ISSN 2395-1621

Effect of Change of Spur Gear Tooth Parameter on Bending Stress by Simulation

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ABSTRACT

In this paper spur gear teeth with circular root fillet radius is used instead of standard trochoidal root fillet radius and analysed by using ANSYS version 14.0. The strength of new modified teeth is studied in comparison with standard design. The analysis shows that circular root fillet has higher bending strength than standard trochoidal root fillet design. The result shows that trochoidal root fillet design is suitable for higher number of teeth and circular root fillet design is suitable for lesser number of teeth.

ARTICLE INFO

Article History

Received: 25th March 2017

Received in revised form :

25th March 2017

Accepted: 25th March 2017

Published online :

4th May 2017

Keywords: Spur Gear, Trochoidal Root Fillet, Circular Root Fillet, Bending Stress.

I. INTRODUCTION

Gear transmission systems play an important role in many industries. The knowledge and understanding of gear behavior in mesh such as stress distribution, work condition and distortion is critical to monitoring and controlling the gear transmission system.

A pair of teeth in action is generally subjected to two types of cyclic stresses: bending stresses inducing bending fatigue and 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, like pitting due to contact fatigue. These types of failures can be minimized by careful analysis of the problem during the design stage and creating proper tooth surface profile, optimal teeth parameters with proper manufacturing methods.

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. Therefore it is important to find out the method of reducing maximum principle stress in the gear there by increasing the life of gears.

Most of them are given solutions to the use of material with improved strength, hardening the surfaces selectively with heat treatment and carburization, and shot peening to improve the surface finish. Many efforts such as altering the pressure angle, using the asymmetric teeth, introducing stress relief feature and using the gear with high contact ratio have been made to improve the durability and strength of the gear.

Geometry of gear :

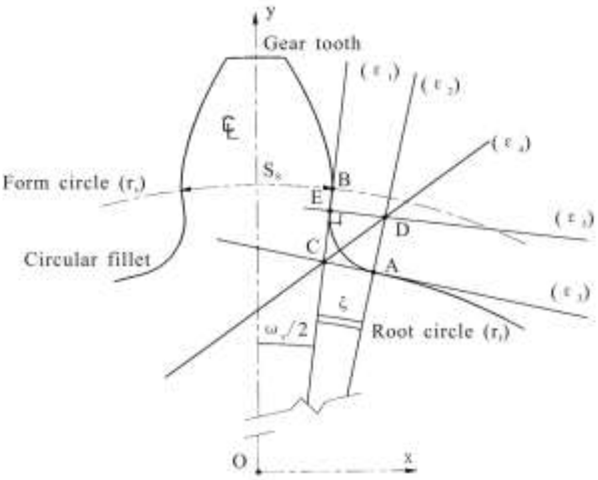


Figure1: Geometry of the circular fillet

Consider the involute spur gear tooth of circular fillet is shown in figure 1. The point 'O' is center of the gear, axis ' Oy' is the axis of symmetry of tooth. Point B is the point where involute profile starts (from the form circle).

Point A is tangent to the circular fillet with the root circle. Point D lying on ε_2. AD represent the center of the circular fillet. Line (ε_3) is tangent to the root circle at A and intersects with the line (ε_1) at C.

From geometry of circular fillet coordinates (points A, B, D) obtained using following equations

$X_A = r_f \cdot \sin(\xi + \Omega_s)$, $Y_A = r_f \cdot \cos(\xi + \Omega_s)$

$X_B = r_f \cdot \sin \Omega_s$, $Y_B = r_f \cdot \cos \Omega_s$

$$Y_D = \frac{\tan(\xi + \Omega_s)}{\cos(\Omega_s) + \sin(\Omega_s) . \tan(\xi + \Omega_s)} \cdot r_s$$

