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Modeling and Analysis of 2-Stage Reduction Gear Box

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Abstract:

A reduction gear box is part of a mechanical system of gears and shafts used to reduce the rotational speed of the input shaft to a slower rotational speed of the output shaft. This reduction in output speed helps to increase the torque of a system. Reduction gears are widely used in power transmission devices to reduce the high rotational speeds.

Gears have wide variety of applications. Gears are the most important component in power transmission system. The gears generally fail when tooth stress exceeds the safe limit. It is essential to determine the maximum stress that a gear tooth is subjected to, under a specified loading. To prevent from failure Analysis is carried on gears.

The present work is directed towards the modeling of 2-stage reduction gear box with its components like helical gears, pinions, integral shaft bearings and housing in a 3D cad tool called SOLIDWORKS 2014sp1. This work investigates the characteristics of an involute helical gear system mainly focused on bending stresses using solid works simulation. The analytical study is conducted by using Lewis formula. The Study is conducted by varying the face width to find the bending stress of helical gear. Finally It is observed that the maximum bending stress decreases with increasing the face width of the gear. This study shows the complex design problem of helical gear and required superior software skills for modeling and analysis.

I.INTRODUCTION:

Power transmission states to convert speed and torque from one rotating power source to another. In this project to design and analysis on the intermediate shaft for stresses and deflections and it is necessary to know the applied forces. If the forces are transmitted through the gears, it is necessary to know the gear specifications. To determine the forces that will be transmitted to the shaft. This project will focus on an overview of a power transmission system design, demonstrating how to incorporate the details of each component into an overall design process.

A typical two-stage gear reduction box is been used to understand the design process. The design sequence is similar for variations of this particular transmission system.

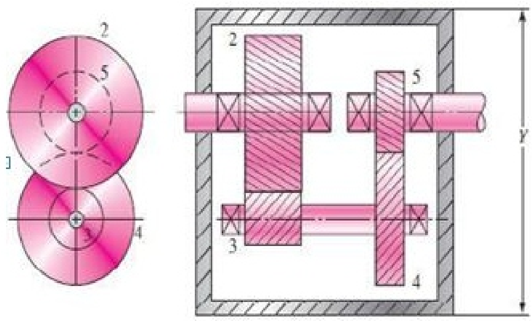

Figure 1: compound reverted gear train.

Transmission:

The term power transmission is defined as the movement of energy from input power source to output device to perform the work. . In mechanical power transmissions, a device is interposed between a source of power and a specific application for the purpose of adapting one to the other. Most mechanical transmissions are rotary speed changers; the ratio of the output speed to the input speed may be constant (as in a gearbox) or variable. In variable-speed transmissions the speed of the gear is varies in discrete steps or continuously varies within the range.

Types of power transmission systems:

Transmissions types include
• Manual Transmission

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• Automatic Transmission.

• Semi-automatic transmission.

a)Manual transmission :

Manual transmissions are the most common type. These are cheaper, lighter; usually give better performance, and fuel efficiency. With a manual gear changer is used for new drivers to learn, and tested, on a car. Some manual transmissions have an extremely low ratio for first gear, called as creeper gear or granny gear. These types of gears are usually not synchronized. This feature is common in pickup trucks, farming, or construction-site work. During on-road use, the truck is driven without using the creeper gear and second gear is used from starting.

b) Semi-automatic:

Semi automatic transmission system is also called as clutch less or automated manual transmission. Many of these transmission systems by using control system to shift the gear from one to another. Semi-automatic systems used a variety of mechanical and hydraulic systems - including centrifugal clutches, torque converters, electro-mechanical (and even electrostatic) and servo/solenoid controlled clutches.

c) Automatic:

Automatic transmissions are easy to use. But in this type a number of problems are occur they were complex and expensive, sometimes had reliability problems have often been less fuel-efficient than their manual counterparts and their shift time was slower than a manual making.

