Finite Element Analysis of Spur Gear with Glass Fibre as Material

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ABSTRACT

Spur gear is the simplest & widely used component in power transmission system. A spur Gear is generally subjected to bending stress which causes teeth failure. However it is observed that performance of the spur gear is not satisfactory in certain applications and therefore it is required to explore some alternate materials to improve the performance of the spur gears. Composite materials provide adequate strength with weight reduction and they are emerging as a better alternative for replacing metallic gears. In this paper we have conducted linear static analysis through Ansys & increased strength and durability for Cast Iron & glass fibre are compared.

Keywords- Spur Gear, Linear static analysis, Cast iron, Glass Fibre, Composite

INTRODUCTION

The basic idea is to study the strength and durability & weight optimization that can be achieved using glass fibre as alternative material to Cast Iron. Low density of Glass Fibre can significantly reduce the weight of Spur gear. Linear static analysis performed on Spur Gear made of Cast iron. Also considerable weight reduction is achieved due to low density of glass fibre.

LITERATURE REVIEW

Shinde S.P., Nikam A.A., Mulla T.S, “*Static Analysis of Spur Gear Using Finite Element Analysis*”, has enlightened on design spur gears to resist bending failure of the teeth, as it affects transmission error

M. Keerthi, K. Sandya, K. Srinivas, “*Static & Dynamic Analysis of Spur Gear using Different Material*”, this paper illustrates composite materials are capable of using in automobile vehicle gear boxes instead of existing cast iron gears with better results.

Kishor N. Naik, DhananjayDolas, “*Static Analysis Bending Stress on Gear ToothProfile By Variation of Gear Parameters With The Help of FEA*” has

various relations between Bending stresses, face width and root radius..

Devendra Singh, “*Analysis Of Spur Gear For Involute Profile With Variation In Different Geometrical Parameters Using Fem*”, has discussed relationship between the various geometrical parameters of the gear and the static loads etc.

CALCULATION OF BASIC DIMENSIONS

To build the 3D model in CATIA we need to obtain few basic dimensions as shown in the fig 1. To start with following input parameters of an Existing Dual Rotor Wind Turbine have been considered.

Power $P_d = 4309.65W = 4.309 kW$

Torque = 211.15N-m

Number of teeth (z_1) = 70

Number of teeth's (z_2) = 14

Module (m) = 3.5 mm

Pressure angle = 20°

Fig.1 Various Dimensions of Spur gear

Calculations for Input Gear

Pitch circle diameter (D):

$$z \cdot m = 70 \cdot 3.5 = 245 \text{ mm}$$

Base circle diameter (Db):

$$D \cos \alpha = 245 \cdot \cos(20^\circ) = 230.22 \text{ mm}$$

Outer diameter (Do):

$$(z+2) \cdot m = (70+2) \cdot 3.5 = 252 \text{ mm}$$

Circular pitch (C):

$$m \cdot 3.142 = m \cdot 3.142 = 3.5 \cdot 3.142 = 10.997 \text{ mm}$$

Addendum (a):

$$\frac{1}{\text{Diametral pitch}} = \frac{1}{P_d} = \frac{1}{0.286} = 3.5 \text{ mm}$$

Dedendum (b):

$$\frac{1.157}{\text{Diametral pitch}} = \frac{1.157}{P_d} = \frac{1.157}{0.286} = 4.04 \text{ mm}$$

Total depth (dt):

$$\frac{2.157}{\text{Diametral pitch}} = \frac{2.157}{P_d} = \frac{2.157}{0.286} = 7.542 \text{ mm}$$

Thickness of tooth (T):

$$\frac{1.5708}{\text{Diametral pitch}} = \frac{1.5708}{P_d} = \frac{1.5708}{0.286} = 5.492 \text{ mm}$$

Face width (F):

$$= 4 \cdot 3.142 \cdot m = 4 \cdot 3.142 \cdot 3.5 = 43.988 \text{ mm}$$

Clearance (C):

$$\frac{0.2}{\text{Diametral pitch}} = \frac{0.2}{P_d} = \frac{0.2}{0.286} = 0.7 \text{ mm}$$

Root diameter:

$$\frac{\text{Number of teeth}'s - 2}{\text{Diametral pitch}} = \frac{N-2}{P_d} = \frac{70-2}{0.286} = 238 \text{ mm}$$

Calculations for Output Gear

Pitch circle diameter (D):

$$z \cdot m = 14 \cdot 3.5 = 49 \text{ mm}$$

Base circle diameter (Db):

$$D \cos \alpha = 49 \cdot \cos(20^\circ) = 46.045 \text{ mm}$$

Outer diameter (Do):

$$(z+2) \cdot m = (14+2) \cdot 3.5 = 56 \text{ mm}$$

Circular pitch (C):

$$m \cdot 3.142 = m \cdot 3.142 = 3.5 \cdot 3.142 = 10.997 \text{ mm}$$

Addendum (a):

$$\frac{1}{\text{Diametral pitch}} = \frac{1}{P_d} = \frac{1}{0.286} = 3.5 \text{ mm}$$

