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Influence of Module, Material Properties, No of teeth & Rim Thickness on Load Sharing Behaviour of Spur Gear Drives

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Abstract

Even though the recent advances achieved in the manufacturing sector make it possible for the production of high quality gears, the designing of such gears using standard procedures yields only conservative results because of several assumptions made in the estimation of actual tooth load at the point of contact. Through an approach based on the load-sharing ratio (LSR), that calculates the tooth load, an optimum design can be achieved. As the mesh stiffness differs at different contact points along the path of contact, it significantly affects the LSR between the simultaneously meshed pairs. The present research work concentrates on the load sharing calculation of spur gear drives using finite element analysis. The influence of module, material properties, number of Teeth & Rim thickness on the load sharing behavior are discussed in this work.

Keywords- *spur gear, load sharing ratio, Module, Rim Thickness, finite element method*

1. INTRODUCTION

In engineering and technology, gear is defined as a machine element used to transmit motion and power between rotating parts by means of progressive engagement of projections called teeth. In recent years, many different approaches have been developed to investigate the behaviour of gears in mesh. Rama Thirumurugan and Muthuveerappan [3] used finite element method to estimate the LSR, maximum contact and fillet stresses in normal and high contact ratio spur gears through single- and multi-point loaded models as well as multi-pair contact model. They have also given regression equations for finding out the LSR, LSR based stresses and respective critical loading point for high contact ratio spur gear drives [4]. They have also extended their study to investigate the load sharing based wear behavior of high contact ratio spur gear drive [5]. Timo Kiekbusch, et al [6], analyzed two- and three-dimensional finite element (FE) models to calculate the torsional mesh stiffness. The results presented are based on the individual stiffness of the three main components – body, teeth and contact. Timo Kiekbusch and Ian Howard [7] made two-dimensional finite element analysis to calculate the torsional stiffness of several pairs of spur gears in contact using an adaptive meshing for the contact zones. Van Melick [8] investigates the steel-plastic gear transmission, using both numerical (FE) and analytical methods aimed to study the influence of the stiffness of the gear material on the bending behaviour of the gear teeth and the consequences on contact path, load sharing, stresses, and kinematics. Wang and Howard [9] analyzed torsional stiffness of a pair of involute spur gears of single and double-tooth models in mesh with rigid elements and it has been shown that the gear body stiffness and the relative strain between consecutive teeth in mesh are significant factors that should be included for accurate stiffness prediction. Wadkar and Kajale [10] examined the change of mesh stiffness during a mesh cycle for metal gears. They found that the mesh stiffness increases, when contact changes from one to two pairs, and it decreases as contact changes from two to one pair. Zeping Wei [11] investigates the characteristics of an involute gear system including contact stresses, bending stresses, and the transmission errors of gears using two dimensional FE analysis.

As the mesh stiffness differs at different contact points along the path of contact, it significantly affects the LSR among the simultaneously meshed contact pairs. Hence importance is given to the load sharing calculation using two dimensional (2D) spur gear FE model. The influence of module, material properties, rim thickness and number of teeth on LSR calculations are highlighted in this work.

2. MODELLING OF GEAR

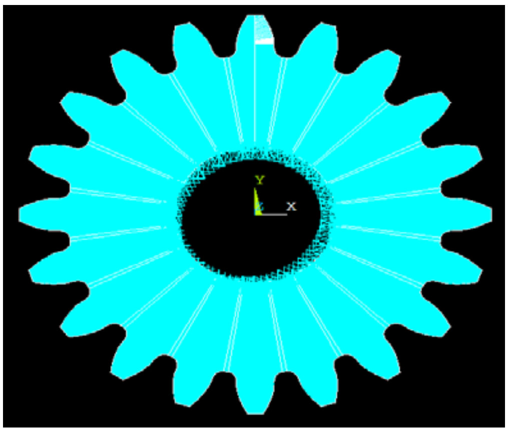

Figure-1 Gear Model

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The spur gear geometrical model is developed in finite element software package ANSYS through APDL (ANSYS Parametric Design Language) program using analytical equations given by Buckingham [1]. The gear specifications considered for analysis in this work are given in Table 1

Table-1 Spur gear specification

Module (m)	3, 7, 12
Number of teeth (Z)	20, 30, 50, 80, 100
Pressure Angle	20
Gear ratio (i)	1
Addendum	1*m
Dedendum	1.25*m
PCD	Z*m
Tooth thickness	1.5708*m
Materials	C45 Steel, Cast Steel, Carbon Fiber, Cast Iron, Plain Carbon Steel
Poisson Ratio	0.3
Young's Modulus	2.01e5 N/mm^2
Rim thickness	3*m, 5*m, 6.5*m, 8*m

An eight noded iso-parametric 2 dimensional element having 2 Degrees of freedom per node (solid 82) is used to descritize the geometric model plane strain condition is implemented. The inner radius of the rim is fixed in all directions. The normal load is applied along the various points on the active profile.

