iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 **Issue:** VI **Month of publication:** June 2017

DOI:

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Bending Stress Analysis of Spur Gear

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Abstract**: *Gears are widely used for the power and motion transmission in various systems. Gears are classified as spur, helical, bevel, worm etc. The spur gears are easy to manufacture and are used on parallel shafts. Spur gears are designed based on beam strength and wear strength criteria. In present study a spur gear is designed based on beam strength criteria analytically. Based on the calculations the gear has been modeled in CATIA V5. After this the same gear is imported in ANSYS Workbench 14.5 and its analysis is carried out with given boundary conditions. The analysis results of bending stress are compared with MATLAB code for further validation.***
Keywords*: **Bending stress, Contact Stress, FEA, Gear, Matlab***

I. INTRODUCTION

Spur gears are subjected two types of stresses as bending stress and contact stress. The bending stress is given by Lewis equation. The Lewis equation assumes that 1. Effect of radial component which produces compressive stress is neglected, 2 tangential component is uniformly distributed over the face width of gear, 3 effect of stress concentration is neglected, 4 at any time only one pair of gear is in contact and carries total load. [1,3,5,8,12] Performed contact stress analysis for using FEA and the results obtained were compared with the theoretical Hertz's equation values. [2] Authors have reported that stress analysis performed with Lewis formula and Hertz equation and results found by AGMA equations are acceptable with FEA results. [4] The study shows the effect of different modules on the contact stresses and finally the results of Hertz theory and Finite element analysis is compared. [6] Shows that bending and contact stress are calculated by theoretical and numerical approach. The results where further compared with FEA result to validate.[7,11,10] Bending stress is estimated analytically and results compared with FEA shows the good agreement.[9] the study is not limited only to bending stress calculation but it also focused on the manufacturing of gear based on composite materials at the critically stressed section using FEA.[11] generation of an asymmetric spur gear tooth and bending stress at the root of Asymmetric spur gear tooth is estimated by FEA and results were compared with the standard spur gear tooth.[13] study focuses on the reduction of stresses occurs on Spur gear by means of different stress relief features. The Bending stress is analysed by means of analytical and FEA procedure method, then with advanced optimization tools this stress value is reduced. [14] Results based on the shows that Polyoxymethylene gears are suitable for the application of sugar cane juice machine under limited load conditions. Hence by replacing the conventional material spur gears by polyoxymethylene gears we can reduce noise, weight, cost etc. The aim of this study is to estimate bending stress with Lewis formula and then compare it with FEA. Here two cases for study are considered in first case gear module is taken as 4mm , number of teeth as 15, and face width is taken as 20,22,24,26,28, 30 mm and in second case gear module is taken as 4mm , number of teeth 16 and face width is taken as 20,22,24,26,28, 30 mm. the aim of study is to verify effect of face width change on Bending stress along with change in number of teeth.

II. GEAR DESIGN

Calculate bending stress for pair identical spur gear with following data.
Sample Calculations:

$$\text{Power (P)} = 5\text{kW} = 5000\ \text{W}$$

$$\text{Speed (N)} = 1500\ \text{rpm}$$

$$T = \frac{60 \times 10^6 \times P}{2 \times \pi \times N}$$

$$T = \frac{60 \times 10^6 \times 5}{2 \times \pi \times 1500}$$

$T = 31830.98\ N.mm$

Tangential force is given by

$$Pt = \frac{2 \times T}{m \times z}$$

$$Pt = \frac{2 \times 31830.98}{4 \times 15}$$

$$Pt = 1061.03\ N$$

Where,

Pt =Tangential Force

Using Lewis Bending stress equation

$$\sigma b = \frac{Pt}{m \times b \times Y}$$

$$\sigma b = \frac{1061.03}{4 \times 20 \times 0.295}$$

$$\sigma b = 45.89\ N/mm^2$$

Where,
σb = allowable bending stress in N/mm^2
m = module of gear in mm
b = face width of gear in mm
Y = module of gear in mm

The material of gear is structural steel and allowable stress is given by

$$\sigma b = \frac{560}{3}$$

$$\sigma b = 186.66\ N/mm^2$$

Since $45.89\ N/mm^2 < 186.66\ N/mm^2$ hence design of gear is safe. Table II shows gear dimensions.

TABLE I
GEAR DIMENSIONS

Parameter	Dimensions
Type of Gear	20° Spur
Power	5 kW
Speed	1500 rpm
module	4 mm
Number of teeth	15, 16
Face widths	20,22,24,26,28,30 mm
PCD	60mm, 64 mm

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ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

III.FINITE ELEMENT ANALYSIS

In finite element analysis of gear material properties and boundary conditions are important. First boundary condition is displacement applied at shaft diameter which restricts gear movement along shaft as shown in figure1 second boundary condition is load (tangential force) as 1061.03 N acting on tooth face as shown in figure 2. Both the gears are having same dimensions except number of teeth.The material of spur gear is taken as structural steel. The properties of material are given in Table II.