Power Transmission Devices:

Power transmission devices are to transmit the power from one point to another point with their axis of motion, and the devices are connected to each other by the following ways.

• Gear Drive
• Chain Drive
• Belt Drive

a)Gear Drive:

Gears are toothed wheels that engage to transmit the rotary power from one point to another point. Gears are classified as follows:

b) Spur gears:

Spur gears are the most commonly used gear type. The teeth which are perpendicular to the face of the gear. Spur gears are most commonly available, and are generally least expensive. The basic descriptive geometry for a spur gear is shown in the figure below.

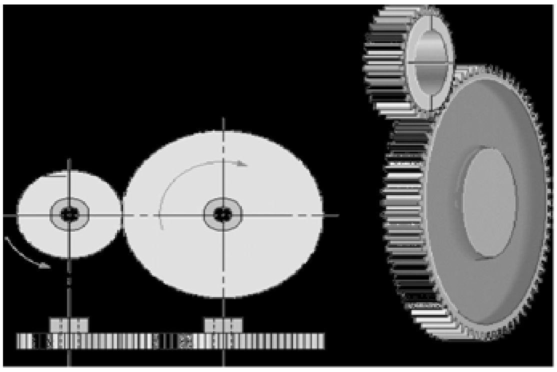

figure: spur gear.

c) Helical Gears:

Helical gears are similar to the spur gears except that the teeth angle to the shaft. Helical gears are used to mesh two shafts are in not parallel, but they primarily used in parallel shaft applications. Helical gears can carry more loads compare to spur gears and transmits more power than spur gear.

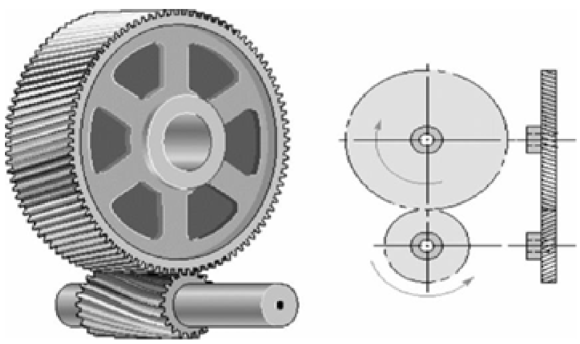

Figure 2: helical gears

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d) Bevel Gears: Bevel gears are primarily used to transmit the power in between intersecting shafts (the axis f the shafts are in not parallel). The teeth of these gears are formed on a conical surface. Hypocycloid bevel gears are a special type of spiral gear that will allow non-intersecting, non-parallel shafts to mesh. In high speed condition it can be noisy.

e) Worm Gears: Worm gears are special gears that resemble screws, and used to drive spur gears or helical gears. Worm gears, like helical gears, allow two nonintersecting shafts. Normally, the two shafts are at right angles to each other. Worm gear is that it is a helical gear with a very high helix angle.

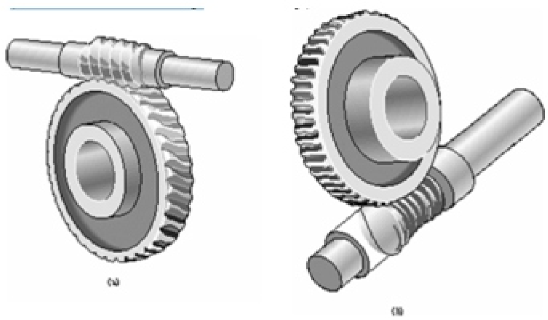

Figure 3: Worm Gears

Gear Trains:

A gear train is formed by mounting gears on a frame; the teeth's of the gears are engage. Gear teeth are designed the pitch circles of engaging gears roll on each other without slipping and the module of both the gears are same, this provides a smooth transmission of rotation from one gear to the another gear.