3. LOAD SHARING

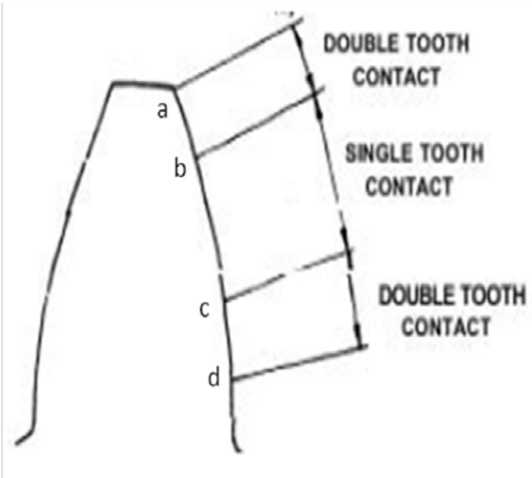

Figure-2 Contact sequence in a mesh cycle

The LSR is the ratio of the load shared by one of the pair to the total normal load. During meshing, the total load is shared among the simultaneously meshed pairs. Contact ratio is a measure of average number of tooth pair in contact during mesh cycle. Generally a contact ratio between one and two is used in standard spur gear transmissions, meaning that for a certain part of the meshing cycle, a single teeth pair carries the load, while for the remaining time of the meshing cycle, two teeth pair share the load. Between point a to b and c to d there exists double teeth pair contact and between b to c there exists a single pair contact (Figure.2).

4. EFFECT OF MODULE, MATERIAL PROPERTIES, NUMBER OF TEETH AND RIM THICKNESS ON LOAD SHARING

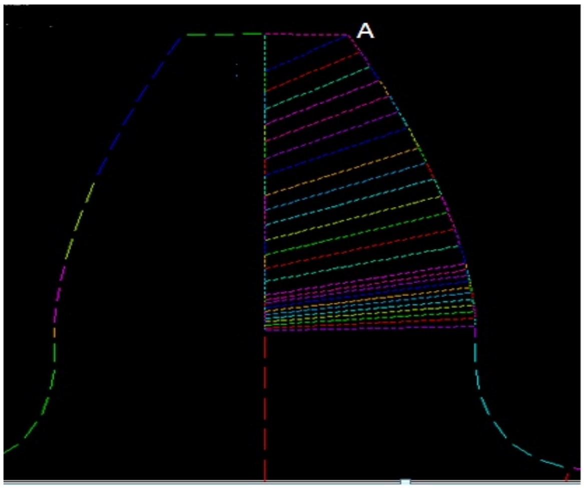

Figure-3 Load Applying Area

Since load shared by a pair of teeth depends on the stiffness of that pair, same has been evaluated using the FE model in this work. The stiffness of the individual tooth depends on the tooth deflection (δ) for the application of the normal load and is given by (K=Fn/δ). Hence it is very important to evaluate the deflection without much error. The equivalent stiffness of a pair in contact is calculated from the individual; stiffness of pinion (k_1) and gear tooth (k_2). The load shared by a pair of teeth in contact is the ratio of the equivalent stiffness of a pair to the total stiffness of the simultaneously contacting pairs and it is given by [2]