TABLE III
MATERIAL PROPERTIES

Material Specifications	Values
Density	7800 Kg/m^3
Modulus of Elasticity	210Gpa
Possions Ratio	0.3
Ultimate Tensile Strength	280 N/mm^2
Tensile Yield Strength	560 N/mm^2

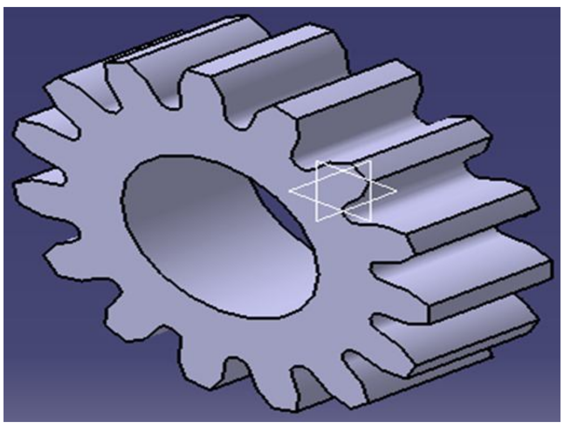

Fig. 1 CAD Model of Gear

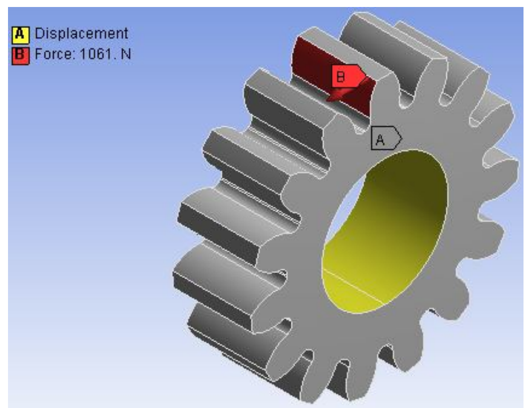

Fig. 2 Boundary Conditions

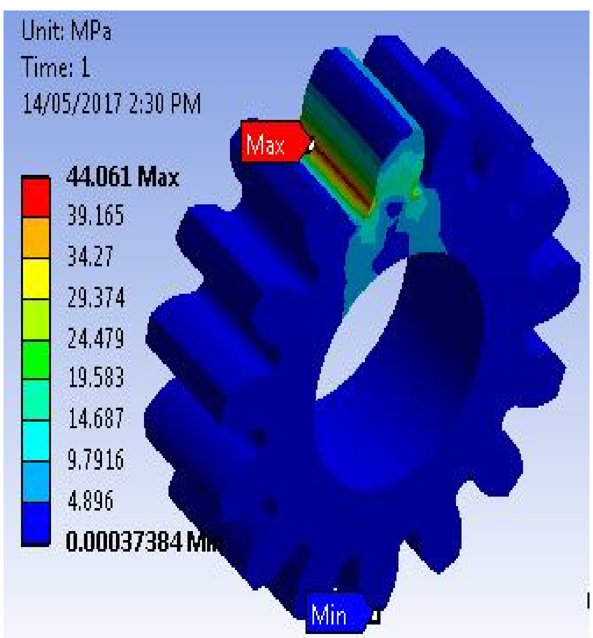

Fig. 3 Stress Plot for 15 Teeth

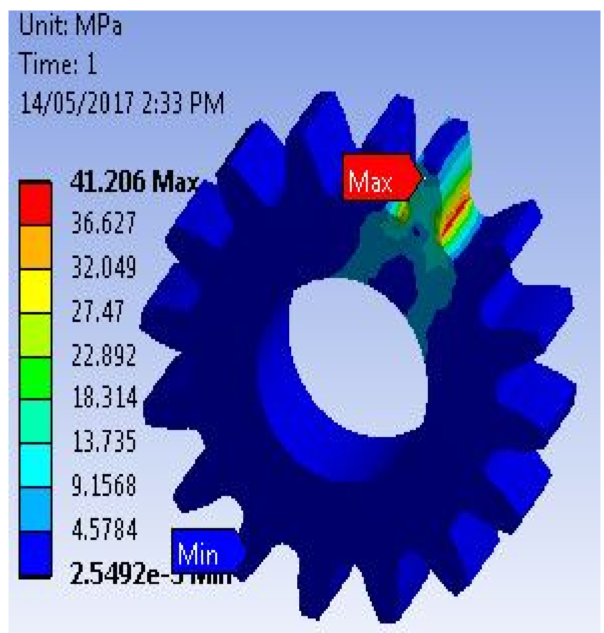

Fig. 4 Stress Plot for 16 Teeth

Volume 5 Issue VI, June 2017
ISSN: 2321-9653
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IV. RESULTS AND DISCUSSION

During the spur gear analysis two cases considered in first case module of gear is taken as 4 mm and number of teeth as 15, and face width of gear is varied as 22,24,26,28,30 mm and result shows that bending stress calculated Analytically for 20 mm face width is 45.89 MPa and from ansys 44.06 MPa and similar results are obtained for other face width values. In second case module of gear is taken as 4 mm and number of teeth as 16, and face width of gear is varied as 22,24,26,28,30 mm and result shows that bending stress calculated Analytically for 20 mm face width is 42.14 MPa and from ansys 41.20 MPa and similar results are obtained for other face width values using Matlab code. The results of both cases are shown in Table III and IV respectively.

