

Comparison of Gray Cast Iron with Aluminum Silicon Carbide and Nylon 66 On Helical Gear

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Abstract-- Gearing system is a standout amongst the most basic parts in a mechanical power transmission framework and in most modern pivoting hardware. As of late, it is required to work machines at different load and speed. Gear teeth ordinarily fizzle when the heap is expanded over a specific limit. Consequently, it is required to investigate elective materials for gear fabricating. Composite materials give sufficient quality weight decrease and they have developed as a superior option for supplanting metallic gears. In this work, an endeavor has been made to supplant the metallic gears of Grey cast iron with the composites. The composites consider were the Aluminum Silicon carbide composite, and Nylon 66 composite. Endeavors have additionally been done for demonstrating the transmitting power gear get together on SolidWorks 2016 and FEA based basic conduct of various material was contemplated. Ansys 18.0 is utilized for the examination instrument in the present work to decide the aggregate disfigurement, Equivalent pressure, Factor of security and weight of the gear get together. Composite gears offer enhanced properties over steel compounds and these can be utilized as a superior option for supplanting metallic gears.

KEYWORDS: Helical Gear, FEA, SolidWorks 2016, Ansys 18.0, Gary Cast Iron, Aluminum Silicon Carbide, Nylon66.

I. INTRODUCTION

A. Gear

A gear is a rotating system element having slit tooth, or cogs, which mesh with another toothed element to transmit torque. Geared devices can trade the speed, torque, and path of an energy source. Gears almost always produce trade in torque, growing a mechanical advantage, via their tool's ratio, and for this reason, can be taken into consideration a simple machine. Two or more meshing gears, working in a series, are known as a transmission.

One of the first-rate strategies of transmitting energy between the shafts is gears. Gears are in the main used to transmit torque and angular speed. The fast improvement of industries inclusive of a car, shipbuilding, and plane requires a superior application of gear era. Customers pick automobiles with an especially efficient engine. This wanted up to a demand for silent transmission. Automobile sectors are one in every of the biggest manufacturers of gears. Higher reliability and lighter weight gears are vital to making vehicle light in weight as lighter cars continue to be in demand. The fulfillment in engine noise discount promotes the production of quieter tools pairs for in addition noise discount. The quality manner of tools noise reduction is attained by using lowering the vibration related to them.

B. Helical Gear

Helical gears are presently getting used increasingly as a power transmitting tools due to their higher operating speed, massive load carrying capacity, noticeably smooth and silent operation. Designing highly loaded helical gears for power transmission systems which are good in strength and low level in noise necessitate suitable analysis techniques.

In this project work have been done on helical gear to increases its load carrying capacity and to make lighter and compact gear for the various application. The gear is design with using the equation of AGMA standard's and the 3D model has been made in SolidWorks 2016 modeling software. The Ansys 18.0 FEM based analysis software was used as the analysis tool to carry out the static structural analysis in order to determine the behavior of different composites compare to gray cast iron. The comparison will be done on Factor of Safety, Maximum Equivalent Stress, Total Deformation and weight of the gear assembly.

II. LITERATURE REVIEW

A.S. Chavan, B.B. Deshmukh, P.V. Pawar, S.V. Wagh, S.S. Pardeshi ^[1] had carried out the analysis of helical gear using AGMA standards and FEM. Here the analysis is done to find out the bending stress and contact stress on material like Gray cast iron and 20MnCr5 (steel alloy). First, an analytical calculation was done on the gear of teeth 59 and pinion teeth 12 with the module of 2.75. 3D model was made in CATIA and analysis was done in ANSYS. The stresses found from ANSYS results are compared with those from theoretical and AGMA values.

Hlwan Htet San, Htay Win, Myint Thein ^[2], they have carried out a contact stress analysis of helical gear for a lightweight car. The work of this paper is to reduce the contact stress happing often on gear by changing the different

values of face width. Contact stress in gear is calculated with help of AGMA equation. The model of helical gear pairs was generated by using SolidWorks software and ANSYS was used for numerical analysis. The result obtained from ANSYS is compared with theoretical values.