$$K_{equ} = K_1*K_2/K_1+K_2 \qquad (1)$$

$$LSR = K_{equ1} / K_{equ1+} K_{equ2} \qquad (2)$$

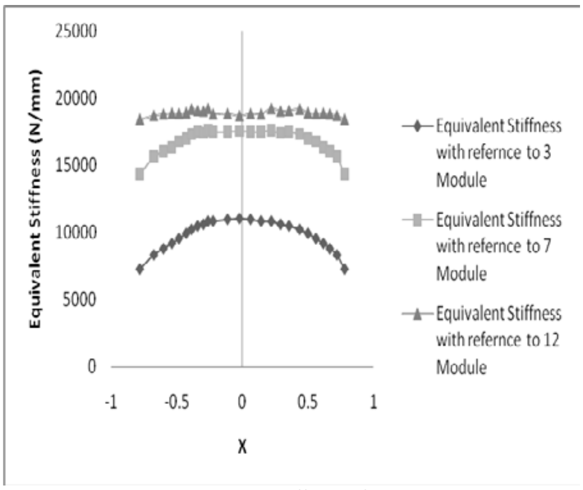

Figure-4 Equivalent stiffness of a contact pair

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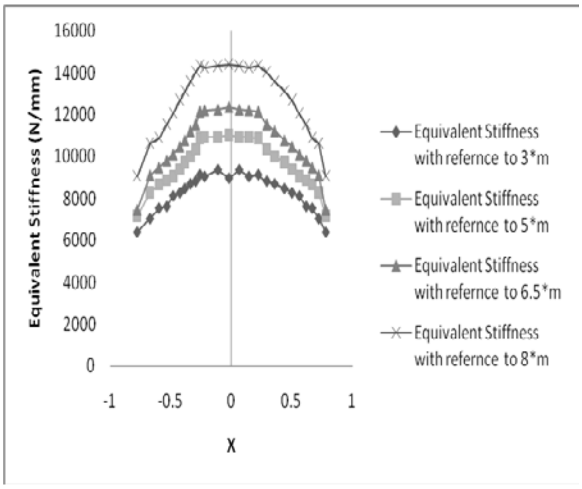

Figure-5 Equivalent stiffness of a contact pair

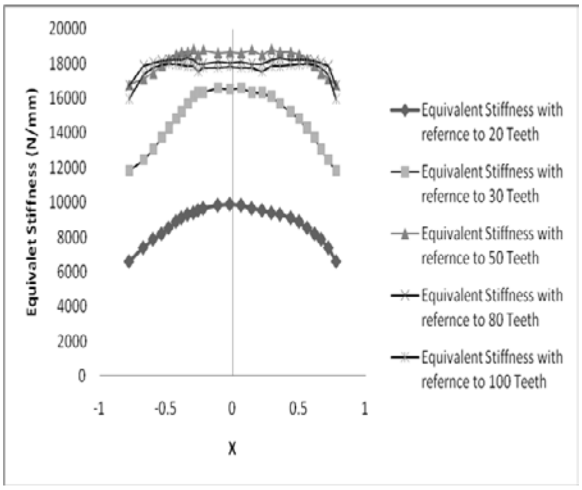

Figure-6 Equivalent stiffness of a contact pair

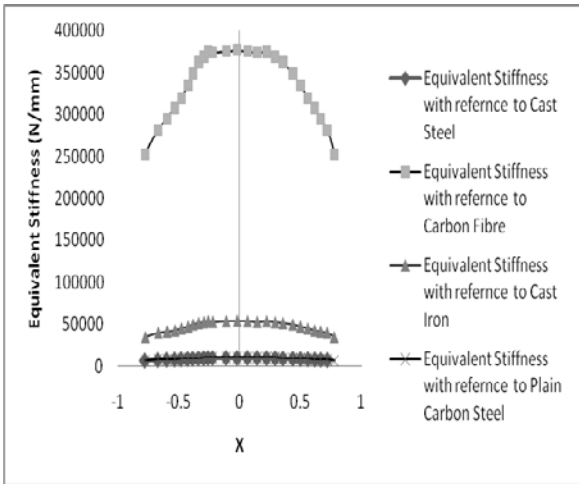

Figure-7 Equivalent stiffness of a contact pair

The variation of equivalent stiffness of the contacting pair with reference to the non-dimensional parameter (x) is shown in Figure - 4,5,6 & 7, where X is the ratio of the distance from the point of contact to pitch point and base pitch. It is observed from the graph that the equivalent stiffness is increasing gradually when the point of contact moves towards pitch point and it is maximum at pitch point. Similar manner it is gradually decreasing while the contact point moves away from the pitch point. This trend is same for all considered in our study.

