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Design and Contact Stress Analysis of a Straight Bevel Gear

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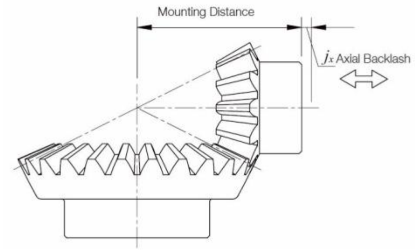
ABSTRACT

Gears are an integral and necessary component in our day to day lives. They are present in the satellites we communicate with, automobiles and bicycles we travel with. Gears have been around for hundreds of years and their shapes, sizes, and uses are limitless. For the vast majority of our history gears have been understood only functionally. That is to say, the way they transmit power and the size they need to be to transmit that power have been well known for many years. It was not until recently that humans began to use mathematics and engineering to more accurately and safely design these gears. The thesis aims to develop a procedure for the creating of geometry and analysis of straight bevel gears. In bevel gear will have a tangential load, radial load and axial load due to the speed and torque .This will be a transient phenomenon and will need careful stress analysis for determining life of the gear. In gear design, the Mechanism will be more Challenging as it should transmit high torque. All gears are not to be used for such high torque applications due to their low capacity and strength. Bevel gears are used in differential drives, which can transmit power to two axles spinning at different speeds, such as those on a cornering automobile, hand drill, to redirect the shaft from the horizontal gas turbine engine to the vertical rotor. In this paper a comparison between Lewis equation and Ansys workbench is done.

The main objective of the project is to design Straight bevel gear with proper dimensions and analysis is carried out to determine the critical stresses and deformations. In this project we assign different materials to find out the better material for bevel gear. The design of bevel gear is done in solid works. And analysis is carried out in ANSYS.

1. INTRODUCTION

A gear is a mechanical device often used in transmission systems that allows rotational force to be transferred to another gear or device. The gear teeth, or cogs, allow force to be fully transmitted without slippage and depending on their configuration, can transmit forces at different speeds, torques, and even in a different direction. Throughout the mechanical industry, many types of gears exist with each type of gear possessing specific benefits for its intended applications. Bevel gears are widely used because of their suitability towards transferring power between nonparallel shafts at almost any angle or speed. Spiral bevel gears have curved and sloped gear teeth in relation to the surface of the pitch cone. As a result, an oblique surface is formed during gear mesh which allows contact to begin at one end of the tooth (toe) and smoothly progress to the other end of the tooth (heel), as shown below in Figure 1.1 Spiral bevel gears, in comparison to straight or zero bevel gears, have additional overlapping tooth action which creates a smoother gear mesh. This smooth transmission of power along the gear teeth helps to reduce noise and vibration that increases exponentially at higher speeds. Therefore, the ability of a spiral bevel gear to change the direction of the mechanical load, coupled with their ability to aid in noise and vibration reduction, make them a prime candidate for use in the helicopter industry.



2. LITERATURE REVIEW

Ratnadeepsinh M. Jadeja, Dipeshkumar M. Chauhan, Jignesh D. Lakhani have done on bending stress analysis of bevel gears which shows that Gears are an integral and necessary component in our day to day lives. They are present in the satellites we communicate with, automobiles and bicycles we travel with. Gears have been around for hundreds of years and their shapes, sizes, and uses are limitless. For the vast majority of our history gears have been understood only functionally. That is to say, the way they transmit power and the size they need to be to transmit that power have been well known for many years. It was not until recently that humans began to use mathematics and engineering to more accurately and safely design these gears. Bevel gears are widely used because of their suitability towards transferring power between nonparallel shafts at almost any angle or speed. The American Gear Manufacturing Association (AGMA) has developed standards for the design, analysis, and manufacture of bevel gears. The bending stress equation for bevel gear teeth is obtained from the Lewis bending stress equation for a beam and bending stress value derive for the spiral bevel gear, straight teeth bevel gear and zerol bevel gear.

Abhijeet .V. Patil , V. R. Gambhir, P. J. Patil have done on Analysis of bending strength of bevel gear by FEM which shows that In bevel gear will have a tangential load, radial load and axial load due to the speed and torque .This will be atransient phenomenon and will need careful stress analysis for determining life of the gear. In gear design, the Mechanism will be more Challenging as it should transmit high torque. All gears are not to be used for such high torque applications due to their low capacity and strength. Bevel gears are used in differential drives, which can transmit power to two axles spinning at different speeds, such as those on a cornering automobile, hand drill, to redirect the shaft from the horizontal gas turbine engine to the vertical rotor. In this paper a comparison between Lewis equation and Ansys workbench is done.

