Paper ID: NITET16

BENDING STRESS AND THERMAL ANALYSIS OF SPUR GEARBY USING FEM

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ABSTRACT

Gear is the one of the important machine element in the mechanical power transmission system. Spur gear is most basic gear used to transmit power between parallel shafts. Spur gear generally fails by bending failure or contact failure. This paper deals with the bending stress calculation of spur gear theoretically and validating it with ANSYS software. These meshed gears from the gear box are subjected to considerable damage throughout its life span due to dynamic excitations caused by terrain undulations, the rotating wheel and track assemblies. The friction between two rolling gears results in generation of heat. Due to this heat generation gears goes into plastic state and gets deformed well before its ultimate tensile strength. The sequence followed is first drafting of spur gear on SOLIDWORKS. Next step is Static structural analysis which determines the bending stress generated in spur gear using FEA software ANSYS. The present work deals with the calculation of static analysis, and thermal analysis of gear by using ANSYS software. In a nutshell this paper explicitly deals with spur gear meshing theoretical calculation after drafting it and validated it by using ANSYS software. The practical implication of this paper is significant as the gear train is a major driver in power transmission systems.

KEYWORDS: spur gear, bending stress, ANSYS, thermal gradient.

INTRODUCTION

Gears are defined as toothed wheels which can transmit power and motion from one shaft to another by means of successive engagement of teeth. A gear is a rotating machine part having cut teeth, which meshes with another part in order to transmit torque. Two gears working in succession are called a transmission and can give mechanical advantage through a gear ratio and thus may be considered a simple machine.Spur gear give 98-99% operating efficiency (VivekKaraveeret al., 2013) [1]. Geared devices can change the speed, magnitude and direction of a power source when they are meshed with each other. However the gear can also mesh with non-rotating toothed part, called a rack, resulting in translation motion instead of rotation. The advantage of gear over pulley is that the gear prevents slipping. When two gears of unequal number of teeth are combined a mechanical advantage is produced, with both rotational speeds and torques of two gears differing in simple relationship [2].

The major types of failure modes in gear systems are tooth bending failure, contact fatigue, surface wear and scoring. For this reason, the stress in the tooth should be carefully studied in all practical gear application. Among the various types gears spur gear with involute profile is the simplest considering the design and manufacturing cost. Involute gears have certain advantages over the cycloidal gears like varying center distance with constant velocity ratio during matting, constant pressure angle with less wear and finally ease of manufacturing. The only problem with the involute profile is the interference. Although the cycloidal gear is not totally obsolete. It is used in spring driven watches, in some instruments [3].

The finite element method is frequently used to analyse the stress level of an elastic body with different geometry, such as gearing. In this project, initially, Finite element Analysis of spur gears is done considering static loading conditions.

SolidWorks is a solid modeler and utilizes a parametric feature-based approach to create models and assemblies. The software is written on parasolid-kernel.

Parameters refer to constraints whose values determine the shape or geometry of the model or assembly. Parameter can be either numeric parameters, such as lengths or circle diameters r geometric parameters, such as tangent, parallel, concentric, horizontal or vertical, etc.

Numeric parameters can be associated with each other through the use of relations, which allow them to capture design intent.

ANSYS is a FEA software used to analyze stress generated in a mechanical component during loading. Complex fluid flow simulations, electromagnetic simulations can also be done using this software. Analysis of any problem on ANSYS, it may be structural, fluid flow, thermal, etc., mainly comprises of three parts. First is Preprocessor. Here the type of analysis to be carried out is defined. Then the type of material its various elastic properties are fed to the software. In the second step Model is prepared and boundary conditions for e.g. Fixed end, free end, point of application of force is defined and model is meshed i.e., divided into n number of parts. The third step is Postprocessor where the results are obtained

LITERATURE REVIEW

Sushovan Ghosh, Rohit Ghosh etal (Dec 2016), carried out Static structural analysis of spur gear pair using FEA analysis. Bending Analysis was carried out using Levi's Beam strength theory. The maximum root bending stresses were found out to be within safety limits. Max equivalent (Von Misesstresse) vs. Torque graph is plotted [4].

V.S.N KarthikBommisetti (May 2009), wrote a thesis named "Finite Element Analysis of Spur Gear Set". The bending stresses were calculated using AGMA standards. The results were validated using FEA software ANSYS [6].

