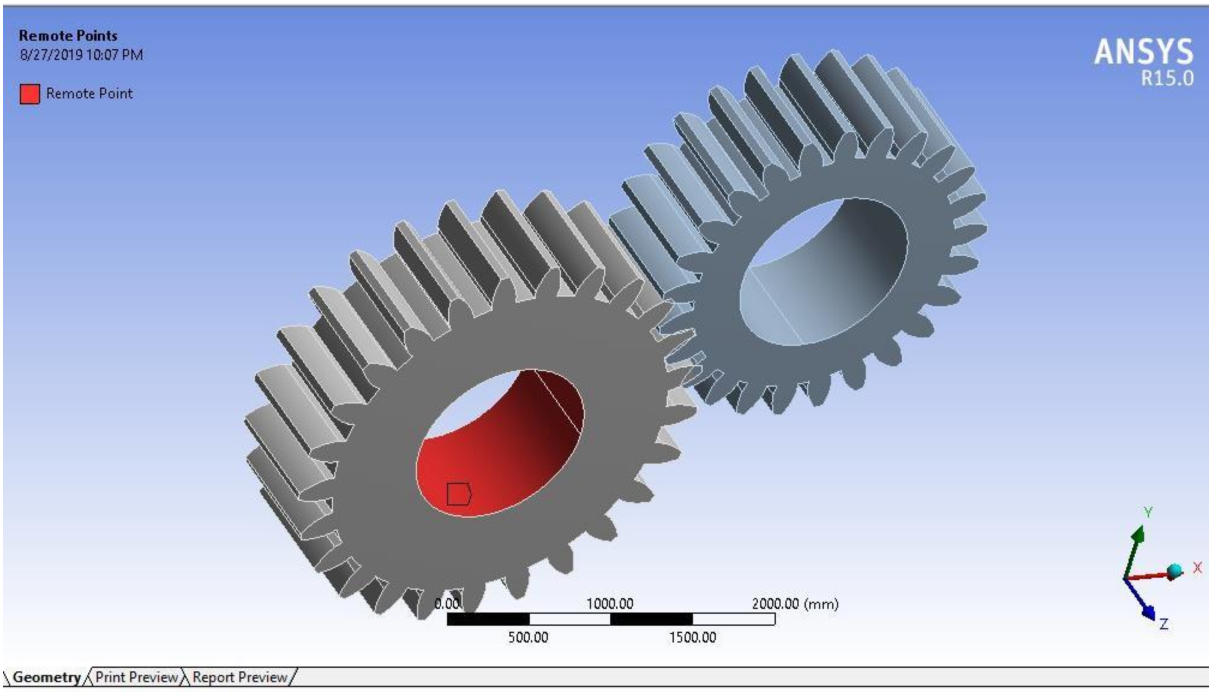


**Figure 13: Remote point**

As it can be seen that the smaller gear is driver gear which helps to drive the larger gear, the smaller gear is highlighted in red colour that gives an environment to rotate another gear.

### 4.4. Applying torque

Within the operating limits of the moment that the gear assembly can tolerate with ease, torque is applied to the driver gear of the assembly.

