DESIGN AND ANALYSIS OF BEVEL GEAR

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Abstract— **The design and analysis of bevel gears are critical in ensuring the efficiency and longevity of mechanical systems that rely on power transmission. This study focuses on the design and structural analysis of bevel gears using ANSYS Workbench, employing stainless steel and nickel materials. The primary objective is to evaluate the performance of bevel gears under various loading conditions, considering material properties, geometric design, and operational stresses. The first step involves designing the bevel gears using appropriate geometric parameters in CAD software, followed by material selection. Stainless steel and nickel alloys are chosen for their excellent strength, corrosion resistance, and durability. Finite Element Analysis (FEA) is performed using ANSYS Workbench to assess key performance indicators such as stress distribution, deformation, and safety factors for both materials. The results are compared to identify which material offers superior performance in terms of load-bearing capacity, durability, and efficiency. The study highlights the critical factors influencing gear performance and provides insights into the optimization of bevel gear designs for various industrial applications.**

Keywords: 3D Modelling, Finite Element Analysis (FEA), Solid works, Bevel gear

I. INTRODUCTION

A bevel gear is a toothed rotating component that transfers mechanical energy or shaft power between shafts that intersect at an angle, including perpendicular. It changes the axis of rotation and can modify the torque, either increasing or decreasing it, while inversely affecting the angular speed.

Fig: 1. Straight bevel gear

Types of bevel gears:

Straight bevel gear: A straight bevel gear is the most basic type of bevel gear, featuring teeth arranged in a straight line that intersects at the gear's axis when extended.

Sprial bevel gear: A spiral bevel gear is a more complex type of bevel gear, distinguished by its curved and then oblique teeth. Unlike the straight teeth of bevel gears, the spiral tooth orientation provides more overlap between teeth, leading to gradual engagement and disengagement.

Zerol bevel gear: Zerol bevel gears are a variation of straight bevel gears, developed by Gleason Works. Unlike straight bevel gears, Zerol bevel gears feature teeth that are curved along their length.

Hypoid bevel gear: A hypoid bevel gear is a specialized type of bevel gear where the shafts are neither intersecting nor parallel. The offset between the two gear axes is referred to as the "offset." The teeth of hypoid bevel gears are helical, similar to those in spiral bevel gears

Applications:

- Hand drills
- Differential mechanisms in vehicles
- Printing presses

II. LITERATURE REVIEW

1. Prakash and Krishnamurthy (2018) used ANSYS Workbench to perform a stress analysis on bevel gears, revealing that varying material properties and loading conditions have a significant impact on the stress distribution.

2. Shen et al. (2020) employed ANSYS Workbench for the optimization of bevel gear tooth geometry,

revealing that a modified tooth profile resulted in a more uniform load distribution and reduced the peak stresses on the tooth surface.

3. Khan et al. (2019) used vibration analysis in ANSYS Workbench to evaluate the dynamic stability of bevel gears, helping to reduce the risk of gear resonance.

4. Lee et al. (2015) conducted a detailed case study using ANSYS Workbench to design and analyze bevel gears for a high-speed automotive transmission. The study involved stress, thermal, and dynamic analysis to ensure the gears could withstand the operating conditions without failure.

III. METHODLOGY

CAD Modelling in Solidworks:

By using solidworks we design a bevel gear model

Table-1 Design Parameters:

variables	values
Outer diameter	78 [mm]
Inner diameter	65 [mm]
Pitch diameter`	72 [mm]
Shaft diameter	35 [mm]
Shaft length	25 [mm]
Bore diameter	20 [mm]
No of teeth	30
angle	90
Thickness of teeth	2 [mm]