D. Ashokkumar, M. Venkaiah (Nov 2015) mentioned in their paper "Structural and thermal Analysis of gear Technology" the effect of heat generated due to friction on helical gear. Bending stresses in helical gear tooth were calculated and validated with FEA software Abacus [7]

PROBLEM STATEMENT

The spur gear pair considered is having an involute profile. Bending analysis and thermal analysis of gear pair is carried out.

Table 1: Dimensions of gear and pinion

Sr no.	Parameters	Gear	Pinion
1	Pitch circle diameter (d)	120mm	60mm
2	Number of teeth (N)	40	20
3	Pressure angle (φ)	20°	20°
4	Addendum (a)	3mm	3mm
5	Dedendum	3.75mm	3.75
6	Base circle diameter (db)	112.76mm	56.38mm
7	Face width (b)	10mm	10mm
8	Dedendum circle diameter	112.5mm	52.5mm

METHODOLOGY

Drafting:

Spur gears were drawn using CAD software SOLIDWORKS. Spur gears are having involute profile. Equation driven curve function of SOLIDWORKS is used for the drawing of spur gears. The parametric equations used are [5]

$X_c = r^* \cos\theta \quad X = X_c + (S^* \sin\theta)$

$Y_c = r^* \sin\theta \quad Y = Y_c - (S^* \cos\theta)$

$S = (\Pi^* r/2)^* t$

Where t varies from 0 to 1

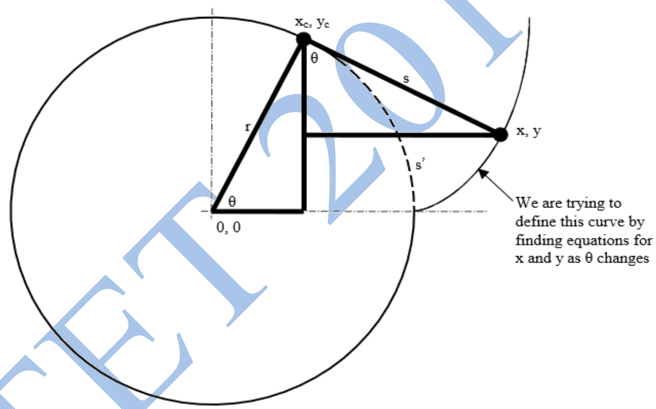

Fig 1 Spur gear Drafting methodology

Calculation of bending Stress:

The analysis of bending stress in gear tooth was done by Mr. Wilfred Lewis in his paper, 'The investigation of the strength of gear tooth' submitted at the Engineers club of Philadelphia in 1892. Even today, the Lewis equation is considered as the basic equation in the design of gears [8]

Assumptions of Levi's Equation:

1. Tooth is considered as simply supported beam
2. Load is distributed uniformly
3. Forces due to tooth sliding friction are negligible
4. Radial component of force is negligible

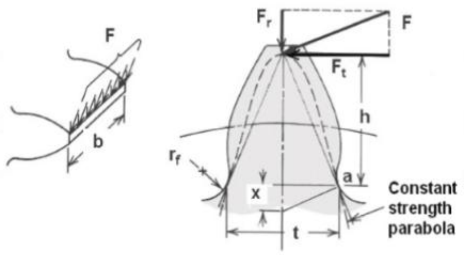

Fig 2 Levi's equation

Power transmitted P=5Kw

RPM of motor=1440

Calculation of beam strength using Levi's equation

$S_b = m^* b^* \sigma_b^* Y$

Where S_b= Beam strength

m= Module

σ_b= Bending strength(allowable)

Y= Levi's form factor

Beam strength for pinion=883.2N
Calculation of bending Stresses using AGMA [7]
Pitch line velocity= $(\Pi * D_p * N)/60000 = 4.52 m/s$
Tangential force on Pinion=P/V=1105.24N
Bending Stress= $(F_t)/(b*m*Y) = 114.58 N/mm^2$

ANALYTICAL PROCEDURE:

Pinion drafted in SOLIDWORKS are imported in ANSYS workbench. File was saved in .STEP format. Boundary conditions in this case are the mating portion of pinion with shaft is considered as fixed. Meshing of pinion was done. For meshing tetrahedral element is selected and medium size mesh is created. Grey cast iron is selected as the material for gear and pinion.

