TRANSFORMING TECHNOLOGY
EXPLORING KNOWLEDGE

Volume 2 Issue 3
July 2014 - September 2014

ISSN: 2322-0821(online)
ISSN: Applied for (Printed)

INTERNATIONAL
RESEARCH JOURNAL
OF ENGINEERING
& APPLIED SCIENCES
www.irjeas.com

Design and Analysis of Spur Gear to Reduce Stresses on Teeth by Introducing Unique Hole on Gear

[1]Yasir Afzal, [2] Vandana Jha

[1] M.Tech Scholar, Dept. of Mechanical Engineering, OIST, Bhopal, INDIA - 462021
[2] Asst. Professor, Dept. of Mechanical Engineering, OIST, Bhopal, INDIA – 462021

Abstract **- This paper describes Stress and drop analysis of a Spur gear. Gears are usually used for transmitting power. They build up high stress concentration at the root and the point of contact. The continuous stressing on the fillets causes the fatigue failure of gear tooth. The main objective of this study is to add round shaped holes to reduce stress attention. A finite element model of Spur gear with a segment of three teeth is measured for analysis and stress concentration reducing holes of various sizes are introduced on gear teeth at various locations. In the paper Static analysis of a 3-D model had been performed by using Inventor. Analysis discovered that round shaped hole introduced along the stress flow direction yielded better results.**

Keywords *- Steel spur gears, Static analysis, Stresses & Displacements of analyzed gears, Round hole.*

I. INTRODUCTION

According to the position of axes of the shafts, the following are the different kinds of gears.

A). Parallel

- Spur gear
- Helical gear
- Rack and pinion

B). Intersecting

- Bevel gears

C). Non – Intersecting and Non parallel

- Worm gears

The gear materials used for the manufacture of gears depend upon the strength and service conditions like ware and noise etc. The gears maybe manufactured from metallic or non – metallic materials.

The cast iron is widely uses for the manufacture of gears due to its good wearing properties, excellent machine ability and ease of producing complicated shapes by casting method. The non – metallic materials like wood, rawhide, compressed paper and plastic like Nylon, Acrylic and Polycarbonate etc are used for gears, especially for reducing weight and noise.

Weight reduction can be achieved above all by the introduction of better material, design optimization and better manufacturing process. The plastic materials have corrosion, low electrical and thermal conductivity, easily formed into complex shapes, wide choices of appearance, colors and transparences. The introduction of plastic materials was made it possible to reduce the weight of the spur gear without any reduction on load carrying capacity and stiffness.

Gears are used for a wide range of industrial applications. They have varied application starting from textile looms to aviation industries. They are the most common means of transmitting power. They change the rate of rotation of machinery shaft and also the axis of rotation. For high speed machinery, such as an automobile transmission, they are the optimal medium for low energy loss and high accuracy. Their function is to convert input provided by prime mover into an output with lower speed and corresponding higher torque. Toothed gears are used to transmit the power with high velocity ratio. During this phase, they encounter high stress at the point of contact. A pair of teeth in action is generally subjected to two types of cyclic stresses:

i) Bending stresses inducing bending fatigue.

ii) Contact stress causing contact fatigue. Both these types of stresses may not attain their maximum values at the same point of contact.

However, combined action of both of them is the reason of failure of gear tooth leading to fracture at the root of a tooth under bending fatigue and surface failure, due to contact fatigue. Stresses developed by Normal force in a photo-elastic model of gear tooth the Fig.1. The highest stresses exist at regions where the lines are bunched closest together. The highest stress occurs at two locations:
A. at contact point where the force F acts
B. At the fillet region near the base of the tooth.