The author **Mohit Singh, Waris Khan, and Sanjeev Kumar** ^[3] has tried to replace the metallic gear of steel alloy with composites materials. The bending stress was calculated using Lewis equation of AGMA standard. The parametric solid model was made using Pro-E software. The analysis was done on ANSYS by applying a different type of torque (350, 400, 420 N). The result was concluded on the basis of stress formation on gear, total deformation, natural frequency and weight of the gear.

K. Naresh and C. Chandrudhu ^[4] in their paper Design and analysis of helical gear, have described the comparison between different material like Chrome stainless steel, Gray cast iron, and aluminum silicon carbide. The gear was design using SolidWorks Premium and analysis was performed using SolidWorks Simulation. Different loading condition (1000, 1500, 2000 N) were taken to find a number of different values of Stress, Strain, and Deformation.

J. Venkatesh and Mr. P. B. G. S. N. Murthy ^[5], have done research on high-speed helical gear by varying the number of teeth (18, 20, 25). The gear was modeled in Pro-E Wildfire software. The material here used was Structural Steel. Contact stress and bending stress were calculated using AGMA standards and was compared with analytical analysis using ANSYS.

Govind T Sarkar, Yogesh L Yenarkar and Dipak V Bhoje ^[6] have done a stress analysis on helical gear. This paper investigates a finite element model for monitoring the stresses induced of a tooth flank, tooth fillet during meshing of gear. Bending stress and Contact stress was calculated using hertz equation of AGMA, by varying the face width and helix angle of the helical gear. The analytical stress calculation was done using ANSYS and was compared with the result of calculation by AGMA equation.

III. METHODOLOGY

The Methodology involves a process or a step which is to be followed for a given experiment or theoretical analysis. In this project, an analysis of helical gear has been done through Computer Aided Design software. The steps involved are as follow.

Step 1: Selection of different materials

Step 2: Selection of application of helical gear

Step 3: Assumption and calculation of different parameters

Step 4: Constructing a 3D model

Step 5: Static Structure analysis

Step 6: Collection of data

Step 7: Result and comparison

Step 8: Conclusion

IV. SELECTION OF MATERIALS

A. Gray cast iron

Gray cast iron is a kind of iron found in castings known for its gray shading and appearance caused by graphite breaks in the material. The properties of the gray iron will change contingent upon what materials are liquefied together to pour into the mold as well as the process that is used for casting.

Gray cast iron has acceptable ductility, tensile strength, yield strength, impact resistance and high thermal conductivity for most of its applications and it is additionally phenomenal in its capacity to hose vibrations making it perfect for hardware bases and also many lodging applications.

Gears, pumps, disc brake, manhole, valves, steering linkages are some of the application of gray cast iron.

B. Composites Materials

A composite material is a material produced using at least two constituent materials with essentially unique physical or synthetic properties that, when joined, deliver a material with qualities not quite the same as the individual material. The individual segments stay isolated and unmistakable inside the completed structure, separating composites from blends and strong arrangements.

The numerous part materials and diverse procedures that can be utilized make composites greatly flexible and proficient. They commonly result in lighter, more grounded, progressively solid arrangements contrasted with conventional materials.

Typical engineered composite materials include:

- Reinforced concrete and masonry
- Composite wood such as plywood
- Reinforced plastics, such as fiber-reinforced polymer or fiberglass
- Ceramic matrix composites (composite ceramic and metal matrices)
- Metal matrix composites
- and other Advanced composite materials

Composite materials are generally used for buildings, bridges, and structures such as boat hulls, swimming pool panels, racing car bodies, shower stalls, bathtubs and many more. The most exceptional models perform routinely on shuttle and aircraft in requesting situations.

