ANALYSIS OF SPUR GEAR

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ABSTRACT:

Spur gear teeth failure due to fatigue because of high stress at root filet is a common phenomenon observed. Therefore significant research activities have been undertaken to reduce the root fillet stress and it has been established that it is possible to reduce the bending stress in spur gear by introducing circular and elliptical stress relief features. However no significant work is carried out on optimization of the stress relief parameters for minimum bending stress. Slight reduction in the root tensile stress results in great increase in the fatigue life of a gear. 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. In present work finite element method is adopted to determine the root fillet stress. The parameters of stress relief features are optimized to minimize the root fillet stress and validated using photo elastic experimental method.

A three teeth gear segment is considered for finite element analysis. The gear segment is meshed with two dimensional 8 node plane stress elements, point load is applied at the highest point of single tooth contact. Boundary conditions of zero displacements along the base and radial edge are applied.

The spur gear with a pressure angle 20 to 25 with an increment of 2.5 and profile shift factor -0.2 to 0.2 with an increment of 0.1 with a number of teeth equals to 30 to 80 with a step of 10 are considered for analysis.

The best result obtained from the above configurations is confirmed by validating the result with the Photoelastic method. It is found that maximum percentage of reduction in root fillet stress in spur gear by introducing optimized circular stress relief feature is 23 %.

Keywords: spur gear, SRF, HPSTC, APDL, Photoelasticity.

INTRODUCTION

One of the primary causes of gear tooth failure is the presence of large tensile stresses in the root fillet of loaded gear tooth. These stresses reduce the overall gear life and can result in catastrophic tooth failure under peak load conditions.

Many attempts have been made by earlier investigators to relate the tooth failure and the tensile stresses observed in loaded gear, and found that maximum principle stress is the key factor, which governs the fatigue life of the spur gear. A small reduction in maximum principle stresses leads to increase in the fatigue life of the gears considerable.

In view of this, a systematic study is carried out to investigate the effects of introducing optimized stress relief features (SRF) of different size and locations. In recent works, the finite element predictions have been replacing the photo elastic experiments as a means of investigating the effects of design parameters on stress. Further, it is specified in the ISO standard that "the finite element method is treated as the most accurate method of gear strength determination and can be used for verification purpose of the results with other methods''. Due to proven track of records and simplicity, Finite Element Method (FEM) is considered as a tool of investigation. Finite element analysis software, ANSYS is used to investigate the stress at root fillet due to SRF. The investigations carried out in the present work have contributed to the knowledge of stress reduction in spur gears due to SRF.

DESIGN OPTIMIZATION

Engineering Design involves the reallocation of materials and energy to improve the quality of life. This occurs in all fields of engineering, including civil, mechanical, electrical, and so forth and often involves trade-offs based on the requirements of each application. The idea of design optimization suggests that for a given set of possible designs and design criteria, there exists a design that is the best or optimal.

Optimization is a part of everyone's life, either consciously or subconsciously. It is our nature to optimize. Investors want the largest return with the least investment or risk. Marathon runners adjust their pace to achieve the best overall time. This article discusses tools that provide a method for systematic optimization of engineering designs. The primary focus here is on the practical application of optimization technology in a computer-aided engineering (CAE) environment [5].

The role of the CAE simulation tool is very important in CAE-based design optimization. Computer-aided-engineering based design optimization does in fact turn CAE *analysis* tools into CAE *design* tools by replacing traditional trial-and error Design approaches with a systematic design-search methodology. Thus, CAE computations that quantify the performance of a particular design are enhanced with information on how to modify the design to better achieve important performance criteria.

FINITE ELEMENT MODEL

The program is coded in ANSYS Parametric Design Language (APDL) and it automate the task of creation model, meshing, applying boundary condition, choosing the appropriate density of the mesh depending on the stress gradient. The PLANE-82 (plane stress) element is chosen for analysis and material property of steel is used for gear.

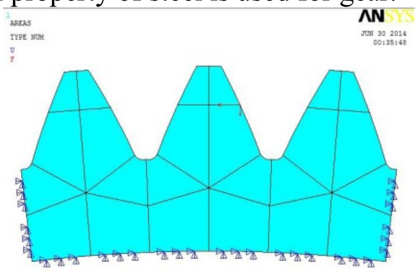


Fig. 1 Finite element model of a three teeth spur gear segment subjected to loading and boundary conditions.

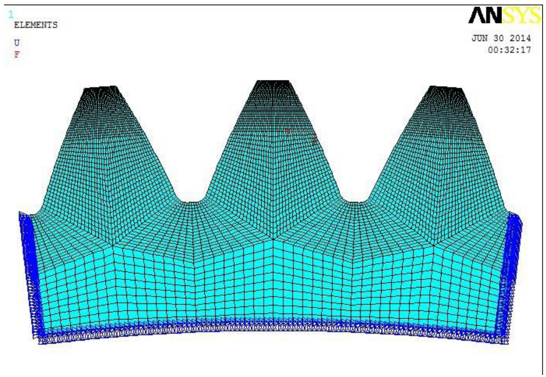


Fig. 2 Finite element model of a three teeth spur gear segment subjected to meshing and boundary conditions.

