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Review Paper on Analysis of Worm Gear

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Abstract: **The worm & worm wheel is used in gear box of Winch machine for lifting sand bucket. During working worm wheel fails due to load coming on the teeth. The failure is due to stress concentration. The crack appears at central thickness of tooth. Hence the tooth breaks at the central thickness. The failure of wheel occurs within period of about 20 days. So the company has to replace the worm wheel which is not cost effective. The stress calculation of worm wheel at tooth thickness is a three dimensional problem. This paper represents the review of analysis of stress pattern by using 3D Photoelasticity techniques & FEA technique.**

Keywords: **Worm Gear, Photoelastictiy, Polariscope, Stress Freezing, FEA,Winch Machine Gear Box.**

I. INTRODUCTION

A. Worm Gearing:

Worm gears are used to transmit power between two non-intersecting, non-parallel shafts. These gears are generally at right angles to each other. It consists of worm and worm wheel. The worm is threaded screw and worm wheel is toothed gear. The worm wheel teeth envelope the treads on worm which gives line contact between mating parts. In other gear types, the drive can be given to any one of the two mating parts. But in worm gears, the drive is given to only worm. The worm can rotate the wheel but worm wheel cannot rotate the worm.

B. Failure of Gears:

Failure of gears may be classified into four categories:

- Surface fatigue (pitting)
- Wear
- Plastic flow
- Breakage

The appearance of the various distress and failure modes can differ between gears that have through hardened teeth and those that have surface hardened teeth. These differences result from the different physical characteristics and properties and from the residual stress characteristics associated with the surface hardened gearing.

II. PROBLEM STATEMENT

The worm and worm wheel is used in winch machine gearbox. During operation it was observed that the worm wheel fails due to load coming on the teeth. The failure starts at the central thickness of tooth and continues up to the root of the tooth. The failure occurs once within operational period of about 20days. So the industry has to replace the worm wheel which is not cost effective.The material of worm is hardened steel and the material of the wheel is phosphor bronze PB2 having approximate composition in percentages as (Cu = 85, Sn = 12, Zn = 0.3, Pb = 0.5, P = 0.4 and other = 2).

III. OBJECTIVES

Following are the main objectives of dissertation work.

1. To find out stresses at tooth root of wheel using experimental analysis using 3D photo elasticity.
2. To find out stresses at tooth root of wheel using FE Analysis using ANSYS.
3. To validate experimentally obtained results with FEA results and plotting final results.

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IV. WORKING METHODOLOGIES

The analysis work will be carried out by using following methodologies.

A. Theoretical Analysis:

This includes theoretical calculations of worm gearing i.e. calculations of forces and bending strength using Lewis equation.

B. Experimental Analysis:

Experimental analysis is one of the techniques to find out stress concentration areas. The experimental analysis will be done using 3D photo elasticity of worm wheel. The procedure includes-

a) Preparation of Model

- Preparation of Pattern.

Prototype of worm wheel itself will be used as a pattern.

- Preparation of Rubber Mould.

The rubber mould will be made out of "Sylartivi-11".

- Casting photoelastic material model and calibration disc.

The model and calibration disc are will be prepared out of Epoxy Resin CY-203 IN araldite mixed with HY-951 hardener.

b) Designing and developing the loading frame.

c) Stress freezing.

d) Slicing of model.

e) Stress analysis.

C. FE Analysis:

The Finite Element Analysis is the effective as well as convenient method to evaluate the stresses of the worm wheel. In this dissertation, the FE analysis will be done with the help of ANSYS software. The procedure includes-

1. Modeling of worm wheel using suitable software using gear parameters.
2. Selection of proper element for meshing.
3. Specifying required material properties like modulus of elasticity, poissions ratio, etc.
4. Applying boundary conditions and constraints.
5. Carrying out the Post Process in ANSYS to solve the problem.
6. Plotting the results.

V. LITERATURE SURVEY

In spite of the wide use of worm gear drives, only few papers have been published on analysis and load distribution calculation of worm gears. Previous works addressing worm gear analysis published by some authors is as follows.

1. PrashantPatil *et.al*, have discussed about 3D Photoelastic and Finite Element Analysis of helical gear. They have discussed an industrial problem which uses spreading machine to spread bagasse. This spreading machine has Positive Infinite Variable (PIV) gearbox which contains helical gears. In working condition, helical pinion fails due to load coming on the teeth. It seemed that the failure was due to stress concentration and bending stresses at tooth root of gear. The calculation of maximum tensile stress at tooth root was a three dimensional problem. Thus they have analyzed the stress pattern by using 3D Photo elasticity techniques. Also they have verified obtained results with FEA. They have found out

that the failure of helical gear of PIV gear box may be due to improper alignment or due to improper heat treatment process during teeth hardening.

2. BhosaleKailash *et.al*, have discussed about an experimental and finite element method of analysis. In their paper, they have analyzed bending strength of helical gear using photoelasticity technique. The experimentally obtained results are verified with finite element results. The conclusion of their work have proved that the error in maximum bending stress calculated by both, experimental and finite element technique, is only about 2.02%. Thus it clears that these both methods are best suitable for bending stress analysis of gears.