On the bases of strength and density of the material, following composites are selected:

- Alumina-Silicon Carbide (AL Sic)
- Nylon 66

V. PROPERTIES OF MATERIALS

Table 1 Properties of Materials

	Property	Unit	Gray Cast Iron	Alumina-Silicon Carbide	Nylon 66
1	Density	Kg m ⁻³	7200	2280	1150
2	Young's Modulus	MPa	1.18x10 ⁵	1.24x10 ⁵	2590
3	Poisson's Ratio		0.294	0.240	0.402
4	Bulk Modulus	G Pa	95.4	79.5	4.4
5	Shear Modulus	G Pa	45.6	50	9.23
6	Tensile Yield Strength	MPa	124	220	72
7	Compressive Yield Strength	MPa	934	270	48
8	Tensile Ultimate Strength	MPa	310	365	120

VI. SELECTION OF APPLICATION OF HELICAL GEAR

There are lots of advantages of helical gear over spur gear, as spur gear have a low load carrying capacity and have a lower speed of working. Therefore, there are many applications of a helical gear. One of the examples is helical gear used in splitter machine to transfer the power from a motor to different shafts revolving at different speeds.

VII. ASSUMPTION AND CALCULATION

A. Design procedure for helical gear

The Gear and Pinion are designed according to the Lewis Equation of AGMA standard. The steps to calculate Modul, Face Width and many more parameters are given below.

- Torque transmitted by pinion $T = \frac{P \times 60}{2\pi N_p} \text{ N-mm}$
- Since both the pinion and gear are made up of the same material, therefore the pinion is weaker. Thus, the design will be based upon the pinion.
- Formative number of teeth $T_E = \frac{T_p}{\cos^3 \alpha}$
- Form Factor $y' = 0.154 - \frac{0.912}{T_E}$
- Peripheral velocity $v = \pi D_p N_p \text{ m/min}$
- Velocity Factor $C_v = \frac{6}{6+v}$
- Tangential tooth load $W_T = \frac{2T}{D_p} \text{ N}$, $W_T = \sigma_0 C_v b \pi y'$
- Face Width $b = 4\pi m$
- Pitch Circle Diameter of Pinion $D_p = m \times T_p \text{ mm}$
- Pitch Circle Diameter of Gear $D_G = m \times T_p \text{ mm}$
-

B. Geometric Properties

To design any component some assumption must be taken. Here the driven and driver shaft is in the ratio of 1:2 and the number of teeth are assumed has 76 for gear and 38 for the pinion. After solving with above equation and assumption we get a gear and pinion of following parameters.

Table 2 geometric properties

GEOMETRIC PROPERTIES	GEAR	PINION
Number of teeth	76	38
Pitch circle Diameter (MM)	266	133
Normal Module	3.5	3.5
Pressure angle (degree)	20	20
Helix angle (degree)	30	30
Face width (MM)	44	44

VIII. DESIGN OF HELICAL GEAR

A. Constructing a 3D Model

A 3D model is made in Computer Aided design software, few of them are SolidWorks, PTC Creo, Catia and many more. In this project SolidWorks 2016 has been used, has it been trouble free software used for making 2D 3D models Drawings animation and lot more.

The Gear and pinion are imported from the tool which is predefined in the software and is assembled together in assembly section.

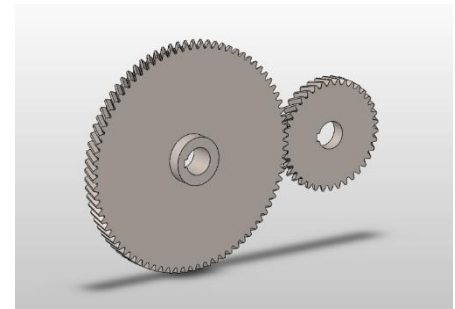


Figure 2 3D model of a gear assembly

B. Analysis

1) *What is Analysis:* An analysis is a process of breaking a complex structure into smaller parts in order to gain a better understanding of it. An analysis is a detailed examination of anything complex in order to understand its nature or to determine its essential features thorough a study. In the world of engineering to analysis something FEA (Finite Element Analysis) or FEM (Finite Element Method) methods are used.

