INFLUENCE OF MISALIGNMENT AND BACKLASH ON SPUR GEAR USING FEM

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Abstract- The main objective of this work is to investigate the influence of shaft misalignment and backlash on the stress generated on the spur gear. Finite element analysis using ABAQUS software is used to determine the stresses and deflections on gear tooth. Three-dimensional finite element model of pinion gear engaged with a solid gear is created. The material is considered homogenous and isotropic with a linear elastic behavior. The gear pair contact position is chosen to determine contact stress assuming small sliding and dry friction contact. Appropriate loading and boundary conditions are considered. Based on the simulation, the influence of different values of misalignment angle and backlash on equivalent stress is examined. It is observed that the highest misalignment angle resulted in the highest generated tooth stresses. Moreover, it can be concluded that the results of this research should be helpful in the design and manufacture of spur gears.

Keywords- Finite Element Method, Stress Analysis, Misalignment, Backlash.

I. INTRODUCTION

Nowadays, progresses in the design and production method of spur gears enable their use in an increasingly wide range of applications. Therefore, there have been many attempts in recent years to understand and describe the process of the meshing of spur gears in order to increase the performance requirements, such as high load capacity, high endurance, low cost, long life, and high speed. In general, the main functions of gear systems are to; reduce the rotational speed, increase the torque applied, change the direction of the power transmissions and distribute the available power between several machines.

During the last decades many research works have been directed towards evaluating stress analysis of spur gear to improve the performance requirements. The analysis of stresses generated in gear teeth is considered as a limiting factor for gear designers. Hence according to the analysis of generated stresses, transmitted load, running speed, tooth geometry and other design considerations can be determined. The importance of stress analysis is focused on the determination of stress concentration regions that failure or fracture may initiate at these regions.

In general, gears may be designed to operate at a nonstandard center distance to introduce backlash, to accommodate space constraints and to adjust for anticipated deflections under load as well as geometry changes due to thermal effects. Therefore, for good operation, center distance must be held within predetermined tolerances. Since the center distance is a machined dimension, it may not come out be exactly what the design calls for. Moreover, due to mounting inaccuracies, misalignment and other faults created during running of gearing system, the desired center distance is practically not possible to accurately reach.

Several researches and studies have been done and used different ways for the generated stresses analysis on the movement transmitting gear teeth. Recently, the stress analysis comes to be simulated by FEA for gear design. The capabilities of FE models, with a vast number of degrees of freedom, have enabled the accurate representation of the gear system. The analysis of gear stress analysis using FE model can mirror each detail of the gear design, while this requires a lot of effort to do substantial changes in the geometry of components. Tae H. Chang and A. Kubo studied the stresses distribution in spur gear and analyzed the stresses and deformations in the gear in order to define the expected failure locations. Also for three dimensional modelling, Simon obtained the loads and stresses distributions on the teeth for spur and helical gears. He also derived an empirical expression for tooth deflection and tooth shearing depending on loading position and geometry. The method enables the use of varying tooth stiffness depending on where contact occurs across the line of action. Lewicki and Ballarini examined the stresses distributions on the spur gear using finite element methods. The influence of misalignment between the rotation axes of the gears as well as shaft centre distance changes on the mesh stiffness was investigated. Also, they reported that the disadvantages of a three dimensional versus a two dimensional model are higher complexity and hardware requirements as well as computation times.
In this paper, finite element contact analysis is chosen for modelling and simulation of gear pair using ABAQUS software. The effect of misalignment of shaft on the stresses distribution and its concentration on the spur gear is investigated. Also, the backlash clearance on the stresses distribution and its

concentration on the movement transmitted gear teeth are studied. In the following sections the development of the three-dimensional finite element model is described. This involves the fully parametrical creation of the gear shape, the meshing and the simulation process.

II. FINITE ELEMENT MODEL

Due to the progress of computer technology and the computational techniques, the FEA becomes a popular and powerful analysis tool to determine the formation of bearing contacts and stress distributions of gear drives. Therefore, in the present study, a detailed 3-dimensional FE model of the gear pair is developed to calculate the stress and deflections on gear tooth.

