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Effect of Stress Relieving Features on Stresses of Asymmetric Spur Gear

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Abstract- **Gears are widely used for transmitting power. They produce high stress concentration at the root and the point of contact. The repeated stresses on the fillets cause the fatigue failure of gear tooth. The gear fails in tensile fatigue, giving catastrophic results with little or no warnings. Therefore for all the reasons mentioned above, this work is of more practical importance. From last few years, gear design has been improved by using improved material, hardening surfaces with heat treatment and carburization, and with improved technique of manufacturing etc. Some more efforts has been made to improve the durability and strength by changing the pressure angle of drive and coast side, using the asymmetric teeth, altering the geometry of root fillet curve and so on. Most of the above methods do not guarantee the interchange ability of the existing gears. The main objective of this seminar is to add circular and elliptical shaped holes to reduce stress concentration. This research work presents the possibilities of using the stress redistribution techniques by introducing the stress relieving features (Circular & Elliptical Holes) in the stressed zone to the advantage of reduction of root fillet stress in spur gear.**

Keywords— Asymmetric Spur Gear, Analysis, Comparison, Stress Relieving Features.

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I. INTRODUCTION

Gears are the most commonly used means of transmitting power in the modern mechanical engineering world. They vary from a small size used in watches to the large sized gears used in lifting mechanisms and speed reducers. They play a vital element role of main and ancillary mechanisms in many machines such as automobiles, tractors, metal cutting machine tools etc. Gears with tooth are used to change the speed and power ratio as well as direction between input and output shaft.

An efficient and reliable system is one in which all the elements are reliable and work efficiently without failure. Hence appropriate care must be taken to all the elements in the system to confirm the overall reliability and efficient working. In spite of this, a deep investigation needs to be carried out to identify the methods to reduce the failures of the gear and to improve the efficiency of the system which has gear as its major element. The design aspect of asymmetric gear teeth is to improve performance of the primary drive profiles at the expense of the performance for the opposite coast profiles. In many cases the coast profiles are more lightly loaded, and are loaded only for a relatively short duration. The main advantage of creating asymmetric gears is contact stress reduction on the drive side, resulting in reduction of gear weight and higher torque density. The items addressed in this article include analysis, design, manufacture and test of gear test specimens with asymmetric teeth. Fredette and Brown [1] in their work used holes drilled across the entire tooth as a function of size and location. The objective of his work was to

find the overall effect of hole size and location on the critical stresses in the gear. In this study holes were drilled along the axis of a test gear segment in an effort to provide stress relief in critical areas. Niels L. Pedersen[2] present that the Bending stress plays a significant role in gear design and its magnitude is controlled by the stress concentration due to the geometrical shape. The bending stress is dependent on shape changes made to the cutting tool. His work shows that the bending stress can be reduced by using asymmetric gear and by optimization of gear shape through changes made to the tool geometry. Costopoulos Th. [3] in his work presented the method for the reduction of gear fillet stresses by using one-sided involute teeth. To increase the load carrying capacity of gear transmissions several tooth designs have been proposed as an alternative to the standard involute. The non-involute teeth have a several disadvantages and for this reason asymmetric teeth have been introduced as a promising alternative.

1.3 IMPORTANCE OF ASYMMETRIC GEARS:

Now a day asymmetric gears are widely used in industries due to some of the following important factors. Following are the important factors

- An increase in the load capacity (15 to 30%) is possible with asymmetric gears.
- Weight and size reduction (10 to 20%) is possible with asymmetric gears.
- A longer life
- Reduction in noise and vibration.

1.4 OBJECTIVE OF THE PRESENT WORK:

The prime objective of this work is formation of asymmetric spur gear. Also to introduce the stress relieving features such as circular and elliptical holes at the stressed zones of symmetric and asymmetric spur gears. The work described herein presents the design, manufacture and test of:

- Symmetric gears with circular root fillet geometry.
- Asymmetric involute gears with circular root fillet geometry.