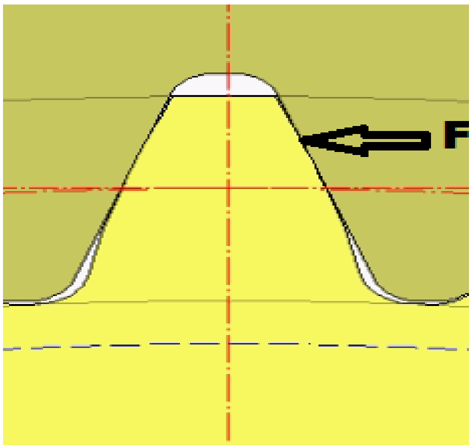


Fig 1.1 - Model of gear tooth

For many years, gear design has been improved by using improved material, hardening surfaces with heat treatment and carburization, and shot peening to improve surface finish etc. Few more efforts have been made to improve the durability and strength by altering the pressure angle, using the asymmetric teeth, altering the geometry of root fillet curve and so on. Some research work is also done using the stress redistribution techniques by introducing the stress relieving features in the stressed zone to the advantage of reduction of root fillet stress in spur 3 Gear. This also ensures interchangeability of existing gear systems.

The studies in which grouping of circular and elliptical stress relieving features are used obtained better results than using circular stress relieving features alone which are used by earlier researchers. In this research work, anround shaped stress relieving feature is tried. A finite element model with a segment of three teeth is considered for analysis and a stress relieving feature of various sizes are introduced on gear teeth at various locations.

II. LITERATURE REVIEW

Investigators analyzing the gear tooth for stresses have done several studies: [1] conducted stress analysis on 8 different gears by determining the highest point of contact for all gears. Stress analysis for the load contact point travelling along the involute curve is done for gears. The point of contact where maximum stress occurs is determined for all eight test gears and the variation of this H (Highest point of Contact) diameter for contact ratio greater than one is studied. Then the gear ratio where it is maximum is taken for application of force for all studies. From the results, he compared the stresses on each gear with their respective highest point of contacts and selected the weak gear among those for stress relief studies. He introduced circular holes as stress relieving features at different locations and also varied the diameters of holes. He concluded with an optimization study of drilling two circular holes, each on two mating teeth at the same location relative to each tooth, stress can be reduced. [2] used elliptical and circular holes as a stress relieving feature. Analysis revealed that, combination of elliptical and circular stress relieving features at specific, locations are beneficial than single circular, single elliptical, two circular or two elliptical stress reliving features. [3] did a study using circular root fillet instead of the standard trochoidal root fillet. The result reveals that the circular root fillet design is particularly suitable for lesser number of teeth in pinion and whereas the trochoidal root fillet gear is more opts for higher number of teeth. [4] did a work which deals with the effect on gear strength with variation of root fillet design using FEA. Circular root fillet design is considered for analysis. The loading is done at the highest point of single tooth contact (HPSTC). [5] used holes drilled across the entire tooth as a function of size and location. The ultimate objective of this work was to find the overall effect of hole size and location on the critical stresses in the gear. [6] on an exact geometry design of the involute gear tooth, a set of profile gears is obtained in order to calculate the 2D contact. A stress analysis was performed for CAD profiles results using the finite element procedure. The paper investigates the 2D analysis versus 3D analysis for stress in the root region of teeth. By this approach, is also investigated the influence of non-uniform load along contact line to the fillet stress. [7] did a research study in which Contact stress analysis between two spur gear teeth was considered in different contact positions, representing a pair of mating gears during rotation. A programme has been developed to plot a pair of teeth in contact. Each case was represented a sequence position of contact between these two teeth. The programme gives graphic results for the profiles of these teeth in each position and location of contact during rotation. Finite element models were made for these cases and stress analysis was done. The results were presented and finite element analysis results were compared with theoretical calculations, wherever available. The idea of using holes to reduce stresses is not a new one.

III. SPUR GEAR

Spur gears are the most common type of gears. They are used to transmit rotary motion between parallel shafts i.e., they are usually cylindrical in shape, and the teeth are straight and parallel to the axis of rotation. Sometimes many spur gears are used at once to create very large gear reductions. Spur gears are used in many devices but not in cars as they produce large noises

Fig 3.1 - Spur Gear

TOOTH PROFILE

CYCLOIDAL

The cycloidal gear profile is a form of toothed gear used in mechanical clocks.