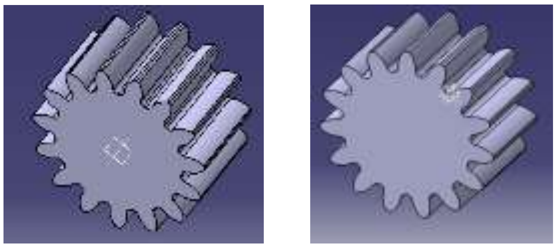
$$Y_D = \frac{1}{\cos(\Omega_s) + \sin(\Omega_s) . \tan(\xi + \Omega_s)} \cdot r_s$$

Modelling of gear :

Gear is modelled using CATIA V5R16. Specifications of gear given in following table :

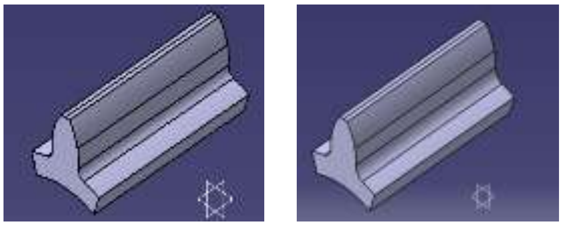
Input parameters	Value
No. of teeth	15
Module (m)	1 mm
Pressure angle (Φ)	20
Helix angle (ψ)	0
P.C.D.	15 mm
Thickness	9.5 mm
Tooth root fillet	Trochoidal and Circular

Table1: specification of gear



Trochoidal root fillet (Full gear) Circular root fillet (Full gear)

Figure 2: Modeling of gear



Trochoidal root fillet (single tooth) Circular root fillet (single tooth)

Figure 3: Modeling of gear

Finite Element Analysis :

A single tooth is considered for finite element analysis. Gear material strength is a major consideration for the operational loading and environment. In modern practice heat treated alloy steel are used to overcome the wear resistance. In this work 20MnCR5 (Case Hardened Steel) is used for analysis. ANSYS version 14.0 software is used for analysis. The gear tooth is meshed in 3-D solid 186 with fine mesh. Solid 186 is a structural 3D 20 node solid element. It has 3 degree of freedom in X, Y, Z direction (Translation). It supports plasticity, creep, stress and large deflection.

Force components for 15 teeth :

Power (P) = 375 watt

Speed (N) = 1500 rpm

Torque (T) = 2380 N-mm

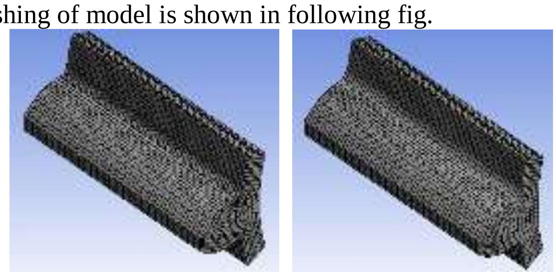
Tangential component (Ft) = 317.33 N

Material properties

Parameter	Value
Density	7700 Kg/m3
Young's modulus	200000 MPa
Poisons ratio	0.27

Table 2: properties of material

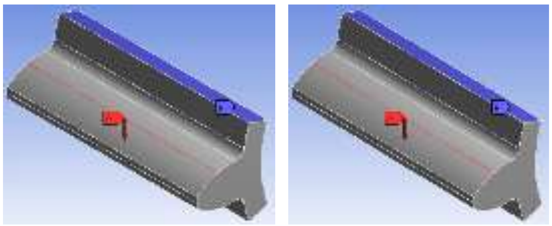
Meshing of model is shown in following fig.



Trochoidal root fillet Circular root fill

Figure 4 : Meshing of gear

Boundary condition of model is shown in following fig.



Trochoidal root fillet Circular root fill

Figure 5 : Boundary condition

Results and Discussion :

Bending stress and deflection were carried out for both trochoidal root fillet and circular root fillet design. Bending stress and deflection values are presented in table.

The result shows that deflection value of both trochoidal and circular root fillet gears are similar. But bending stress developed in circular root fillet has less stress (106.64 MPa compared to trochoidal root fillet gear (122.95 MPa).

