# Design and FEM Analysis of Helical Gear

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## ABSTRACT

*In this paper the problem of the failure of gear in speed reduction gearbox developed by Laxmi Hydraulic Pump (LHP) Pvt Ltd, Solapur is resolved by replacing the existing material by a material SAE8620. The Gear and Pinion using AGMA and FEM analysis Method. In the gear design, the bending stress and surface strength of the gear tooth are considered to be one of the main factors to the failure of the gear. In this paper bending and contact stresses are calculated by using analytical method as well as Finite Element Method. To estimate bending stress modified Lewis beam strength method is used as well as AGMA method. Software is used to generate the 3-D solid model of helical gear. Ansys software package is used to analyze the bending stress. Contact stresses are calculated using modified AGMA contact stress method. Ansys software package is used to analyze the contact stress and bending stress. The main objective of this study has to investigate the stresses induced by gear tooth profile. Finally, the results obtained by theoretical analysis and Finite Element Analysis are compared to check the correctness. Estimated stress is used to calculate module of gear which can withstand easily at given loading conditions. A conclusion has arrived on the material which is best suited for helical gear based on the results.*

*Key Words: Bending stress, Contact stress, Helical gear, Pinion, Using ANSYS method.*

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## 1. INTRODUCTION

This One of the best methods of transmitting power between the shafts is gears. Gears are mostly used to transmit torque and angular velocity. It is widely used because it is capable of transmitting power in a very small centre distance between two parallel shafts. Gear transmission systems play an important role in many industries such as automobile industry. The knowledge of gear behavior in mesh such as stress distribution, work condition and distortion is critical to monitoring and controlling the gear transmission system. A pair of teeth in action is generally subjected to two types of stresses- bending stresses inducing bending fatigue and contact stress causing contact fatigue In present times, helical gears are being utilized as a power transmitting gears because of their moderately smooth and quiet Operation, huge load conveying limit and higher working velocity and smoother engagement of teeth; power can be exchanged between two non-parallel shafts, they are highly effective .The tooth bending stress and surface contact stress of these gears had always been one of the major areas of research for scholars. The designing of a helical gear pair is a complex process. Helical gear can fail due to excessive bending stress at root of gear tooth or surface contact stress. This can be changed by minimizing bending stress and contact stress or by modifying the geometry or parameters of the gear tooth.

## 2.LITERATURE REVIEW

Linhong Xu et al., has done work on "Stress Analysis and Optimization of Gear teeth .the operational performance of gear regarding smoothness, quietness, wear and life span is largely affected by how gear and pinion teeth make contact tooth profile plays a very important role in influencing contact condition during gear transmission. In this paper a kind of Modification of teeth profile, crowned teeth, is presented and analyzed by using ANSYS. Analytic results are presented to demonstrate the better performance of gear under heavy load in gear transmission and relationship between drum shaped size design and load [3].

B.Venkatesh, et al., said that, the stresses generated and the deflections of the tooth have been analyzed for different materials. The results obtained by theoretical analysis and Finite Element Analysis are compared to check the correctness. A conclusion has been arrived on the material which is best suited for the marine engines based on the results. Basically the project involves the "design, modeling and manufacturing of helical gears" in marine applications. It is proposed to focus on reduction of weight and producing high accuracy gears [4].

Arvind Yadav et al., has done his work on "Different types Failure in gears". The objective of this paper to present their recent development in the field of gear failure analysis. By the help of this paper we can know about different types of failure detection and analyzing techniques which is used to reduce these failures from gears. the intention of this paper is not to provide detailed description of the causes of gear failure but it focused on the different types methodology, that is used by the various researcher in the past recent year to find out causes of failure in gear and what is final result of that to reduce the failure in gear [5].