Gears trains are classified into following types:

- Simple gear train.
- Compound gear train.
- Reverted compound gear train.
- Planetary gear train.

a)Simple Gear Trains:

A simple gear train is used a large distance is covered between the input and output shafts. In this gear train each gear is mounted on its own shaft. Ina simple gear train each shaft carries only one train the expression for the simple train's velocity ratio.

b) Compound gear trains:

In compound gear train at least one shaft carries more than one gear. In compound gear train to get the train ratio is greater than 10:1.there are four gears in the figure gear 3 and 4 are mounted on single shaft and they have same angular velocity.
The train ratio now:

$$m_V = \left(-\frac{N_2}{N_3}\right)\left(-\frac{N_4}{N_5}\right)$$

This can be generalized for any number of gears in the train as:

$$M_v = \pm \frac{\text{product of numberof teeth on driver gears}}{\text{product of number of teeth on driven gears}}$$

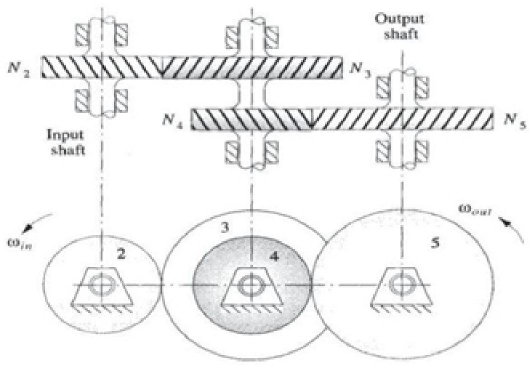

Figure 4: Compound gear train

c) Reverted compound trains:

it is similar to the compound gear train but both they are used only a small space between the input and output shafts and large change in speed. There are two major differences between compound and reverted gear trains.First difference is the input and output shafts are lie on the same axis. Second, the distance between the centers of the two gears in each pair is same. Fig shows a reverted gear train

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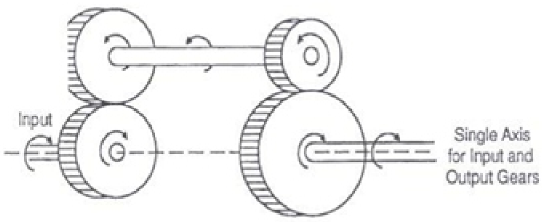


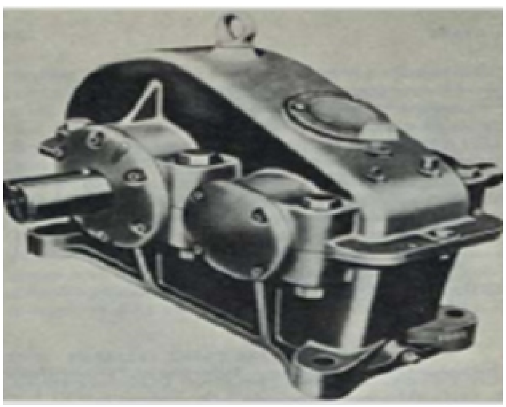
Figure 5: Reverted gear train

d) Planetary Gear Trains:

A planetary gear train is more complex than other types of gear trains. In a planetary gear train at least one gear revolves around another gear in the gear train. . In this type of gear train the sun gear is located at the center of the system; the planet gear revolves around the sun gear. The whole system is held by the planet carrier.

II.REDUCTION GEAR BOX:

Reduction gear box consists of 2 gears having same no. Of teeth but different diameters. The number of teeth is proportional to the circumference of the gear; the smaller circumference gear will have fewer teeth than the larger one. The smaller gear makes two revolutions for every one revolution of large gear. The amount of torque obtained at larger gear is twice comparing to the torque available in smaller gear. The speed of the output gear is decreases and the torque is increasing proportionally.An automobile drive train is an example for multi-stage gear reduction system. An engine runs at 1500 to 3000 revolutions per minute (RPM).initially the vehicle is in stationary position. In this time it requires more torque to move the vehicle, but the engine runs more speed. By using reduction gear box to reduce the speed of the propeller shaft. By using different gear ratios used in gear box, the gear ratios are 3:1, 4:1, 5:1 and final gear ratio is 60:1.



