"INVESTIGATION OF EFFECT OF HELIX ANGLE AND PRESSURE ANGLE ON BENDING STRESS OF HELICAL GEAR."

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Abstract - Purpose Gear design is a highly complex process. The consistent demand to build low cost, quieter and efficient machinery has resulted in a gradual change in gear design. Gear parameters such as pressure angle, helix angle etc. affect the load carrying capacity of gear teeth. Adequate load-carrying capacity of a gear is a prime requirement. The failure at the critical section because of bending stress is an unavoidable phenomenon. Besides this fact, extent of these failures can be reduced by proper gear design. The stresses produced under dynamic loading conditions in machine member differ considerably from those produced under static loading. Design/methodology/approach The present work is intended to study effect of pressure angle and helix angle on bending stress at root of helical gear tooth under dynamic state. Photostress method has been used as experimental methods. Theoretical analysis was carried out by Velocity Factor method and Spott's equation. LS DYNA has been used for FE analysis. Findings The results show that experimental method gives bending stress closer to the true value and bending stress varies with Pressure angle and Helix angle. Photostress technique gives clear knowledge of stress pattern at root of tooth. Originality/value The outcomes of this work help designer to use optimum weight to torque ratio of gear this is ultimately going to reduce total bulk of gear box.

Keywords- Helical Gear, Helix Angle, Contact Ratio, Bending Stress, Contact Stress

I. INTRODUCTION

Gears are the most common means used for power transmission. They can be applied between two shafts which are Parallel, Collinear, Perpendicular and intersecting, Perpendicular and nonintersecting, Inclined at any arbitrary angle.Gears are made to high precision Purchased from gear manufacturers rather than produced, with the rotational speeds, and the torques, of the two gears differing in proportion to their diameters. In transmissions with multiple gear ratios—such as bicycles, motorcycles, and cars—the term "gear" as in "first gear" refers to a gear ratio rather than an actual physical gear. The term describes similar devices, even when the gear ratio is continuous rather than discrete, or when the device does not actually contain gears, as in a continuously variable transmission. An external gear is one with the teeth formed on the outer surface of a cylinder or cone.Conversely, an internal gear is one with the teeth formed on theinner surface of a cylinder or cone. For bevel gears, an internalgear is one with the pitch angle exceeding 90 degrees. Internalgears do not cause output shaft direction reversal.

a) *General nomenclature*
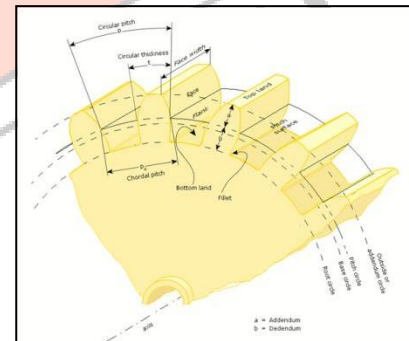
Photoelastic stress analysis technique based on concept of material birefringence is a non destructive and highly efficient method of structural analysis. The possibility of using photo elasticity to visually represent stress pattern during operation has

made in house However it is necessary to design for a specific application so that proper selection can be made. Used to be called toothed wheels dating back to 2600 b.c.

Gear terminology:

Clearance (c): is the addendum minus is the addendum minus dedendum. ,,

Working depth: Working depth: is the distance that one tooth of a is the distance that one tooth of a meshing gear penetrates into the tooth space.

Base circle: is an imaginary circle about which is an imaginary circle about which the tooth the tooth involutes profile is developed.

Fillet: is the radius that occurs where the flank of is the radius that occurs where the flank of the tooth meets the dedendum circle.