The spur gear is designed according to AGMA standard and gear design handbook. The specifications of the spur gear are presented in Table 1. First of all, solid model of the gear geometry consisting of lines and areas using INVENTOR software is created using a very high number of key points, as shown in Figure 1. Next, the solid model is imported to ABAQUS software to further analysis and simulation. The material properties of the pinion and gear are selected as homogenous and isotropic with a linear elastic behavior and listed in Table 2. Then, as the contact between pinion and gear is the most important and critical part of the gear pair simulation, the interaction between the gear pair is chosen to determine contact stresses assuming small sliding and dry friction contact. After that, the gear pair is completely meshed using a mapped meshing. A completely meshed gear pair is shown in Figure 2. The constraints used in the model are as follows: the hub of the gear is completely constrained from motion; the nodes at the hub of the pinion can only rotate around the centre of the pinion. Finally, the solving process is started using quasi-static process and a fully automated post processing is conducted.

Table 1 Gear parameters

Parameter	Assigned value
Desired gear ratio	1.5263
Module	2
Center distance	48mm
Number of teeth	Pinion 19 Gear 29
Face width	23mm
Pressure angle	20º
Clearance	0.5 mm
Root fillet	0.3mm

Table 2 Material properties

Property	Assigned value
Density	7850 kg/m³
Elasticity modulus	210 GPa
Poison ratio	0.3

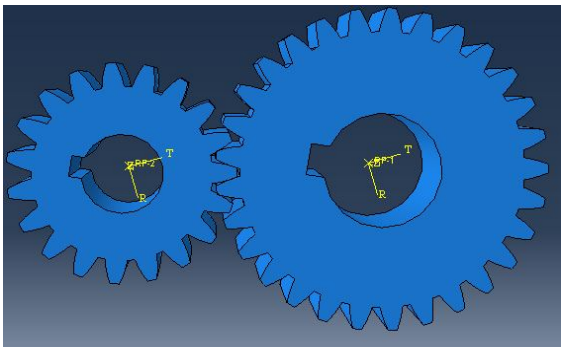


Figure 1 solid model of gears

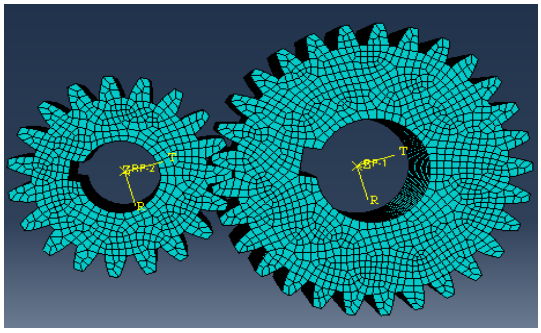


Figure 2 Mesh of spur gears

III. RESULTS AND DISCUSSIONS

The stress distribution obtained from ABAQUS of the modeled gear for various misalignments and backlash for the given loads and boundary conditions are observed. The results reveal that the stress is distributed uniformly but maximum stresses are developed near the root of the bottom gear, as shown in Figure 3. The results obtained from the study of the misalignments and backlash under different values of friction coefficient (μ) will be shown below.

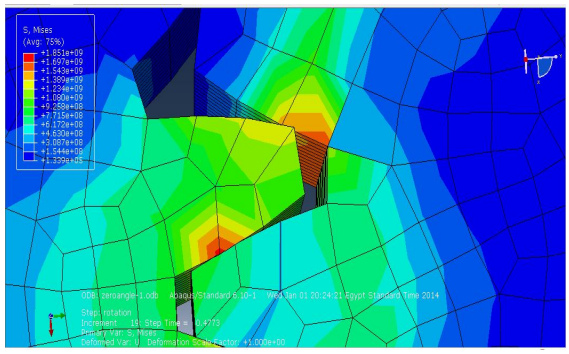


Figure 3 Maximum stress concentration

A. Effect of misalignment angle

In recent years, the research on the static contact problem of gear drives has been described by many

researchers. One of the most important reasons for increasing the stresses concentration on gear teeth is the misalignment of the shafts that transmitting the movement. In additions, the misalignment made non uniform distribution of transmitted loads along gear face, which is caused generation of the stresses concentration in specific region. In this section the influence of misalignment on the stresses under different values of coefficient of friction is considered using three cases namely; misalignment angle about y-axis and misalignment angle about z-axis. The simulation results of each case will be discussed as following:

B. Misalignment Angle around Y-Axis

In this subsection the misalignment angle around Y-Axis is investigated for different values of the coefficient of friction (μ). From Figures (4,5), it can be seen that the value of maximum stress increases with increasing the misalignment angle in Y-direction, this occurred in one side of the gear face where load is concentrated while decreasing gradually in the other side. The stress increases in two regions, the first one is located in the point of action between the two meshing gears while the second position is at root –fillet. This result is a good agreement for the trend displayed by Aziz.

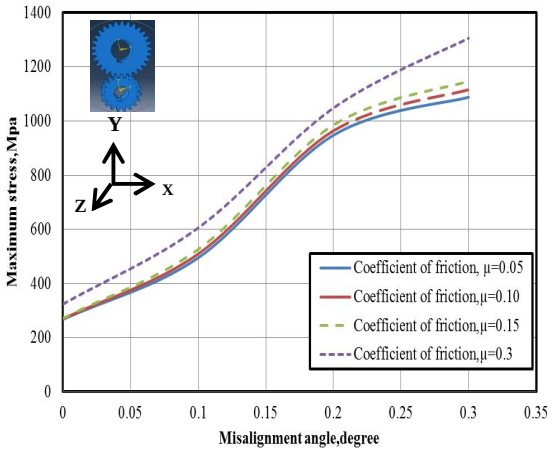


Figure (4) Effect of misalignment angle about Y-axis

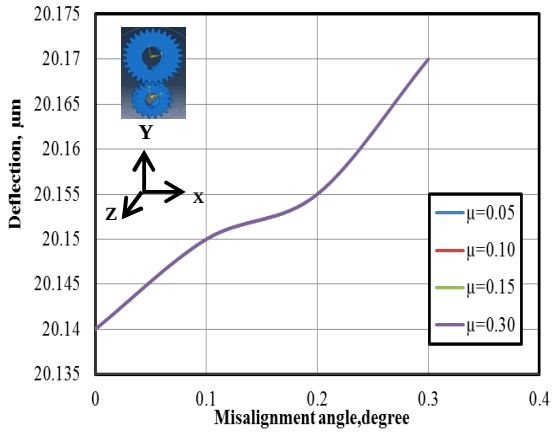


Figure (5) Effect of misalignment angle about Y-axis

C. Misalignment Angle around z-Axis

In this subsection the misalignment angle around Z-Axis is examined for different values of the coefficient of friction (μ). From Figures (6, 7), it can be seen that the value of maximum stress increases with increasing the misalignment angle but the maximum stresses at this case are lower than previous case because the stress is not concentrated on the side of the tooth. Also, it is found that at misalignment angle (0º) the stresses at this case are larger than the previous case because of decreasing the contact area. Moreover, it is observed that deflection at this case is not affected by misalignment angle like the previous case because the stress is not concentrated on the side of the tooth like the other one.

