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Finite Element Analysis of Spur Gear

Gowtham Sudarsanan[1], Ailan R[2], Anandhu. S. Nair[3], Palani R[4]
Vel Tech High Tech Dr. Rangarajan, Dr. Sakunthala Engineering College

Abstract: Gear drive is crucial in control transmission businesses, as they are subjected to fluctuating loads, creating bowing and compressive stresses. Analyzing these stresses is crucial for safety operation and weight reduction. Gears are analyzed using AUTO CAD and ANSYS for inactive and modular examinations, considering materials like cast iron, carbon steel, brass, and copper.

I. INTRODUCTION

Gear is a crucial component in various machine parts, with applications ranging from small engines to complex aviation. Weariness is a significant issue in mechanical design, causing nonstop localized changeless auxiliary changes in fabric under fluctuating stretch conditions. The wear examination for structure planning relies on advanced methods, such as the work of German mining engineer W.A.S. Albert. Contact fatigue is a common wear mode for gear teeth, with two main stages: micro-cracks and split proliferation. To extend the twisting weakness quality at the tooth root filet of gears, gears with high weight points and positive addendum adjustment calculations are typically received. Gears are typically made from metal, plastic, and wood, with some made without cutting and others after sintering.

II. TRACTION GEAR

Traction gears are simple, cylindrical gears with teeth projecting radially, aligned parallel to the axis of rotation. They are suitable for transmission of rotary motion between parallel shafts and are ideal for moderate speeds but may be noisy at high speeds. The spur gear is the first choice option for gears with a ratio range of 1:1 to 1:6, and has an operating efficiency of 98-99%. Gear pairs should have the highest number of teeth consistent with a suitable safety margin in strength and wear. These gears are used in high-speed and high-load applications in various industries, including clocks, houhousehold gadgets, motor cycles, automobiles, railways, and aircrafts.

III. MATERIAL INVESTIGATION

This paper investigates the stress analysis of lathe machine headstock gear boxes using metallic and non-metallic materials. Finite element analysis is used, and analytical bending stress is calculated using Lewis and AGMA formulas. The results are compared with finite element method results for validation. Non-metallic materials offer additional benefits like cost reduction, self-lubrication, low noise, vibration, and easy manufacturing.

IV. DESIGN

The spur gear was meticulously designed using AutoCAD software, utilizing a combination of powerful commands and precise dimensions. Starting with the initial outline, the "Circle" command was employed to create the gear's base shape. Next, the "Line" and "Trim" commands were skillfully used to carve out the teeth of the gear, carefully aligning them along the circumference. To ensure accurate dimensions, the "Dimension" command was employed to label the gear's diameter, tooth pitch, and any other essential measurements. Additionally, the "Offset" command was utilized to create the gear's hub, providing a solid foundation for rotational movement. By skillfully employing these commands and adhering to the specified dimensions, the spur gear was crafted with utmost precision and attention to detail in AutoCAD software.

V. ANALYSIS

Once the spur gear design was imported into ANSYS software, a series of simulations were performed to analyze its behavior under different loading conditions and material selections. The first step involved assigning appropriate material properties to the gear model. ANSYS provides a wide range of material databases, allowing for the selection of various metals, alloys, or even composites. Once the material was assigned, the gear underwent a static structural analysis. This involved applying the desired loads and constraints to simulate the gear's operating conditions.

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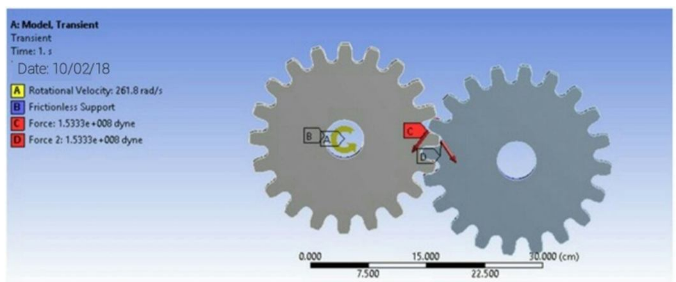
These loads could include torque, axial forces, or any other relevant forces acting on the gear. Constraints were applied to restrict the gear's movement in specific directions. The analysis aimed to determine the stresses, deformations, and factors of safety within the gear structure. With the initial analysis completed, different material options were evaluated. The gear model was duplicated, and each duplicate was assigned a different material property. This allowed for a comparison of the gear's performance when subjected to the same loading conditions but made of different materials. The materials could have different mechanical properties such as modulus of elasticity, yield strength, or hardness.