TABLE IIIII

CASE I: MODULE = 4MM, NUMBER OF TEETH = 15

Face width (b) mm	Bending Stress Analytically	Bending Stress Ansys	Bending Stress MATLAB
20	45.89	44.06	45.91
22	41.71	39.85	41.74
24	38.24	36.23	38.26
26	35.30	33.34	35.31
28	31.00	30.18	32.79
30	30.59	28.72	30.61

TABLE IVV

CASE I: MODULE = 4MM, NUMBER OF TEETH = 16

Face width (b) mm	Bending Stress Analytically	Bending Stress Ansys	Bending Stress MATLAB
20	42.14	41.20	42.17
22	38.31	37.08	38.33
24	35.12	33.96	35.14
26	34.58	31.26	32.43
28	32.11	28.89	30.12
30	29.97	26.93	28.11

V. CONCLUSION

The gear is designed based on beam strength criteria analytically and numerical analysis of gear is done with two different cases. The study result shows that bending stress values obtained from both methods are well within acceptable limits and hence gear designed is safe. The bending stress results obtained by matlab code are also similar to analytical results.

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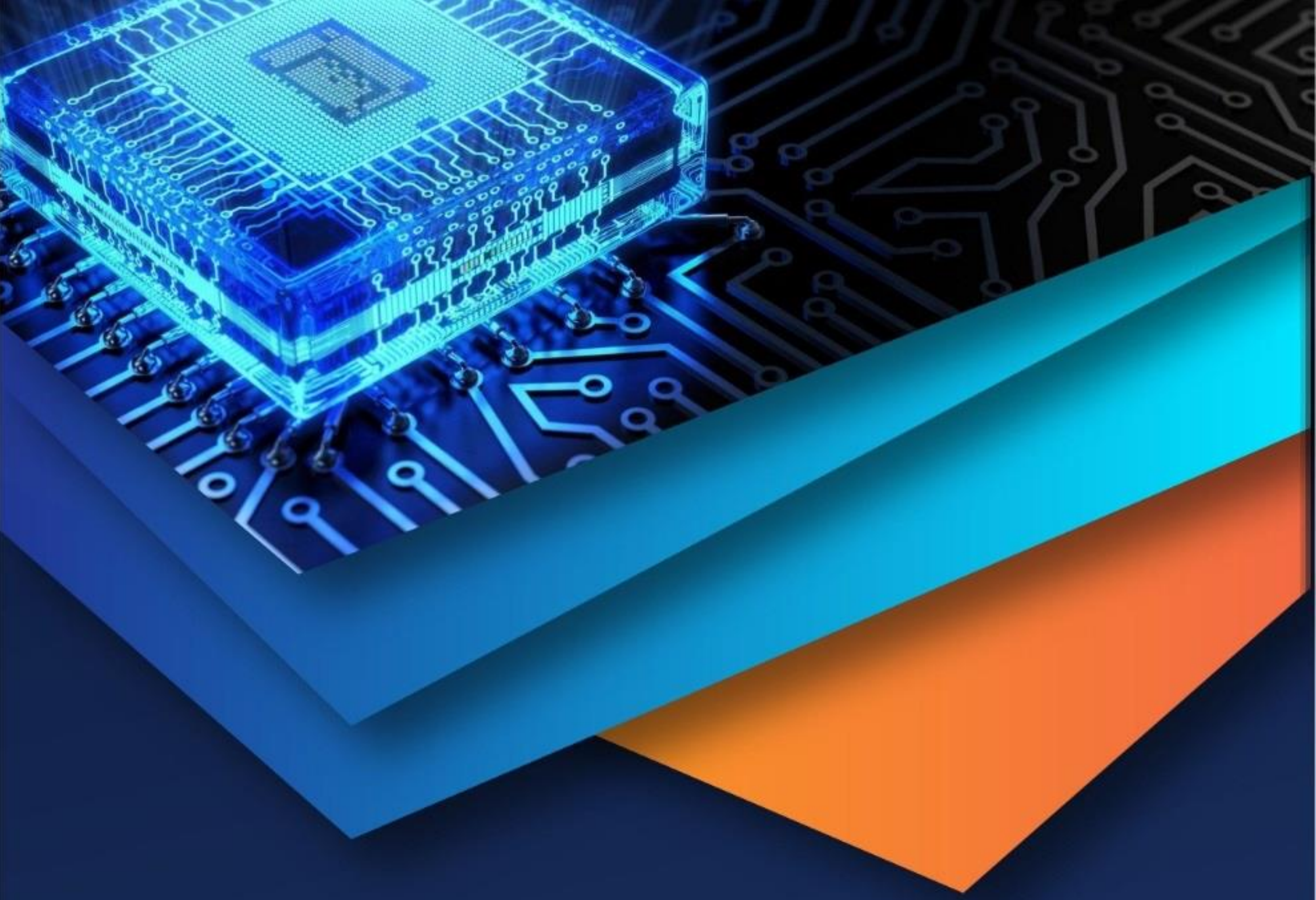

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