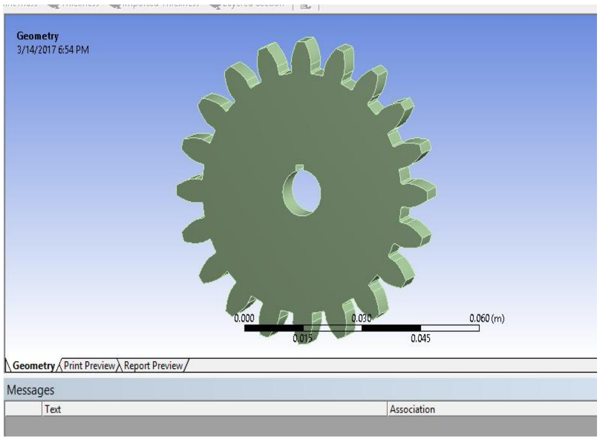

Fig 3 Pinion

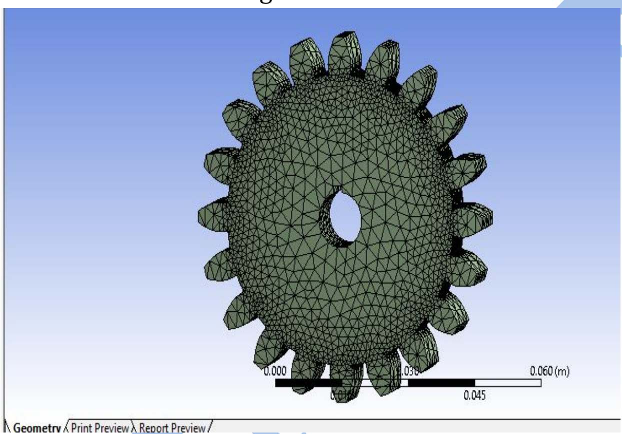

Fig 3 Meshing

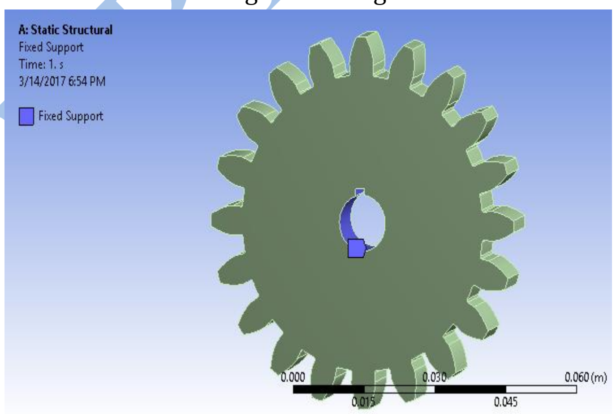

Fig 4 Boundary Conditions

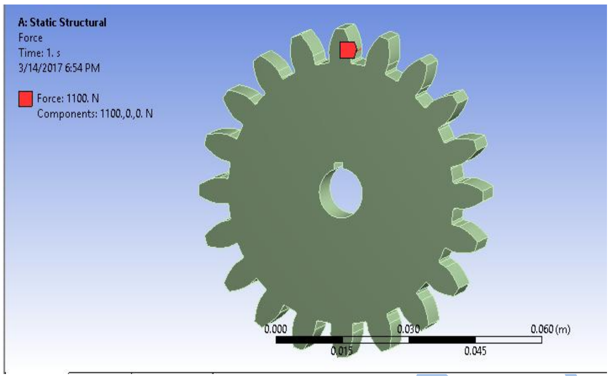

Fig 5 Force Application

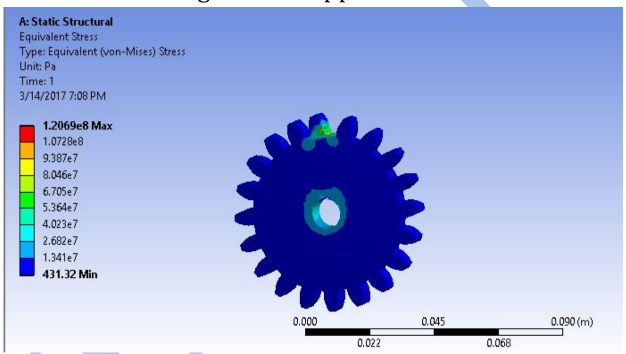

Fig 6 Results

Thermal Analysis
Calculation of heat flux
Heat generated due to friction is given by
$q = \mu * P * U$
Where q=heat flux
μ=Coe. of friction
A=Sliding contact area
U= Relative velocity
$P = F_t/A = (1100/67.87) = 16.20 mm^2$
$U = V_{gear} - V_{pinion} = 4.52 m/s$
$q = 0.3*16.2*10^4*4.52 = 219672 W/m^2$
Analytical Procedure

Spur gears in mesh are imported in workbench through SOLIDWORKS. They are meshed and heat flux q is applied to a face of pinion in spur gear mesh. Convection film coefficient is given as $50 W/m^2k$. Directional heat flow is studied and temperatures at different points is observed. Material of pinion and gear is selected as grey cast iron.