III.RELATED WORK:
Introduction to solid-works:

Solid Works is mechanical design software and it is developed by DASSAULT SYSTEMS. It is easy-to-learn for mechanical designers to sketch ideas, features, dimensions, produce models and detailed drawings. The modules consists of solid works are part, assembly and drawing etc.

Modeling Of 2-Stage Reduction Gear Box:
Problem statement:

A helical reduction unit has to transmit30N-m input power of 12kw with a total reduction of 11.6. Speed N=1500 rpm. Applying Alloy steel material to the both pinion and gears.

Considering helix angle for helical teeth around 14 degree we consider that the pinion will be minimum 16 teeth.Let the pinions and gears have following teeth. Z1=16 and Z2=51 at the first stage and Z3=16 and Z4=58 at the second stage.

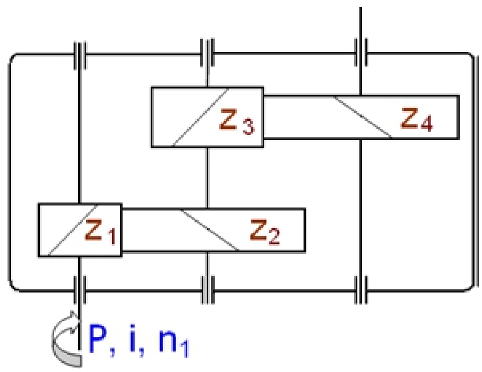


Figure 7: reducer sketch

Therefore, transmission ratios are:

$$i_1 = \frac{Z_2}{Z_1} = \frac{51}{16} = 3.19 \ ; \quad i_2 = \frac{Z_4}{Z_3} = \frac{58}{16} = 3.63 \ \text{and}$$

$$i_t = i_1 \times i_2 = \frac{Z_2}{Z_1} \times \frac{Z_4}{Z_3} = \frac{51}{16} \times \frac{58}{16} = 3.19 \times 3.63 = 11.58$$

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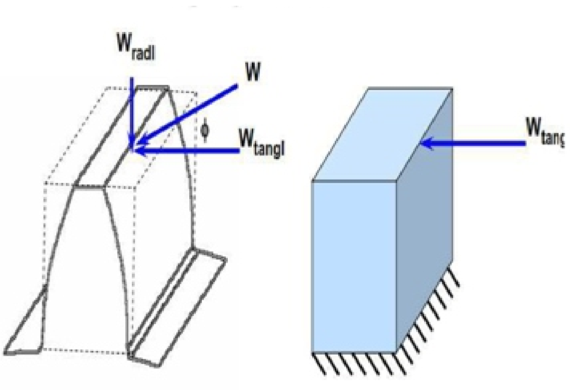

Figure 8: tangential force.

$$\sigma_b = \frac{W_T}{b.\pi.m.\bar{y}.Cv}$$

σ_b = allowable static stress, W_T = tangential tooth load, Cv = velocity factor,

b = face width, m = module and $\bar{y}$ = Lewis factor corresponding to the formative or equivalent number of teeth

Torque transmitted (T), $T = \frac{P*60}{2\pi N}$, P = power in (Kw), N = revolution per min,

$v = \frac{\pi D \cdot N}{60}$, D = Diameter of gear, t = Number of teeth

$$\bar{y} = 0.175 - \frac{0.841}{T_E}, \ t = \frac{D}{m}, \ T_E = \frac{t}{\cos^3 \alpha}$$

$$C_v = \frac{6}{6+v}$$

Geometrical parameters of first stage:

symbol	Parameter	Pinion1	Gear1
m	Module	3	3
b	Face width	40	32
T	No. of teeth	16	51
α	Helix angle	14	14
D	Pitch circle diameter	48	153
	Profile	20 deg full Depth involute	20 deg full depth involute