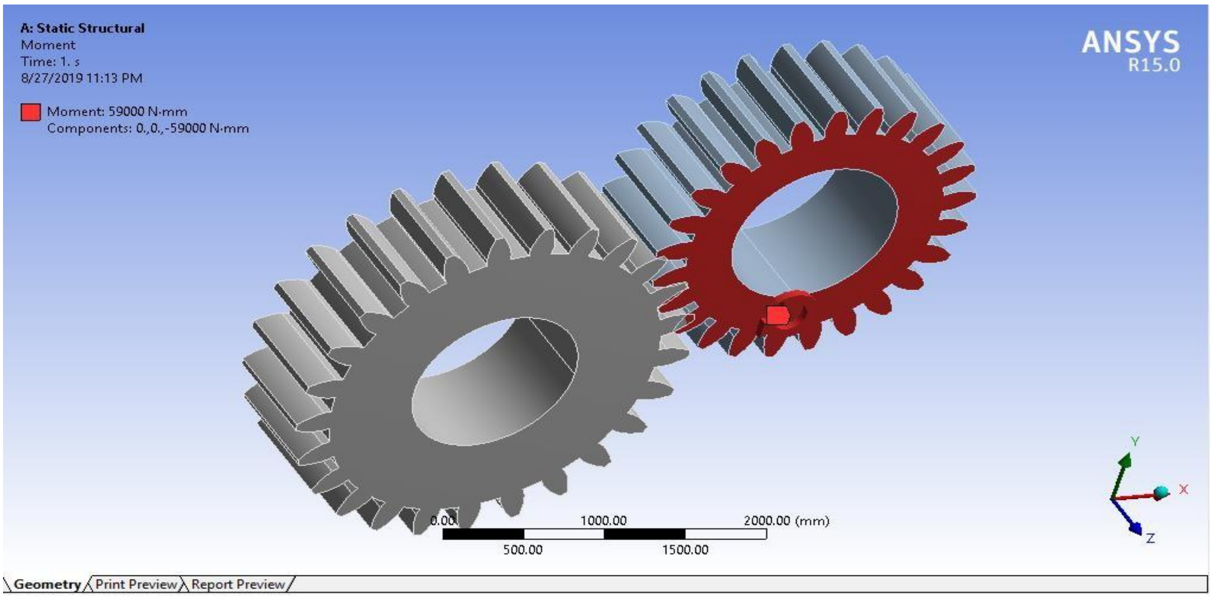

**Figure 14: Gear moment face selection**

Moment of magnitude 59000 N.mm is applied in z direction highlighted in red colour which is the maximum torque that this specific spur gear can withstand.

4.5. Result Phase

The solution phase, when we choose the necessary outcomes, begins once all the necessary data has been set to the desired settings. Under our predetermined boundary conditions, it is the last stage of the study that can be utilized to identify all of the following variables.

**Total Deformation**

We learned about the entire deformation that each gear point can withstand after looking at the figure.

This gear can withstand a minimum deformation of 2.1358 * 10-5 mm. After then, the geometry will start to break down, moving from red to blue. Because they can tolerate high load conditions, the blue portions are in the safe zone.

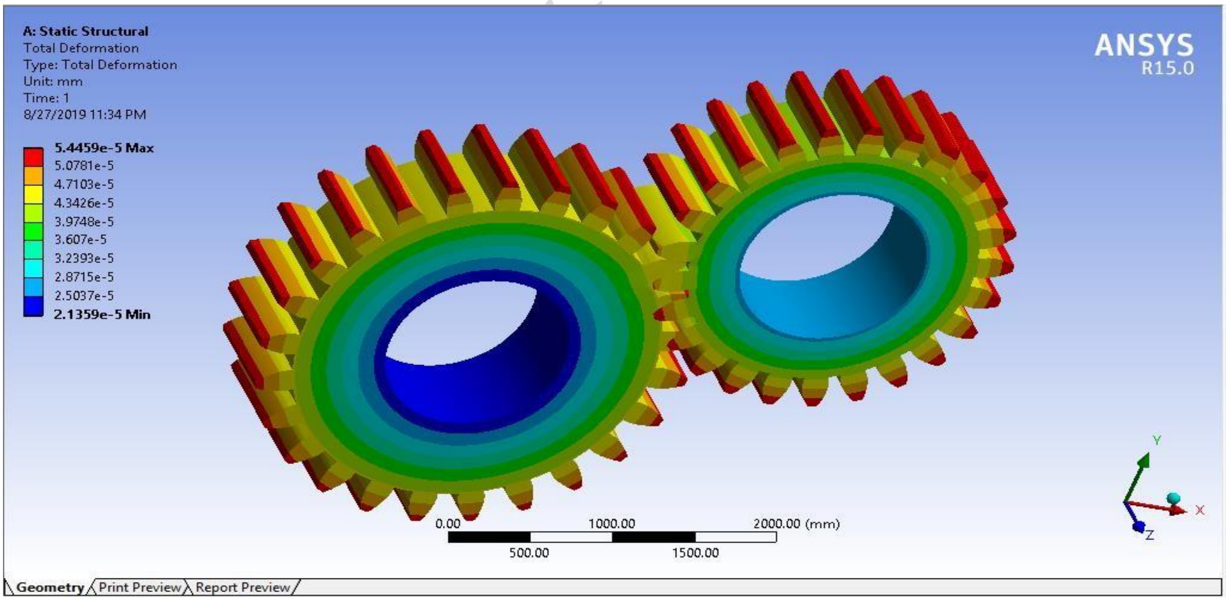


**Figure 15: Total deformation of Spur Gear**

**Equivalent Stress**

We learned about the concentration of tension on the teeth of both gears after looking at figure. The teeth are under the most tension when they are red, and the least amount of stress when they are blue. Since the greatest equivalent stress is