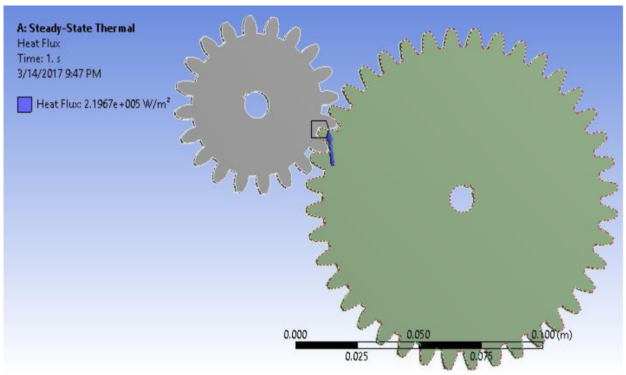

Fig 7 Heat Flux

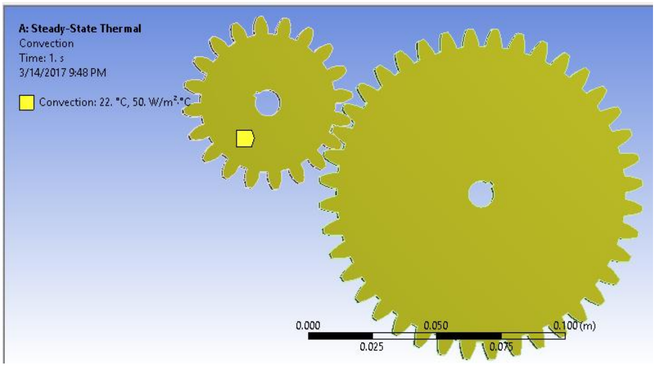

Fig 8Convection

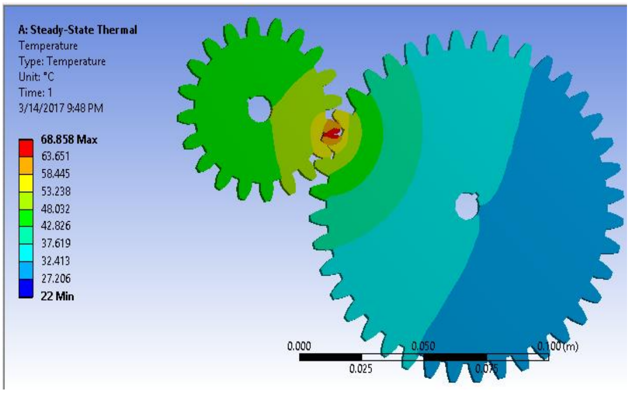

Fig 9 Temperature

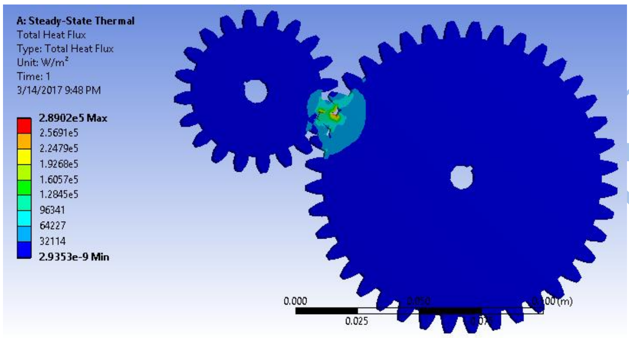

Fig 10 Total Heat Flux

CONCLUSIONS

Following are the conclusions:

Parameter	Analytical stress	ANSYS Stress	% error
Bending stress	114.58N/mm²	120.69N/mm²	5.3

As it can be seen that the % error is less. Hence results are validated.

Parameter	Result
Temperature	68.5°c
Total Heat Flux	2.89e5 W/m²

SCOPE FOR FUTURE WORK

1. Surface wear is one of the major failure mode in gear systems, therefore surface wear prediction methodology of gear pair may be carried out.
2. Present study may be extended to different complex cases of multi axial fatigue loading of proportional nature.
3. Carryout fatigue reliability assessment of test gear under random loading both by S-N curve approach and fracture mechanics approach.
4. Fatigue and realibility analysis under non-stationary random loading may be carried out.

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