3.MODELING PROCEDURE FOR BEVEL GEAR

3.1 Design Procedure Of Pinon Gear:

Modelling Procedure For Pinon Gear 1:

Software used: Solid Works 2014

SNo	Geometry Name	Gear 1	Gear 2
1	No. of teeth	20	30
2	RPM	10000rpm	10000 rpm
3	Rotational velocity	200 radian per sec	200 radian per sec
4	Diametric pitch	12.25 mm	20 mm
5	Addendum	200 mm	300 mm
6	Dedendum	160 mm	258 mm
7	Face width	6.67 mm	7.104 mm
8	Diameter	21 mm	31 mm
9	Material type	SAE 9310	SAE 9310

Design Inputs Of Bevel Gear Table-1

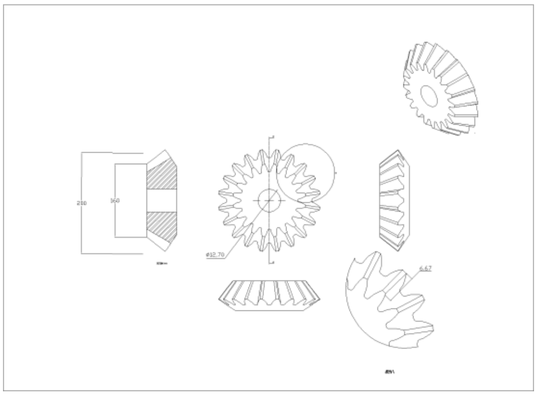


fig. 3. Modeling Procedure For Pinion Gear 1:

Steps: Double click on Solid works 2014 → new → part →

1. Select the Sketcher→ Draw the profile as per dimensions→ click on Exit sketch after complete of Profile→ Feature → click revolved Boss/Base 0 to 360.

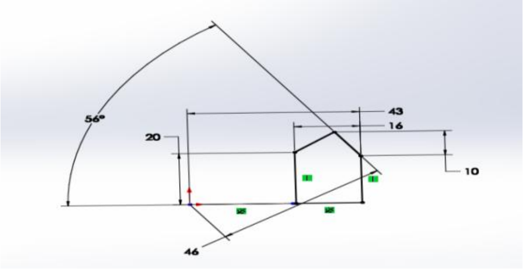


Fig 3.1 2D Drawing of Pinon Gear

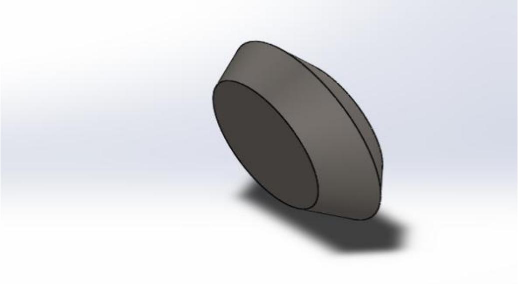
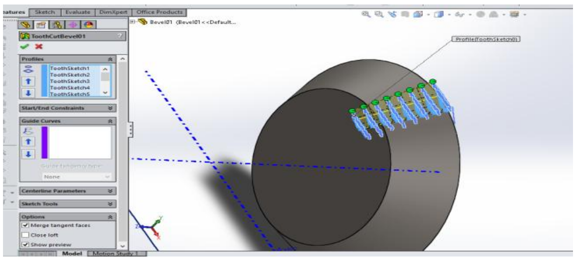


Fig 3.2 3D Model of Pinon Gear

2. Go to Reference Planes/points/lines→ Draw the profile as per dimensions→ Lofted Cut Select



ToothSketch1
ToothSketch2
ToothSketch3
ToothSketch4
ToothSketch5

None

☑ Merge tangent faces
☐ Close loft
☑ Show preview

Fig 3.3 Teeth Generation process of Pinon Gear

3. Select Circular Pattern→Select Feature of Groove cut→Make Pattern

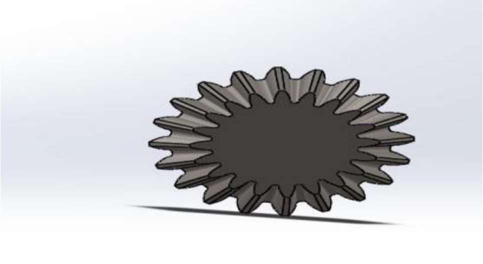


Fig 3.4 3D Model of Pinon Gear

4. Select Sketcher→Make Profile as per below→Select Extruded Cut

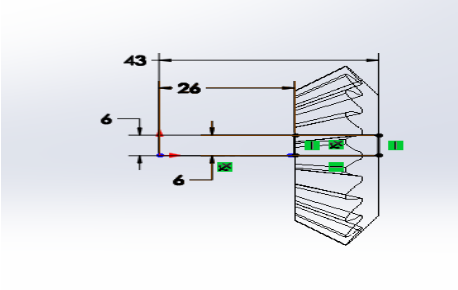


Fig 3.5 2D Model of Pinon Gear

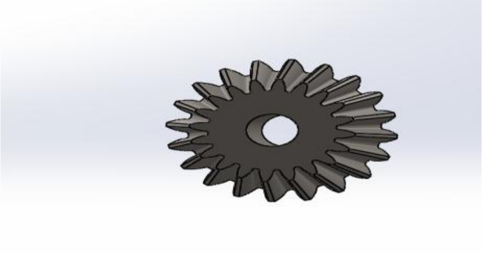


Fig 3.6 Final 3D Model of Pinon Gear

5.2 Design Procedure Of Driven Gear

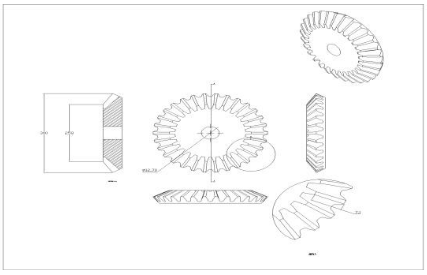


Fig.3.7.2D Drawing of Driven Gear

3.2 Modelling Procedure Bevel Gear 2:

Software used: Solid Works 2014

Steps:

Double click on Solid works 2014 → new → part →

1. Select the Sketcher→ Draw the profile as per dimensions→ click on Exit sketch after complete of Profile→ Feature → click revolved Boss/Base 0 to 360.