The gear tooth profile is based on the epicycloid and hypocycloid curves, which are the curves generated by a circle rolling around the outside and inside of another circle, respectively. An advantage of the cycloidal teeth over the involute one is that wear of Cycloidal tooth is not as fast as with involute tooth. For this reason, gears transmitting very large amount of power are sometimes cut with cycloidal teeth.

- Since the cycloidal teeth have wider flanks, therefore the cycoidal gears are stronger than the involute gears, for the same pitch. These are preferred for cast teeth.
- In cycloidal gears, the contact takes place between a convex flank and concave surface, whereas in involute gears, the convex surfaces are in contact. This condition results in less wear in cycloidal wear and however the difference in wear is negligible.
- The interference in cycloidal gears does not occur at all. Though there advantages of cycloidal gears they are outweighed by the greater simplicity and flexibility of the involute gears.

INVOLUTE

The involute gear profile is the most normally used system for gearing. In an involute gear, the profiles of the teeth are involutes of a circle. The involute of a circle is the spiraling curve traced by the end of an imaginary taut string unwinding itself from that stationary circle called the base circle. In involute gear design, contact between a pair of teeth occurs at a single instantaneous point. Rotation of the gears causes the location of this contact point to move across the respective tooth surfaces.

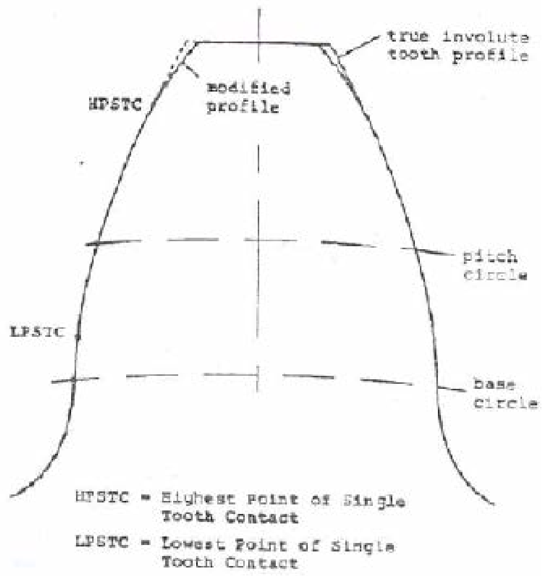


Fig 3.2 - Involute profile of gear tooth

- Involute teeth are very easy to manufacture and the actual distance between the centers may deviate slightly from the theoretical distance without affecting the velocity ratio or general performance. Because of this distinct advantage, gears with involute profile teeth are used more than those with cycloidal teeth.

International Research Journal of Engineering & Applied Sciences
www.irjeas.com, ISSN: 2322-0821, Volume 2, Issue 3, July 2014 – September 2014, Page 33-38

- In involute gears, the pressure angle, from the start of the engagement of teeth to its end remains constant. It is necessary for smooth running and less wear of gears. But in cycloidal gears, the pressure angle is maximum at the beginning of engagement, reduces to zero at pitch point, starts increasing again and becomes maximum at the end of engagement. This does not yield smooth running of gears.

- The face and flank of involute teeth are generated by a single curve whereas in cycloidal gears, double curves are required for the face and flank respectively. Thus the involute teeth are 14 easy to manufacture than cycloidal teeth. The only disadvantage of involute teeth is that the interference occurs with pinions having smaller number of teeth.

GEAR GEOMETRY

Here we present the calculations for the gear we will use for our stress concentration reduction studies. The gear geometry calculations are as follows: Considering the pressure angle (φ) = 200 Pitch circle Dia. (PCD) = module(m) x no. of teeth Tooth thickness = (π x module) /2 Root fillet = 0.2 x module Addendum Dia.(Da)= PCD +2 x module Dedendum Dia.(Dd) = PCD – 2.5 x m Base circle dia. (Db) = PCD x cos φ