Module: replaces diametric pitch in metric pitch in metric system. A gear is a rotating machine part having cut teeth, which mesh with another toothed part to transmit torque. Geared devices can change the speed, torque, and direction of a power source. Gears almost always produce a change in torque, creating a mechanical advantage, through their gear ratio, and thus may be considered a simple machine. The teeth on the two meshing gears all have the same shape. Two or more meshing gears, working in a sequence, are called a gear train or a transmission. A gear can mesh with a linear toothed part, called a rack, thereby producing translation instead of rotation. The gears in a transmission are analogous to the wheels in a crossed, belt pulley system. An advantage of gears is that the teeth of a gear prevent slippage. When two gears mesh, if one gear is bigger than the other, a mechanical advantage is the potential to create significant efficiency and economical benefits in all aspect of engineering's and industry. Stress freezing photo elasticity is a responsive and inexpensive tool for stress analysis in the industrial environment. Pressure angle of gear plays a vital role in the design of gear, because it simultaneously affects the base circle radius of the involutes profile and minimum number of teeth to avoid interference varies. In past 14.5^0 pressures angle is used but the most common pressure angle now in use is 20^0, for aircraft gears pressure angle more than 20^0 is often used. Because as 14^0 gears are weak in load carrying capacity. The 30^0 pressure angle gears have strong and thicker at root of teeth so they generally run with more noise. Less than 20^0 pressure angle may be used to get smooth and quitter running. Moreover the Lewis form factor that is used in Lewis equation to account for bending stress at tooth root and incremental dynamic load depends upon pressure angle.

II.   LITERATURE REVIEW

Considerable research work in the area of design and optimization of spur gear has been carried out. It is seen that a very little work has been carried out in the area of helical gear. The gears are used for power transmission in different applications. One of the reasons of failure of gear may be due to failure of teeth. A failure occurs due to excessive bending stress and tension at a critical section giving rise to stress concentrations. With the use of photo elastic and finite element analysis many researchers have worked on the problems of analyzing stresses in different types of machine components and to determine the stress concentration factor to be applied in design. Three dimensional photo elastictechnique and FEA finds application in engineering.

Before undertaking present work, the literature survey has been carried out. A brief review of some selected references is presented here. **Paul Wyluda et.al [1]** have carried out an elastic-plastic finite element analysis of the quasi-static loading of two acetal copolymer gears in contact. According to the International Standard for calculation of load capacity of spur and helical gears, the tooth root tensile stress has relevance to plane strain conditions.. Load verses rotation of the gear set is compared to actual experimental results. The results indicate that to optimize a gear set, a non-linear analysis is required to be performed. Only under low loads and deformation can a linear elastic approach be suitable. Clearly combining computer simulations with material and component testing has led to a far better understanding of copolymer acetal gear design; this understanding could not be achieved by either simulation or testing alone. It is envisioned that with a few more material tests, the torque-displacement response of the gear pair can be simulated with confidence thus advancing the technology of copolymer acetal gear applications.

Cornwll R.W [2] has presented work on compliance and stress sensitivity of spur gear teeth using strain gauges. For measurement of maximum bending stress at tooth root, the gauges were placed at the 30^0 tangency location.

Jose L F Freire et.al [3] has explained details of photo elasticity technique. Photo elasticity indicates not only the most loaded areas of the observed component, but also provides accurate stress values at any critical point. Photoelasticity is a branch of Photomechanics. It employs models constructed from materials transparent to the light being used. These materials display birefringence under applied stress and are observed under polarized light using an instrument called a polariscope.

Donald Berghaus [4] has combined photoelastic data with finite element data for stress solutions over regions partially bounded by free surfaces and axes of symmetry. Least square solution has been provided without presumed values of applied forces at element nodes.

Fred B. Oswald et al. [5] carried out strain gauge analysis of low contact ratio spur gear to measure dynamic load using NASA gear noise rig. For analysis strain gauges were installed in the tooth root fillets of gear.

III.   PROBLEM IDENTIFICATION

3.1 Concluding remarks:

From the extensive review of the literature work carried out, it is seen that considerable research in the field of stress analysis of spur gear but very few works is available in the field of helical gear. There is no any experimentation work that studies the effect of pressure angle on bending stress at root of tooth of helical gear. A very few pertinent references are available on analysis of helical gear. From the extensive review of the published research work on stress analysis at root of tooth of gears, it is seen that the main issues in the helical gear as follows:

1. It is seen that mathematical modeling and design and manufacturing of gear analysis are the ticklish problems.
2. The complex helical gear geometry and variable length of tooth contact lines during meshing period results in complex load distribution in gear mesh.
3. Experimental methods are necessary for validation of theoretical and numerical analysis. Even though these methods are complicated, laborious, expensive, these can be applied for special cases like analysis of gear teeth.
4. Current trends in engineering globalization require research to revisit various normalized standards to determine their common fundamentals and those approaches need to identify "best practices" in industries. In this regard, some work on helical is required.

