ANALYSIS OF STRESS RELIEVING FEATURES OF ASYMMETRIC SPUR GEAR

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ABSTRACT
Gears are commonly used for transmitting power. They develop high stress concentration at the root and the point of contact. The repeated stressing on the fillets causes the fatigue failure of gear tooth. If gear fails in tensile fatigue, the results are catastrophic and occur with little or no warnings. Therefore for all the reasons mentioned above, this work is of more practical importance. For many years, gear design has been improved by using improved material, hardening surfaces with heat treatment and carburization, and shot penning 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. Most of the above methods do not guarantees the interchange ability of the existing gear systems. The main objective of this seminar is to add circular shaped holes to reduce stress concentration. This work presents the possibilities of 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 gear.
KEYWORDS: Asymmetric Spur Gear, Strain Gauges and Strain Meter, CAE

INTRODUCTION
1.1 GEAR TECHNOLOGY
Gears are the most common means of transmitting power in the modern mechanical engineering world. They vary from a tiny size used in watches to the large gears used in watches to the large gears used in lifting mechanisms and speed reducers. They form vital elements of main and ancillary mechanisms in many machines such as automobiles, tractors, metal cutting machine tools etc. Toothed gears are used to change the speed and power ratio as well as direction between input and output.

LAW OF GEARING
A primary requirement of gears is the constant angular velocities or proportionality of position transmission. Precision instruments require positioning fidelity. High-speed and/or high-power gear trains also require transmission at constant angular velocities in order to avoid severe dynamic problems. Constant velocity (i.e., constant ratio) motion transmission is defined as "conjugate action" of the gear tooth profiles. A geometric relationship can be derived for the form of the tooth profiles to provide conjugate action, which is summarized as the Law of Gearing as follows:
"A common normal to the tooth profiles at their point of contact must, in all positions of the contacting teeth, pass through a fixed point on the line-of-centres called the pitch point."
Any two curves or profiles engaging each other and satisfying the law of gearing are conjugate curves.
Fig 1.1 shows two mating gear teeth, in which

- Tooth profile 1 drives tooth profile 2 by the instantaneous contact point K.
- N_1N_2 is the common normal of the two profiles.
- N_1 is the foot of the perpendicular from O_1 to N_1N_2
- N_2 is the foot of the perpendicular from O_2 to N_1N_2.

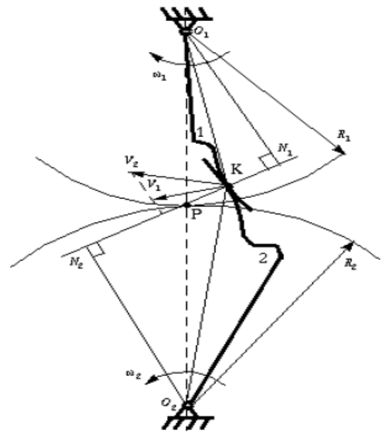

Fig 1 Law of Gearing

Although the two profiles have different velocities V_1 and V_2 at point K, their velocities along N_1N_2 are equal in both magnitude and direction. Otherwise the two tooth profiles would separate from each other. Therefore,
$O_1N_1.\omega_1 = O_2N_2.\omega_2$
It is noticed that the intersection of the tangency N1N2 and the line of center O1O2 is at point P, Thus, the relationship between the angular velocities of the driving gear to the driven gear, or velocity ratio, of a pair of mating teeth is

$$\frac{\omega 1}{\omega 2} = \frac{O_2P}{O_1P}$$

Point P is very important to the velocity ratio, and it is called the pitch point. Pitch point divides the line between the line of centers and its position decides the velocity ratio of the two teeth. The above expression is the fundamental law of gear-tooth action.

1.2 CLASSIFICATION OF GEARS:

Generally gears are categorized into three distinct types based on relative positions of axes of shafts:

a) The transmission of power and motion between the parallel shafts. Ex: Spur and Helical gears.
b) The transmission of power and motion between those shafts whose axes are intersecting and angle between them is 90°. Ex: Bevel and Spiral bevel gears
c) The transmission of power and motion between those shafts which neither parallel nor intersecting the angle between axes is 90° but they are in different planes. Ex: Worm and Worm wheel, Crossed helical gears, Hypoid gears.