Pawan kumar et al., studied Design and Thermal Analysis of Helical Gearbox. The work presented here is the study of thermal analysis of a 3 stage helical gearbox. Firstly the design of the gearbox is done by empirical formulas. The 2D drawing is then drafted to a 3D model by 3D modeling software. The thermal analysis is done for the temperature generated at the tip of the mating gears [6].

Govind T Sarkar studied the bending and surface stresses of gear tooth are major factor for failure of gear. Stress Analysis of Helical Gear by Finite element Method This paper investigates finite element model for monitoring the stresses induced of tooth flank, tooth fillet during meshing of gears. The involute profile of helical gear has been modeled and the simulation is carried out for the bending and contact stresses and the same have been estimated. To estimate bending and contact stresses, 3D models for different helical angle, face width are generated by modeling software and simulation is done by finite element software packages. Analytical methods of calculating gear bending stresses uses bending equation and for contact stress contact equation are used [7].

A.Y Gidado et al., has done work on "Design, Modeling and Analysis of Helical Gear According Bending Strength Using AGMA and ANSYS" there are two kinds of stresses in gear teeth ,root bending stresses and tooth contact stresses. These two stresses results in the failure of gear teeth, root bending stress results in fatigue fracture and contact stresses results in pitting failure at the contact surface. So both these stresses are to be considered when designing gears. In this paper one of the principal failure modes are studied based on the calculation of bending stress. To estimate the bending stress, three dimensional solid models for different face width are generated by Pro/Engineer that is a powerful and modern solid modeling software and the numerical solution is done by ANSYS, which is a finite element analysis package. In this paper a helical gear was modeled on Pro engineer wildfire 4.0 and stress analysis part is done on ANSYS 11.0.The results are then compared with both AGMA and FEM procedures [8].

J. Venkatesh et al., said that, in gear design the bending stress and surface strength of the gear tooth are considered to be one of the main contributors for the failure of the gear in a gear set. In this "Design and Structural Analysis of High Speed Helical Gear "Using Ansys paper bending and contact stresses are calculated by using analytical method as well as Finite element analysis. To estimate bending stress modified Lewis beam strength method is used. Ansys software package is used to analyze the contact stress. Finally these two methods bending and contact stress results are compared with each other [9].

Babita Vishwakarma, et. al., reported that Gears are one of the most critical components in mechanical power transmission systems. The bending and surface strength of the gear tooth are considered to be one of the main contributors for the failure of the gear in a gear set. Thus, analysis of stresses has become popular as an area of research on gears to minimize or to reduce the failures and for optimal design of gears. "Finite Element Analysis of Helical Gear Using Three-Dimensional Cad Model "This paper investigates finite element model for monitoring the stresses induced of tooth flank, tooth fillet during meshing of gears. To estimate bending and contact stresses, 3D models are generated by modeling software CATIA V5 and simulation is done by finite element software package ANSYS 14.0. Analytical method of calculating gear bending stresses uses Lewis and AGMA bending equation. Study is conducted by varying the face width to find its effect on the bending stress of helical gear. It is therefore observed that the maximum bending stress decreases with increasing face width. The stresses found from ANSYS results are compared with those from theoretical [10].

S. Jyothirmai, et. al., studied the theoretical basis and performance characteristics of helical gear design, a complete mathematical description of the relationship between the design parameters and the performance matrices is still to be clearly understood because of the great complexity in their interrelationship. The objective of this work is to conduct a comparative study on helical gear design

and its performance based on various performance metrics through finite element as well as analytical approaches. helical gear are studied through finite element approach (FEA) in ANSYS and compared with theoretical analysis of helical gear pair [11].

## 3. PARAMETRIC MODELING OF HELICAL GEAR

The Five stage speed reduction gear box is developed by LHP is used to reduce the 1390 rpm of input motor to the output 1.1 rpm. There is failure of gear tooth of fifth stage gear due to incorrect design and material having less strength than requirement. So we change the material and selected as per strength, cost and hardness requirement of material SAE8620. We redesign this gear and modified the module using material SAE8620.While redesigning some of specifications like pressure angle, helix angle , face width etc we kept same as previous design as per companies requirement.

