"Stress Analysis of Spur Gear using Different Gears Design"

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Abstract - *Gear is one of the most important machine elements in the mechanical power transmission system. It is a rotating machine part having a tooth that meshes with another toothed part in order to transmit torque/motion from one shaft to another shaft in such a way that their ratio of angular velocities is constant. Generally, two types of cyclic stress are subjected on a spur gear tooth in action, contact stress and bending stress. The bending stress and total deformation of the gear tooth is the primary objective of modern gear design. The main objective of the project is to suggest a suitable gear design for the use of TATA SUPER ACE MODEL. While designing the gears, we have considered 5 different Spur gear of Structural Steel material. We first calculated the theoretical value by using the Lewis Bending equation. Then, we modelled these Gears using SOLIDWORK 2021 software and did an Static analysis on ANSYS Workbench 19.2 to find the stresses and deformation . Thus, we validate the result by comparing the values Lewis equation and ANSYS results. Through this, we obtained stresses..*

KeyWords: Spur Gears, SOLIDSWORKS, ANSYS Workbench, Structural Steel, Bending stress, Contact stress, TATA SUPER ACE MODEL

1.INTRODUCTION

Spur Gears: Spur gears are simple types of gears which are used for power transmission between two reciprocating shaft. It has two gears, one is the driving gear and second is the driven gear. In Spur gears, the teeth are parallel to the axis of rotation. It is mainly used when the axis of driving and driven shaft are parallel and coplanar. The compressive strength created on gear tooth is negligible.

It can be classified into two pressure angles, 20 degree and 14 ½ degree. They are manufacture by either involute profile or cycloidal profile. The minimum number of teeth on a gear with a normal pressure angle of 20 degree is 18. Spur gears are excellent at moderate speed but tends to be noisy at high speed.

It has a simple and compact design which makes easy to design and install the gears in restricted spaces. These gears increase or decrease shaft speed with high degree of precision at a constant velocity. They does *not slip during any operation and their durability*

decreases their risk of premature failure. The simplicity of design allow greater manufacturability, making them less expensive to fabricate and purchase. It has the power transmission efficiencies between 95% and 99% and can transfer large power with minor power loss. They are used in high speed and high load application in all trains and a wide range of velocity ratios. Hence, they found application right from clocks, household gadgets, motor cycles, automobiles and railways to aircrafts.

Fig . 1: Spur Gear

1.2 LITERATURE SURVEY

There has been a lot of research being carried out on spur gears with different parameter like module, teeth , thickness, gear material and gear design

1) Putti Srinivasa Rao et al. In this paper the contact stresses were calculated by the Hertz's equation and then the 3D gear model was tested in ANSYS simulation and the conclusion was drawn.

2) Deepika Potghan et al. in his paper studied the stress analysis of spur gear with three different materials to determine the contact stresses in the gear tooth. The materials were grey cast iron, high carbon steel and medium carbon

steel. The result of analytical solution i.e. by hertz equation and by FEA results are comparing, the less difference between thevalues of contact stresses found.

3) Seok-Chul Hwang et al studied the contact stress analysis for a pair of mating gears during rotation. He investigated respective variation of contact stress analysis for spur gear with the different contact position in a pair of mating gears.

4) P.B. Pawar et al. investigated the contact stress and bending stress between the different material gears i.e. Alloy steel, Nylon and Al-sic by analytical and FEA. He concluded that that Nylon gears has minimum stress among all.

5) V. Siva Prasad el al [4]. studied analysis of different polymer gears namely nylon, polycarbonate and it is checked as an alternative to cast iron. He concluded that Nylon gears are suitable for the application of sugarcane juice machine under limited load condition in comparison with cast iron gears.

6) Mahebub Vohra et al [6] studied Metallic material cast iron and Non-metallic Nylon spur gear. He concluded that the finite element analysis software Ansys have values of stress distribution similar to theoretical values. Non-metallic gears can be used as an alternative tometallic gears.

2. O*BJECTIVE OF WORK:*

The objective of the work is to reduce the stress distribution, deformation and weight of spur gear by using different gear design. The designs are then compared with each other according to final result we consider the best gears for TATA SUPER ACE MODEL.