1.3 IMPORTANCE OF ASYMMETRIC GEARS:

Now a day due to some of the following important factors asymmetric gears are widely used in industries. 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 (a finer pitch along with more teeth leads to higher contact ratio for a given center distance).

1.4 OBJECTIVE OF THE PRESENT WORK:

The principal objective of the work is to establish an empirical relation for spur gear to predict the root fillet stress induced in the gear geometry by introducing the stress relieving features at the stressed zone. The load is applied at Highest Point of single Tooth Contact (HPSTC). This is accomplished by the following sequential objectives:

- The prime objective of the present work is to establish empirical relations to predict the percentage of reduction in root fillet stress in spur gear by introducing circular stress relief feature.
- To develop an efficient and reliable program in ANSYS Parametric Design Language (APDL) to automate the process of finite element analyses. The data obtained by these analyses is used to establishing the empirical relations specified above.

1.5 PROJECT METHODOLOGY:

In the present work the analysis of a symmetric gear tooth and an asymmetric gear tooth of same dimension has been done using ANSYS14.5 to find out maximum bending stress at the fillet region of gear tooth. Modeling of

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these gears has been done using 3-D modelling software Catia V5 R21 parametrically with the gear design parameters as mentioned below. To model parametrically first the parameters have been collected or referred from reference [11]. The parameters have been mentioned below in the chapter gear geometry.

ANALYTICAL METHOD

A spur gear with module 3.5 mm, number of teeth 24, pressure angle 20 degrees is considered for analysis and also a asymmetric spur gear with 6mm module, number of teeth 30, pressure angle at drive side 25 degrees and 20 degrees for coast side is considered for analysis. Catia V5R20 software is used for geometry of gear teeth, the location and size of the 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 principal stress is obtained without any stress relieving features.