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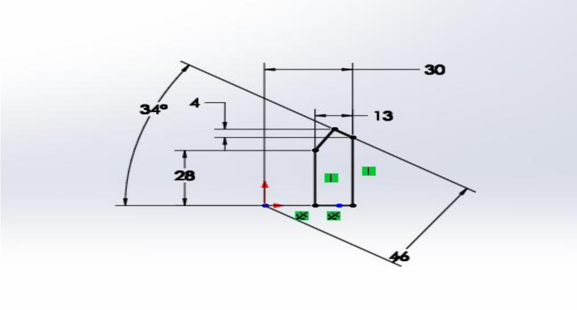


Fig 3.8 2D Drawing of Driven Gear

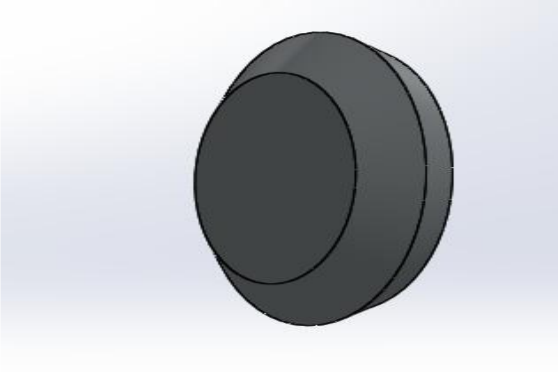


Fig 3.9 3D Model of Driven Gear

2. Go to Reference Planes/points/lines→ Draw the profile as per dimensions→ Lofted Cut Select final output

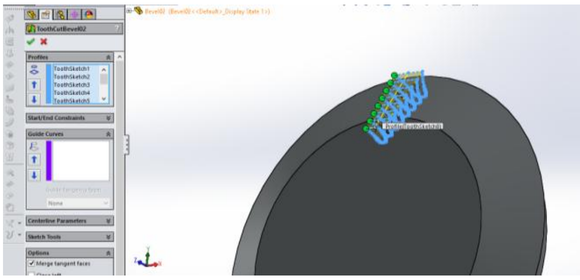


Fig 3.10 Teeth Generation process of Driven Gear

3. Select Circular Pattern→Select Feature of Groove cut→Make Pattern

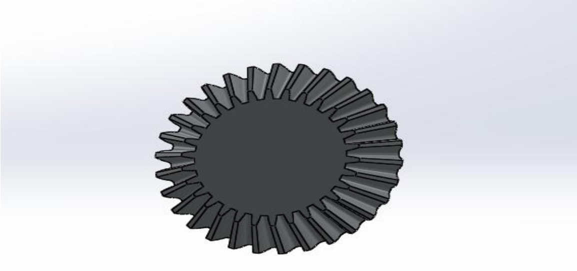


Fig 3.11 3D Model of Driven Gear

4. . Select Sketcher→Make Profile as per below→Select Extruded Cut

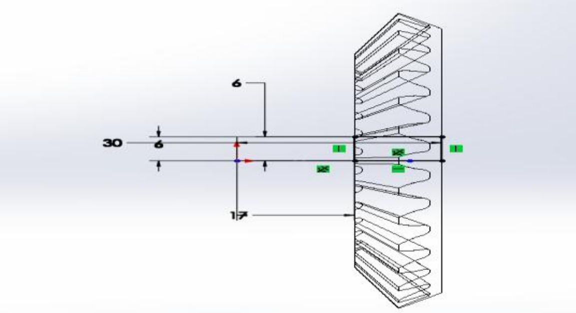


Fig 3.12 Final 2D Drawing of the Driven Gear

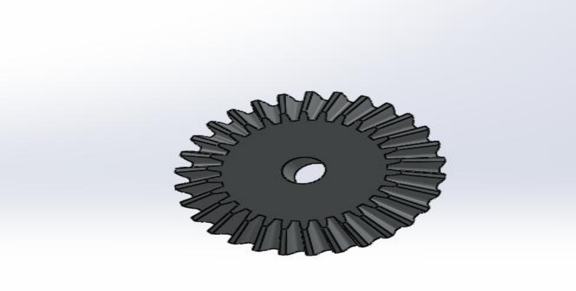


Fig 3.13 Final 3D Model of the Driven Gear

5.3 Assemble Contact Of Bevel Gear:

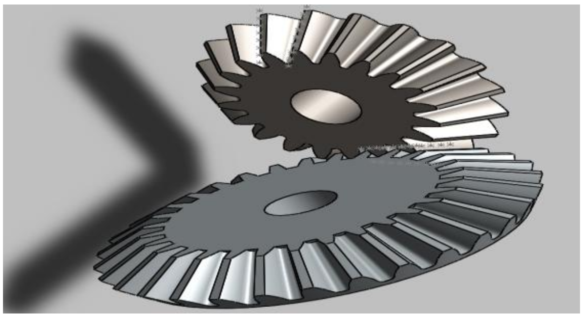


Fig 3.14 Assemble Contact Of Bevel Gear

4. MODEL IMPORTED INTO ANSYS

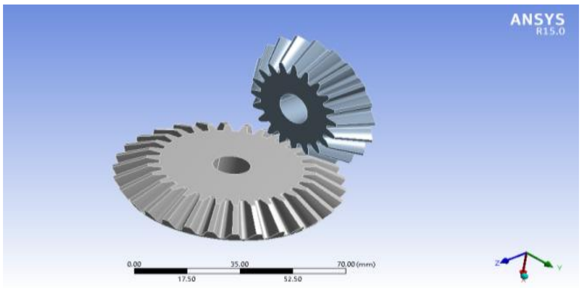


Fig – 4.1. Model Of The Bevel Gear

MESH MODEL

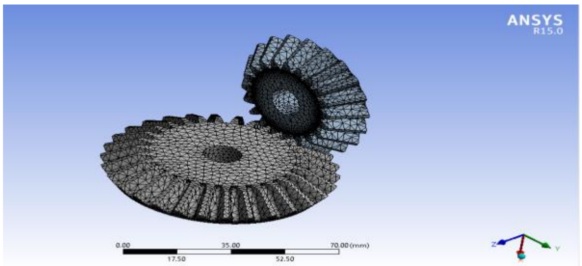


Fig. 4.2 Meshed model for the Base model position

LOAD AND BOUNDARY CONDITION

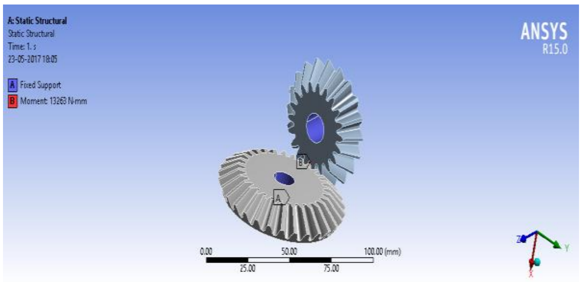


Fig. 4.3 Boundary Conditions of the Base model position

AT CONTACT REGION

Fig. 4.4 .Contact Region of the Bevel Gear

CASE1: MATERIAL OF STEEL STRUCTURAL FOR BEVEL GEARS

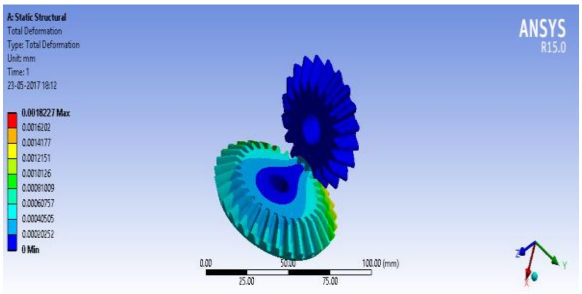


Fig 4.5 - :Deformation of model

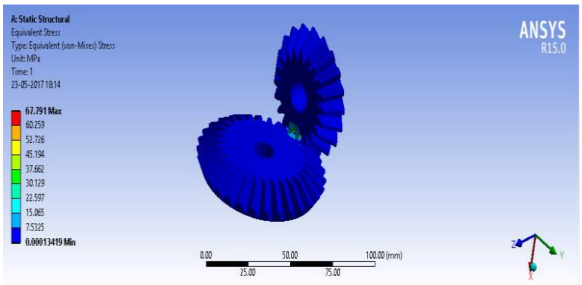


Fig 4.6 - :Von mises stress contact region

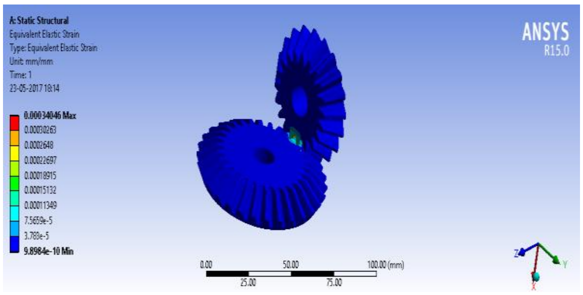


Fig 4.7 - : Von mises strain contact region

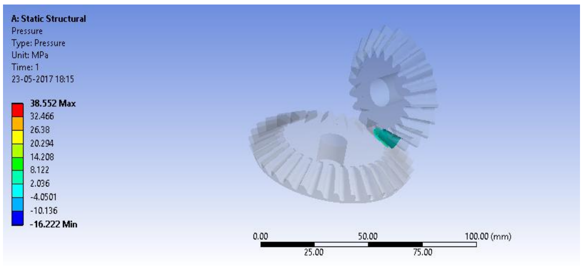
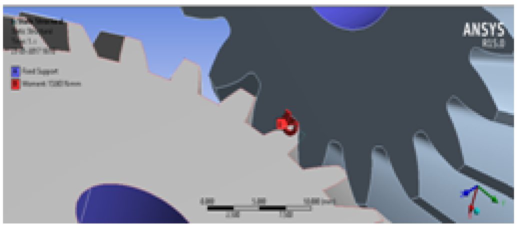