IV. PARAMETERS OF GEAR

Module (m) = 2 Pitch circle dia (d) = 50mm No. of teeth (N) = 25 Tooth thickness (t) = 3.14mm Root fillet = 0.628mm Addendum dia (Da) = 54mm Dedendumdia (Dd) = 45mm Base circle dia (Db) = 46.984mm Material used: Steel Properties of Steel: Young's modulus = 21000 MPa Poison's ratio = 0.3

V. GEAR DESING CALCULATION

The Pitch Diameter (D) = 50 The Pitch Radius (R) = D/2 = 25 The Base Circle Diameter (DB) = D * COS (PA) = 1.25 * COS (14.5 deg) = 46.984 The Base Circle Radius (RB) = DB/2 = 23.492 The Addendum (a) = 1/P = 1/6.28 = .15924. The Dedendum (d) = 1.157/P = 1.157/6.28 = .18424 Outside Diameter (DO) = D+2*a = 50.318 Outside Radius (RO) = 25.159 Root Diameter (DR) = D-2*d = 1.1054 Root Radius (RR) =o.5527 For method [9] described below following calculations are also required: 1. Circumference of the Base circle, (CB) = Pi * (DB) = Pi * 46.984 = 147.6 2. 1/25th of the Base Circle Radius, (FCB) = .9396 3. Number of times that FCB can be divided into CB, (NCB) = 157.08 4. 360 degrees divided by NCB, (ACB) = 2.29 5. Gear Tooth Spacing (GT) = 360/T = 14.4 degrees.

VI. RESULT AND DISCUSSION

PHYSICAL

Mass	0.00636366 kg
Area	708.981 mm^2
Volume	810.658 mm^3
Center of Gravity	x=37.8155 mm y=20.4405 mm z=4 mm

Table 6.1 – Physical Dimensions

MESH SETTINGS

Avg. Element Size (fraction of model diameter)	0.1
Min. Element Size (fraction of avg. size)	0.2
Grading Factor	1.5
Max. Turn Angle	60 deg
Create Curved Mesh Elements	No
Use part based measure for Assembly mesh	Yes

Table 6.2 – Mesh Settings

MATERIAL(S)

Name	Steel	
General	Mass Density	7.85 g/cm^3
	Yield Strength	207 MPa
	Ultimate Tensile Strength	345 MPa
Stress	Young's Modulus	210 GPa
	Poisson's Ratio	0.3 ul
	Shear Modulus	80.7692 GPa

Table 6.3 – Material Properties

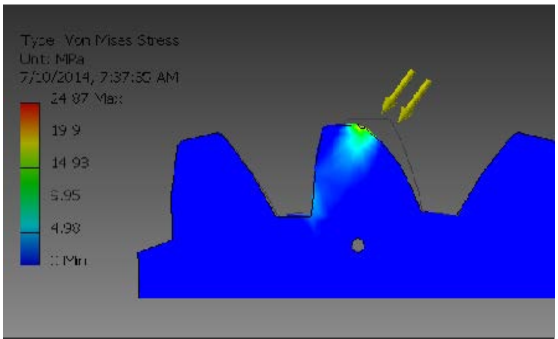
RESULT SUMMARY

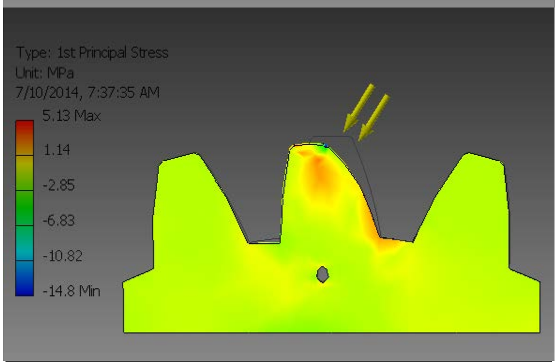
Name	Minimum	Maximum
Volume	810.658 mm^3	
Mass	0.00636366 kg	
Von Mises Stress	0.00330766	24.8742 MPa