Specification of Gearbox and gear

Input power: - 0.37kw      Gear teeth:-50 pressure angle :- $20^0$      No. of stages :-5   Input speed :-1390 rpm

pinion teeth :-13      final output :-1.1rpm      Torque :-300kgm      Helix angle : $23^0$      Face width :- 70mm

**Chart for Selection of Material**

| Material | Ultimate Tensile strength in MPa | Yield Tensile strength in MPa | BHN | Cost per kg |
|---|---|---|---|---|
| 20MnCr5 | 1000 | 600 | 578 | 42 |
| SAE8620 | 1157 | 833 | 450 | 45 |
| 13Ni3Cr80 | 970 | 810 | 285 | 57 |
| 42CrMo4 | 551 | 241 | 270 | 52 |

By comparing tensile strength, Hardness and Cost SAE8620(20NiCrMo2) is better material and suited for our requirement.

## 4. BENDING EQUATION

Bending failure and pitting of the teeth are the two main failure modes in a transmission gearbox.. This bending stress Equation was derived from the Lewis formula.

$$\sigma_b = \frac{F_t P_d}{bY}$$

Bending Stress is given by,

Y is called the Lewis form factor. The Lewis equation considers only static loading and does not take the dynamics of meshing teeth into account. The maximum stress is expected at the point which is a tangential point where the parabola curve is tangent to the curve of the tooth root fillet called parabola tangential method.. The AGMA equation for bending stresses given by,

The AGMA equation for bending stresses given by,

$$\sigma_b = \frac{F_t}{bm_nJ}K_vK_oK_s(0.93\,K_m)$$

where Ka = Application factor, KS = Size factor, Km = Load distribution factor, KV = Dynamic factor, Ft = Normal tangential load,

J = Geometry factor

## 4.1 AGMA BENDING AND CONTACT STRESS ANALYSIS OF GEAR AND PINION

AGMA Bending Stress For pinion

As per AGMA standard equation the bending stresses are as:

$$\sigma_b = \frac{Ft}{bm_n J} K_v K_o (0.93 K_m)$$

$F_{t = 33821.86\ N}$

$$\sigma_{b=520N/mm^2}$$

## 4.2 AGMA Bending Stress For Gear

As per AGMA standard equation the bending stresses are as:

$$\sigma_b = \frac{Ft}{bm_n J} K_v K_o (0.93 K_m)$$

$F_{t = 37000N}$

$$\sigma_{b=486.88N/mm^2}$$

## 4.5 CONTACT STRESS

Contact stress causes deformation, plastic or elastic. The contact area will change depending on the magnitude of the contact stress. Therefore, it is very important to calculate the actual stress at the point of contact, the so-called contact stress One of the main gear tooth failure is pitting which is a surface fatigue failure due to repetition of high contact stresses occurring in the gear tooth surface while a pair of teeth is transmitting power. The surface compressive stress (Hertzian stress) is found from the equation

$$\sigma_c = \sqrt{\frac{Ft}{\pi B \cos\phi} \times \frac{\frac{1}{r1} + \frac{1}{r2}}{\frac{1-\upsilon 1^2}{E1} + \frac{1-\upsilon 2^2}{E2}}}$$

$$r1 = \frac{d_{p\sin\phi}}{2}, \quad r2 = \frac{d_{g\sin\phi}}{2}$$

AGMA Contact Stress Equations

$$\sigma_c = C_p \sqrt{\frac{Ft\left(\frac{\cos\varphi}{0.95CR}\right)K_v K_o (0.93\ K_m)}{bdl}}$$

$$C_p{}^2 = \left\{ \frac{1}{\dfrac{1-\upsilon 1^2}{E1} + \dfrac{1-\upsilon 2^2}{E2}} \right\}$$