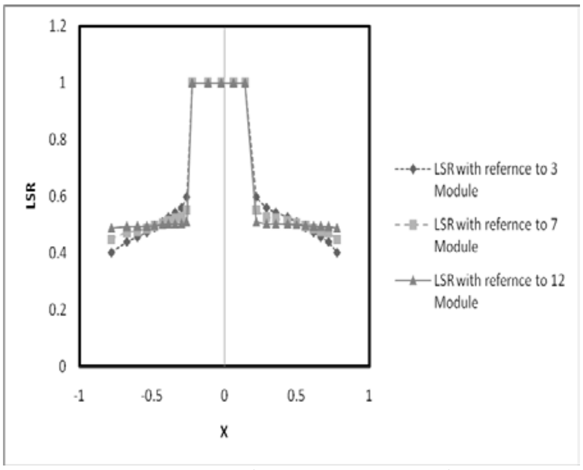

Figure-8 Variation of LSR along the path of contact

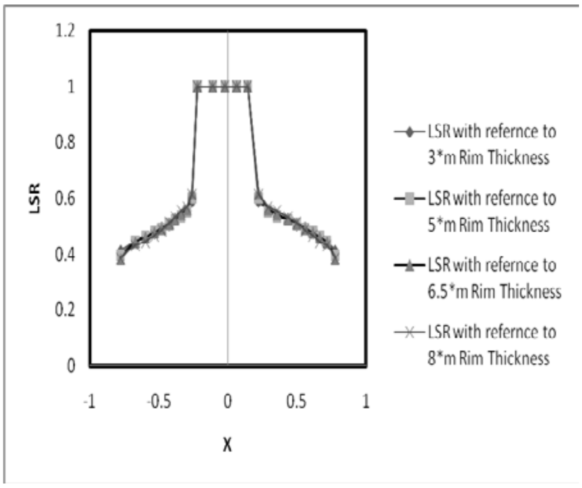

Figure-9 Variation of LSR along the path of contact

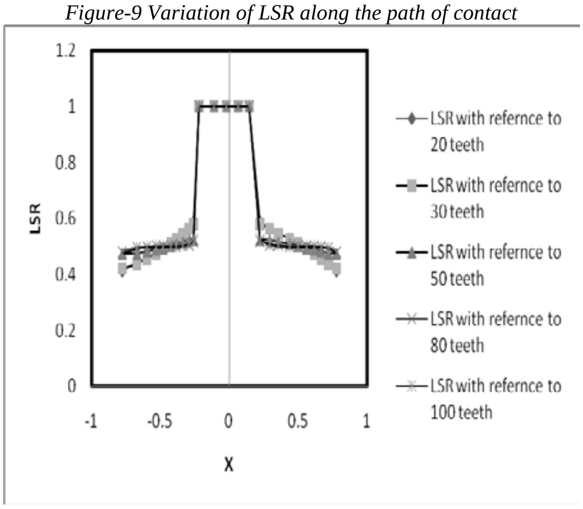

Figure-10 Variation of LSR along the path of contact

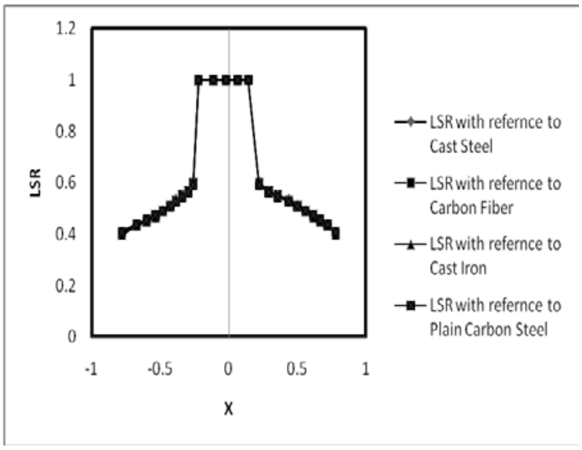

Figure-11 Variation of LSR along the path of contact

The load sharing calculated based on the equivalent stiffness of a pair with reference to the deflection observation point A is shown in Figure-8, 9, 10 &11. It is evident that the load sharing calculated based on the stiffness evaluation with reference to all shows approximately same trend in single tooth contact point. But the load sharing calculated is not same in the double pairs contact region of different number of teeth and module, but same in different rim thickness and materials. It shows that load sharing will change according to number of teeth and module of the teeth.

5. CONCLUSION

2D spur gear at finite element model has been generated and analyzed in this work. The influence of module, material properties, number of teeth and rim thickness on load sharing behaviour are analyzed. Load sharing calculated based on different module shows linear variation during double tooth pair contact region. It shows that load sharing is improved by increasing of the module (Fig.8). The load sharing trends and values are more or less same, when it is calculated based on different rim thickness and material properties. and load sharing is approximately about 40% at the beginning and end of contact and it is about 60% just before and after the single pair contact (Fig.9 &11). Load sharing calculated based on different number of teeth shows linear variation during double tooth pair contact region. It shows that load sharing is improved by increasing of the teeth (Fig.10).

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