

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Special Issue 9, May 2016

Stress Analysis of Aero Engine Spur Gear

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ABSTRACT: The context of this paper pertained to Aircraft gear design, which gives details about reduction of contact stresses in aero engine spur gears. Also discussed about changing the geometrical features like change in module, pressure angle and mass optimisation are verified with specified boundary conditions. The results are compared with set standards and design conditions.

KEYWORDS: Aircraft Spur Gear Design, Spur Gear, Mass Optimisation, Module, Pressure Angle.

I. INTRODUCTION

When gears are subjected to loading, gear undergoes both bending stress and contact stress. Bending and contact stresses analysis is an important phenomenon for the analysis of gears. Theoretically, bending stresses are analyzed by Lewis equation and contact stresses are analyzed by hertz equation. Pitting is a type of failure occurs on the surface of the gear tooth due to repetitive loadings which leads to surface traction and finally to catastrophic failure. So the duty of an engineer is to examine the surface and conduct many tests to avoid the failure. As the surface of two teeth gets contact, the surfaces of the tooth are elastically deformed and vibrations of the gears also cause internal dynamic forces. The main cause for this surface failures are heavy loads acting on the mating teeth exceeding the critical levels and sudden acceleration and deceleration of gears leads to failure. So it is important to reduce the stresses developed at the contact of the gear.

II. LITERATURE SURVEY

Deepikapotghan and Dr. Suman Sharma [1] and Mahesh badithe [2] studied the decrease in contact stresses using different types of stress relieving features like circular, elliptical and aerofoil shape hole on mountings of the gear. The standard gear model is modelled using CATIA V5. Later meshed and analysed using ANSYS. Both papers concluded that feature containing aerofoil shape hole yields the best results. Alkunte suryakanth [3]: described the reduction of contact stress value by decreasing the weight of the gear. This is possible by placing the holes on the rim of the gear. So that mass of the gear is reduced in turn the contact stress value of the gear is also reduced.

Contact problems are nonlinear problems which requires significant data source. Here frictional effects are neglected due to small frictional forces. Hence hertz theory is applied to frictionless contact and perfectly elastic solutions. Consider the two cylindrical surfaces of radius R_1 and R_2 , length of contact as L and Force exerted by one cylinder on other cylinder is P . Pressure distribution on a cylinder surfaces takes an elliptical shape as shown in Figure 1. It is important to be noted that the developed contact stress to be reduced this leads to increase in efficiency of the gear this leads to decrease the power losses caused by contact stress. It can be reduced by increasing the module and pressure angle of the gears in the gear set, as it is increased the pitch circle diameter of the gears increases, hence stress developed at mated surface of the gear decreases. Contact stresses developed can also be reduced by using mass optimization technique.

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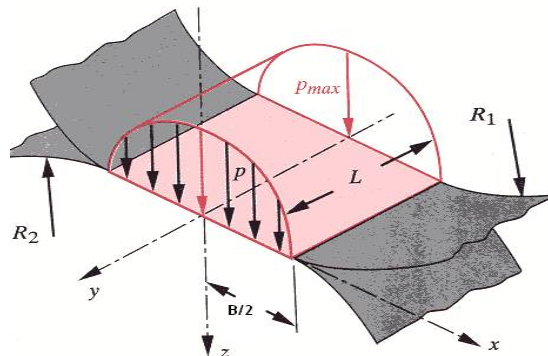


Figure1: Ellipsoid structure during contact of two cylinders.

III. PROBLEM DEFINITION

Initially pinion and gear are modelled as per the given data shown in Table 1. Here pinion shaft is subjected to more torque with a normal tooth load of 533.08 N.

Table 1: Data given Input

Sl no	Accessory	Power		Speed (rpm)	Direction of rotation
		kW	hp		
1	Gear	17.15	23	12650	CCW
2	Pinion	22.37	30	12235	CW

The gears are mist lubricated and max temperature on the gears is limited to 120-130° c at mesh point. The general data and gearing properties are given below.

Gear Material Properties:

Alloy: Case Carburising Steel.

- Physical Properties
Density (gm./cc): 7.85
- Mechanical Properties:
Hardness (BHN): 340-410 in hardened and tempered condition
240(max) in annealed conditions
- Tensile Properties:

The tensile properties of the gear set are important characteristics for the gear. The properties used for the gear set are as given in Table 2.

Table 2: Tensile Properties

UTS(MPa)	Young's modulus (N/mm ²)	Poisson's ratio
1180-1380	2.1e ⁵	0.3

The gear set is designed to the standards using design calculations and the data obtained are as given in the Table 3.

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Table 3: Pinion and Gear Details

SL NO	GEAR MANUFACTURING DATA	
1	Module	2.5
2	No Of Teeth	29/30
3	Pressure Angle	25°
4	Whole Depth	3.871
5	Base Helix Angle	0°
6	Pitch Diameter	46.4/48

Inputs given to gear:

- Power of the driver
- Speed of the pinion
- Speed of the gear
- No. of teeth on the pinion
- No. of teeth on the gear
- Module
- Pressure angle
- Face width of the gear

IV. METHODOLOGY

Initially as per the requirement of the aerospace engine data as given in problem definition, gear set is designed, modelled and assembled using CATIA V5 tool. Model made by CATIA V5 tool is imported to ANSYS Work Bench 13. Then problem is solved by using following steps.

- Imported model is assessed by the required properties using engineering data source.
- In the modelling section each gear is assessed with required properties as given in problem definition.

Modelling:

Gear set is designed using set standard equations. Designed gears are modelled using CATIA V5 and modelled gears are assembled using CATIA V5 assembly modeller with the help of contact constraint, manipulation commands. Eight circular holes are added to the pinion gear with equal space as shown in the Figure 2.