3.2. Problem Definition:

In Shivprasad Industries, Kolhapur, Helical gears are manufactured these gears are used in Printing machines these machines are used to Printing technology. Positive infinite Variable (PIV) gear box is used to transmit to power to belt conveyor of spreading machine .This PIV gear box consist of helical gears. The power transmitted by gear box is 1 kW at (150 to 200)rpm. In working condition of gear box it has been observed that pinion helical gear mounted on motor shaft fails due to load coming on teeth, It seems that the failure is due to stress concentration and bending stresses at the tooth root of gear. The crack is initiated just near to high stress concentration region of gear that is at the root of tooth.

Fig .3.1 Damaged Helical Gear of Gearbox

3.2 Objective:

1.   To carry out the theoretical static analysis of bending stress at root of tooth of helical gears of different pressure angle.

2.   To carry out the 3D photoelastic analysis of bending stress at root of tooth of helical gears of different pressure angle in static condition.

3.   To carry out the bending stress analysis at root of tooth of helical gears with different pressure angle in static condition by using analysis FE software like ANSYS.

IV.   METHODOLOGY

In 3D photoelastic analysis, the material fringe values are estimated from disc to calibrate photo elastic material. These findings are applied to determine the actual stresses developed in a model and by scaling the model to prototype. The results obtained from this method depend largely on photo elastic model. Therefore, the preparation of the model, itself has its own significance in entire process of photo elastic stress analysis to handle the particular problem. Similarly, in strain gauge analysis, important parameters that should be considered to maintain accuracy in the results are selection of strain gauges and their mounting locations. In the process of gear design pressure angle is an important parameter as base circle radius of tooth profile and minimum number of teeth to prevent interference depends upon it. Asymmetric gears have different pressure angles on drive side and coast side .The critical thickness of tooth increases due to this asymmetry. Due to low weight to torque ratio asymmetric gears are extensively used in automobile industry, wind turbine industry and aerospace industry . The virtual number of teeth and pitch circle radius very with helix angle. In this work three different methods have been used to analyze the effect of pressure angle and helix angle on bending stress at critical section of the tooth of helical gear. In theoretical method bending stress has been evaluated using Lewis equation, experimental analysis have been carried out by using 3D photo elasticity. For FE analysis ANSYS software has been used. Entire analysis process involves helical pinion with three different pressure angles i.e full depth 14.00, 200, 300 each subjected to three different torques with three different helix angles (100, 1500, 200) for each of them. Specifications of helical gears in mesh are identical except pressure angle and helix angle, the gear ratio being 1:1.

4.1 Theoretical Analysis
4.1.1 Force analysis in helical gear:

Helical gears force analysis can be done in similar manner as is done in spur gear. Helix angle causes creation of additional force component. It is seen as an axial force resulting in axial thrust on the bearings. The pictorial view of tooth forces in helical gear is as shown in figure 3.1. In a helical gear, tooth force P_N is normal to the tooth surface making pressure angle with horizontal plane. This tooth force has three components acting at right angle to one another.
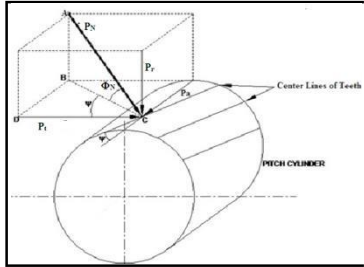

Figure 4.1 Forces in helical gear

4.1.2 Lewis equation for bending stress of gear:

Bending stress at critical section of gear tooth can be evaluated by using Lewis equation developed by Wilfred Lewis in 1892. Lewis equation is based on various assumptions and gear tooth is considered as cantilever beam as shown in figure 3.2.
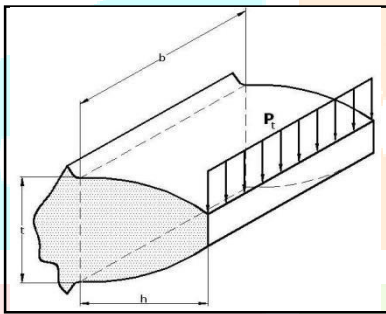

