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Structural and Modal Analysis of Bevel Gear Used in Compressor

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ABSTRACT:

A compressor is a mechanical device that increases the pressure of a gas by reducing its volume. Compression of a gas naturally produces heat. Gear is a machine element used to transmit motion and power between rotating shafts by means of progressive engagement of projections called teeth. Generally gear transmits motion or power between rotating shafts when the centre between two shafts is comparatively low. Bevel gears are mechanical devices used for transmitting mechanical power and motion. These gears are widely used for transmitting power and motion between nonparallel axes and are designed to transmit motion between intersecting axes, generally at right angles. Materials used range from steel, cast iron, nickel chromium molybdenum steel, stainless steel, phosphor bronze. The aim of the project is to design a bevel gear used in a compressor by using the empirical formulas for nickel chromium molybdenum alloy steel. A 2D drawing is drafted from the calculations and the bevel gear is modeled in 3D modeling software Pro/Engineer. To validate the strength of bevel gear, Structural and Modal analysis are to be done on the gear. In structural analysis, ultimate stress limit for the design is found and in modal analysis, mode shapes of the gear for number of modes can be analyzed. The analysis is done for two materials nickel chromium molybdenum alloy steel and phosphor bronze to verify the best material for the bevel gear. Pro/ENGINEER is the standard in 3D product design, featuring industryleading productivity tools that promote best practices in design. ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of userdesignated size) called elements.

Key Points: Auto cad, Pro-E, Ansys, Gear terminology

INTRODUCTION TO GEARS:

A gear is a rotating machine part having cut *teeth*, or *cogs*, which *mesh* with another toothed part in order to transmit torque. Two or more gears working in tandem are called a *transmission* and can produce a mechanical advantage through a gear ratio and thus may be considered a simple machine. Geared devices can change the speed, magnitude, and direction of a power source. The most common situation is for a gear to mesh with another gear, however a gear can also mesh a non-rotating toothed part, called a rack, thereby producing translation instead of rotation. The gears in a transmission are analogous to the wheels in a pulley. An advantage of gears is that the teeth of a gear prevent slipping.

General Nomenclature:





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Rotational frequency, n

Measured in rotation over time, such as RPM.

Angular frequency, ω

Measured in radians per second. $1RPM = \pi / 30$ rad/second

Number of teeth, N

How many teeth a gear has, an integer. In the case of worms, it is the number of thread starts that the worm has.

Gear, wheel

The larger of two interacting gears.

Pinion

The smaller of two interacting gears.

DIFFERENT MODULES IN PRO/ENGINEER:

- PART DESIGN
- > ASSEMBLY
- > DRAWING
- > SHEETMETAL

MODEL OF BEVEL GEAR

Sketch



I. Structural Analysis of Bevel Gear using Nickel Chromium Molybdenum Steel

Imported Model from Pro/Engineer



Element Type: Solid 20 node 95 Material Properties: Youngs Modulus (EX) 210000N/mm² Poissons Ratio (PRXY) : 0.3 Density

:

0.00000803 kg/mm³

Meshed Model



Loads

 $Pressure - 0.209 N/mm^2$



Solution

Solution – Solve – Current LS – ok

Post Processor

General Post Processor – Plot Results – Contour Plot - Nodal Solution – DOF Solution – Displacement Vector Sum



General Post Processor – Plot Results – Contour Plot – Nodal Solution – Stress – Von Mises Stress



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Structural Analysis of Bevel Gear using Phosphor Bronze

Imported Model from Pro/Engineer



Element Type: Solid 20 node 95 Material Properties: Youngs Modulus (EX) 137000N/mm²

> Poissons Ratio (PRXY) : 0.346 Density :0.00000925 kg/mm³

Meshed Model



Loads

 $Pressure - 0.209 N/mm^2$



Solution

 $Solution-Solve-Current\ LS-ok$

Post Processor

General Post Processor – Plot Results – Contour Plot - Nodal Solution – DOF Solution – Displacement Vector Sum