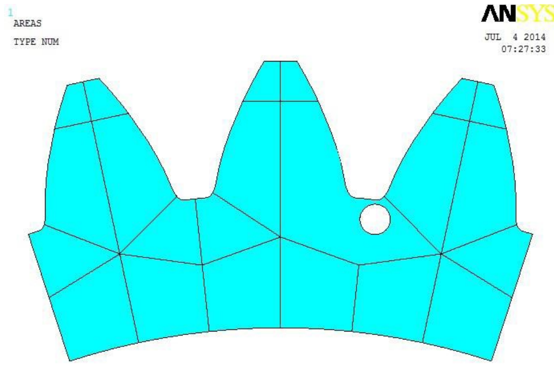


Fig. 3 Finite element model of a three teeth spur gear segment with circular stress relief feature.

Fig 1 and 2 shows the geometric model of three teeth spur gear geometry. The Highest Point of Single Tooth Contact (HPSTC) point load of 400N is applied on three teeth spur gear segment. The location of the finite element model boundary condition and the element mesh density is investigated. Fixed boundary conditions are applied along both the radial edges and arc of the rim of the Spur Gear as shown in Fig 1 and 2. And Fig. 3 shows Finite element model of a three teeth spur gear segment with circular stress relief feature.

Photoelasticity

Photoelasticity is an experimental technique based on a property called double refraction, or birefringence, of some transparent materials. The birefringence in a stressed photoelastic model is controlled by the state of stress at each point in the model. In normal photoelastic analysis, half-and whole-order fringes are determined from the light- and dark field isochromatic fringe patterns, and the fractional fringe orders are evaluated through either the Tardy method, use of a compensator or by fringe multiplication. In general, the process can be very tedious and time consuming. Therefore, various systems that incorporate photometric instruments or video (CCD) cameras and computers have been developed in the past 30 years to overcome this difficulty. Such developments have made the photoelastic method more efficient and accurate. In this experimental method, the isochromatic and isoclinic fringe patterns are extracted, and photoelastic parameters, namely, isochromatic fringe orders and isoclinic angles or principal stress directions, are assigned to their fringes. To obtain each principal stress, the principal-stress differences and principal-stress directions are used as data in the separation of two principal stresses.

RESULTS AND DISCUSSION

Table 1: Best Percentages of reduction of root fillet stress in spur gear using optimized circular stress relief feature

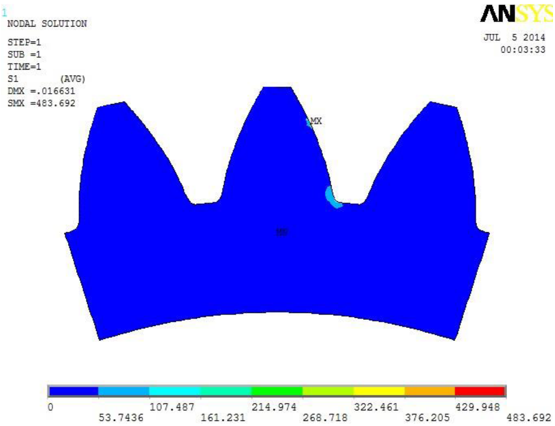


Fig 4.Maximum Principal Stress distribution in spur gear without SRF, σ1=129 MPa

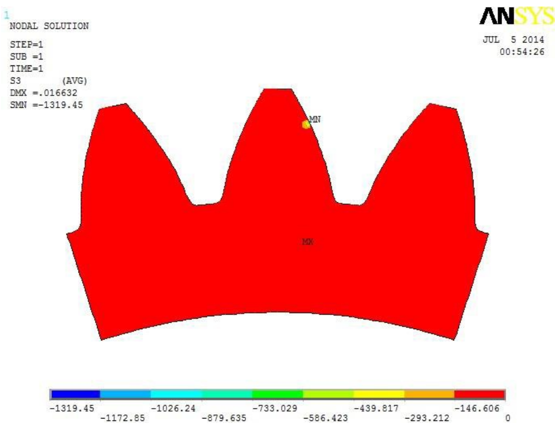
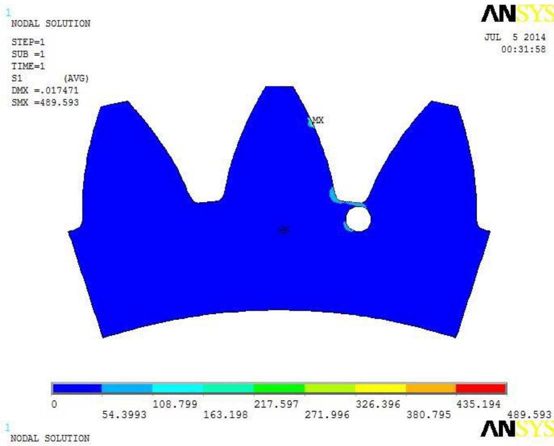


Fig.5 Minimum Principal Stress distribution in spur gear without SRF, σ3= -155 MPa