1.5 PROJECT METHODOLOGY:

The project work expressed here is carried out in the following ways-

i) Modeling of Gears
ii) Introduction of Geometrical Stress Relieving Features
iii) Finite Element Analysis
iv) Experimental Analysis

II.FEA ANALYSIS

The prime focus of this chapter is to develop an efficient and reliable computer aided technique to generate gear geometry. Model of spur gear is generated using Catia software and by selecting the faces of spur gear tooth addition of geometrical features like circular and elliptical holes has been carried out. Also by varying the pressure angle of drive side of symmetric spur gear geometric model of asymmetric spur gear is generated. These geometric models are used to compute the root fillet stress, in a static loaded spur gear using finite element methods (FEM).

A finite element model with a 24 teeth is considered for analysis. A point load of 300 N is applied at the tip of the gear. The teeth are meshed with two dimensional 8 node Structural Solid element. A standard spur gear of 24 teeth with module 3.5mm, pressure angle 20^0, radius factor 0.7 and another asymmetric gear of 24 teeth with module 3.5mm, pressure angle 25^0 on drive side and 20^0 on coast side with radius factor 0.7 and modulus of elasticity of gear material is equal to $2.1x10^5$ N/mm^2 and Poisson's ratio equal to 0.3 is considered for analysis. The FEA results of root fillet stress (without holes) are compared with the stress calculated using the experimental set-up and strain meter.

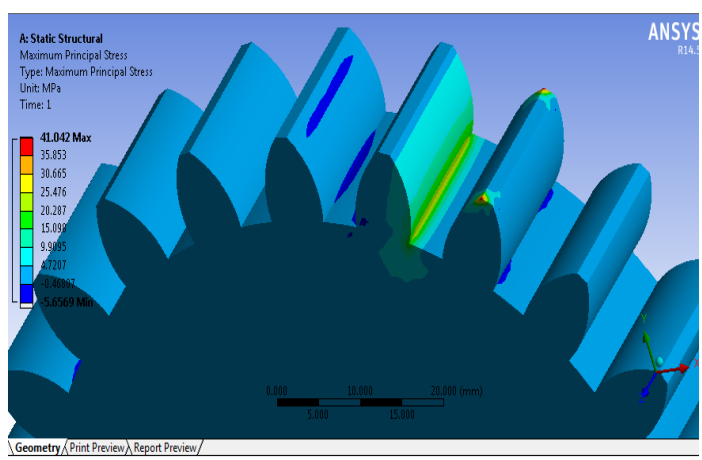

Fig1. Max. Principal Stress of Spur Gear without Stress Relief Feature

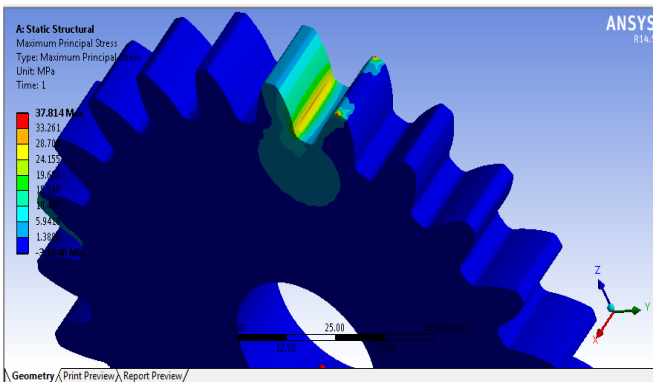

Fig2. Max. Principal Stress of Asymmetric Spur Gear without Stress Relief Feature

Fig1 and Fig2 show the maximum principal stress pattern of simple and asymmetric spur gear without any stress relieving features. The FEA results of root fillet stress without holes are compared with the stress calculated using the gear root fillet stress with holes. The maximum principle stress is obtained without any stress relieving features.

Configurations of stress reliving feature used, for the various analyses are as follows:

- Circular stress reliving feature of same size at different locations (Fig3).
- Elliptical stress reliving feature of different sizes and at different location (Fig4).
- Circular stress reliving feature of different sizes and at same location.
- Elliptical stress reliving feature of different sizes and at same location.

