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OPTIMIZATION TECHNIQUE OF EPICYCLIC GEAR TRAIN AND FAILURE OF GEARS: A REVIEW

ADARSH KUMAR [1], ATUL ANAND[2], DEEPAK KUMAR[3], HARISH YADAV[4], MUBINA SHEKH[5]

[1234]UG Scholars, Mechanical, IMS Engineering College, Ghaziabad, India.
[5]Assistant Professor, Mechanical, IMS Engineering College, Ghaziabad, India.

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ABSTRACT:- *In this review paper, Epicyclic gears train are one of the most critical components in mechanical transmission System in which failure of any of single gear affect whole transmission system and in turn, it becomes necessary to eliminate causes of failure to minimize them. This review paper deals with the optimization of gear design leading to the reduction in load failure of gear. It is found that high volume gearbox cost depends upon material costs and weight of gears. It is difficult to find an optimum solution for given space and weight restrictions. The study carried out in this review paper shows the optimization techniques of Epicyclic Gear train to reduce load failures for design improvement and optimizations of products.*

Keywords: **Epicyclic gear trains, Optimization, gear load failures**

1. INTRODUCTION

Studying most of the research papers it was found that the extensive research in the field of epicyclic gear design has already been performed. The advantages of planetary gear trains are higher torque capacity, lower weight, small size and improved efficiency. Planetary Gear Box weighs 60% and half the size of a conventional gearbox [11]. In the design of planetary gearbox, iterative considerations need to be given for composite arrangement to have the minimum number of components, higher transmission efficiency, and higher load carrying capacity. High reductions ratios are possible in single stage differential planetary gear arrangement but will work for low torque applications only like positioning systems in robotics, aerospace. It was found that high volume gearbox cost is much dependent on material cost and weight of planetary drives. In short, the planetary gears systems have high torque density, compact, low inertia and can be grease lubricated for life, which are demands of industrial applications [7]. In most of the research paper, it was found that optimization of gear had been done with trial and error method which on much further utilization results in design modification with limiting stress values.

2.Theory

A Epicyclic Gear train consists of one or more planet gears revolving around a sun gear. An Epicyclic Gear train is usually employed to achieve high reduction ratio in small and power dense packages to use in various applications such as automatic automobile transmissions and hybrid transmission systems.

The advantages of epicyclic gear trains are higher torque capacity, lower weight, small size and improved efficiency of the planetary design. Efficiency loss is generally of order 3% per stage resulting in the large proportion of the energy transmitted by gearbox. There is greater stability in epicyclic gear train due to even distribution of masses. Some of the disadvantages of epicyclic gearbox are High bearing loads, constant lubrication requirement, inaccessibility and design complexity.

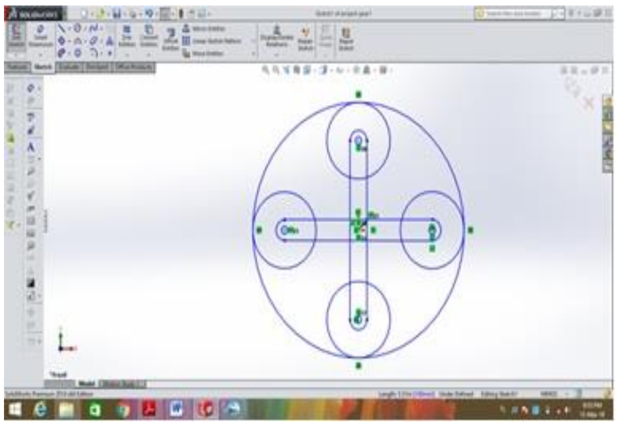

Figure.1Epicyclic Gear Train

2.2 Gear Mechanism:

For transmission of power, gears have been in use since the dawn of civilization. Ancient Engineers were aware of the desired performance parameter such as gear ratio, centre distance and the available power source (water current, wind horsepower) and used them to define gear parameter (diameter, number and shape of the teeth). They are manufactured gear using the available material, technology and tools. From these facts, it is seen that it is necessary to vary the ratio of the speed of rotation of the vehicle wheels to the speed of rotation of the engine.

2.3 Optimization of gearbox:

There is the following method to use the optimum number of gears and reduce the complexity of the gearbox system.

2.3.1 Finite Element Method

2.3.2 Optimization technique

2.3.1 Finite Element Method:

For the design analysis of epicyclic gearbox system Finite Element method was used. The researcher takes the input provided in the file and obtains the solution for field variable. Common outputs obtained are Displacement Stress, Strain and acceleration. ANSYS is engineering stimulation software which offers a wide range of multiphysics numerical solvers thus providing virtual access to any field of engineering simulation that a design process may require. The static structural analysis system is used for the static analysis of the epicyclic gearbox housing. The structural analysis uses FEA tool for product design validation. ANSYS static structural provide the ability to simulate every structural aspect of the product like the linear static analysis that simply provides stresses or deformations.

