GEAR FAILURE INVESTIGATION AND OPTIMIZATION

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Abstract: Spur gears are widely used in industries for transmission. Also, the standard size of gears availability makes it a easy choice for various applications. During the testing condition of an industrial gearbox, gear tooth failures observed on a single shaft. Such tooth failures resulting into dissatisfaction and required investigation. This failure is due to continues contact of gear and pinion with each other, which result in to fatigue failure. These failures can be minimized providing proper root radius and with proper manufacturing method. The targeted aim of this project is to study the root cause of failure and improve the life of gear using FE Analysis.

Index Terms **– Gear, fatigue, failure, Ansys, FEA**

I. INTRODUCTION

Spur gears are a type of cylindrical gear, with shafts that are parallel and coplanar, and teeth that are straight and oriented parallel to the shafts. They are the simplest and most common type of gear – easy to manufacture and suitable for a wide range of applications. The teeth of a spur gear have an involute profile and mesh one tooth at a time. The involute form means that spur gears only produce radial forces, but the method of tooth meshing causes high stress on the gear teeth. Because of this, spur gears are typically used for lower speed applications, although they can be used at almost any speed.

During the testing condition of a gearbox, multiple gear tooth failures observed on a single shaft. Such tooth failures resulting into dissatisfaction and required technical investigation.

This failure is due to continues contact of gear and pinion with each other, which result in to fatigue failure. Once the failure occurred, gear has to be replaced and test cost incurred is higher.

These failures can be minimized by finding the root cause of the problem & taking corrective action.

II. OBJECTIVE

To develop and build a FE model for the existing design.

To calculate the stress and fatigue safety factor in existing design & propose the optimized design.

To compare the FE results with hand calculation for allowable stress and suggest best suitable option to customer to get over failure issues.

III. METHODOLOGY

To study Spur Gear in more detail.

To understand the principles of designing Spur Gear.

To understand the various analyses to be carried out on spur gear.

To import a 3-D model of Spur Gear in Ansys SpaceClaim.

Evaluation of stresses using finite element analysis.

Analytical calculation of stress.

Design optimization.

IV. LOAD CALCULATION

Tangential force = [9.5 x 10^6 x W] / [n x r]

W is power (15 Kw)
n is speed (250 rpm)
r is gear pitch radius (55 mm)

Force to be applied = 10400 N

Suitable loads and boundary conditions are used for this analysis. To represent a worst-case scenario and for ease of calculations, a single cyclic sector of gear is only considered for analysis. In this analysis it is expected that a force equivalent to 527 N-m torque should be transmitted through gear mechanism. Hence to simulate this condition inner diameter of gear is constrained in all directions. Force is applied on gear tooth contact area and side faces are constrained with frictionless support.

V. RESULTS AND DISCUSSION

Stresses calculated in the root fillet of initial design is 550 MPa. By using modified goodman approach, the fatigue safety factor is calculated as 0.91. The factor of safety less than 1 would not be an ideal condition for gear running during testing/operation. Hence an increase in fillet radius is proposed to be 1.4 mm which is 1 mm in existing design. The Fe calculation was repeated for optimized design and the stress value in fillet was calculated as 480 MPa. This results in fatigue factor of safety 1.1 which is higher than 1.0 and this would represent a safe design. The standard Lewis equation provides an approximation of recommended stresses at gear tooth root fillet. The analytical calculation shows allowable stress value as 471 MPa which is good match to FE results of stress in modified design. This gives a good confidence for the proposal to avoid gear failures by modifying the root radius from 1mm to 1.4 mm.

Fatigue factor of safety using Goodman method:

$$\sigma_a = \frac{(\sigma_{\max} - \sigma_{\min})}{2}$$

$$\sigma_m = \frac{(\sigma_{\max} + \sigma_{\min})}{2}$$

Fatigue factor of safety = Modified Goodman

$$\frac{1}{(\sigma a / Se + \sigma m / \sigma ut)}$$

σa = Alternating stress

Se = Endurance strength of material = 40% of UTS

σm = Mean stress

σut = Ultimate strength of material (880 MPa)

Fatigue factor of safety = $\frac{1}{(\sigma a / Se + \sigma m / \sigma ut)}$

Lewis equation = Permissible working stress at the root of the teeth is given by,

Sigma = $\frac{6 \times F \times l}{b \times t^2}$

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