Fig 4.8 - : Contact stress on contact region



MODEL ANALYSIS:

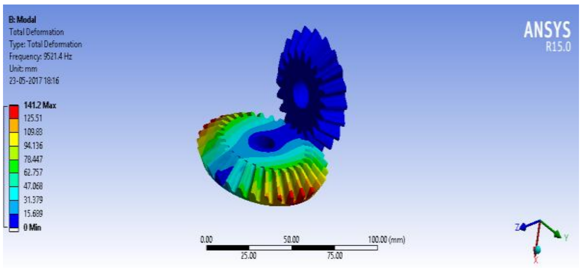


Fig 4.9 - : Mode shape at mode1

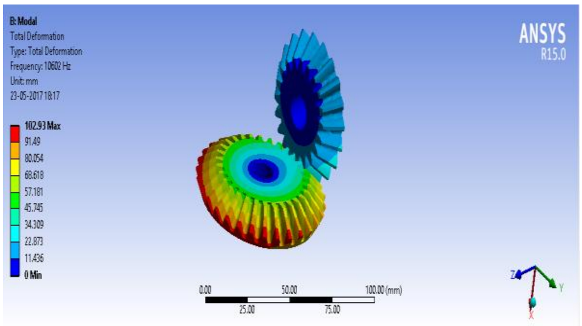


Fig 4.10 - : Mode shape at mode3

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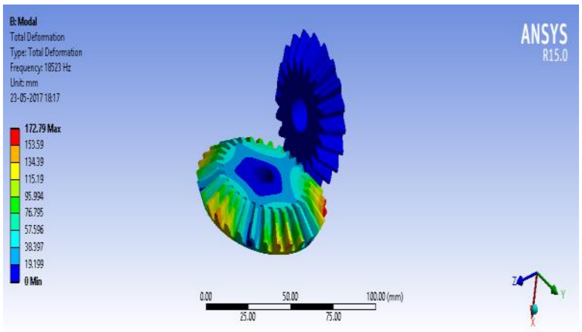


Fig 4.11 - : Mode shape at mode6

HARMONIC ANALYSIS:

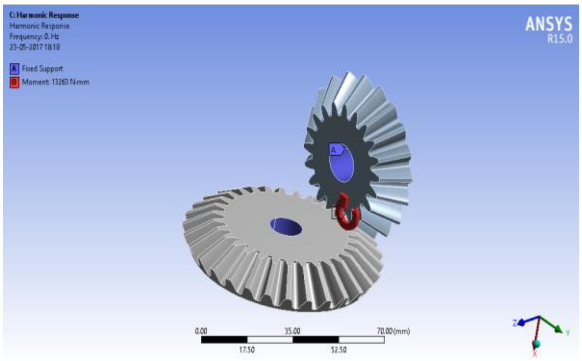


Fig 4.12 - : Load and boundary conditions

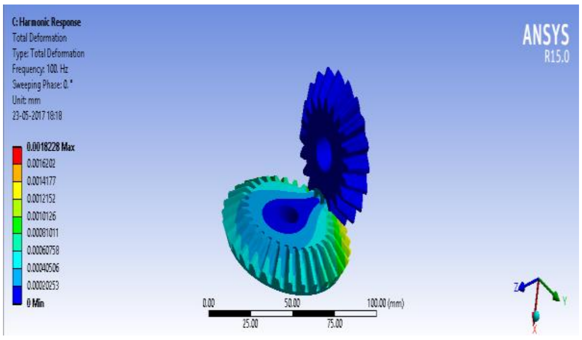


Fig 4.13 - :Harmonic deformation

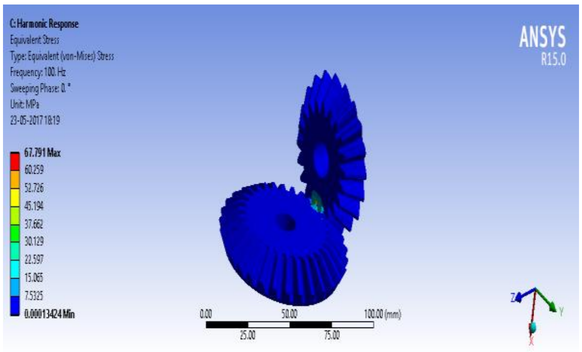
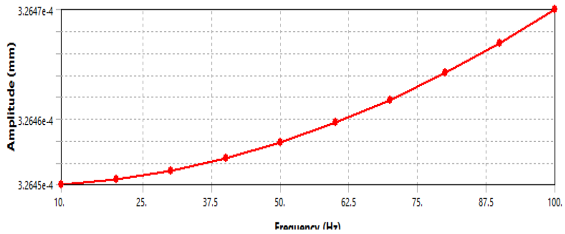
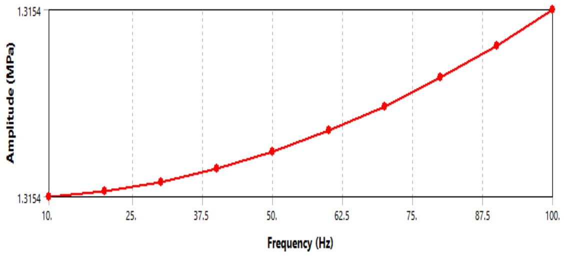