General Post Processor – Plot Results – Contour Plot – Nodal Solution – Stress – Von Mises Stress



II. MODAL ANALYSIS OF BEVEL GEAR USING NICKEL CHROMIUM MOLYBDENUM STEEL

Imported Model from Pro/Engineer



Element Type: Solid 20 node 95 Material Properties: Youngs Modulus (EX) 210000N/mm²

Poissons Ratio (PRXY) : 0.3

Density

 $:0.00000803 \text{ kg/mm}^3$

Meshed Model



Loads Pressure – 0.209N/mm²

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Main menu>Preprocessor>Loads>Analysis Type>

New Analysis> Select Modal>

Click> OK Main menu>Preprocessor>Loads>Analysis Type>

Analysis Options>

No. Of Modes to Extract: 5 Click> OK

Main menu>Solution>Solve>Current Ls>Ok

Results:

Main menu>General Postproc>Read Results> First Set Plot result>Deformed Shape> Def+ Undeform > Click> OK



Main menu>General Postproc>Read Results> Next Set

Plot result>Deformed Shape> Def+ Undeform > Click> OK



Main menu>General Postproc>Read Results> Next Set

Plot result>Deformed Shape> Def+ Undeform > Click> OK



Main menu>General Postproc>Read Results> Next Set

Plot result>Deformed Shape> Def+ Undeform > Click> OK



Main menu>General Postproc>Read Results> Next Set

Plot result>Deformed Shape> Def+ Undeform > Click> OK



III. MODAL ANALYSIS OF BEVEL GEAR USING PHOSPOR BRONZE

Imported Model from Pro/Engineer



Element Type: Solid 20 node 95 Material Properties: Youngs Modulus (EX) 137000N/mm²

Poissons Ratio (PRXY) : 0.346

:



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Density :0.00000925 kg/mm³

Meshed Model



Loads

 $Pressure - 0.209 N/mm^2$



Main menu>Preprocessor>Loads>Analysis Type>

New Analysis> Select Modal> Click> OK Main menu>Preprocessor>Loads>Analysis Type> Analysis Options> No. Of Modes to Extract: 5 Click> OK Main menu>Solution>Solve>Current Ls>Ok

Results

Main menu>General Postproc>Read Results> First Set Plot result>Deformed Shape> Def+ Undeform > Click> OK



Main menu>General Postproc>Read Results> Next Set

Plot result>Deformed Shape> Def+ Undeform > Click> OK



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Plot result>Deformed Shape> Def+ Undeform > Click> OK



Definitions of Results obtained:

Displacement - A vector quantity which refers to the distance which an object has moved in a given direction. It is measured as the length of a straight line between the initial and final positions of a body. Von Mises Stress - The Von Mises criteria is a formula for combining these 3 stresses into an equivalent stress,



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which is then compared to the tensile stress of the material.

IV. **RESULTS**:

As per the analysis images

•	Displacement (mm)	Von Mises Stress (N/mm ²)
 Nickel 	0.717e ⁻³	0.416013
Chromium		
Molybdenum		
Steel		
 Phosphor 	0.001045	0.411
Bronze		

The yield stress for Nickel Chromium Molybdenum Steel is 360.6Mpa. The yield stress for Phosphor Bronze is 69Mpa.

V. CONCLUSION:

Bevel gears are mechanical devices used for transmitting mechanical power and motion. In our project, we have designed and modeled a bevel gear used in a compressor. Modeling is done using Pro/Engineer. We have performed Structural and modal analysis using Nickel Chromium Molybdenum Steel and Phosphor Bronze. From the structural analysis, by observing stress values for both the materials, both the values are less than their respective yield stresses. So we can decide that our design is safe. Modal analysis is done on the bevel gear to analyze the mode shapes of the gear for 5 number of modes. From the analysis results, the stress values for both the materials are same. But the displacement value for Nickel Chromium Molybdenum Steel is less than that of Phosphor Bronze. So we conclude that for our designed bevel gear, the better material is Nickel Chromium Molybdenum Steel.

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