Table 1
Geometrical parameters of second stage

symbol	Parameter	Pinion2	Gear2
m	Module	4	4
b	Face width	51	40
T	No.of teeth	16	58
α	Helix ang	14	14
D	Pitch circle diameter	64	232
	Profile	20 deg full depth involute	20 deg full depth involute

Table 2
Modeling of gear 1 in first stage:

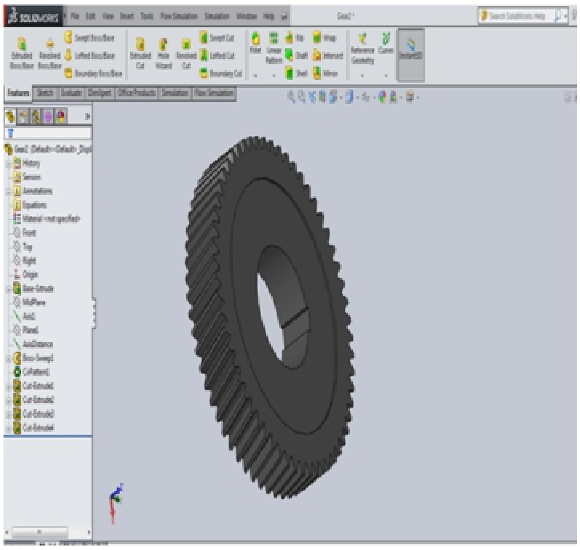

Figure 9: gear1 of 51 teeth in the first stage

Modeling of pinion1 in first stage:

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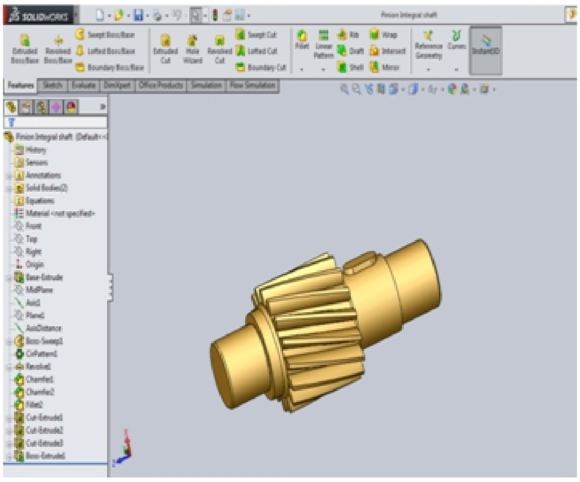

Figure 10: pinion 1 of 16 teeth in first stage

Modeling of gear2 in second stage:

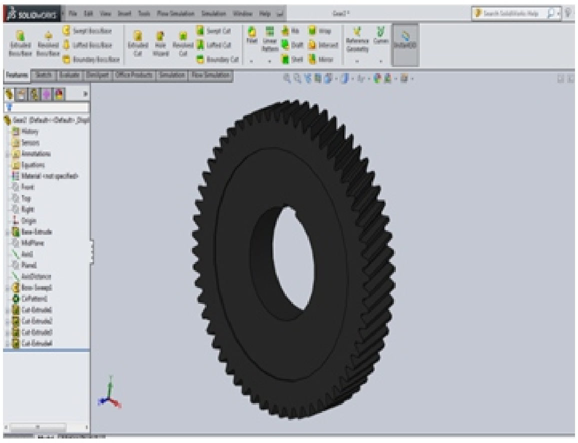

Figure 11: gear2 of 58 teeth in the first stage

Assembly of 2-stage reduction gear box:

The gears, pinions, shaft and ball bearings are assembled in the gear housing as shown.