Fig 4.14 - :Harmonic- stress



FREQ VS AMP



FREQ VS STRESS

CASE2: MATERIAL OF CAST IRON FOR BEVEL GEARS

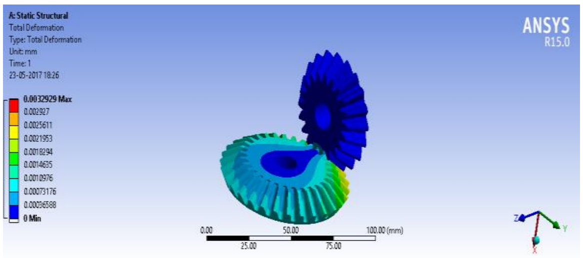


Fig 4.15 - : Deformation of model

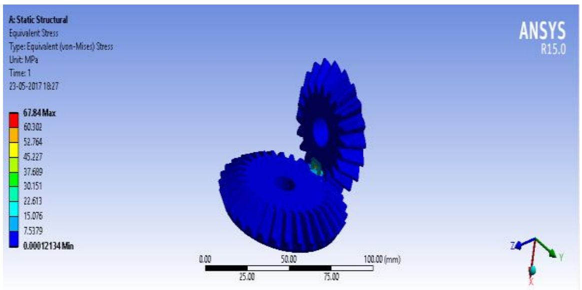


Fig 4.16 - :Von miseses stress contact region

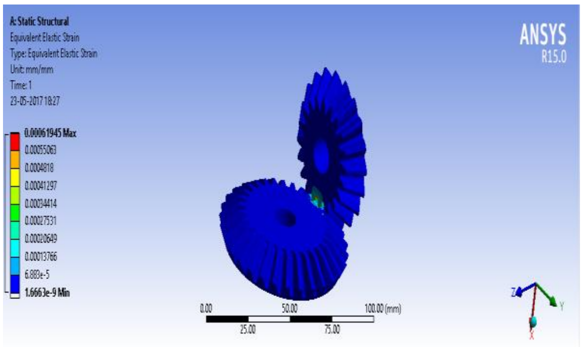


Fig 4.17 - : Von mises strain contact region

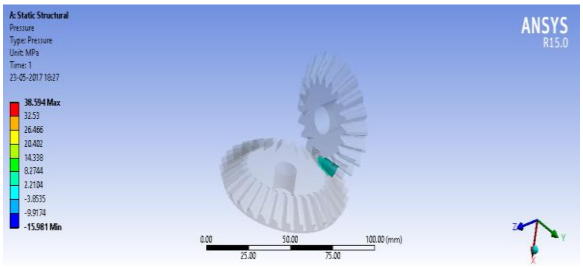


Fig 4.18 - : Contact stress on contact region

MODEL ANALYSIS:

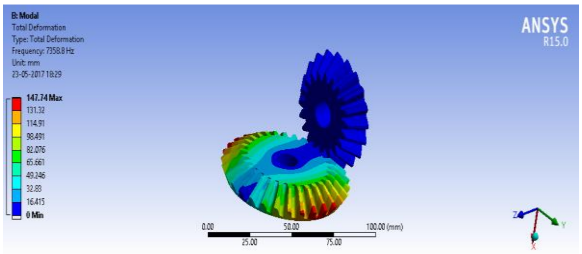


Fig 4.19 - : Mode shape at mode1

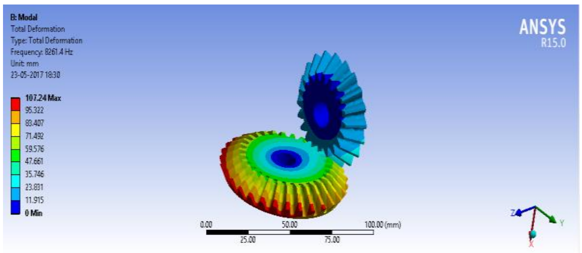


Fig 4.20 - : Mode shape at mode3

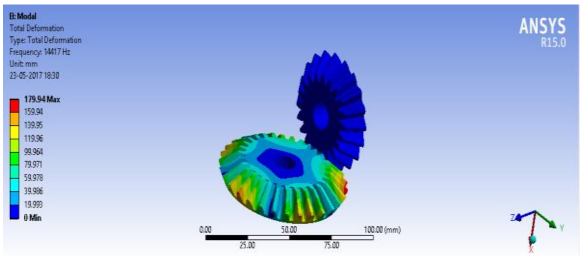


Fig 4.21 - : Mode shape at mode6

HARMONIC ANALYSIS:

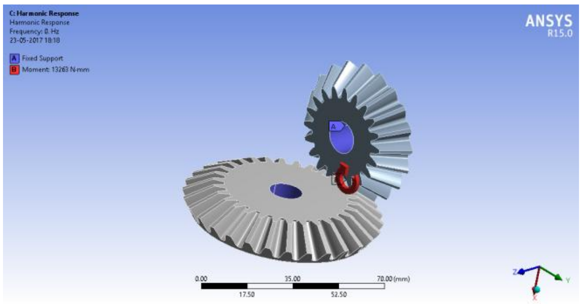


Fig 4.22 - : Load and boundary conditions

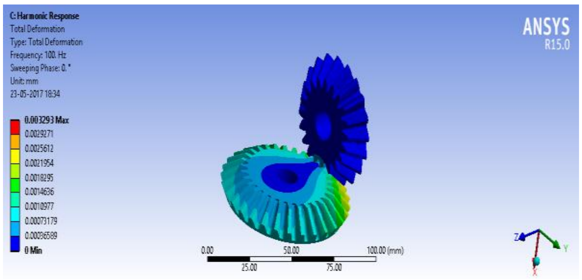


Fig 4.23 - : Harmonic deformation

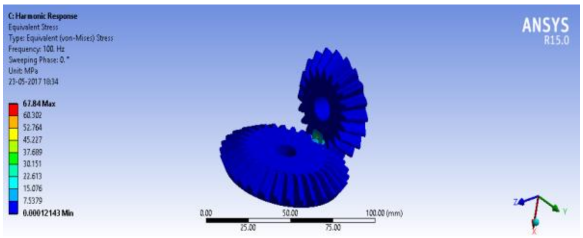
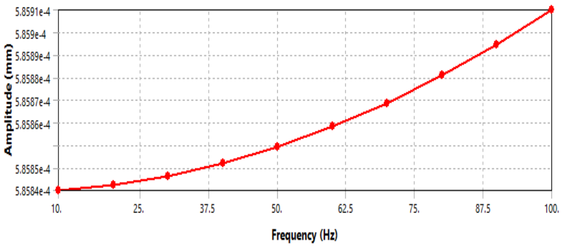
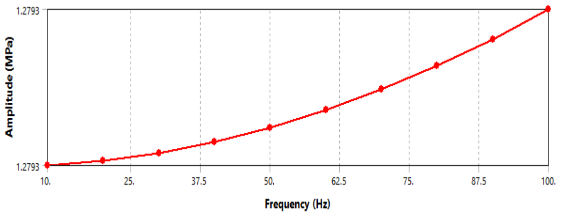


Fig 4.24 - : Harmonic- stress



FREQ VS AMP



FREQ VS STRESS

RESULT TABLES:

Natural Frequencies Of The Bevel Gear With Different Materials

MODE NO.	STEEL	CAST IRON	AL ALLOY	POLYETHALYNE
1	9521.4	7358.8	9585	2072.2
2	10263	7920.8	10348	2185.7
3	18523	14417	18444	3847.9

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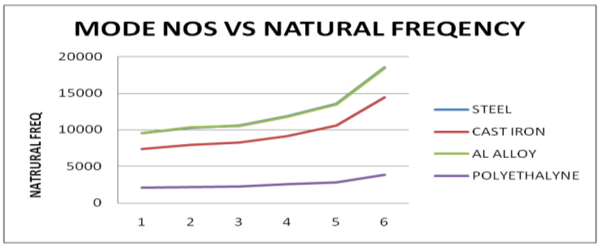
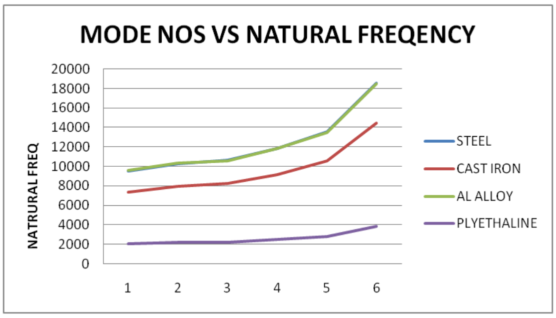
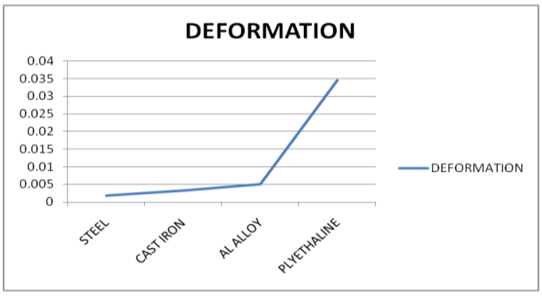
Graph Plot Between Mode Numbers And Freqency