3. W. T. Moody *et.al*, have published various techniques of analysis of mechanical component in Photoelastic and Experimental Analog Procedures Engineering Monograph No. 23. Along with the theory of technique, they have explained all details including material requirement, instrument used for analysis, calibration techniques, the polariscope, nature of light and plane polarization, 3D photoelasticity, the photoelastic interferometer, the babinet compensator, the beggsdeformeter, the electrical analogy tray, the membrane analogy, photoelastic materials and model preparation, photoelastic model loading frame assembly.

4. Dr. V. B. Sondur *et.al*, have discussed about theoretical and finite element analysis of load carrying capacity of asymmetric involute spur gears. In this paper, they have presented a method for investigating the bending stress at the critical section of "Asymmetric Involute spur Gear". The gears with different pressure angle have been modeled by using CATIA software and analysis was carried out. The results obtained by theoretical method have been verified by using ANSYS. From their work they have proved that bending stress can be minimized up to 20% by increasing pressure angle from 20° to 35°. Thus from their work it is clear that FEA can be the best technique for designing and analyzing mechanical component.

5. Pravin M. Kinge *et.al*, have analysed gearbox used in sugar industry. The main objective of analysis was to improve the life of the gear. The reason found for failure of the gear was due to wear of gear teeth edges. This is caused due to high stress concentration along gear teeth edges. To relieve these stress concentration three modifications in the design were done using ANSYS and again stress analysis of the modified gears carried out. The three design modifications were done as first, the edges of the gear teeth were tapered by an angle of 20^0, second, making groove in the gear wheel and third, making holes at the roots of the gear teeth. They have proved that the expected increase in life of the gears of the gearbox would be three years.

6. Gitin M. Maitra, V.B. Bhandari, PSG College of Technology, Norton, P. C. Gope, M. F. Spotts *et.al* have explained all the details of every type of gear including geometry, gear related parameters, force calculations, deflections, effect of heat generation, stress concentration, design criterion, load rating and efficiency of gears, friction in worm gears, material selection and strength rating of worm gears in their respective books.

7. James W. Dalley *et.al*, have explained various experimental techniques which can be used for analysis including fracture mechanics, strain measurements with electrical strain gauges and strain gauge circuits, Moiré method, theory of photoelasticity and brittle coating methods in the book 'Experimental Stress Analysis', McGraw-Hill Inc.

8. L. S. Shrinath *et.al*, have given all the detailed procedure regarding nature of light, 2D photoelasticity and 3D photoelasticity. They also have given various experimental analysis techniques like holography, Moiré method, brittle coating method, strain measurement, strain gauges etc. in their book named 'Experimental Stress Analysis', Tata McGraw-Hill Publishing company.

9. Nitin S. Ghokhale *et.al*, have explained the finite element method in detail. They have explained about introduction, history of FEA, types of analysis, meshing, elements, material properties, boundary conditions, nonlinear analysis, thermal analysis, dynamic analysis, CFD etc. in the book named 'Practical Finite Element Analysis', Finite to Infinite Publications, Pune.

According to the literature survey from above mentioned references, it is clear that 3D photoelasticity technique can be used for analysis of worm gears to find out stresses at the tooth root as this techniques has been used by authors and their results are very much fine. It is also clear that the 3D photoelasticity gives stress concentration areas and magnitudes of stresses. Also FEA can be effective technique which can be used to validate the experimentally and theoretically obtained results. The references from books give details about the worm gearing and details of methods of analysis.

Also from several published papers, we get the literature about the various kinds of failures of gears, their failure reasons and preventive actions as well as corrective actions to be taken.

VI. ANALYSIS BY LEWIS EQUATION

In finding the tooth size and strength, it is safe to assume that the teeth of worm gear are always weaker than the threads of the worm. In worm gearing, two or more teeth are usually in contact, but due to uncertainty of load distribution among them it is assumed that the load is transmitted by one tooth only.

The analysis of bending stress in gear tooth was done by Mr. Wilfred Lewis known as Lewis equation. In the Lewis analysis, the gear tooth is treated as a cantilever beam. The tangential component (Pt) causes the bending moment about the base of tooth.

We know that according to Lewis equation, the bending strength cab be evaluated.

$$P_t = \sigma_b C_v b \pi m_n Y$$

Where

P_t = Permissible tangential tooth load or beam strength of gear tooth.

σ_b=Bending stresses.

C_v= Velocity factor.

b = Face width.

m_n= Normal module.

Y= Tooth form factor or Lewis factor.

Therefore according to Lewis equation,

σ_b=16732.57/ (0.9658×25.08× π×3.878×0.392)

$$\boldsymbol{\sigma_b = 144.64\ N/mm2}$$

The bending stress value is 144.64 N/mm^2. The ultimate tensile strength of the phosphor bronze (PB2) material is 320 N/mm^2. Therefore with reference to these results, it can be stated that, the design of worm wheel is safe as bending stress value is far less than the ultimate tensile strength of the PB2 material. The factor of safety is about 2.21.

Also the hardness of the phosphor bronze PB2 is 110 BH, which is acceptable value, thus it states that the gear material used is suitable for respective application.

VII. CONCLUSION

The value of bending stress by theoretical analysis is found out using Lewis equation. Now the experimental & FE analysis will be done to find out stresses and to validate the obtained results of experimental analysis with FEA. Depending upon the results, correct solution will be provided to the company.

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