2) *What is FEA:* Finite element analysis is a computerized method for predicting how a product reacts to real world forces, vibration, heat, fluid flow, and other physical effects. FEA shows weather a product will break, wear out or work in the way it was designed. Here FEA is done in truly outstanding and most broadly utilized programming ANSYS 18.0.

3) *Process of Analysis:* A process of analysis in ANSYS software. A file from SolidWorks is imported to Ansys in a format of Parasolid (*.x_t)

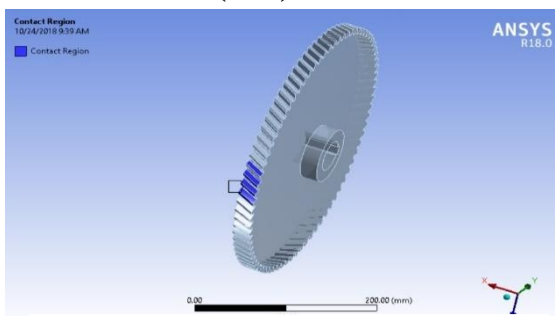


Figure 3 Contact region of gear

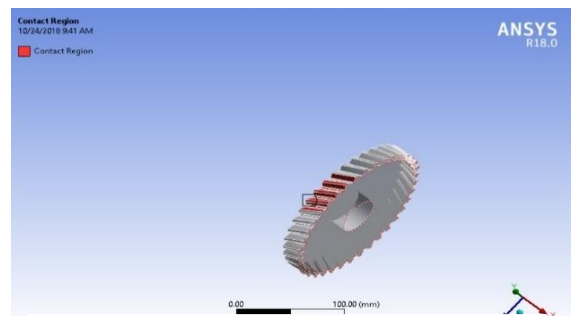


Figure 4 Contact region of pinion

4) *Meshing:* Meshing is defined as the process of dividing the whole component into number of elements so that whenever the load is applied on the component it distributes the load uniformly. Mesh are generated into number of small polygonal or polyhedral shapes. Meshing is done using high relevance therefore more accuracy towards the result. 412228 Nodes and 219566 Elements are generated in this assembly.

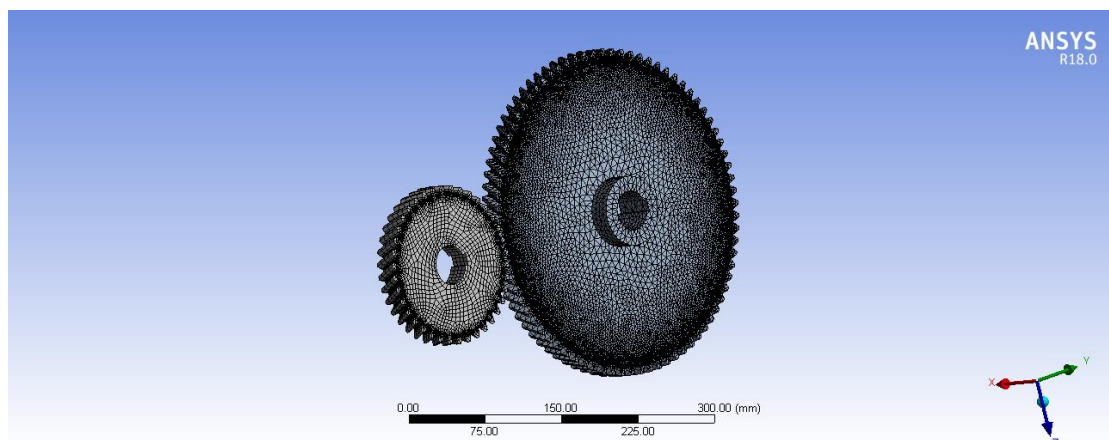


Figure 5 Meshing of gear assembly

5) *Boundary Condition:* Boundary condition are constraints necessary for the solution of a boundary value problem. A boundary value problem is a differential equation to be solved in domain on whose boundary set of conditions. The fixed support is given to the hub of the gear, and frictionless support is given to the hub of pinion. A moment of 3×10^5 N-mm is given to the pinion.