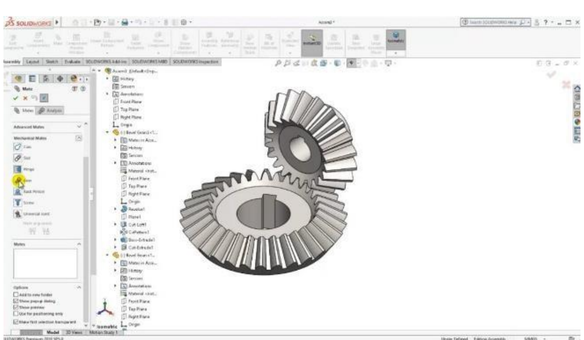


Fig 2. Bevel gear design

Analysis on ANSYS WORKBENCH:

1. Setup the Simulation in ANSYS Workbench

- **Launch ANSYS Workbench:**
  - Open ANSYS Workbench and drag the "Static Structural" system into the project schematic.
- **Import the Geometry:**
  - Double-click the Geometry cell and import your bevel gear model.

2. Material Properties

- **Assign Material Properties:**
  - Define the material properties for the bevel gear. We are taking stainless steel' and nickel materials are used
  - Include properties like Young's modulus, Poisson's ratio, density, and yield strength.

Table-2 material properties

3.

Properties	Stainless steel	nickel
Young's Modulus	1.98e+05 Mpa	2.1e+05 Mpa
Density	8.055e-06 kg/mm^3	8.9e-06 kg/mm^3
Poisson's ratio	0.29	0.31

Meshing

- **Generate the Mesh:**
  - Apply an appropriate mesh for the bevel gear. The mesh should be fine enough in areas of high stress concentration, such as the tooth roots and contact areas, to ensure accurate results.
  - You can use "Tetrahedral" elements, depending on the complexity of the geometry.

4. Boundary Conditions

- **Define Boundary Conditions:**
    - Fixed Support: Apply fixed boundary conditions at the outer surface of the gear.
    - Contact Definitions: Set up the contact between the bevel gear and its counterpart (gear pair or shaft). Define the contact as "frictionless support"
    - Apply the moment on bevel gear teeth where it

5. Load Applications

- Apply force and momentum on the teeth of bevel gear

6. Solution Setup

- Choose static structural for simple cases and also choose transient thermal for finding heat flux

7. Solving

- Run the simulation to analyse stress, deformation, strain and total heat flux.

Analysis Results:

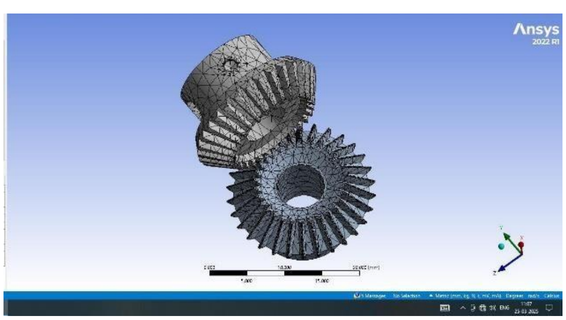
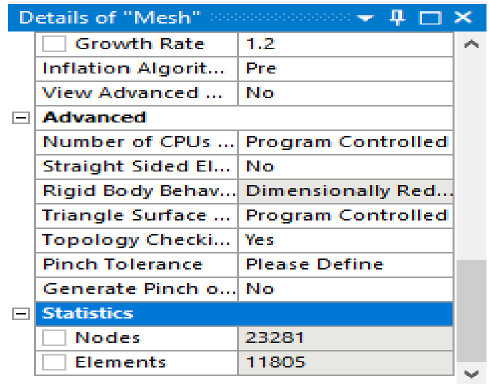


Fig-3 Mesh of the Geometry



Details of "Mesh"

Growth Rate	1.2
Inflation Algorit...	Pre
View Advanced ...	No
Advanced	
Number of CPUs ...	Program Controlled
Straight Sided El...	No
Rigid Body Behav...	Dimensionally Red...
Triangle Surface ...	Program Controlled
Topology Checki...	Yes
Pinch Tolerance	Please Define
Generate Pinch o...	No
Statistics	
Nodes	23281
Elements	11805

Fig-4 Mesh detials

RESULTS AND DISCUSSIONS

Total Deformation: Both materials exhibited elastic deformation under the applied torque. The deformation was higher for stainless steel, indicating that it may be more susceptible to permanent deformation under high loads, while nickel alloy showed less deformation.