2.3.2 Optimization Technique:

The Optimization Toolbox is a collection of function that extends the capability of the MATLAB numeric computing environment. The toolbox includes routines for various types of optimization that includes Linear programming, Non-linear least squares with bound constraints, nonlinear system of equation solving, unconstrained nonlinear minimization, nonlinear minimization with bound constraints etc. Optimization concerns the minimization or maximization of functions. Function for nonlinear equation solving and least squares problems are also provided.

3. Failure of Gears of Gearbox-

Gear systems or gear train tends to play a very vital role in all industries and also in our day to day life. Gearbox failure can be caused by fundamental design issue, manufacturing defect, deficiencies in the lubricant or lubrication system, excessive time at standstill, high loading, and many other reasons.

3.1 Surface destruction

3.2 Breakage of the tooth due to static and dynamic load; The complete breakage of the tooth can be avoided by adjusting the parameters in the gear design, such as module and face width so that the beam strength of the gear tooth is more than the sum of static and dynamic loads. The surface destruction or tooth wear is classified according to the basis of their primary causes. The basic types of gear tooth wear are given below:

3.1.1 Abrasive wear:

Foreign particles in the lubricant, such as dirt, rust, weld, spatter or metallic debris can scratch or Brinell the tooth surface. Abrasive wear can be prevented by the provision of oil filters, increase surface hardness and use of high viscosity oils. A thick lubrication film developed by these oils allow fine particles to pass without scratching.

3.1.2 Corrosive wear:

Corrosive wear is due to the chemical action of the lubricating oil or the additives. The tooth is roughened due to wear and can be seen in the Fig. 2. Chemical wear of flank of internal gear caused by the acidic lubricant.

3.1.3 Adhesive wear:

Unlike scoring, adhesive wear is hard to detect. It occurs right from the start. Since the rate of wear is very low, it may take millions of cycles for noticeable wear. Prior to full load transmission, gears are run in at various fractions of full load for several cycles. The surface peaks are quashed over a long period of running and the surface gets the polished appearance.

3.1.4 Scoring:

Scoring is due to the combination of two distinct activities first, lubrication failure in the contact region and second, establishment of metal to metal contact. Later on, welding and tearing action resulting from metallic contact removes the metal rapidly and continuously so far, the load, speed and oil temperature remain at the same level. The scoring is classified into initial, moderate and destructive.

1. Initial scoring:

Initial scoring occurs at the high spots left by the previous machining. Lubrication failure at these spot leads to initial scoring or scuffing. Once these high spots are removed, the stress comes down as the load is distributed over a larger area. The scoring will then stop if the load, speed and temperature of oil remain unchanged or reduced. Initial scoring is non-progressive and has the corrective action associated with it.

2. Moderate scoring:

After initial scoring if the load, speed or oil temperature increases, the scoring will spread over to a larger area. The Scoring progresses at the tolerable rate. This is called moderate scoring.

3. Destructive scoring:

After the initial scoring, if the load, speed or oil temperature increases appreciably, then severe scoring sets in with heavy metal tore regions spreading quickly throughout. Scoring is normally predominant over the pitch line region since elasto hydrodynregion. In dry running, surfaces may seize.

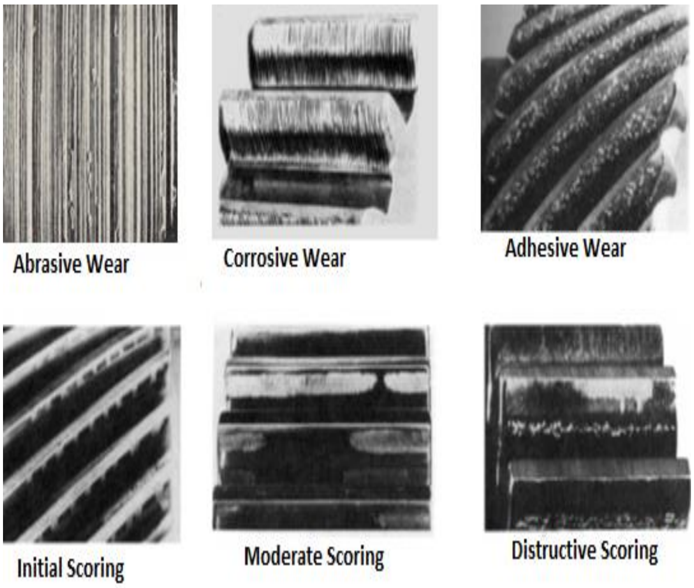

Figure.2 Surface destruction

3.2 Gear failure due to Load:

3.2.1 Micropitting on gear teeth: Micropitting can affect gears and failures due to micropitting are very common in gearboxes. Micropitting occurs when the lubricant film between contacting surfaces is not thick enough and the surfaces have high amounts of sliding action. Micropitting results in a frosted or matte finish surface in affected areas. Micropitting-related failures can be prevented by changing lubricant type or by reducing component surface roughness.