0.01052 MPa, the blue portion will endure an endless number of cycles.

## 5. Conclusion & Future Recommendations

**Following are the conclusion and recommendations as follows.**

### 5.1. Conclusion

By saving money and time on each research project, the software plays an important and cost-effective role, according to the study conducted for the literature review. Our study utilised ANSYS for stress analysis of gears, specifically examining multiple spur gears to evaluate the behaviour of stress distribution in relation to load, hence reducing costs and time. Our study concentrated on stainless steel gear because to its superior strength and corrosion-resistant characteristics, as evidenced by the data collected. FEA can help you figure out how likely it is that a thing will break, wear out, or work as it should. So, FEA may be very helpful and useful in the product development process since it can help you predict how a thing will work when it is used.

### 5.2. Ideas for Additional Work

The authors suggest that by resolving the issue rose in the first section, more research could be conducted on the same experimental site. Due to time constraints, we were unable to complete the work, however there are other performance metrics that might have been assessed and interpreted. Since stainless steel is more costly than other materials, cast iron and other materials are also suitable for consumers on a tight budget. For correct installation and upkeep, the instruction manual ought to be supplied.

## 6. Acknowledgement

The writers would want to thank everyone for their assistance, encouragement, and support. Above all, we are thankful to our Lord Almighty, who provided us the strength and wisdom necessary to finish this research. We really thank our supervisor for helping us with the research by offering advice, being patient, and sharing his knowledge and efforts while letting us work at our own pace.

## References

1. Karthick, M., Ramakrishna, C. S., Pugazhenthi, R., Gudadhe, N., Baskar, S., & Kumar, R. (2023). Contact stress analysis of xylon coated spur gear using ANSYS workbench. Materials Today: Proceedings.

2. Kapelevich, A. L. (2021). Direct gear design. CRC Press.
3. Jangra, D., Antil, P., Sidh, K. N., Pradeep, H., Rani, A., Kamboj, R., ... & Singh, J. (2025). Gear faults diagnosis: a comprehensive review of experimental and theoretical studies. Structural Health Monitoring, 14759217251324698.
4. Qin, W. J., & Guan, C. Y. (2014). An investigation of contact stresses and crack initiation in spur gears based on finite element dynamics analysis. International Journal of Mechanical Sciences, 83, 96-103.
5. Ziółkowski, M., & Dyl, T. (2020). Possible applications of additive manufacturing technologies in shipbuilding: A review. Machines, 8(4), 84.
6. Czerwinski, F. (2021). Current trends in automotive lightweighting strategies and materials. Materials, 14(21), 6631.
7. Nesbitt, E. (2019). Current engine noise and reduction technology. CEAS Aeronautical Journal, 10(1), 93-100.
8. Terrin, A., Dengo, C., & Meneghetti, G. (2017). Experimental analysis of contact fatigue damage in case hardened gears for off-highway axles. Engineering Failure Analysis, 76, 10-26.
9. Doll, N. P. (2015). Modeling thermomechanical behavior of polymer gears (Doctoral dissertation, University of Wisconsin--Madison).
10. Liu, Y., Gao, J., Yuan, Y., & Wang, S. (2024). Wind turbine gear reliability analysis considering dependent competing failure. Quality and Reliability Engineering International, 40(1), 644-663.
11. ROY, M. R. (2021). STRESS ANALYSIS ON SPUR GEAR IN MARINE APPLICATOINS BY FEM TECHNIQUE (Doctoral dissertation, Andhra University).
12. Jain, A., Agarwal, C., Saloda, M. A., & Khidiya, M. S. (2020). Contact stress and bending stress analysis of a pair of mating spur gears by theoretical and finite element analysis approach. International Research Journal of Engineering and Technology, 7, 90-97.
13. Muhammad, A., & Shanono, I. H. (2021). Contact stress analysis of a spur gear using Lewis and Hertz theory. Applied Research and Smart Technology (ARSTech), 2(2), 41-46.
14. Alam, J., Panda, S., & Dash, P. (2023). A comprehensive review on design and analysisof spur gears. International

Journal on Interactive Design and Manufacturing (IJIDeM), 17(3), 993-1019.

