Modeling of a SURFACE CONTACT STRESS FOR A GEAR SYSTEM USING FINITE ELEMENT METHOD

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Abstract

This paper presents a surface contact stress modeling of a spur gear using deterministic and Finite Element Method (FEM) via static stress analysis. Contact area or surface which is the critical part in gear system is needed for particular observation and investigation due to failure probability. Prior to this section, this research focus on understanding of stress distribution in spur gear system. A gear design is developed on CAD program by integration of equation control in order to have a flexibility of design intend. A FEM analyst is carried out to formulate and solve large systems of algebraic equations to obtain the relationship between the stress and force of the contact surface. Loading conditions and constraints are modeled due to affects of gear mechanism which influence the gear transmission. Result by FEM is compared with deterministic result for a validation procedure. Analysis of the results shows that the FEM have a good agreement comparing with the deterministic calculation.

Keywords

Spur gear, stress and Finite Element Method.

INTRODUCTION

Now days, there are so many mechanisms those involve with load and the requirement to understand the stress in component is increased. The mechanisms and the stress always come together and they have a strong relation between each other.

Gear system is very common component in mechanical system and world wide usage in machine driving mechanism. The function of the gear system is to increase or decrease a load transfer in machine component.

For gear system, modeling stage is very important to determine the increasing or decreasing of the load ratio. In design stage, size, type of gear and material properties play an important rule in giving the specific output for the gear system as a torque. Modeling will help the designer to fabricate a suitable part for a specific application.

With the current trend now, modeling and simulation using computer is growing very fast and the demand is increasing dramatically by a year. Mathematical model through FEM is most suitable application in engineering design with high capability in analysis option. The performance of the FEM solver is influenced by the computer performance too. With the mature of the computer technology expansion, benefit for the computational mechanics is increased.

LITERATURE REVIEW

A contact of a gear tooth is very complex problem to solve. The complexity is increase with the influence of manufacturing and assembly technique. The basic errors that usually happen are lead crowning and shaft misalignment. The contact stress is affected by these errors. Some time, tooth modification is needed in order to fix the tooth assembly. Li (2007) provides a precise theoretical method to be able to calculate surface contact stress and root bending stress of a pair of spur gears with manufacturing error, assembly error and tooth modification.

With the demand of modeling using computational mechanics is increased, Brauer [1] and Lunin [2] were successfully developed a gear mechanism simulation using computer aided design (CAD) software. How ever, in term of time consume, is not very efficient. It is because a lot of mesh involved in a 3D modeling.

In order to expand the fundamental of gear modeling, Brauer was provided a general finite element model of involute gear. The model present was complete with the mathematical description include the root surface. The capability of addendum modification is also provided for the flexibility of gear modeling [3].

Static stress exist because of the load applied and by the same load, part got a motion. That means the equation of the dynamic mechanism is dependent with the static stress result. Consider this factors, modeling the part by finite element method will make simulation become easier. The stress and displacement results will come together with the kinetic and kinematic information.

The critical part that needs a particular observation and investigation is only at contact area or surface. Some advance interpolation technique is needed to model the critical area. Prior to this section, this research focus on understanding of stress distribution in gear system. This paper will presents a modeling of surface contact stress between a pair of spur gear using finite element method. The results is validate with deterministic calculation.

MODELING STRATEGY

The modeling is started with a design in computer aided design (CAD) software. The design of the gear must properly construct in order to avoid a modeling error. The error occur at design stage will dramatically increase in analysis stage especially by the involvement of multiple function [2]. The model was developed as illustrates in Fig. 1.

The gear system is developed to decrease the force. It is using nine type of gear which is variable in size. The gear ratios are decreasing the torque to 21.125 times and there have three levels of gears.

For the first level, it has two type of gear; one is the spur gear with 12 tooth and other one is gear with 39 tooth. Ratio for the load transmission is 3.25. For the second level, it contains two types of gear which are the spur gear with 12 tooth and a gear with 39 tooth. The ratio reduction for this level is also 3.25. For the third level, it is attached by five types of gears. A single spur gear at the middle of the level and four gears connect this gear in rectangle. The spur gear is fabricated with 14 tooth and the rest four gears are fabricated with 28 tooth. Ratio for this gear system is two. Therefore, the overall ratio is 21.125.

An equation control is used for the purpose of geometry correction and updating. A complete design file is exported to computer aided engineering (CAE), as a first step for analyze the reliability of the model.