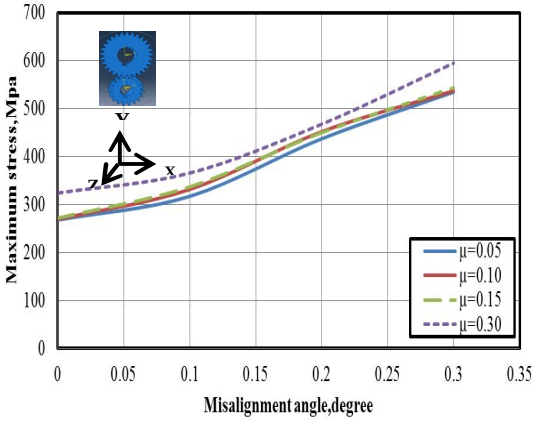


Figure (6) Effect of misalignment angle about z-axis

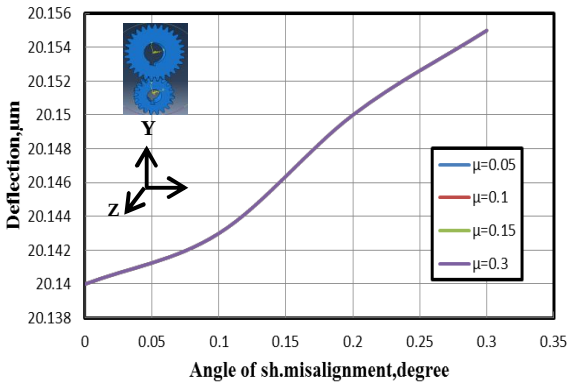


Figure (7) Effect of misalignment angle about z-axis

D. Effect of center distance (clearance ΔC)

The second internal excitation studied in this study is the backlash between teeth. This effect appears in gears due to manufacturing errors, to ensure lubrication or to eliminate interference. Backlash is defined as the excess of thickness space of a tooth compared to the conjugated tooth thickness. It can be introduced by machining tooth profile or by varying the center distance between gears. To introduce this effect, a nonlinear function is considered in the tooth deformation assessment. Figures (8, 9) illustrate the dependence of maximum stresses and deflection on changing of center distance (clearance ΔC) at

coefficient of friction, μ=0.3. It can be seen that the value of maximum stress and deflection decreases with increasing the value of clearance as the contact ratio decreases, as found in. Therefore, the failure of gear teeth is expected for operating at a non-standard value of center distance and backlash may increase excessively with increasing the center distance then problems may occur in power transmission.

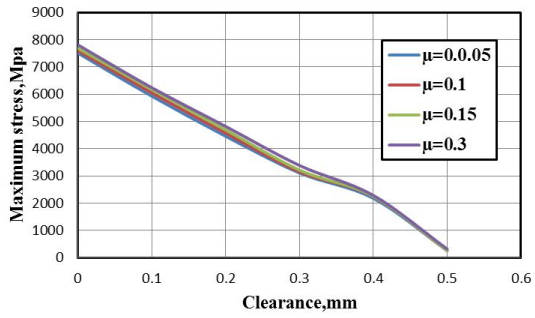


Figure (8) Effect of clearance at μ=0.3.

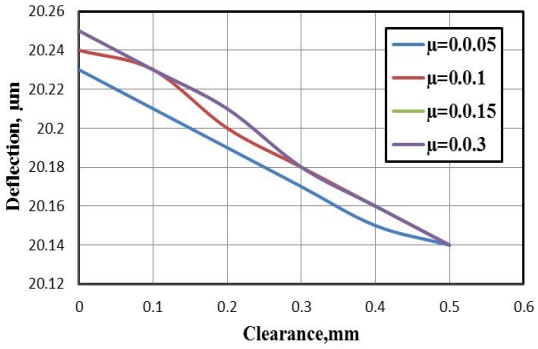


Figure (9) Effect of clearance at μ=0.3.

CONCLUSIONS

From this study the following conclusion can be get:

1. The results showed clearly, that generated stresses corresponding values of deflection are increased gradually with increasing misalignment angle about z and y axes and with increasing friction coefficient
2. Increasing the deformation of gear with increasing misalignment angle.
3. The stresses generated on gear teeth change with changing operating center distance of gearing, whereas the maximum generated stresses (observed in contact and root areas) decrease with increasing center distance as the contact ratio decreases.
4. According to the values of generated stresses, the tooth fracture can be predicted.
5. Backlash may increase excessively with increasing the center distance then problems may occur in power transmission.

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