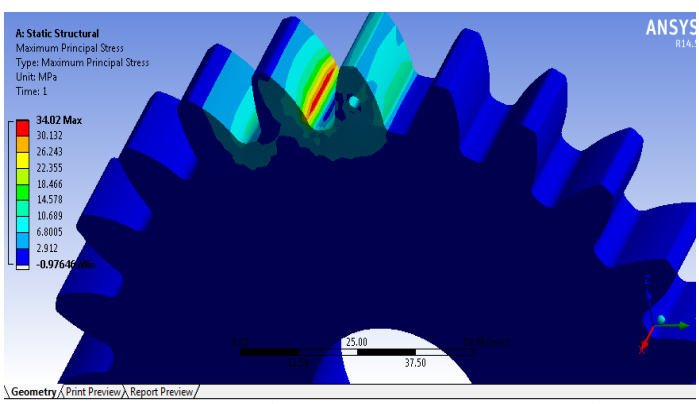

Fig3. Max. Principal Stress of Spur Gear with circular Stress Relief Feature

The FEA results obtained from addition of circular stress relieving features of same size at different locations for symmetric and asymmetric spur gear is tabulated below.

Table1: Stress relief features of different size at Same locations (Circular holes)

Sr. No.	C_x (mm)	C_y (mm)	Dia. Of hole (mm)	Max. principle Stress in MPa
1	9.39	13.86	1	34.15
2	9.39	13.86	1.5	34.58
3	9.39	13.86	2	33.25
4	9.39	13.86	2.5	36.12
5	9.39	13.86	3	36.78
6	9.39	13.86	3.5	38.53

From Table1 a graph of diameter of circular hole and maximum principle stress is plotted below.

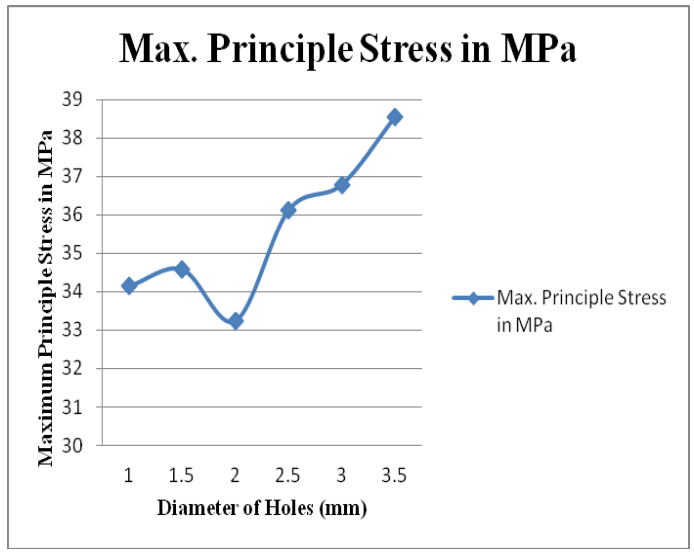

Fig4. Diameter of Hole Vs Maximum principle Stress

The graph from Fig4 shows that lowest value of maximum principle stress is obtained for the circular hole of 2mm diameter.

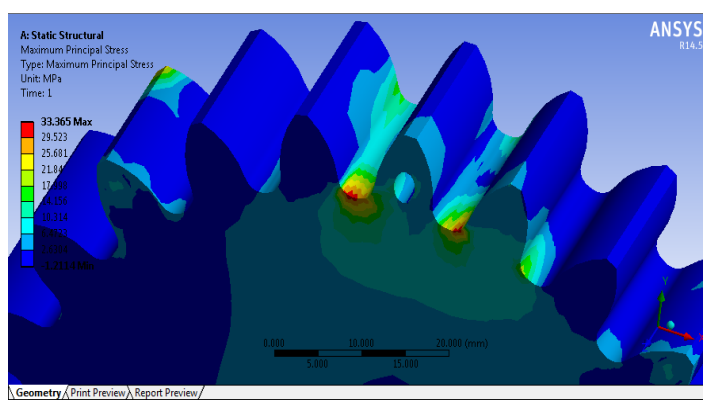

Fig5. Max. Principal Stress of Spur Gear with elliptical Stress Relief Feature

From analysis of spur gear with elliptical stress relieving

feature is carried out for different locations of elliptical holes and results obtained are tabulated in Table2.