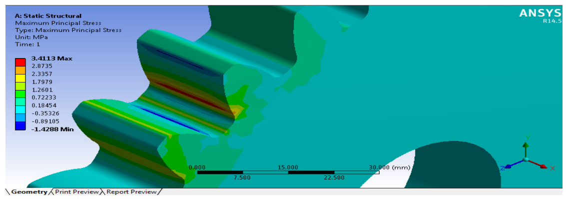

Fig2. Stress Analysis of Simple Spur Gear

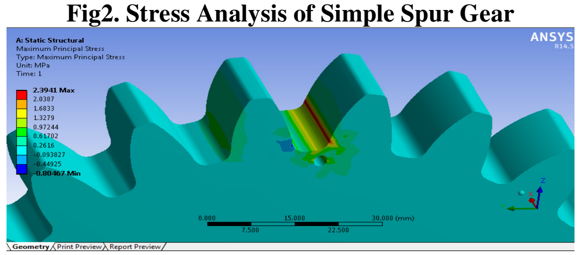

Fig3. Analysis of Spur Gear with Hole at Root of Teeth

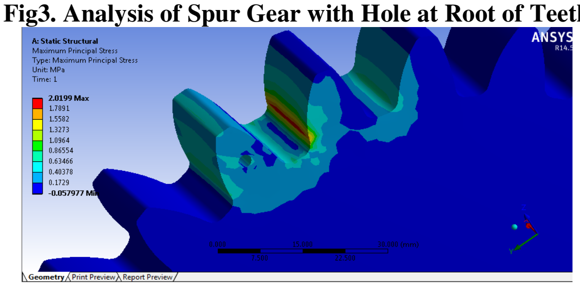

Fig4. Analysis of Gear with Hole at Centre of Tooth

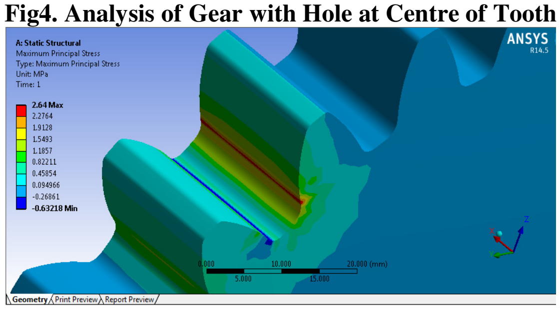

Fig5. Analysis of Asymmetric Spur Gear

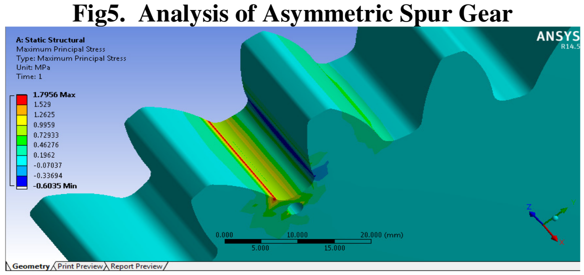

Fig6. Analysis of Asymmetric Spur Gear with Hole at Root of Tooth

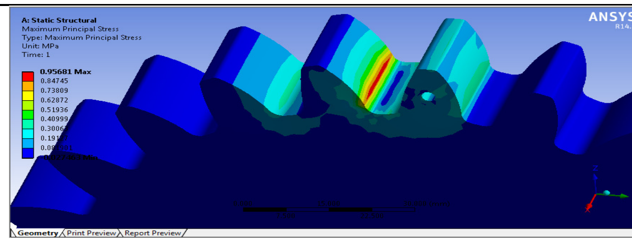

Fig7. Analysis of Asymmetric Spur Gear with Hole at Centre of Tooth

The following table shows the analytical results obtained by analysis of different spur gears using ansys.

Sr. No.	Part	Analysis Result
1	Simple Spur Gear	3.41 Mpa
2	Asymmetric Spur Gear	2.64 Mpa
3	Spur Gear With Hole At Root of Tooth	2.39 Mpa
4	Asymmetric Spur Gear With Hole At Root of Tooth	1.79 Mpa
5	Spur Gear With Hole At Centre of Tooth	2.01 Mpa
6	Asymmetric Spur Gear With Hole At Centre of Tooth	0.95 Mpa

EXPERIMENTAL WORK

The experimental work can be carried out by using following experimental set-up. It consists of two mating gears with shaft and loading assembly. Below fig, shows that the reading obtained with a simple gear with 24 nos. teeth and another gear of 18 nos. teeth. The strain obtained with 24 teeth gear is 16 µe and the strain obtained with 18 teeth gear is 10 µe. So the stress can be calculated by taking Young's modulus as 2.1MPa.

$$E = \frac{\sigma}{e}$$

$$2.1\times 10^{5} = \frac{\sigma}{1.6\times10^{-5}}$$

$$\sigma = 2.1\times1.6 = 3.36 \text{ Mpa for 24 teeth gear}$$

$$E = \frac{\sigma}{e}$$

$$2.1\times 10^{5} = \frac{\sigma}{1.0\times10^{-5}}$$

$$\sigma = 2.1\times1.0 = 2.1 \text{ Mpa for 18 teeth gear}$$

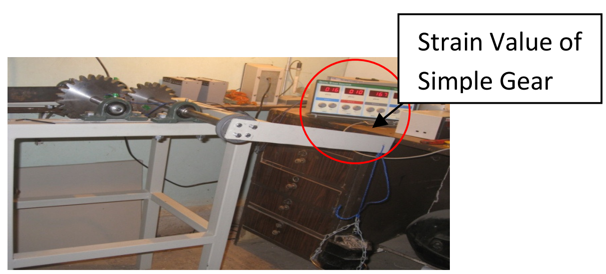

Fig8. Experimental Set-Up

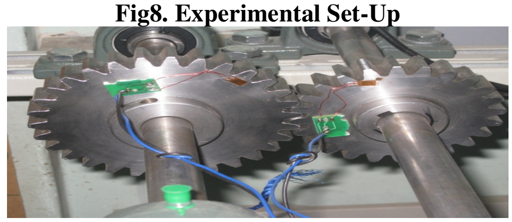

Fig9. Strain Gauges Applied on Gear Teeth Face

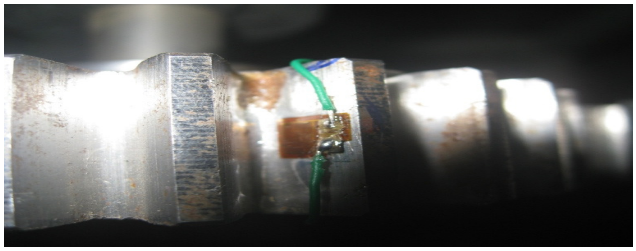

Fig10. Strain Gauges Applied on Root of Teeth

COMPARISON OF RESULT

Following table shows the comparison of results obtained from analytical and experimentally.

