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Review on Failure Analysis of Cooling Tower Fan Gearbox

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Abstract- *In this paper, the failure of pinion gear has been selected as investigation topic. However, this study also includes the failure analysis of gearbox of cooling tower fan. A gear is used to transmit torque. Gears are generally like worm gears, spur gears, helical gears, rack & pinion, herringbone or a double helical gears, hypoid gears, bevel gears etc. The various applications of these gears are varied from small wrist watches to massive machinery such as aerospace industry, automobile, rolling mills, transmitting & hoisting machines, marine engines, and etc. The problem identified here is the pinion gear in the fan gear box is failing prematurely; the life of the gear is less than 1 month. Pinion gear was observed during the visual inspection and it was found with broken teeth. After completion of this project, the solution found on the problem will increase the life of pinion gear as well as the gear box.*

Keywords:*Gear failure, Cooling tower fan, Gear box, Pinion Gear, etc.*

INTRODUCTION

This project is related to gear failure in Cooling tower fan gear box for thermal power plant. This is an industry based project. Mahesh Casting works, M.I.D.C., Nagpur has been assigned the work of designing the gears for the gear box by thermal power plant. During the visit to Mahesh Casting Works, the problem was discussed. The pinion gear in the fan gear box is failing within less than one month. Due to this failure of pinion gear whole gear box failing prematurely. The desired life is minimum 24 months for gear box of fan by the thermal power plant. Because of that failure they have to shut down the Cooling tower fan. Due to this thermal power have the problem of loss in efficiency.

During this project, various causes' of gear box failure will be identified and rectified by using data collected from the industry. The objective is to rectify design of gears in gear box after studying the failure parameters.

REASONS FOR FAILURE OF GEARBOX

Cooling tower fans work under different and very high load conditions. For small time periods, they frequently only run at highest load. Due to high and different stresses for a long period, mechanical components like the gearbox of a fan can lead to failure. As there are many rotatory equipments like bearings and gears. The failures of these gears, bearings, misaligned drive shafts, and extreme vibration is common reasons for failure of the gearbox while working condition.

These failures can be detected with predictive diagnostics: -

Defects In The Bearing: -

Bearings are working under variable, high load and undesirable environmental conditions. Due to the force applied to bearings the defects often developed quickly and cause to friction, bearing damage as well as gearbox failure. [12]

Fig 1: Defects in the bearing[12]

Misalignment of Shaft: -
The length of the shaft in a cooling tower fan is quite large because of this misalignment of the shafts is a common problem. Due to the stress in the shaft can damage couplings which cause for bearing fatigue, and lead to breakage of the shafts. [12]

Fig 2: Misaligned shafts[12]

Issue Related To Coupling: -
Because of the extreme misalignment of shafts coupling can be damaged, due to this shaft get separated. The serious coupling damage leads to gearbox failure. [12]

Fig 3: Failure of coupling[12]

Figure 4: Broken teeth of pinion gear[12]

Broken or Worn Teeth: -
Misalignment of the shafts is the reason for the increase in load on input gear, which leads to the improper meshing of the gears and produces debris. Misaligned and damaged gears can effect in failure of gearbox. [12]

THE FAILURE OF GEAR
While designing the gear, maintenance is necessary in order to avoid the failure of the gear. The failure of the gear can be taken place into following five types:

- Wear
- Scoring
- Plastic flow
- Pitting
- Tooth breakage

Wear: -
The wear is take place on the tooth of gear. It can identified as metal removal from the tooth or less reliably from a surface. Wear on a gear tooth takes place due to the absence of an oil film, there must be a metal to metal contact for this situation, rough abrasive particles present in a blend with the oil.

Scoring: -
The scoring is similar to the adhesive wear. It damages the surfaces of the tooth that during the relative motion. Due to the absence of lubricating oil causes for metal-to-metal contact. The welding action takings place in between the interlocking teeth. Metal particles get removed from the surfaces of gear tooth, which scratch teeth flakes during sliding. Scoring is happening in a high contact pressure area.