Table2: Stress relief features of Different Size at Different Location with Elliptical Holes

Sr. No.	C_x (mm)	C_y (mm)	Major Axis (mm)	Minor Axis (mm)	Max. Principle Stress in MPa
1	15.39	14.65	2.5	2.10	34.44
2	9.39	13.86	2.253	2.00	32.85
3	11.26	13.11	2.18	1.88	33.25
4	11.46	13.16	2.05	1.68	33.35
5	11.62	13.22	2.00	1.52	33.67

From Table2 a graph of Major axis diameter and maximum principle stress is plotted below.

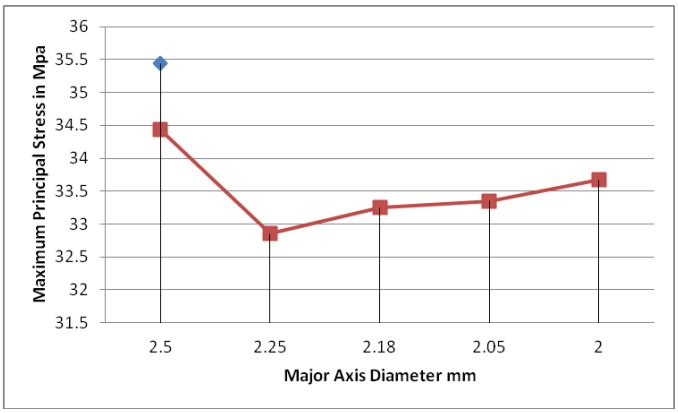

Fig6.Major axis Diameter Vs Maximum principle Stress

It shows that the minimum stress value obtained is 32.85 MPa for hole diameter of 2.25 mm.

III.EXPERIMENTAL ANALYSIS

The experimental work is carried out by using following experimental set-up. It consists of two mating gears with shaft and loading assembly. Strain gauges are fixed on faces of root of teeth at the stressed zone and strain values are recorded by using strain meter. Fig7. shows the reading obtained with a simple gear with 24 nos. teeth and asymmetric gear of 24 nos. teeth. The strain obtained with a simple gear of 24 teeth is 16 µe and the strain obtained with an asymmetric gear of 24 teeth is 10 µe. So the stress can be calculated by taking Young's modulus as 2.1MPa.

$E = \sigma/e$

$2.1\times 10^{5} = \sigma/17.1\times10^{-5}$

$\sigma = 2.1\times17.1 = 35.91$ MPa for simple gear of 24 teeth.

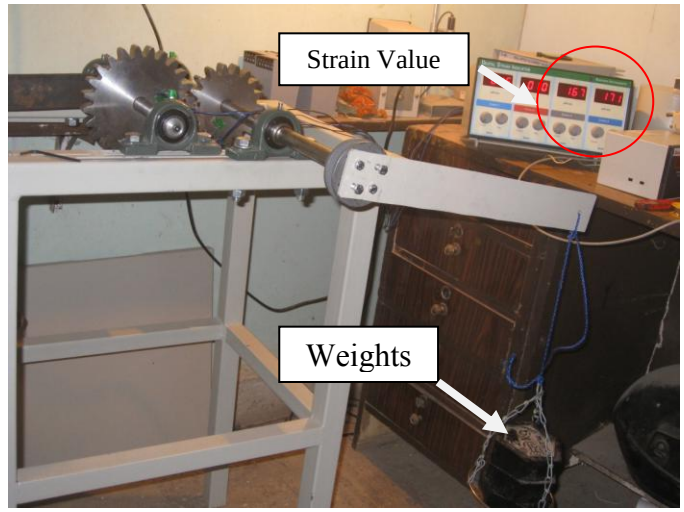

Fig7.Experimental Set-up

$E = \sigma/e$

$2.1\times 10^{5} = \sigma/16.7\times10^{-5}$

$\sigma = 2.1\times16.7 = 35.07$ MPa for asymmetric gear of 24 teeth

By using experimental set-up as shown in Fig7. Strain values are recorded using strain meter for symmetric and asymmetric spur gears mating assemblies.