Macropitting on gear teeth:

Macropitting occurs when the contact stress in the gear exceeds the fatigue strength of the material. Macropitting that occurs before the end of the design life is an indication that one or more design assumptions, such as contact stress, material properties, lubricant condition or applied load, were not met. Macropitting results in craters on the gear tooth. Beach marks due to the presence of corrosion and lubricant in the crack are sometimes present and indicate a fatigue progression process. Macropitting failures can be prevented by reducing loads, improving gear profiles to reduce stress, using cleaner steel, or increasing material strength, through alloy selection or a heat treatment process.

3.2.3 Fretting Corrosion:

Fretting is a surface-wear phenomenon that occurs when two contacting surfaces have small oscillating relative motions, with no lubricant film between the surfaces. Fretting corrosion can be identified by the presence of ruts along the lines of contact, along with the presence of reddish-brown or black wear debris. Fretting corrosion can be prevented by minimizing the amount of time that a gearbox spends without rotating or by improving transportation conditions, depending on the cause of the fretting corrosion.

3.2.4 Axial Crack:

Axial cracking is a phenomenon that occurs in bearings, almost always on the bearing inner ring. Failures of this type have become very common in wind turbine gearboxes and were the subject of an article in the June 2013 issue of North American wind power. The cracks develop in the axial direction, perpendicular to the direction of rolling. Axial crack failures are most likely to occur in through-hardened bearings. Axial crack failures can be prevented by using case carburized bearings, ensuring that the appropriate amount of retained austenite is present, applying a black oxide coating, and ensuring the correct level of interference fit exists between the bearing inner ring and the shaft on which it is mounted.

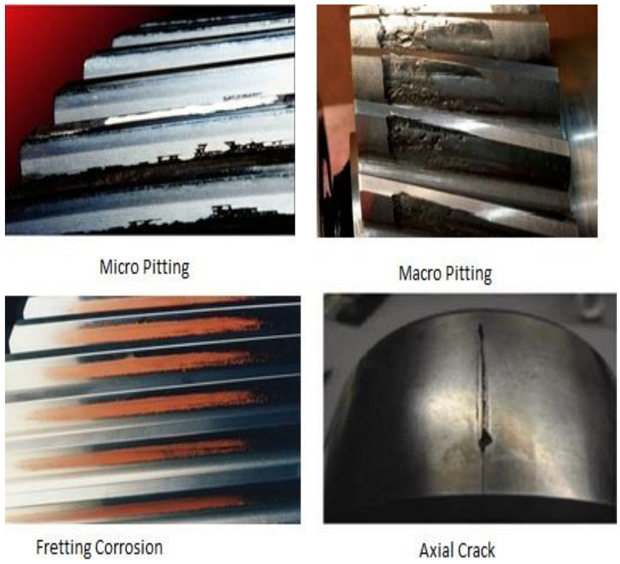

Figure.3 Failure due to load

4. Methods to overcome these failures: In present world gearbox manufacturing companies attempt to optimize their gear designs to obtain low-cost high-efficiency solutions. This optimization of designs mainly occurs in two components areas viz. housing of gearboxes and mating parts of gearboxes. In the epicyclic gearbox, gears are manufactured by standard company procedures and standards. In the given case housing of gearboxes contributes one-third of the total weight of the gearbox thus providing a scope to optimize overall mass by reducing the mass of the housing which can be solved by Finite Element Method (FEM). Below are the steps carried out to research such problems: -

- Manual load calculation for epicyclic gear box
- CAD & FE Modelling
- FE analysis of epicyclic gearbox housing

- Identify the potential area for the reduction of mass optimization
- Results & Discussion.

5. CONCLUSION:

By carrying out critical review of research on epicyclic gear train and gearbox it can be concluded that the design parameters like Number of teeth, module, number of planets, face widths, tooth profile modification, material are very important in deciding the load capacity in bending and wear, life and cost of gears. By this methodology, one can obtain deflections and stresses for different loading conditions for existing epicyclic gearbox housing. After implementing optimisation techniques weight of the epicyclic gearbox housing should be reduced. Finite Element Analysis should be carried out to check whether the optimized design of epicylic gearbox housing is safe or not. In the design of planetary gearbox, iterative considerations need to be given for composite arrangement to have the minimum number of components, higher transmission efficiency, and higher load carrying capacity. Multi-criteria Mathematical modelling methods can be applied to planetary gears and it determines a set of Pareto optimal solution for various objective functions.

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