15. Eskezia, E., & Abebaw, M. (2022). Effect of Gear Materials on the Surface Contact Strength of Spur Gears. Proceedings of Engineering and Technology Innovation, 22, 50.
16. Hwang, S. C., Lee, J. H., Lee, D. H., Han, S. H., & Lee, K. H. (2013). Contact stress analysis for a pair of mating gears. Mathematical and Computer Modelling, 57(1-2), 40-49.
17. Pasha, M. S., Aslam, M. F., Hamza, M., Ali, N. M., Jabbar, I., Ahmed, S., & Abbasi, H. K. J. (2025). Sustainable construction: Performance analysis of concrete incorporating E-waste plastic aggregates and silica fume. Construction and Building Materials, 474, 141103.
18. Rashid, M., Haider, S., Rizwan, A., Naseer, M. W., Aslam, M. F., Hamza, M., ... & Tariq, M. A. U. R. (2025). Mitigating Soil Erosion in Arid Landscapes: Integrating RUSLE and Geospatial Analysis for Sustainable Land Management. Environmental Challenges, 101210.
19. Anjum, N., Ashraf, J., Ahmad, M., Ghani, U., Hamza, M., & Aziz, A. (2025). Numerical Investigation of Flow Dynamics in a Sharp-Crested Weir with Variable Geometry. Construction Technologies and Architecture, 17, 191-201.
20. Tufail, S. A., Jazaei, F., Bakhshaee, A., Ashiq, M. M., & Hamza, M. (2024, December). Assessment of microplastic contamination in biosolids from wastewater treatment plants and its implications for terrestrial environments. In AGU Fall Meeting Abstracts (Vol. 2024, No. 1086, pp. H33L-1086).
21. Khan, M. S., Tufail, M., & Mateeullah, M. (2018). Effects of waste glass powder on the geotechnical properties of loose subsoils. Civil Engineering Journal, 4(9), 2044-2051.
22. Khan, M. S., Khattak, A., Yaqoob, M. U. Z. A. M. I. L., & Alam, K. A. S. H. I. F. (2021). ``Strength and thermal conduction assessment of lightweight aromatic hydrocarbon waste polystyrol glass concrete,". Journal of Engineering Science and Technology, 16(2), 1082-1097
23. Shah, M. M., Yaqoob, M., Jibran, A. A., Rashid, A., Kundi, H., & Khan, M. S. (2020). Integrating heat repulsion and strength evaluation of cost-effective GLP concrete redeeming the cement

proportions utilizing thermocouples. Journal of Technology and Engineering Studies, 6(2), 6-40003.

24. KHATTAK, M. Y., & ALI, S. (2022). Evaluating the durability of recycled brick aggregates against sulfate attack. Journal of Engineering Science and Technology, 17(5), 3410-3423.
25. Ruiz-Ponce, G., Arjona, M. A., Hernandez, C., & Escarela-Perez, R. (2023). A review of magnetic gear technologies used in mechanical power transmission. Energies, 16(4), 1721.
26. Liou, J. J., & Rakuff, S. (2018). The development of worm drives. Power Transmission Engineering, 38-43.
27. Barathula, S., Kandasamy, R., Fok, P. J. Y., Wong, T. N., Leong, K. C., & Srinivasan, K. (2024). Heat load prediction in flow boiling using boiling-induced vibrations aided with machine learning. International Journal of Heat and Mass Transfer, 232, 125890.
28. Al Ali, M. (2024). Engineering Aspects of Metallic Design. In Fundamentals of Orthopedic Design with Non-parametric Optimization (pp. 7-52). Singapore: Springer Nature Singapore.