3 . GEAR SPECIFICATIONS:

For calculating bending stress, total deformation we have taken a standard model for designing of spur gear tooth. The following data is given for the design of 20 degree full depth spur gear made of Structural steel used in TATA SUPER ACE model application transmitting torque of 135.24Nm and power transmission of 35.40kW

Symbols	Units	Value
Pitch circle diameter (D_p)	mm	180
Pitch circle radius (R_p)	mm	90
Number of teeth on pinion (Np)	-	18
Number of teeth on gear (Ng)	-	18
Pressure angle (ϕ)	Degree	20
Addendum (Ha)	mm	20
Dedendum (Hd)	mm	11.57
Module (m)	mm	10
Addendum circle diameter (Da)	mm	200
Dedendum circle diameter (Dd)	mm	156.86
Base circle diameter (Dh)	mm	169.155
Face width (B)	mm	54
Tooth thickness (t)	mm	15.71
Clearance (c)	mm	1.57

Table. 1: Specifications of Spur gear

3.1 MATERIAL SELECTION:

STRUCTURAL STEEL

Property	Value
Density	7850 kg/m3
Young's modulus	200 GPa
Poisson's ratio	0.3
Bulk modulus	166 GPa
Tensile yield strength	250 MPa
Ultimate tensile strength	460 MPa

Table. 2: Material properties of Structural Steel

4. METHODOLOGY:

In this project we are going to design a spur gear and perform stress analysis using Finite element analysis (FEA) on Structural Steel material and compare those values with the calculation that we have performed using Lewis equation.

STEP:1
We calculate the bending stress by Lewis bending equation

STEP:2
A 3D model of Spur gear of different design is designed on Solidworks2021 software for obtaining the variation between stress considering the calculated values in the specifications table.

STEP:3
Converting the 3D model in the IGES format and export it into ANSYS Workbench where we did Static Structural project for all sizes. Then we mesh the models and applied the boundary conditions.

STEP:4
We calculate the stress of different design in Ansys and compare it with theoretical calculation.

4.1 MATHEMACTICAL CALCULATION OF BENDING STRESS BY LEWIS BENDING EQUATION:

Model = TATA SUPER ACE
Engine = TATA475 TCIC BSIII,
Torque(T) = 135.24 Nm
Speed(N) = 2500 rpm
Power(P) = 35405.74 W = 35.40 kW
Torque (T) = F×(d/2)
Where, F-load,
d- Pitch circle diameter (z×m=180mm)
F = T/ (d/2)
F = 135240 / 90
Load (F) = 1502.66 N
Using Lewis equation,
Tangential load, F =b×y×pc×σb
pc =π×m = 31.41 mm
y= Lewis form factor=0.134mm
b = face width = 54mm
The maximum allowable stress= 8.7413N/mm2
Ultimate tensile strength for structural steel=460 MPa
Allowable stress for structural steel = ultimate tensile strength/3= 460/3 = 153.33 N/mm2> 8.7413N/mm2
So, the design is safe.

4.2 3D CAD MODELS:

We have designed 5 different spur gears in SOLIDWORKS 2021

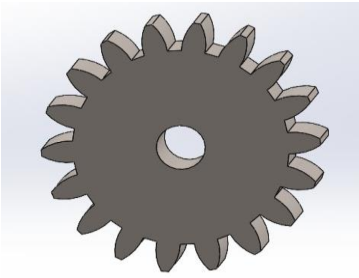

Fig .2 : Design no 1

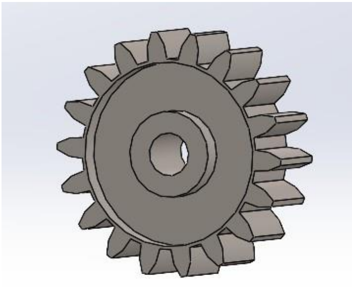

Fig.3: Design no 2

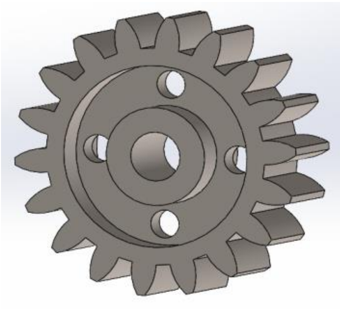

Fig. 4: Design no 3

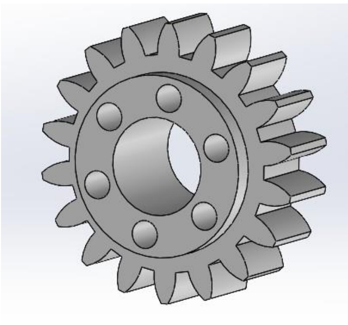

Fig.5: Design no 4

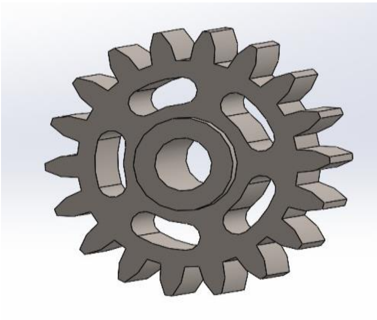

Fig. 6: Design no 5

4.3 CONTACT REGION:

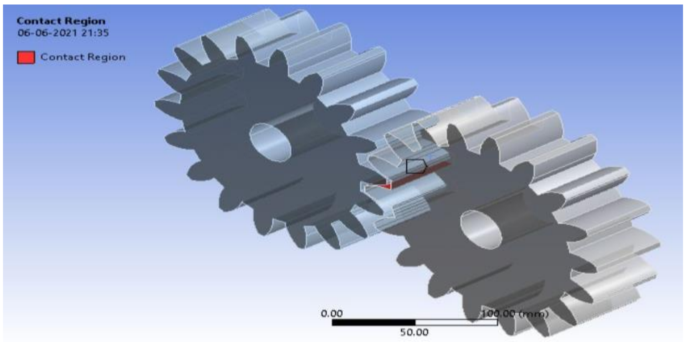

Fig no 7: Contact region between two gears

4.4 MESHING OF GEARS:

With the help of mesh control method we select the Tetrahedron Meshing with fine meshing for the entire geometry. We have repeat the same for all sizes.
Nodes: 18320
Elements: 9542

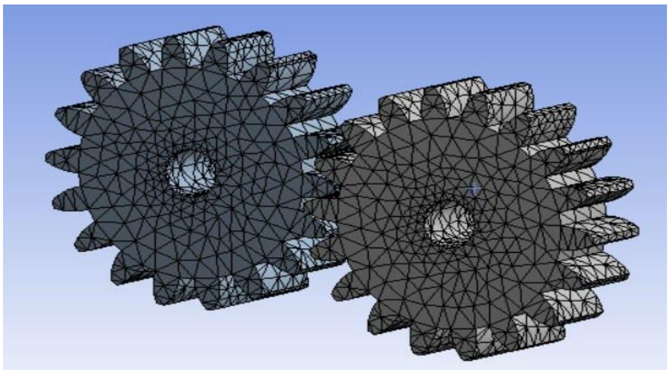

Fig. 8: Meshing of gears

4.5 BOUNDARY CONDITIONS:

Fixed support is applied on the circular base of driven gears. Frictionless support is applied on the driving gear. A torque of 135.24 Nm on the face of driving gear.

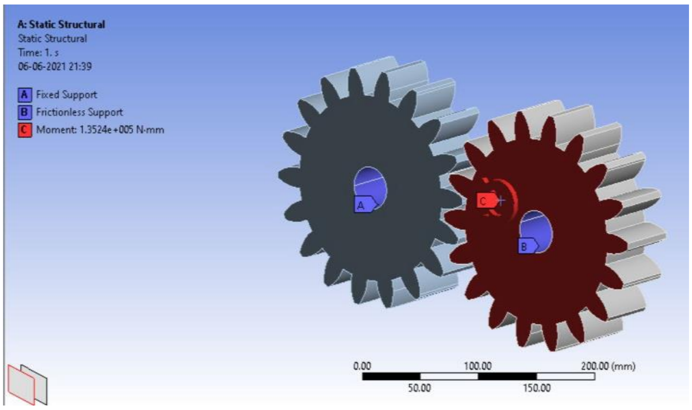

Fig. 9: Boundary condition of Spur gear

5.RESULTS AND DISCUSSION:

Analysis Results for Spur Gear of different design

Static Structural analysis of Structural Steel gear

1] For Design no 1:

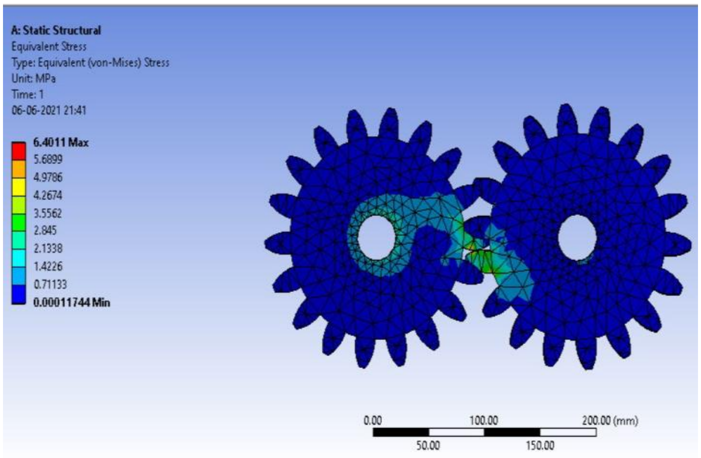

Fig .10: Von-mises stress in design no 1

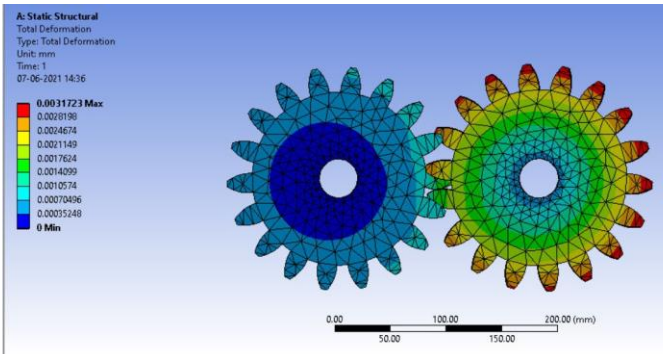

Fig.11: Total deformation in design no 1

2] For design no 2

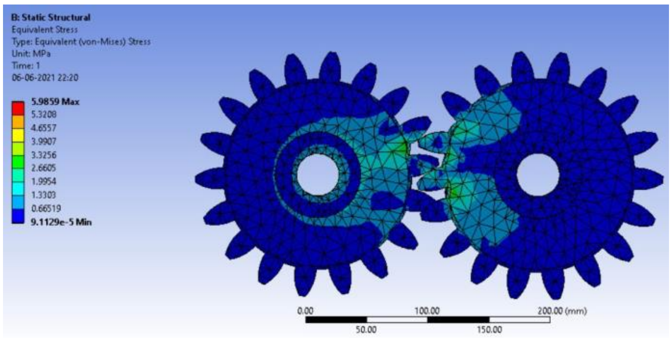

Fig.12: Von-mises stress in design no 2

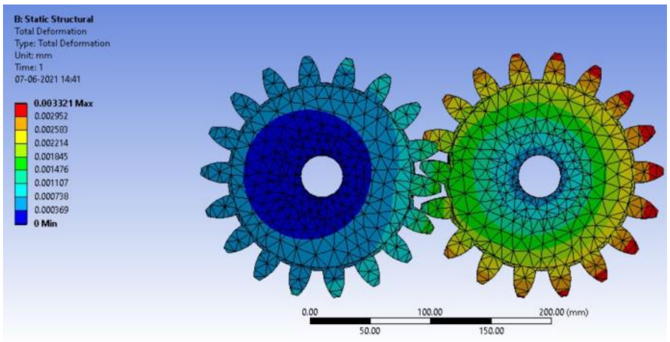

Fig .13: Total deformation in design no 2

3] For Design no 3

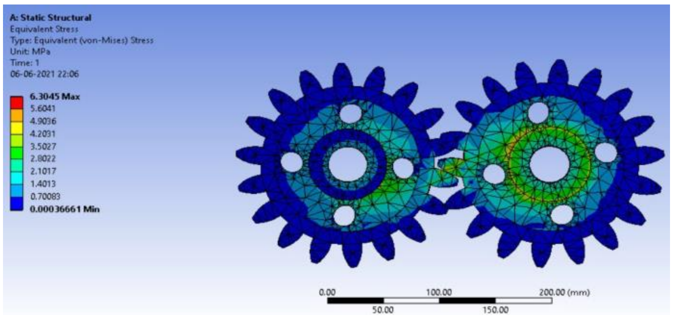

Fig .14: Von-mises stress in design no 3

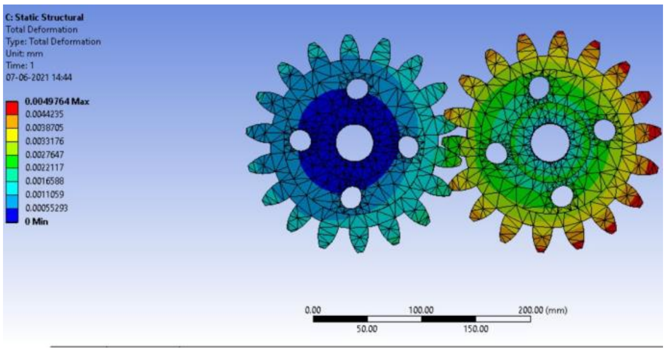

Fig.15: Total deformation in design no 3

4] For Design no 4

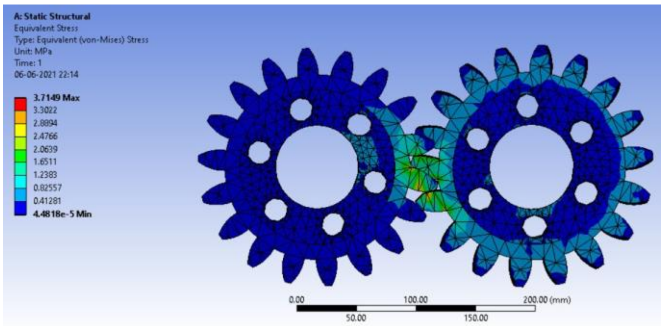

Fig .16: Von-mises stress in design no 4

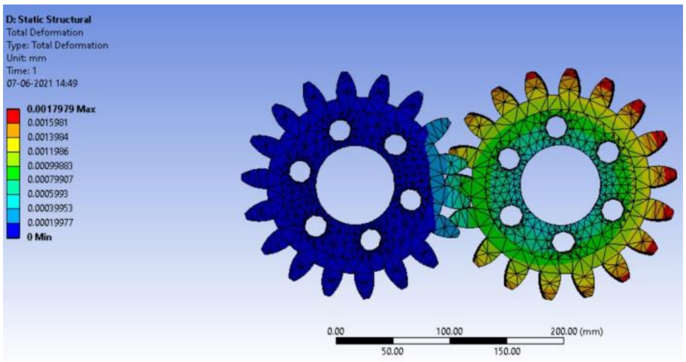

Fig.17: Total deformation in design no 4

5] For Design no 5

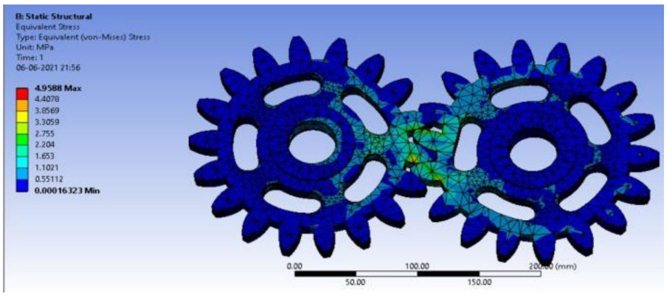

Fig.18: Von-mises stress in design no 5

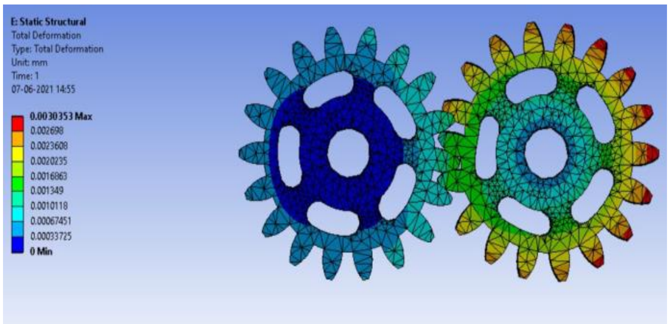

Fig .19: Total deformation in design no 5

Sr No.	Total Deformation (mm)	Von – Mises Stress (MPa)	Mass (kg)
Design no 1	0.00317	6.4011	19.894
Design no 2	0.00332	5.9859	13.389
Design no 3	0.0049	6.3045	13.705
Design no 4	0.00179	3.7149	19.415
Design no 5	0.0030	4.9588	16.567

Table.3: Comparing different types of gear design

6.CONCLUSION:

The following conclusions can be drawn from the analysis conducted in this study.

We have performed Structural analysis on different Spur gear design. By comparing the analysis for different design we have concluded that the design no 4 gear having the maximum stress of 3.7146 MPa and total deformation of 0.00179 is best among all other results .We can say that the Design no4 Spur gear is more advantageous than the other types of gears design in the application of TATA ACE MODEL .

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