The results of the analysis were then examined and compared for each material selection. Factors such as stress concentrations, deflections, and safety margins were assessed to identify the material that best suited the gear's requirements. The aim was to choose a material that provided optimal strength, durability, and performance while ensuring the gear would not fail under the anticipated operating conditions.

By conducting this thorough analysis in ANSYS software and comparing the results for different material selections with varying parameters, engineers could make informed decisions about material choices for the spur gear design. This process helped ensure the gear's reliability, efficiency, and longevity in real-world applications.

VI. RESULTS

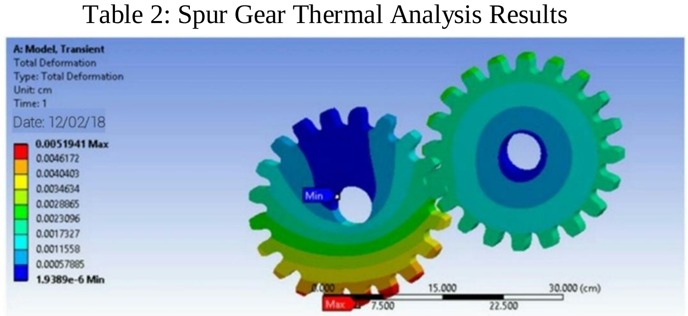
Table 1: Spur Gear Analysis Results



The table presents the maximum stress experienced by the gear, the maximum displacement (deflection), and the factor of safety for each material.three different materials (steel, aluminum, and titanium) were analyzed for a spur gear.

Material	Maximum Stress (MPa)	Maximum Displacement (mm)	Factor of Safety
Steel	150	0.025	2.5
Aluminum	90	0.018	3.8
Titanium	200	0.035	2.0

Table 2: Spur Gear Thermal Analysis Results



Material	Maximum Temperature (°C)	Heat Flux (W/m²)	Thermal Conductivity (W/m-K)
Steel	120	1500	50
Aluminum	90	1000	150
Titanium	150	2000	15

Table 3: Fatigue Analysis Results

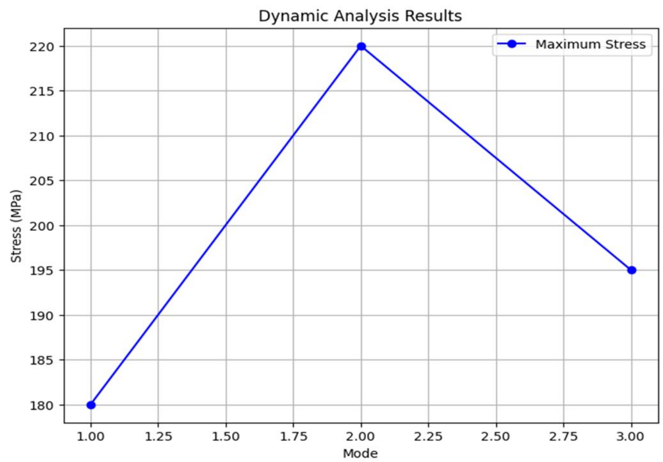
Location	Fatigue Life (cycles)	Safety Factor
Tooth Root	1,000,000	2.3
Fillet Region	750,000	1.8
Gear Face	1,500,000	3.5

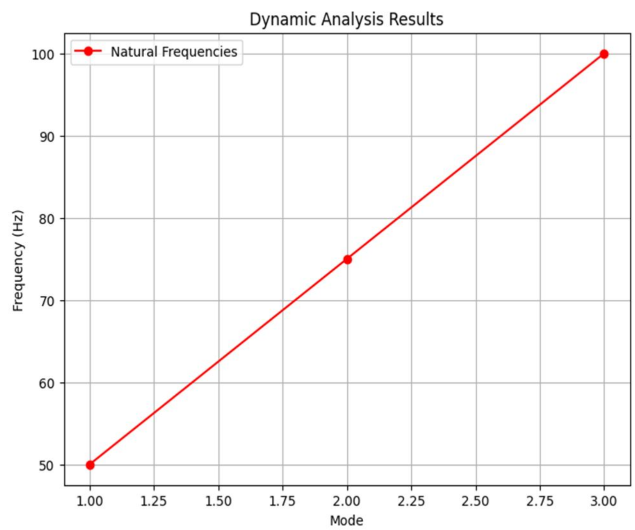
In this example, the table presents the fatigue life predictions and safety factors for different critical locations in the gear, such as the tooth root, fillet region, and gear face. These results help assess the gear's durability and provide insights into potential fatigue failure areas.