Figure 4.2 Gear tooth as cantilever beam

The tangential component of resultant force due to transmitted torque produces the bending moment about the base of gear tooth. In Lewis equation the effect of the radial component of resultant force as well as stress concentration has not been taken into account. At any instant only one pair of teeth is assumed to be in contact and total load is subjected to it.
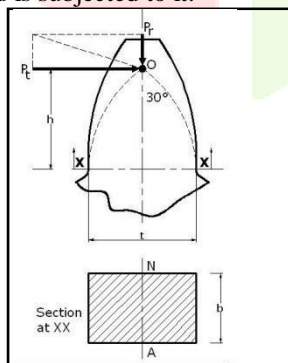

Figure 4.3 Gear tooth as parabolic beam
4.1.3 Beam strength of helical gear:

In order to determine beam strength, helical gear is treated as a formative spur gear. The formative gear means a spur gear which is imagined to be in a plane perpendicular to the tooth element. The beam strength of formative spur gear is given by equation 3.11,

$$S_b = m \times b \times \sigma_b \times Y$$
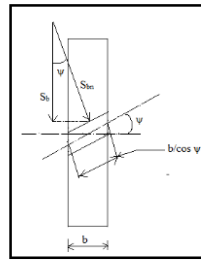
$$(3.11)$$

Figure 4.4 Geometrical interpretation of beam strength in helical gear

VI.   RESULT AND DISCUSSION

For enhanced accuracy and higher endurance of gear, clear knowledge of gear tooth stress all along cobweb is necessary. As such in this essay, bending stress analysis at critical section of helical gears have been carried out. By seeing the contrasting torques, squeeze angles and helix angles for helical gear, bending stress behavior were observed through the empirical method, FEA method and abstract method . The results are esoteric compile in the table number 4.1.

The results shows that there is appropriately good agreement between bending stresses at critical area under static condition by all design methods. The bending stresses at demanding area by theoretical method and finite element analysis are very close to each other, recorded error in reach 8.19%. The maximum error recorded between experimental and finite element analysis results is 8.22%, whereas between experimental and theoretical results is 9.34%.
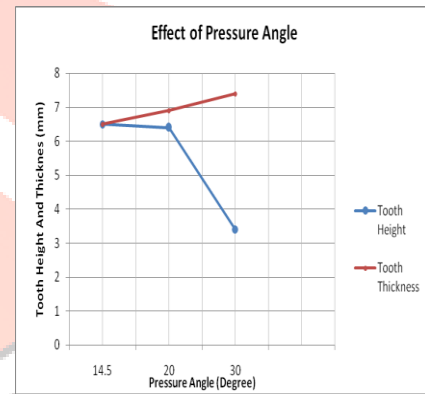
Effect of pressure angle on the tooth height and the tooth thickness
Figure Number 4.1

The amount number 4.1 shows the effect of burden angle on the tooth height and the tooth density of differing gears used for this study. Why the bending stresses are decreased with inbound in bend the pressure angles of gear? And how does the congestion angle play a vital role in gear design? strength. These questions can be acknowledge by the above graph. It shows that the tooth thickness at critical area increases and the tooth height decrease with burden angle which advance the tooth strength.

For consistent pressure angle, the helix angle is directly comparable to the tooth thickness i.e. as the angle value increases the tooth thickness also increases. It leads to more amount sharing circulation area of tooth at root and result in increasing stress absorbing ability. Thus greater value of the helix angle will increase the stress carrying capacity of the gear. In this contact, for higher value of helix angle, the bending stress generated at the root of tooth is less. The experiments were attend for different gears in which the gear with pressure angle 30º and helix angle 20º, is having higher tooth thickness around 7.8 mm, while gear with pressure angle 14.5º and helix angle 10º, is having less thickness of 6.7mm.

Results indicates the effect of helix angle on arching stress achieve at critical section of the tooth. The bending stresses are decreased with increase in the compel angle for constant helix angle. The bending repeat are also decreased with the increasing value of the helix angle as number of choppers in contact increases with boost in helix angle

VII.   .CONCLUSION

From theoretical calculations it is come to know that, Pressure angle increases bending stress decreases like that helix angle increases bending stress decreases. That is Pressure angle and helix angle is inversely proportional to the bending stress.

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