Dedendum (b):

$$\frac{1.157}{\text{Diametral pitch}} = \frac{1.157}{P_d} = \frac{1.157}{0.286} = 4.04 \text{ mm}$$

Total depth (dt):

$$\frac{2.157}{\text{Diametral pitch}} = \frac{2.157}{P_d} = \frac{2.157}{0.286} = 7.542 \text{ mm}$$

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$$= 4 \cdot 3.142 \cdot m = 4 \cdot 3.142 \cdot 3.5 = 43.988 \text{ mm}$$

Clearance (C):

$$\frac{0.2}{\text{Diametral pitch}} = \frac{0.2}{P_d} = \frac{0.2}{0.286} = 0.7 \text{ mm}$$

Root diameter:

$$\frac{\text{Number of teeth}'s - 2}{\text{Diametral pitch}} = \frac{N-2}{P_d} = \frac{14-2}{0.286} = 42 \text{ mm}$$

GENERATION OF CAD MODEL

Dimensions required for modelling are calculated in the earlier steps. Further CAD model of a Gears have been prepared in CATIA. And importing those features 3D model is prepared as shown in fig.2.

Fig.2- 3D model of input and output gears

FINITE ELEMENT MODELLING OF SPUR GEAR

Initially the .igs file from CATIA is imported to the meshing software Hypermesh. The CAD data of the Gear is imported and the surfaces were created and meshed. The model is imported in ANSYS to perform linear analysis and maximum displacement and von-mises stress are obtained. Initially Linear static analysis is performed on Gear Pair with Cast iron material & later it is performed on Gear pair of glass fibre.

Table 1- Properties of Cast iron

Property	Value
Young's Modulus	120 Gpa
Poisson's Ratio	0.26
Density	7200 kg/m ³
Yield Stress	200 Mpa
Ultimate Tensile Strength	310 Mpa

Table 2- Properties of Glass Fibre

Property	Value
Young's Modulus in X Dir.	40300 Mpa
Young's Modulus in Y Dir.	6210 Mpa
Young's Modulus in Z Dir.	40300 Mpa
Poisson Ratio	0.2
Density	1.9×10^{-9} tonne/mm ³
Shear Modulus in XY Plane	3070 Mpa
Shear Modulus in YZ Plane	2390 Mpa
Shear Modulus in XZ Plane	1550 Mpa

Boundary Conditions, von mises stress and displacement for Cast Iron Gear Pair

Boundary Conditions:

Fig.3: Boundary Conditions for Cast iron spur gear

Von mises Stress

Fig.4: von-mises stress for cast iron spur gear

Displacement

Fig.5: Displacement for Cast iron spur gear

Boundary Conditions

Fig.6: Boundary Conditions for Glass fibre spur gear

Von mises stress

Fig.7: von-mises stress for Glass Fibre spur gear

3.Displacement

Fig.8: Displacement for Glass Fibre spur gear

Observing the Results obtained it was seen that we could optimize the thickness of the gear for glass fibre and iterations were carried out for various thickness for glass fibre gears. Results obtained are tabulated in table 3 below.

Table 3 Comparison of Iterations for thickness

Sr. No	Iteration number	Thickness (mm)	Stress (Mpa)	Deformation (mm)	Weight (Kg)
1	1	30	3.5790	0.002808	2.606
2	2	20	6.2778	0.004139	1.737
3	3	15	8.5335	0.005513	1.303
4	4	10	13.4130	0.008420	0.869

From CATIA model it is seen that weight of the gear can be reduced using Glass Fibre of same dimensions as of cast iron and also for smaller face width to give same strength and durability

compared to the Cast iron spur gear with larger facewidth.

Table 4 Comparison of Weight for facewidth

Sr. No	Material	Stress (Mpa)	Deformation (mm)	Weight (Kg)
1	Cast Iron	2.9940	0.000674	14.48
2	Glass Fiber	3.3253	0.002563	3.821

Table 5 Comparison of Weight for same strength

Sr. No	Material	Stress (Mpa)	Deformation (mm)	Weight (Kg)
1	Cast Iron	2.9940	0.000674	14.48
2	Glass Fiber	13.4130	0.008420	0.869

CONCLUSIONS

The comparison, between Linear static analysis results of Spur Gear with Cast iron and Glass Fiber as materials, has been performed and it is summarized in table.4 shown above.

The comparison, between Spur Gear with Cast iron and Glass Fiber as materials for same Strength and durability has been performed and it is summarized in table.5 shown above.

Percentage decrease in weight through iterations for same dimensions of gear is 73.61 %.

Percentage decrease in weight through iterations for same strength and durability is 93.998 %.

Below 10 mm, the deflection increase will be unsafe because, if the deflection increases further then there might be the failure in the gear pair.

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