where

$$CR = \left( \frac{\sqrt{(r1+a)^2 - rb1^2} + \sqrt{(r2+a)^2 - rb2^2} + (r1+r2)\sin\varphi}{\pi m \cos\varphi} \right)$$

$$I = \frac{\sin\varphi \cos\varphi}{2} \frac{i}{i+1}$$

AGMA Contact Stress**--**As already mentioned high contact stresses results in pitting failure of the gear tooth, it is necessary to keep contact stresses under limit. As per AGMA contact stress equation are used as

$$\sigma_c = C_p \sqrt{\frac{FT\left(\dfrac{\cos\varphi}{0.95CR}\right) K_v K_o (0.93 K_m)}{bdl}}$$

$C_{p}=161$ as per material          b=70          Kv= 1          CR=1.5          l= 0.2345          Ko= 1 d= 49.46

contact stress = 774   $N/mm^2$

## 5. FEM PACKAGE

ANSYS is the name commonly used for ANSYS mechanical, general-purpose finite element analysis (FEA) computer aided engineering software tools developed by ANSYS Inc. ANSYS mechanical is a self-contained analysis tool incorporating pre-processing such as creation of geometry and meshing, solver and post processing modules in a unified graphical user interface The following steps are used in the solution procedure using ANSYS

1. The geometry of the gear to be analyzed is imported from solid modeler Pro/Engineer in IGES format this is compatible with the ANSYS.

2. The element type and materials properties such as Young's modulus and Poisson's ratio are specified.

3. Meshing the three-dimensional gear model..

4. The boundary conditions and external loads are applied.

5. The solution is generated based on the previous input parameters.

6. Finally, the solution is viewed in a variety of displays.

### 5.1 FEM Bending Stress Analysis:

In this section, the teeth bending stress of helical gear is calculated using ANSYS. For this purpose the modeled gear in Pro/Engineer is exported to ANSYS as an IGES file and then an automatic mesh is generated

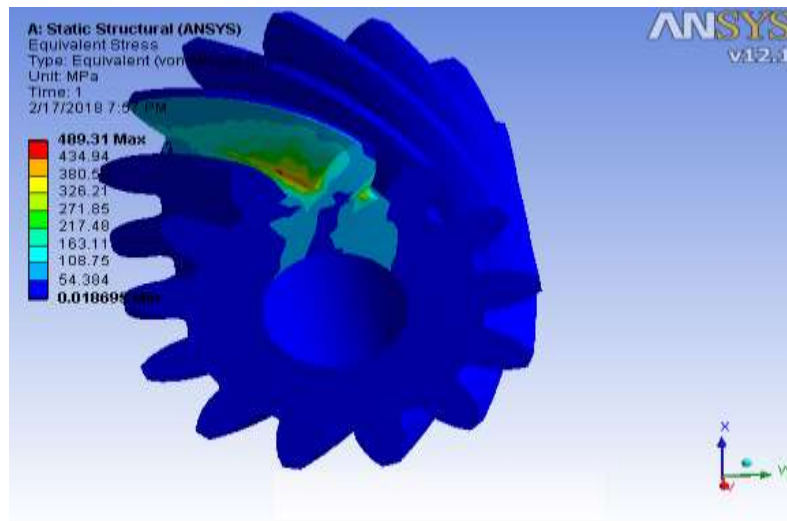### 5.2 FEM results for bending stress of pinion-