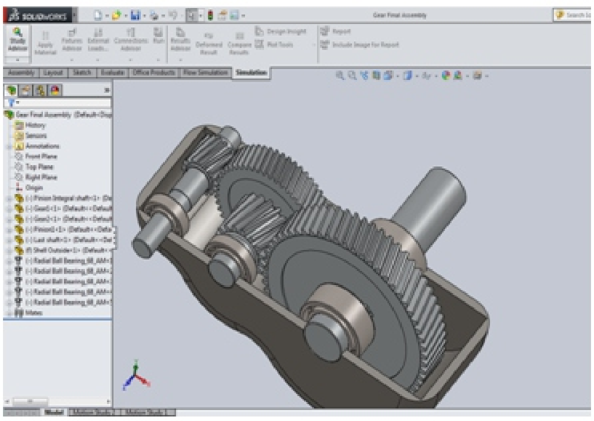

Figure 12: Assembly of 2-stage reduction gear box

IV.SOLIDWORKS SIMULATION:

Solid-Works Simulation is a analysis system fully integrated with Solid-Works. It provides simulation solutions for linear and nonlinear static, frequency, buckling, thermal, fatigue, pressure vessel, drop test, linear and nonlinear dynamic, and optimization analyses.

Powered by fast and accurate solvers, it enables you to solve large problems intuitively while you design. It comes in two bundles: Solid-Works Simulation Professional and Solid-Works Simulation Premium to satisfy your analysis needs. Solid-Works Simulation shortens the time for optimum design.

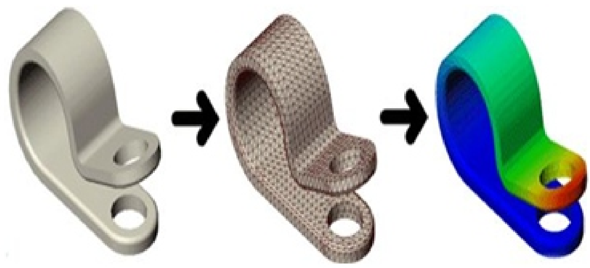

Figure 12: simulation example

V.STATIC ANALYSIS ON HELICAL GEARS:

Results for helical gear of face width 32mm:

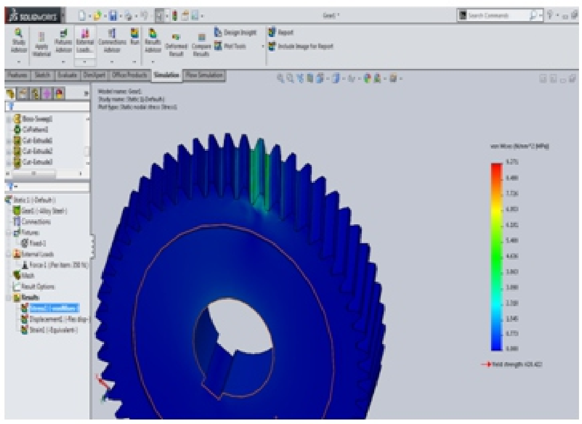

Figure 13: bending stresses developed in the helical gear of face width32mm Results for helical gear of face width 33mm:

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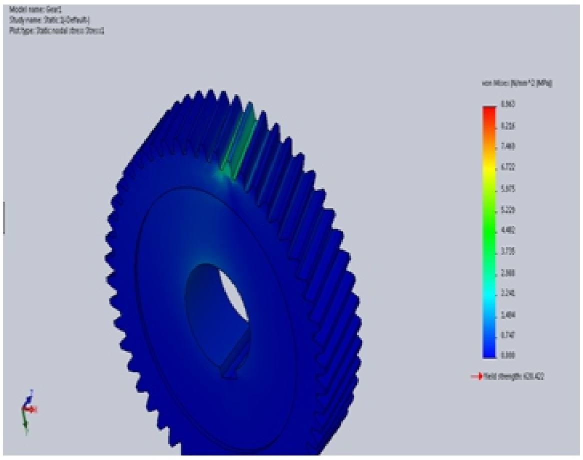

Figure 14: bending stresses developed in the helical gear of face width33mm Results for helical gear of face width 34mm:

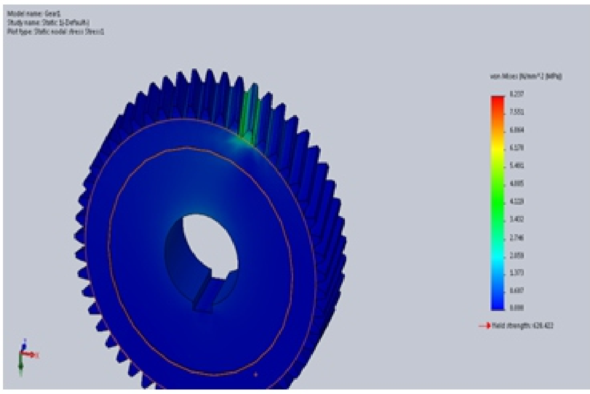

Figure 15: bending stresses developed in the helical gear of face width34mm Results for Helical Gear of Face Width 35mm:

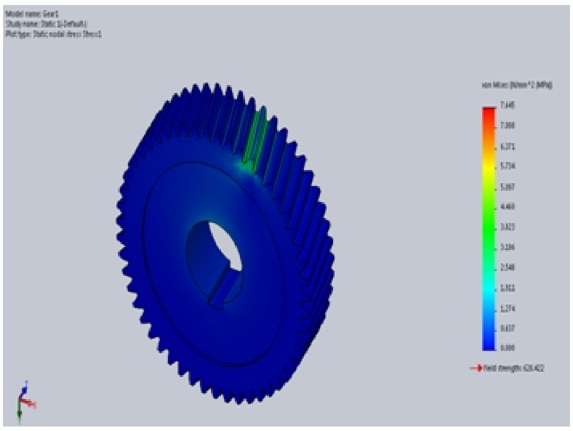

Figure 16: bending stresses developed in the helical gear of face width35mm.

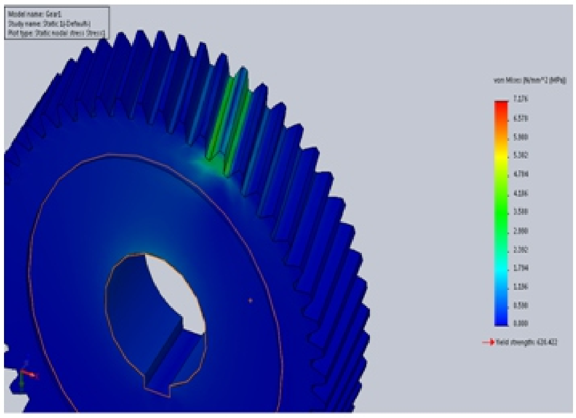

Figure 17: bending stresses developed in the helical gear of face width36mm

RESULTS AND DISCUSSIONS

The structural analysis of helical gear is carried by using FEA in solid works simulation. The load is applied on the gear tooth by applying analysis to perform the analysis and results are evaluated. Face width is an important parameter in design of a gear. To change the face width of the gear the bending stress values are compared to theoretical values. The face widths of the gears are 32 mm to 36 mm respectively. From results with the increase of face width decreases the bending stress on gear tooth.

Comparison of theoretical stress values and solid works values:

Face width (mm)	Bending stresses Mpa (Lewis equation)	Bending stresses Mpa (static analysis)
32	9.673	9.271
33	9.376	8.963
34	9.109	8.237
35	8.842	7.645
36	8.596	7.176

Table 3

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VI.CONCLUSIONS:

The 2-stage reduction gear box with all its components like helical gears, pinions, integral shaft and radial ball bearings are modeled in a 3D cad tool called SOLIDWORKS 2014.and analysis is done in solid works simulation. The strength of the gear is an important parameter while designing a gear. In this project to compare the theoretical and simulation values of helical gear by varying the face width of the gear. Finally the design is safe.

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