Table2. Comparison of Analytical and Experimental Results

Sr. No.	Part	FEA Result	Experimental Result
1	Simple Spur Gear	3.41 Mpa	3.36 Mpa
2	Asymmetric Spur Gear	2.64 Mpa	2.73 Mpa
3	Spur Gear With Hole At Root of Tooth	2.39 Mpa	2.31 Mpa
4	Asymmetric Spur Gear With Hole At Root of Tooth	1.79 Mpa	1.68 Mpa
5	Spur Gear With Hole At Centre of Tooth	2.01 Mpa	2.10 Mpa
6	Asymmetric Spur Gear With Hole At Centre of Tooth	0.95 Mpa	1.05 Mpa

From the above results we can conclude that the maximum principal stresses obtained with asymmetric spur gear are less as compared to simple spur gear. Also addition of circular stress relieving feature at centre of spur gear tooth gives better results than at the base of teeth & from above results graphs are plotted in MATLAB of force versus maxmimum principal stress.

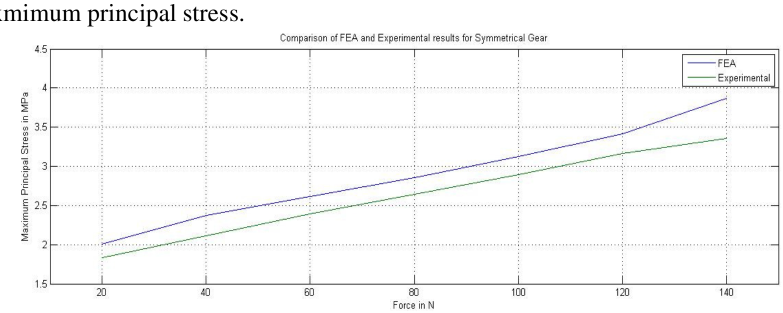

Fig. 11. Comparison of FEA & Experimental Results for Symmetrical Gear

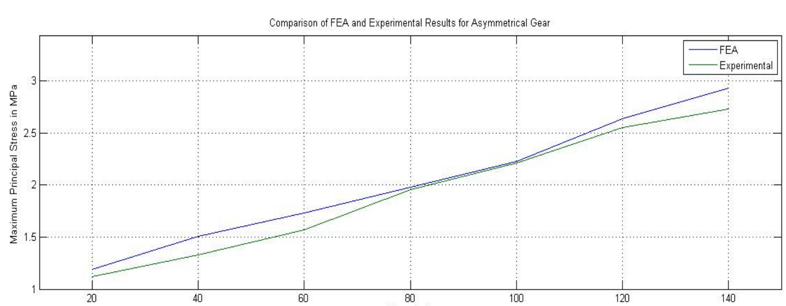

Fig. 12. Comparison of FEA & Experimental Results for Asymmetrical Gear

CONCLUSION

- The main aim of the above study is to relieve stress from the maximum value to as minimum as possible. So the highest point of contact of teeth is selected as pressure application point which causes highest stress.
- Stress relieving feature having a circular shape is used in the path of stress flow which helped to regulate stress flow by redistributing the lines of force.
- In this study, the best result is obtained by introducing the circular stress relieving feature at centre of tooth.
- The asymmetric spur gear having circular stress relieving feature at centre of tooth gives better results than the results obtained with simple spur gear having circular stress relieving feature at centre of tooth.
- The work presented is carried for static condition the method can be extended for dynamic analysis by defining the contact element.

FUTURE IMPROVEMENTS

- 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.
- The method can be extended for the deflection analysis of spur gear.
- Some more positions of the circular shape stress relieving feature can be experimented.
- This can be extended to Bi-directional gears.

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