Start working using finite element method, the CAD model was meshed and defined using brick element. The constraint was declared by a pin at the centre of the gear. A torque is applied at the pin to drive the gear mechanism and at the same time applied a load to a part.

Consider assembly of the main and pinion gear, the affect of the contact surface will result the stress around the gear part. To make it happen, contact surface need to be identify and it is driven by actuator element. It should be noted that, actuator elements are used to specify the relative motion of two points of a structure or mechanism.

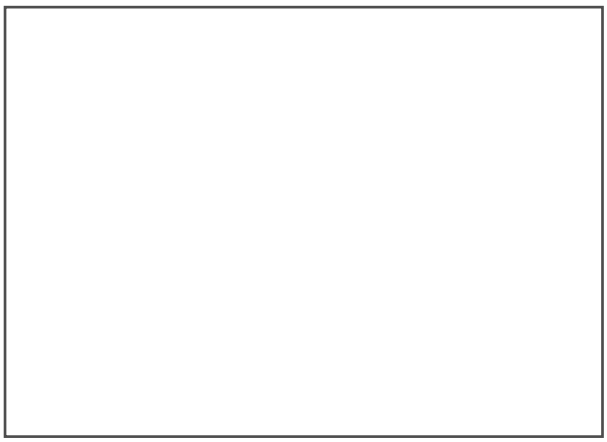

Figure 1: Isometric design view and direction of the motion

Following are the equation used for calculating the gear force and torque. Using an equilibrium concept, total moment for each of the gear is zero.

= 0 (1)

Gear A. = 0: (2)

Gear B. = 0: (3)

The stress is calculated by the given force in Equ. 1-3.

(4)

The stress calculation result is validated with the FEA results.

DETERMINISTIC AND FEA

RESULTS

This calculation is to determine surface contact stress between a pair of spur gear. In this analysis, the result from the deterministic method is compared with the finite element analysis (FEA).

1 Level 3 of the Gear System Analysis

Denoting by F, the magnitude of the tangential force between gear teeth, F = 3711.56 N. The area of the contact surface equal to

8.27*10m. The stress is determined as 449.96*10^5 Nm.

Force at gear with 28 tooth is calculated as 220472 N while force at gear with 14 tooth is equal to 93333 N.

Figure 2: Stress analysis of level 3

Figure 2 shows the stress analysis of spur gear (Level 3) which is the maximum stress is 449.96x10^5 Nm. The value stress from

calculation is 397.21 x10^5 Nmas shown in Table 1.

2 Level 2 Gear System Analysis

Denoting by F, the magnitude of the tangential force between gear teeth, F = 4241 N and the surface contact stress equal to

1.31*10Nm. Force at gear with 39 tooth is determined as 373334 N while force at gear 12 tooth is equal to 114867 N.

Figure 3: Stress analysis of level 2

Figure 3 shows the stress analysis of spur gear (Level 2) which is the maximum stress is 1.31×10^5 Nm. The value stress from calculation is 1.09×10^5 Nmas shown in Table 1.

3 Level 1 Gear System Analysis

Finally, for level one, the magnitude of the tangential force between gear teeth, F = 1303 N and the surface contact stress, 398471 Nm. Force at gear 39 teeth is calculated as 114867 N and force at gear 12 teeth, is determined as 35343 N.

Figure 4: Stress analysis of Level 1

Figure 4 shows the stress analysis of spur gear (level 1) which is the maximum stress is 3.98×10^5 Nm. The value stress from calculation is 3.12×10^5 Nmas shown in Table 1.

The results comparison of maximum stress between deterministic and FEM show that the minimum error is 11.49 and the

maximum error is 21.68.

Table 1. Comparison between the deterministic and FE of maximum stress at the contact surface of the spur gear.

Gear			Error
	(105 Nm-2)	(105 Nm-2)	
Level 3	449.96	397.21	11.49
Level 2	1.31	1.09	17.06
Level 1	3.98	3.12	21.68

The error occur because of the area calculation is not very precise. The touching area cannot specify accurately base on the mesh shape is not symmetry.

The result of the maximum stress is happened at the contact surface of a pair of spur gear. The maximum force is transmitted by the maximum stress along the area contact. The calculation of the contact area needs to specify very well. Overload is directly effected the contact surface between the gear and probability of failure is among this region.

CONCLUSION

The result of the analysis has shown that the surface contact stress of a spur gear using deterministic and FEM has a good agreement between of them. By using FEM, the stage of the analysis is shorts and creates an efficient work of design and modeling stage. This method is useful and practical to be applied for a product development and fabrication of new product.

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