Stress plots for Generic FE model with SRF



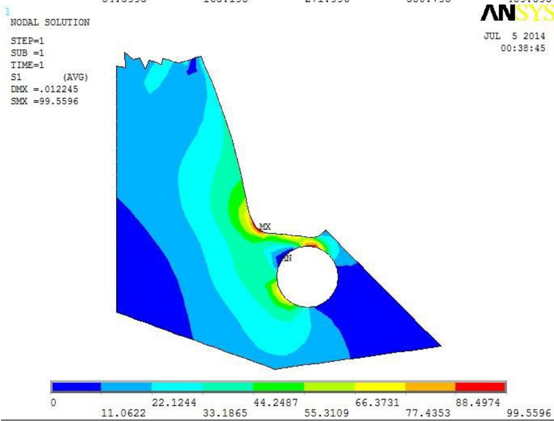


Fig. 6 Maximum Principal Stress distribution in spur gear with SRF, σ1=99.6 MPa

Stress plots for Photoelastic FE model

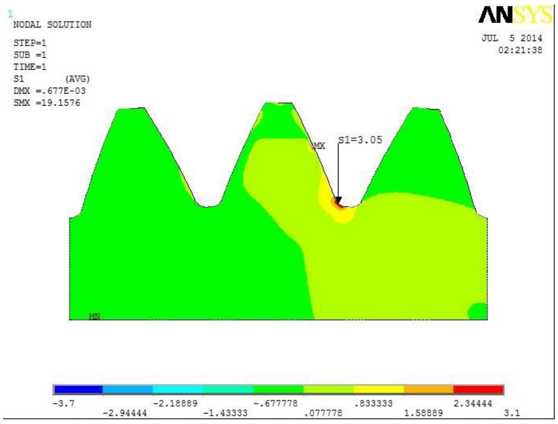


Fig. 7 Maximum Principal Stress distribution in spur gear without SRF, σ1=3.1 MPa

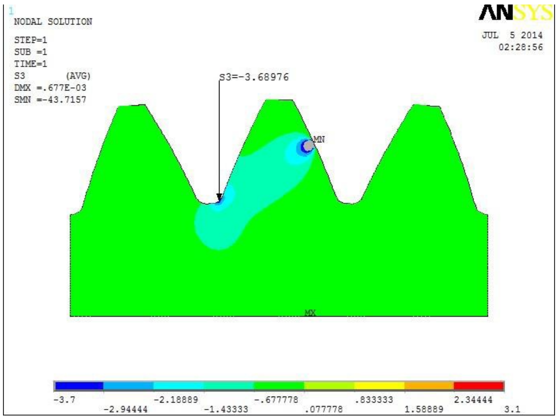


Fig. 8 Minimum Principal Stress distribution in spur gear without SRF, σ3= -3.7 MPa

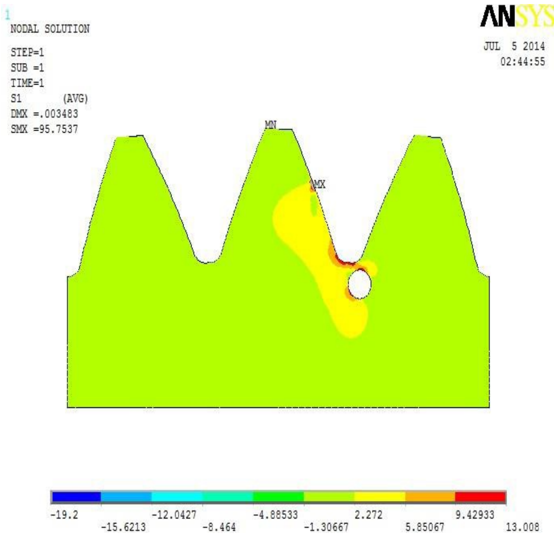


Fig. 9 Maximum Principal Stress distribution in spur gear with SRF, σ1=13 MPa

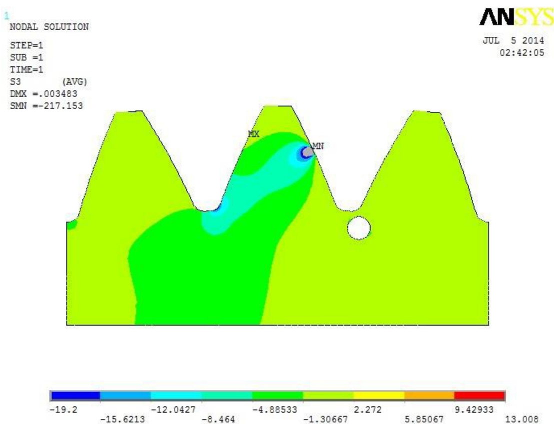


Fig. 10 Minimum Principal Stress distribution in spur gear without SRF, σ3= -19 MPa

CONCLUSION

1. All the objectives are met and results obtained are satisfactory.
2. It is possible to reduce the stress at the root fillet by introducing circular stress relief features of appropriate size at suitable location.
3. The percentage reduction in maximum principal stress is insignificant in gears with profile shift factor less than zero.
4. The highest reduction in maximum principal stress of 22.9% and 23.45% is attained for one circular hole SRF respectively.

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