Plastic Flow: -
Plastic flow in the tooth surface takes place due to the high contact stresses in sliding and rolling action of the mesh. Surface and Sub-surface material shows the metal flow and surface distortion. Usually, metal flow happens in the soft gear material. In a case of heavyweight loads because of impact loading it results in the case-hardened gears. This is also recognized as a cold flow.

Pitting: -
Pitting is basically a type of surface fatigue. Mainly it caused by high loading in uneven tooth surface and the contact stress is above the surface fatigue strength of the material. In the fatigue region, material is detached from the surface and there is a formation of a pit in the material

of gear tooth. Due to that pit, stress concentration takes place in the nearby region. Pitting spread over the complete surface. Due to the pitting and high contact stresses, fracture of tooth surface happens. The failure proceeds during the cycle of running.

Tooth breakage: -

Bending fatigue failure: -

Due to bending fatigue a crack get initiated in the root section of the gear tooth which cause for gear tooth failure.

Overload breakage: -

A overload load may due to bearing seizure, failure of rotary equipment, external material passes through the mesh, or an unpredicted misalignment of shafts. A overload fracture results in a stringy, fibrous break display indication of having been pulled or torn apart.

LITERATURE REVIEW

Prafulla M. Chor et. al. authors had found that due to excess wear the tooth of gear gets weakened. They had done contact stress analysis on the spur gear train. By using strain gauge they had determined the maximum contact stress. Mainly the causes for the wear are misaligned in the shaft, wrong viscosity oil selection, and high contact stress, which is greater than the surface-fatigue strength of the material. It was found that the contact stresses of a gear are greater than fatigue strength of a gear material from the results by experiment method. The module of gear should be increased to reduce that contact stresses. If the module of gear gets increased then contact stress are declining up to the limiting value. [1]

N. K. Jain et. al. had done a study on failure analysis of the gearbox of an air cooled condenser. Which was failing within 3 months after it fitted into a condenser? The problem was recognized by maintenance engineers by doing condition monitoring of gearbox. By doing a visual examination of failed gear they found that occurrence of spalling and destructive pitting is the main reason for failure. Some suggestions were given to increase the failure life of gearbox like the gears should be case hardened instead of complete hardened. The surface finish of a gear should have better-quality so that fraction of maximum to average surface irregularity is less than 5. [2]

J. Venkatesh et. al. has studied that in designing of gears the bending stress and surface strength of a gear tooth are taken in to consideration, is one of the main providers for the failure of the gear in a gear set.Thus, the analysis of stresses has turn out to be common as an area of research on gears to lessen or to reduce the failures and for optimum design of gears. In this research paper bending and contact stresses, are intended by using an analytical method as well as Finite Element Analysis. To evaluate bending stress modified Lewis beam strength method is used. On the basis of the results if the material strength value is standard then a gear with the lowest no. of teeth with any maximum helix angle of additional face width is preferred.[3]

Shanavas S. has investigated the features of static stress of the involute composite spur gear system which includes the contact stresses and bending stresses of the gears in mesh and by equating it with the present involute C.I. spur gear arrangement. The goal is to exchange the cast iron spur gear with Carbon fiber epoxy compound spur gear because it have great strength, small weight, and damping features. A pair of the involute spur gear is drawn in a CAD system PRO-E software and FEA is completed by using ANSYS 13 software. The contact stresses and bending stresses in a tooth root are studied using the 3-D model. The bending stress found by FEA method is equated with bending stress found by Lewis equation and the contact stress achieved by FEA method is equated with contact stress got by Hertzian equation. [4]

Govind Sarkar et. al. have studiedthe nature of contact between the mating teeth demand for some study in contact stress. The AGMA has delivered the empirical relation for contact combined with bending stress. The Lewis equation and the Hertzian approach also provide the relation of contact and bending stresses respectively. The work is done mainly concentrated on the justification of the AGMA and Hertzian and Lewis theory using FE approach. The geometric model of helical tooth profile was done and it was properly constraint and overloaded to generate FE model after meshing the same. The size of mesh and type of elements were critically chosen after needed considerations. The no. of elements was decided by slowly increased them till deflection and stress did not show the major changes. [5]