**Figure 1. FEM results for bending stress of pinion**
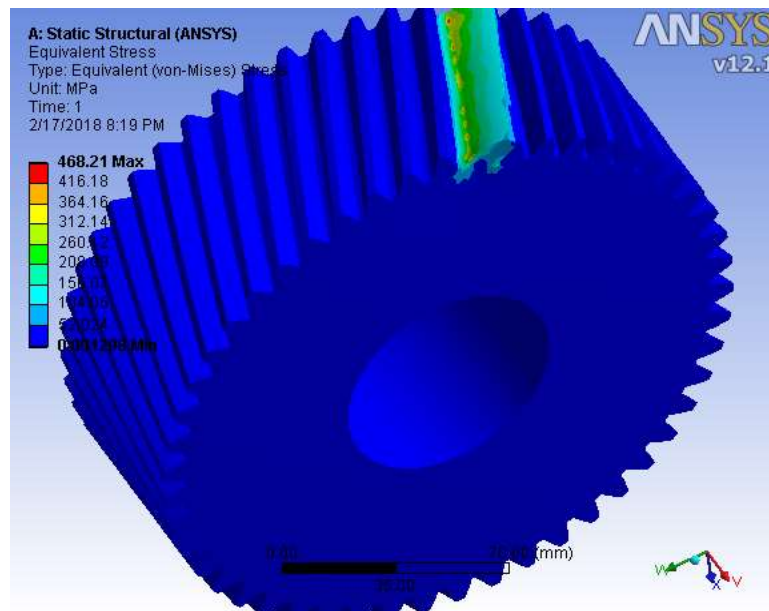
### 5.3 FEM results for bending stress of gear-



**Figure 2. FEM results for bending stress of gear**

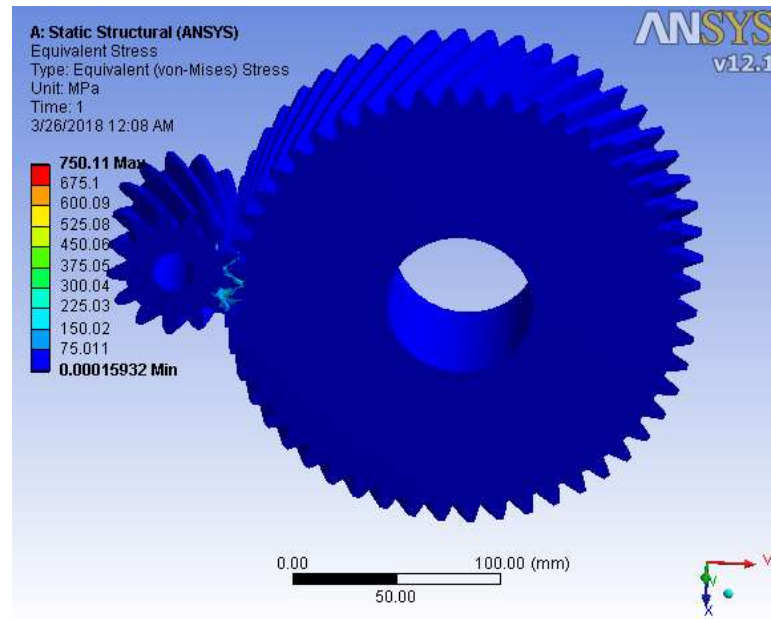**5.4 FEM results for contact stress -**



**Figure 3. FEM results for contact stress**

## 7. CONCLUSIONS

Theoretical.design.is carried.out using.standard.design.formulae.as per AGMA procedure and carried out analysis by ANSYS .The following. table.2 shows the comparison the theoretical design values with Ansys value.

**Table1. Details of Gear and Pinion**

| Name | No. of Teeth | Bending Stress by AGMA | Bending stress by Ansys | Difference in % |
|------|------|------|------|------|
| Pinion | 13 | 520 | 489.31 | 5 |
| Gear | 50 | 486.88 | 468.21 | 3 |

**Table1. Analysis details of Gear and Pinion**

| Sr No. | Name | Contact Stress by AGMA | Contact stress by Ansys | Difference in % |
|------|------|------|------|------|
| 01 | Assembly of Gear and pinion | 774 | 750.11 | 3 |

By replacing the existing material, 20MnCr5 by SAE8620, the gear will be strong enough to withstand in given conditions.

## ACKNOWLEDGMENT

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