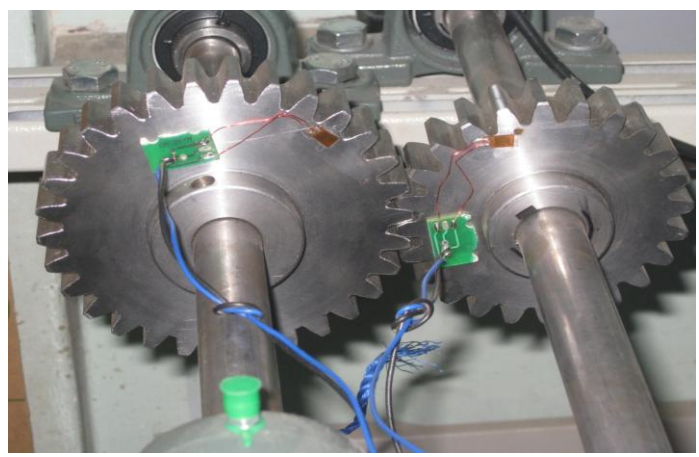

Fig8 Strain Gauges Applied on Gear Teeth Face

Fig8. Shows strain gauges applied on faces of spur gear teeth.

IV. RESULTS AND DISCUSSIONS

Analysis shows that the case with two circular holes having parameters for 1st hole, x= 9.39 mm, y= 13.86 mm, and 2nd hole, x= 13.47 mm, y= 9.87 mm. and one elliptical hole shows the greater benefit in comparison with other cases. As the location of stress relieving feature approaches the high stress effective zone up to a certain value, the results are found to be beneficial. Later on the benefit reduces, it indicating that the benefit becomes more sensitive as the location of the stress relieving features approaches the zone of stress concentration

to a certain value only. It is important to note that introduction of more than one stress relieving feature has added advantage.

Table3: Comparison of FEA and Experimental Results

Sr. No.	Part	FEA Result in MPa	Expt. Result in MPa	% Reduction
1	Simple Spur Gear	35.58	36.12	1.50%
2	Asymmetric Gear	34.44	35.55	3.22%
3	Gear With Circular Hole At Root	35.1	35.7	1.70%
4	Asymmetric Gear With Circular Hole At Root	33.67	34.85	3.50%
5	Gear With Circular Hole At Centre	34.24	35.65	3.24%
6	Asymmetric Gear With Circular Hole At Centre	33.25	34.73	4.45%
7	Gear With Elliptical Hole At Centre	34.4	35.85	3.92%
8	Asymmetric Gear With Elliptical Hole At Centre	32.85	35.98	9.52%
9	Gear With Elliptical Hole At Root	33.93	35.19	3.71%
10	Asymmetric Gear With Elliptical Hole At Root	33.35	35.58	6.68%

As Table3 clearly shows that percentage maximum principle stress reduction is more for asymmetric spur gear with elliptical stress relieving feature at the centre of tooth than it is obtained with symmetric spur gear.

V: CONCLUSION

In this project work, FEA and experimental study of spur gear and asymmetric spur gear is done thoroughly. The spur gear and asymmetric spur gear with circular and elliptical stress relieving features is studied with FEA, experimental and graphical results obtained. These results lead to following conclusions,

- It is observed that minimum stress at the fillet region is obtained with asymmetric spur gear with elliptical stress relieving feature at the centre of the tooth is 32.85 MPa.
- In this study, the best result is obtained by introducing the elliptical stress relieving feature at centre of tooth.
- The percentage stress reduction obtained is 9.52% with elliptical stress relieving features at the centre of asymmetric spur gear tooth as compared to obtained as 3.92% with symmetric spur gear tooth.
- The asymmetric spur gear having circular and elliptical stress relieving feature at centre of tooth gives better results than the results obtained with simple spur gear having circular and elliptical stress relieving feature at centre of tooth.

VI: FUTURE SCOPE

- The method can be extended for the fatigue analysis of gear. The comparative study can also be done by using three dimensional models and two dimensional models.
- Instead of circular and elliptical stress relieving feature it can be doneby using different geometrical shapes.

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