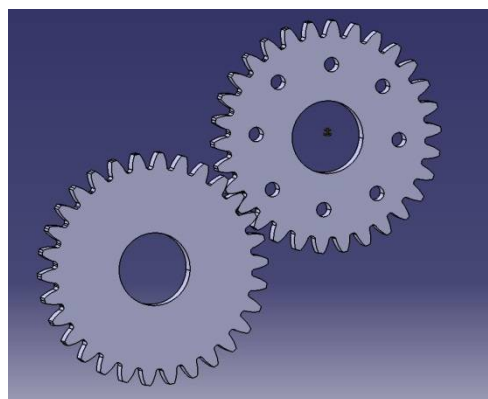


Figure 2: Assembly

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Meshing:

Model is meshed using face meshing, mapped meshing, refinement is done to the contact surfaces using Ansys workbench 13 Refinement is done to improve the accuracy of the result. Element of mesh is triangular mesh element and it is of 1mm elemental length as shown in Figure 3.

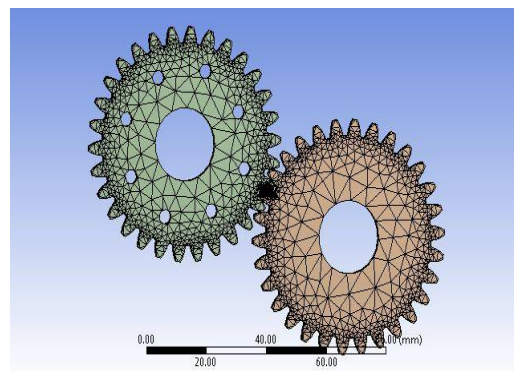


Figure 3: Meshing

Boundary conditions:

Boundary conditions are applied so that driver gear in CCW and pinion in CW are rotated. Rotational inertia force is applied on each gear as per to the given data as shown in figure no 4.

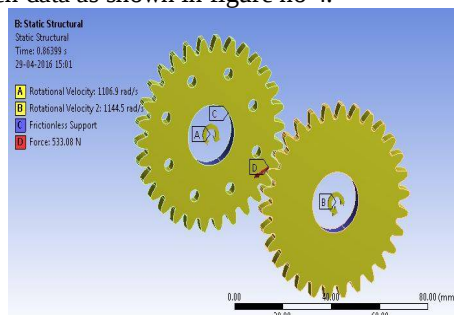


Figure 4: Boundary condition

Results obtained using FEA are compared with results using Hertzian equation is given by equation (1)

Hertz Contact Stress Equation:

$$\text{Contact Stress} = \sqrt{\left[F \left(1 + \frac{R_1}{R_2} \right) / R_1 * B * \Pi \{ (1-\mu^2)/R_1 + (1-\mu^2)/R_2 \} \right] \sin \phi} \quad (1)$$

Where,

F = Force on the tooth, B = Base width, μ = Poisons ratio,
 ϕ = Pressure angle, R_2 = Radius of driven gear, R_1 = Radius of driving gear,
Contact stress = $\sqrt{181416.410} = 425.930$ MPa.

Post processor and Results:

In post processor, required results are determined. i.e. Equivalent stress, fatigue life, stress factor etc. The results obtained for the module 2.5 and pressure angle 25(non-optimised) gear set results are shown in Figure 5. The results obtained for the module 2.5 and pressure angle 25(optimised) gear set results are shown in Figure 6.

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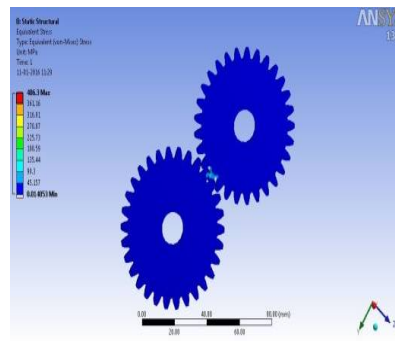


Figure 5: Equivalent stress

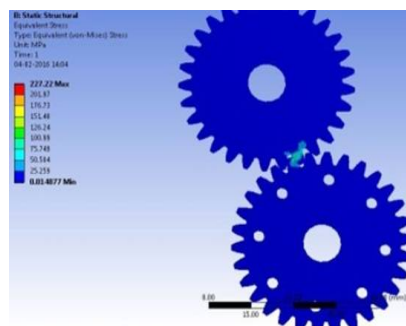


Figure 6: Mass optimization technique

V. COMPARISON

Equivalent results of non-optimised pinion gear are compared. The contact stress value obtained analytically using hertz equation is 425.930 MPa. The value of stress with unoptimised mass is 406.3MPa. The value of stress with Optimised mass is 227.22MPa and the difference between contact stress value obtained by optimised and unoptimised mass is 179.08 MPa. Comparisons of results are tabulated in Table 5.

Table 5: Comparison of results

Sl no	Analytical Results(MPa)	Un Optimised Contact stress(MPa)	Optimised Contact stress (MPa)	Difference(MPa)
1	425.930	406.3	227.22	179.08

VI. CONCLUSION

From the above analysis it is concluded that, efficient reduction of contact stress can be achieved by using mass optimisation technique, as the mass is reduced in a gear set the contact stress developed decreases considerably. The stress obtained in unoptimised gear set is compared with optimised gear set. It is seen that contact stress value decreased from 406.3MPa to 227.3MPa.Hence as the mass of the gear reduced, the stresses developed at the contact surfaces are decreased.



ISSN(Online) : 2319-8753
ISSN (Print) : 2347-6710

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