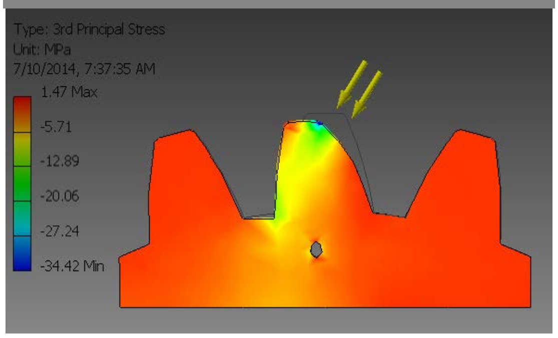
	MPa	
1st Principal Stress	-14.8024 MPa	5.1253 MPa
3rd Principal Stress	-34.4209 MPa	1.47053 MPa
Displacement	0 mm	0.000330067 mm
Safety Factor	8.32188 ul	15 ul

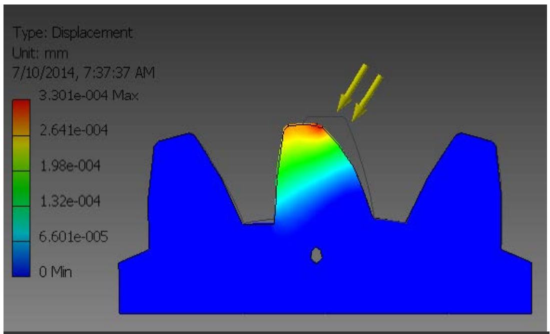
Table 6.4 – Result Summary

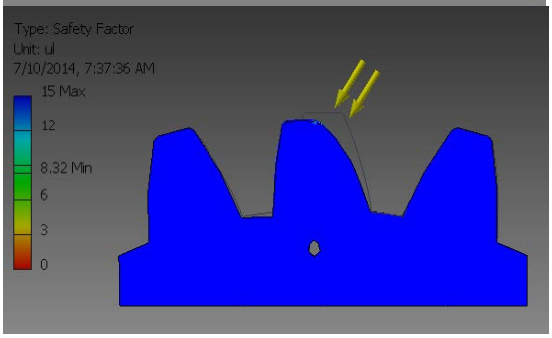
VII. ANALYSIS OUTPUT











VIII. CONCLUSION

The main aim of the above study is to relieve stress from the maximum to as minimum as possible. So the highest point of contact of teeth is selected as pressure area point which causes highest stress. Stress relieving feature having a shape of circle is used in the path of stress flow which helped to regulate stress flow by redistributing the lines of force. This also yielded better results when compared to elliptical. In this study, the best result is obtained by introducing round hole result displayed a stress reduction.

IX. REFERENCES

[1] R. Yakut, H. Düzcükoğlu*, M.T. Demirci Mechanical Education Department, University of Selcuk, Campus, Konya, Turkey, Received 30.09.2009; published in revised form 01.11.2009

[2] K. Mao, A new approach for polyamide composite gear design, Wear 262 (2007) 432-441.

[3] M.H. Tsai, Y.C. Tsai, A method for calculating static transmission errors of plastic spur gears using fem evaluation, Finite Elements in Analysis and Design 27 (1997) 345-357.

[4] C.H. Kim, Durability improvement method for polyamide spur gears, Tribology International 39 (2006) 1454-1461.

[5] S. Senthilvelan, R. Gnanamoorthy, Effect of rotational speed on the performance of

unreinforced a glass fibre reinforced nylon 6 spur gears, Materials and Design 28 (2007) 765-72.Analysis‖. and Testing Materials Science, 12 (3), 2006, 220-225. 10.2

[6] Machine drawing by N.D.BHATT

[7] Machine design by S.M.D.JALALUDEEN.

[8] Design data book compiled by PSG College of Technology, COIMBATORE.

[9] Machine design by BANDARI.

[10] Theory of machines by KHURMI.

AUTHORS' PROFILE

Yasir Afzal is post graduate student in Oriental Institute of Science & Technology, Bhopal (INDIA). He is a mechanical engineer and has a keen interest in Advance Materials.

Vandana Jha is a product design engineer and possesses three years experience in industry. Currently she is designated as Asst. Professor in Dept. of Mechanical Engineering in Oriental Institute of Science & Technology, Bhopal.