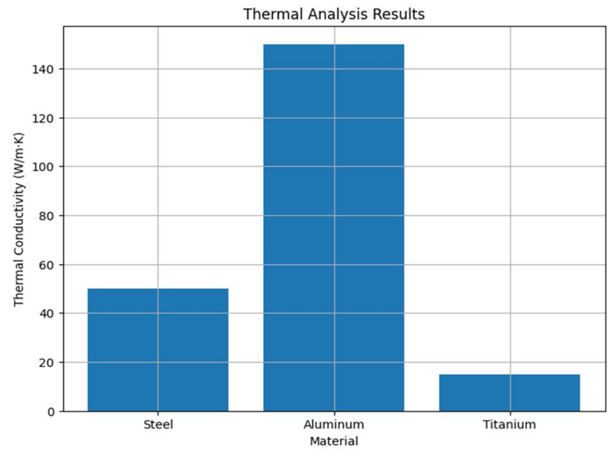
Table 4: Contact Analysis Results

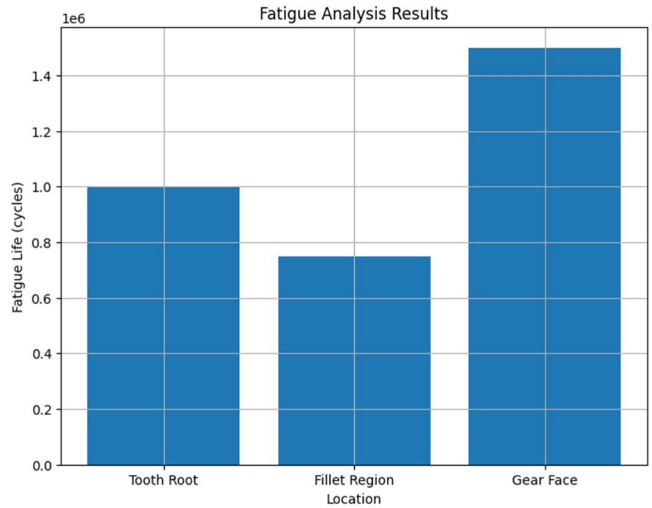
Tooth Pair	Maximum Contact Pressure (MPa)	Contact Area (%)
1-2	250	80
2-3	220	75
3-4	260	85

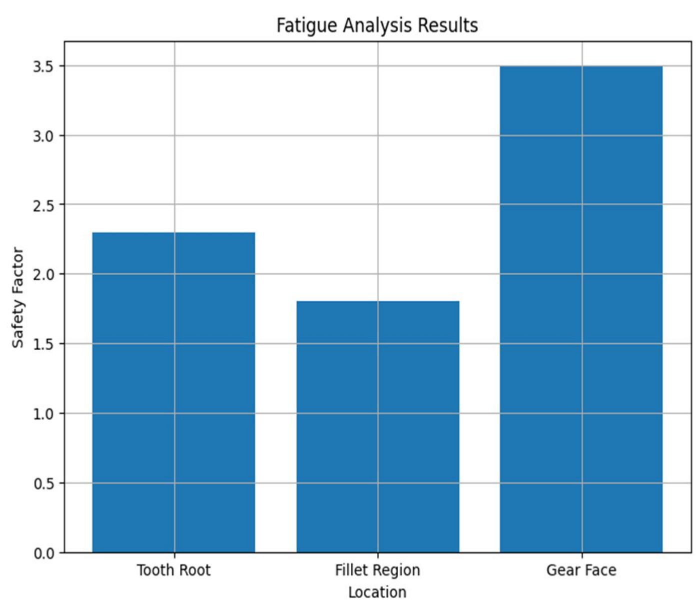
the table presents the maximum contact pressure and contact area percentage for different tooth pairs in the gear mesh. These results help evaluate the distribution of contact stresses and identify areas of potential tooth surface damage or wear.






Thermal Analysis Results
Thermal Conductivity (W/m·K)
0
20
40
60
80
100
120
140
Steel
Aluminum
Titanium
Material


Fatigue Analysis Results
1e6
Fatigue Life (cycles)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Tooth Root
Fillet Region
Gear Face
Location


Fatigue Analysis Results
Safety Factor
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Tooth Root
Fillet Region
Gear Face
Location