Deflection of trochoidal and circular root fillet gear is shown in following fig.

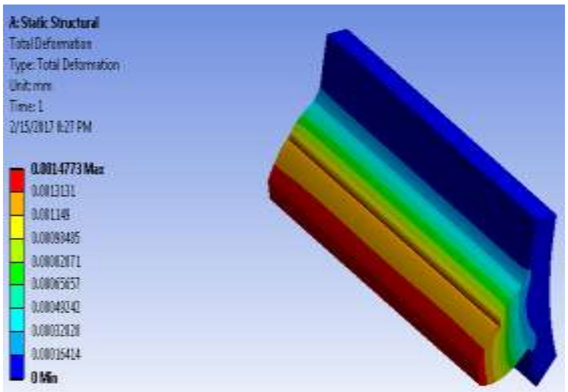


Figure 6: Deflection of Trochoidal root fillet

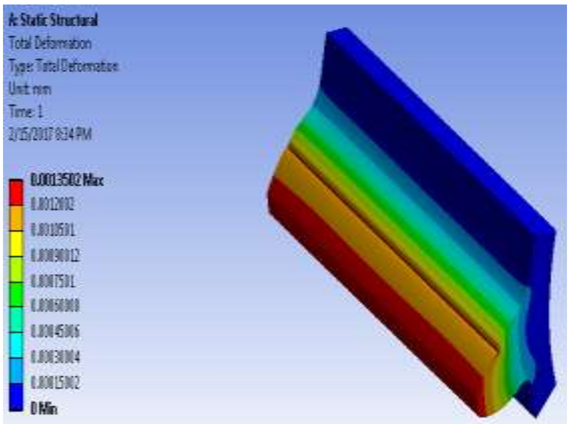


Figure 7: Deflection of Circular root fillet

Bending stress of trochoidal and circular root fillet gear is shown in following fig.

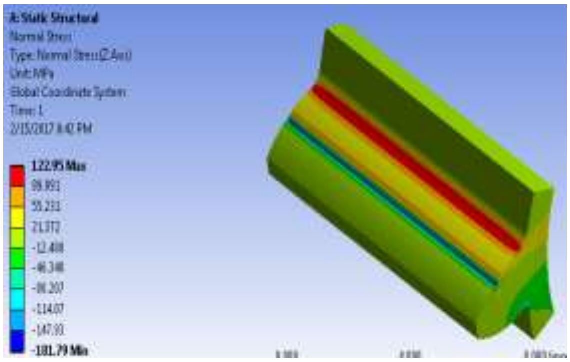


Figure 8: Bending stressTrochoidal root fillet

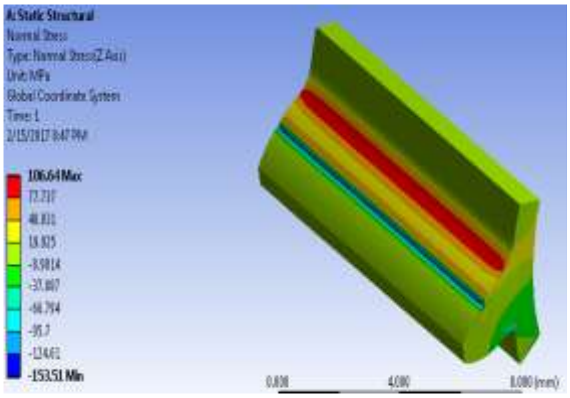


Figure 9: Circular root fillet

Conclusion :

The effect of proposed circular fillet design on the bending stress induced in spur gear was investigated in comparison with standard trochoidal circular root fillet design. From the results it concludes that deflection in trochoidal and circular root fillet gear tooth is almost same. But there is reduction in bending stress value for circular root fillet design compared to bending stress value in trochoidal root fillet design.

From the results it found that 13.27 % reduction in stress when circular root fillet design is used instead of standard trochoidal root fillet design for existing gear (15 no. of teeth).

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