A. Al-Meshari et. al. authors have done a study on failure of a cooling fan gearbox. Failure analysis was meant to identify root cause of gear failure to avoid their reoccurrence. To investigate the original cause of failure they have used several techniques like visual inspection, metallographic examinations, various chemical analyses and hardness testing. From the investigation, they found that gears were failed by contact fatigue enhanced by higher & irregular loads. Remedial action suggested for

improving failure was to decrease gearbox start & stop frequency to lessen loads on gear surfaces. [6]

Panya Srichandr et. al. both had done an investigation on the gearbox of a steel mill in which premature failure of helical gear has occurred. For the investigation, they had done visual examination of failed gear. To enhance the results of a visual examination test they have used dye-penetration test. Due to this test crack originating zone in the failed gear were observed. They had also done SEM as well as microstructure examination of gear tooth surface to identify spalling and pitting areas on the surface. It was concluded the helical gear prematurely failed because of fatigue fracture started by surface and subsurface damages causing excessive contact stress. This stress at gear tooth surface is a result of replacement of more powerful motor. The fracture starts from pitting area at the surface of a gear tooth tracked by fatigue crack beginning, crack development, and final breakage. The pitting happened as the end result of excessive stress. [7]

Ali Raad Hassan has mentioned transient stress analysis on spur gear for calculating the mesh forces using a contact stress analysis. Natural frequencies and dynamic answer of a spur gear sector are examined using a 2-D F. E. model that give suggestions of significant benefits for dynamic gear analysis. The gear teeth were analyzed for various operating speeds. A major feature of this modeling is to determine the mesh forces using a contact stress analysis. ANSYS software has been used for a suggested model to calculate the natural frequencies by taking help of the Block Lanczos technique. The dynamic reaction of gear tooth by considering the impact of speed of the gear have been calculated and design parameters have been discussed. [8]

Zlaivei Yu et. al. has studied failure of idler gear of a gearbox of diesel engine. The micro crack surface displays brittle cracking structures & micro fracture shows inter angular cracking structures. The overdue brittle fracture is main failure mechanism of idler gear. Thorough metallurgical examinations on carburized layer have been done & core zone were displayed. Failure reasons were evaluated. The concluding result of this study shows that specified material has no clear metallurgical occurrence & forging defects can detected in crack origin zone. The 2 fracture zones formed on futile gear whose macro factography displays brittle fracture features and micro factographyintergranularfracture structures.[9]

Tezcan Sekercioglu et. al. both had inspected breakage of spiral bevel gear for truck differential created from case reinforcing steel. In order to study reasons of failure specimens prepared from broken spiral bevel gear were subjected to investigate such as hardness chemical analysis, visual inspection & metallurgical test on the gearsurface was observed the effect of microstructure onthe facture was measured. And result shows that the Low surface hardness value of calculated contact stress were greater thanallowable contact stress which is emphasized inthis research paper.[10]

Osman Asi has done an investigation on helical gear which is installed in a gearbox. A failed helical gear has been undergone some test to find the failure cause which was like photo documentation, chemical analysis, visual inspection & metallographic analysis. By doing all examinations, the author found that spalling and destructive pitting were active on the surface of every tooth at pitch line. SEM examination shows that breakage failure occurs because of tooth bending fatigue. From the evaluation, it was found that primary cause of helical gear failure was probably misalignment of helical gear. Crack formation on gear tooth surface is happening because of spalling and destructive pitting. [11]

CONCLUSION

A short review of failure analysis of gear by using recent techniques & different conventional techniques for various types' of gears was discussed here. Failure types in the most of the gear are high stress, low cycle fatigue fracture, abrasion wear and plastic deformation. Most of the researchers have investigated the various type's of gears which are like spur gear, double reduction helical gear, helical gear, bevel gear, etc. They have used contact stress analysis, failure analysis, CAE analysis, transient stress analysis, and fatigue failure analysis for investigation of root cause of failure. The purpose of this work is to identify the parameters causing the premature failure of the gear.and to design the gears for Cooling tower fan gearbox for long fatigue life cycle.

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