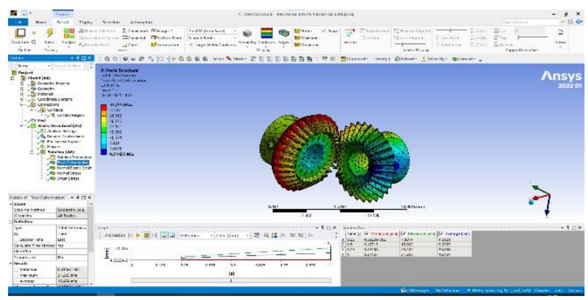


Fig-5 Total Deformation

Equivalent Stress: The maximum stress regions of the bevel gear were identified. Stainless steel showed a lower stress distribution under similar loading conditions compared to nickel alloy. This suggests that stainless steel gears can handle a lower load but may wear out more quickly compared to nickel alloy gears, which are better suited for high-stress and high-temperature conditions.

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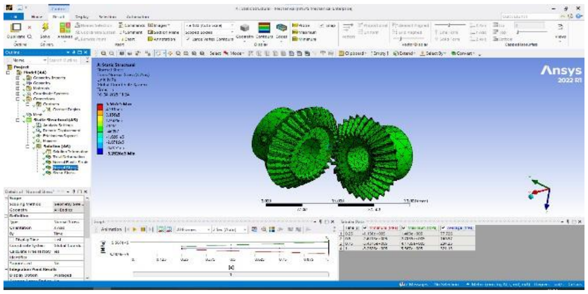

Fig-6 Stress Distribution

Equivalent Elastic Strain: The equivalent strain observed in stainless steel was found to be slightly higher than that of nickel material.

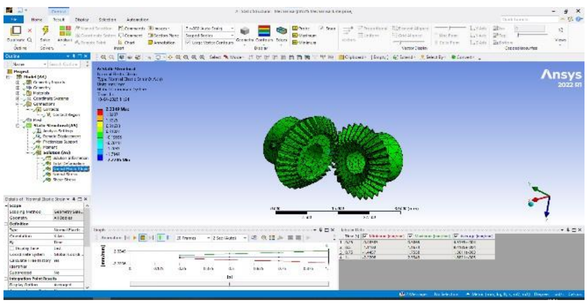

Fig- 7 Equivalent stress

Total Heat Flux: The total heat flux observed in stainless steel was found to be higher than that of nickel material

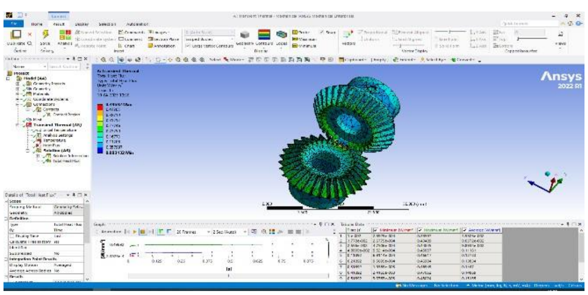

Fig-8 Total heat flux

CONCLUSION

A structural and modal analysis of straight bevel gear is conducted using ANSYS software

1. The total deformation observed in stainless steel is comparatively higher than nickel material.
2. The equivalent stress observed in stainless steel was found to be higher than that of nickel material.
3. The total heat flux observed in stainless steel was found to be higher than that of nickel material.

FUTURE WORK

1. Investigate the effects of gear geometry and loading conditions on the behaviour of bevel gears.

2. The effects of material properties and geometric parameters on the behavior of bevel gears should be further investigated.

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