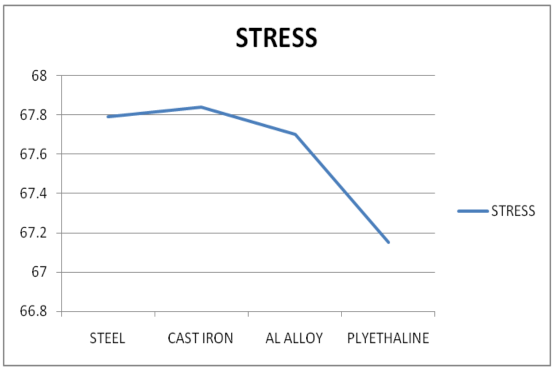


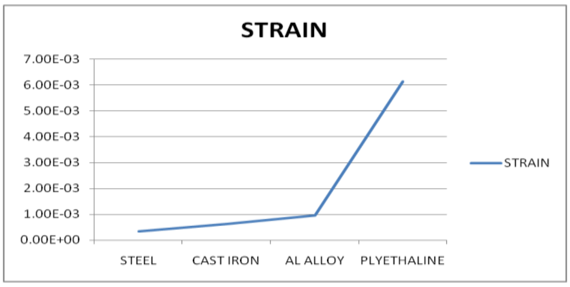
Static Analysis Table

S.NO.	MATERIAL	DEFORMATION	STRESS	STRAIN
1	STEEL	0.0018	67.791	3.40E-04
2	CAST IRON	0.0032	67.84	6.19E-04
3	AL ALLOY	0.0051	67.7	9.57E-04
4	POLYETHALYNE	0.03454	67.15	6.13E-03









ANALYTICAL CALCULATION

BENDING STRESS IN BEVEL GEAR

As per the AGMA the bending stress in bevel gear is calculated by the equation, and equation is as following

$$\sigma_B = \frac{2T}{d}\,\frac{Gr}{FmJ}\,\frac{K_a K_m K_s}{K_v K_x}$$

Where, T = Torque = 600 Nm,
d = Diameter of gear = 219.82 mm,
F = Face width = 62.35 mm,
m = Module = 7.6 mm,
Gr = Gear ratio = 0.58
J = Geometry factor of gear = 0.21
Ka = Application factor = 1
Km = Load distribution factor = 1.6
Ks = Size factor = 1
Kv = Dynamic factor = 1
Kx = Gear geometry factor = 1 for straight teeth bevel gear
= 1.15 for spiral bevel gear adn zerol bevel gear

7.1.2 Design Inputs

SR. NO.	DESCRIPTION	VALUE	UNIT
1	POWER TRANSMITTED	2.2	KW
3	NUMBER OF TEETH ON PINION	20	NOS.
5	PITCH CIRCLE DIAMETER OF PINION	60	MM
6	MODULE MM	3	MM
7	PRESSURE ANGLE	20	DEGREE

Load Calculation:

Load calculation involves calculating torque and tangential load acting on prototype of bevel gear.

Consider a bevel gear

The speed of bevel gear (n) = 720rpm

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Power transmitted Kw = 2.2

Torque transmitted (Mt)

Mt = [60×106 (KW)] / 2π n p

$$Mt = \frac{2\times60\times10^{6}}{2\times\pi\times n}$$

$$Mt = \frac{2\times60\times10^{6}}{2\times\pi\times1440}$$

Mt = 13262.91 N-mm

Tangential component,

Pt × d/2=Mt.

$$Pt = \frac{13262.91\times2}{60}$$

Pt = 442.09 N

Therefore,

Torque on pinion =972.61Nmm

Force acting on gear tooth= 972.61N

Bending stresses

$$\sigma_b = \frac{P^t}{m\times b\times y\left(1-\frac{b}{A_0}\right)}$$

Where,

Y = Lewis form factor,

M = Module,

b = Face width,

$\left(1 = \frac{b}{A_0}\right)$ = Bevel Factor,

$$A_0 = \sqrt{\left(\frac{D_P}{2}\right)^2 + \left(\frac{D_g}{2}\right)^2}$$

$$A_0 = \sqrt{\left(\frac{60}{2}\right)^2 + \left(\frac{90}{2}\right)^2}$$

A_0 = 54.08 mm

$$B = \frac{A_0}{3} = \frac{54.08}{3} = 18.02$$

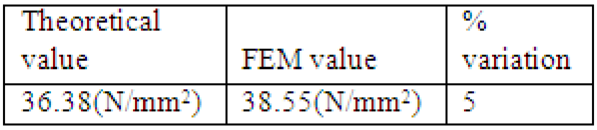
$$\sigma_b = \frac{442.09}{3\times18\times0.337\times\left(1-\frac{18}{54.08}\right)}$$

σ_b = 36.38 N/mm^2

Therefore, theoretically bending strength of bevel gear is 36.38 N/ mm^2

CONCLUSION

In bevel gear the bending stresses produced at critical section (root of tooth) are maximum as compared to spur gear. The calculation of maximum stresses in a bevel gear at tooth root is three dimensional problems. The accurate evaluation of stress state and distribution of stress is complex task. The stresses produced at any discontinuity are different in magnitude from those calculated by elementary formulae. In theory of bevel gear we are considering that load is acting at one teeth and the stress is calculated. But, in case of FEM a load acting at contact of teeth . So a pressure will act along the teeth of bevel gear. There is fairly good agreement between analytical and finite element results. The error in maximum bending stress is found to be 10 %. Static analysis is performed on various materials like steel, cast iron, Al alloy & polyethylene. From the result graphs it indicates polyethylene is best suits for given loading condition and same proved in dynamic analysis also.



Theoretical value	FEM value	% variation
36.38(N/mm^2)	38.55(N/mm^2)	5

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