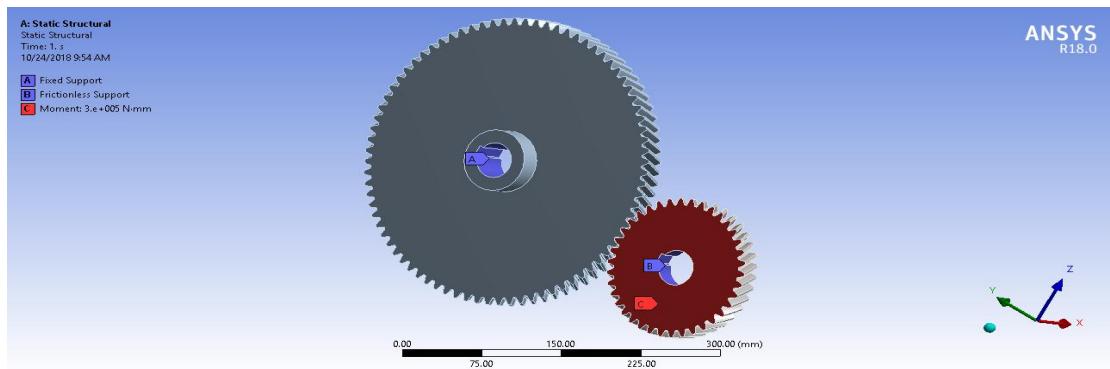


Figure 6 Boundary Condition

The required solution Maximum equivalent stress, Total deformation and Factor of Safety are entered into the solution, then after the high-performance software will solve and the result will be generated. The solution of different parameter of different material are given below.

6) Gray Cast Iron:

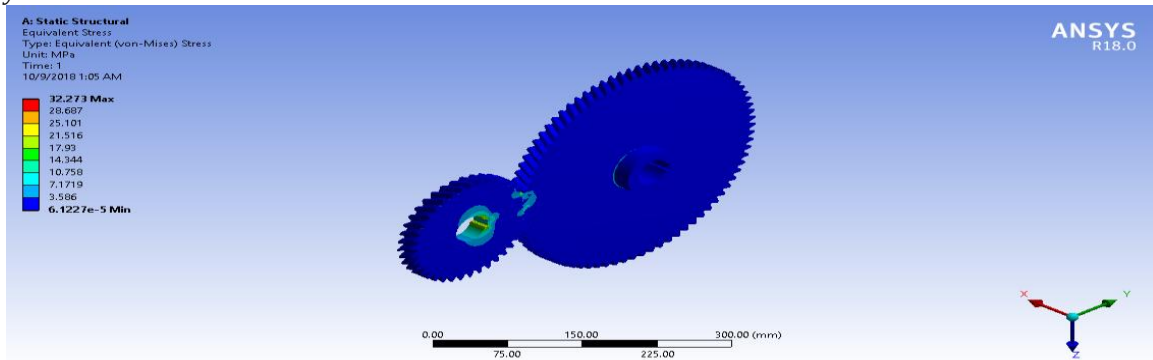


Figure 7 Equivalent Stress of Gray Cast Iron

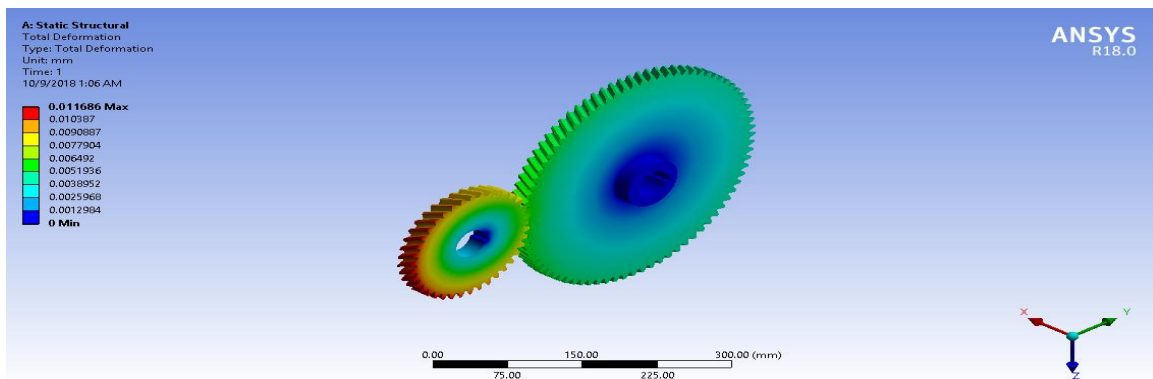


Figure 8 Total Deformation of Gray Cast Iron

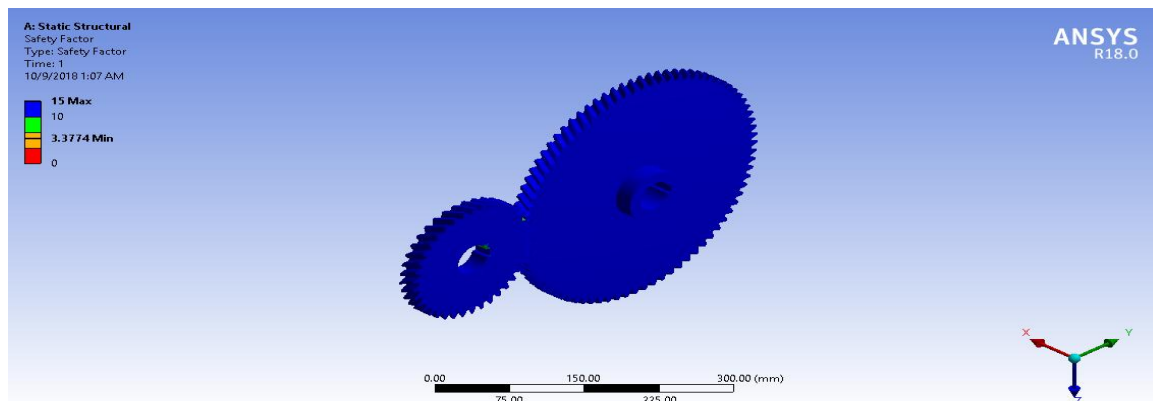


Figure 9 Safety Factor of Gray Cast Iron

7) Alumina Silicon Carbide:

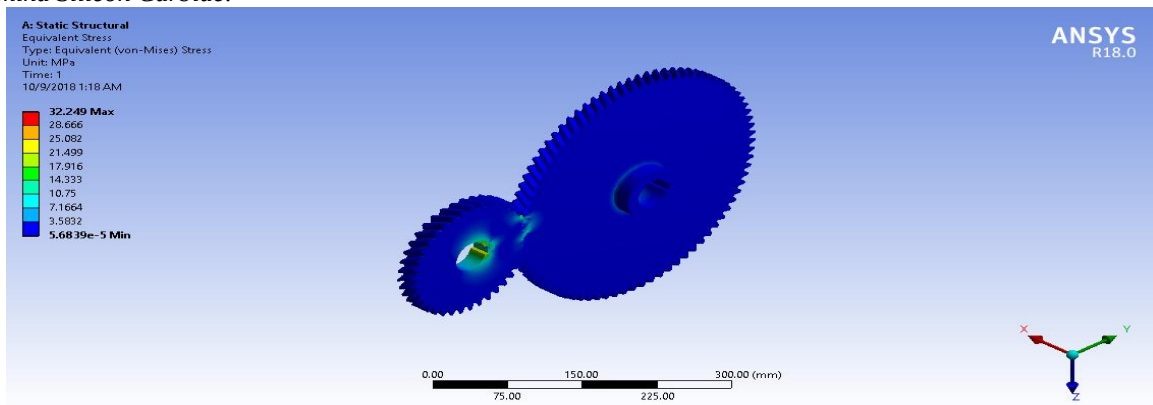


Figure 10 Equivalent Stress of Alumina Silicon Carbide

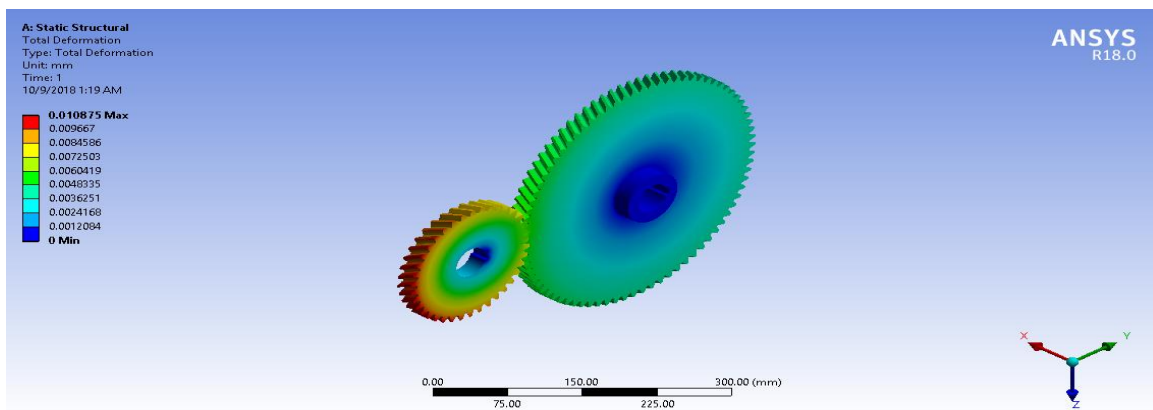


Figure 11 Total Deformation of Alumina Silicon Carbide

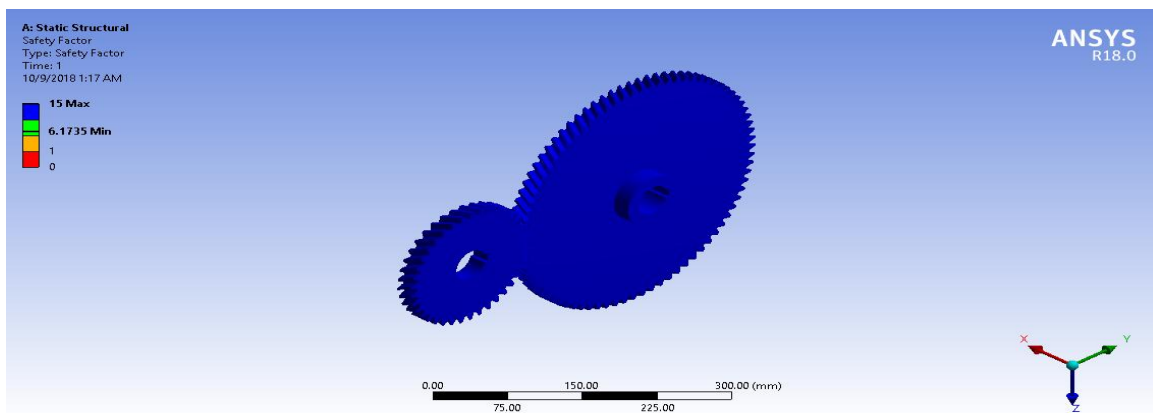


Figure 12 Safety Factor of Alumina Silicon Carbide

8)Nylon 66:

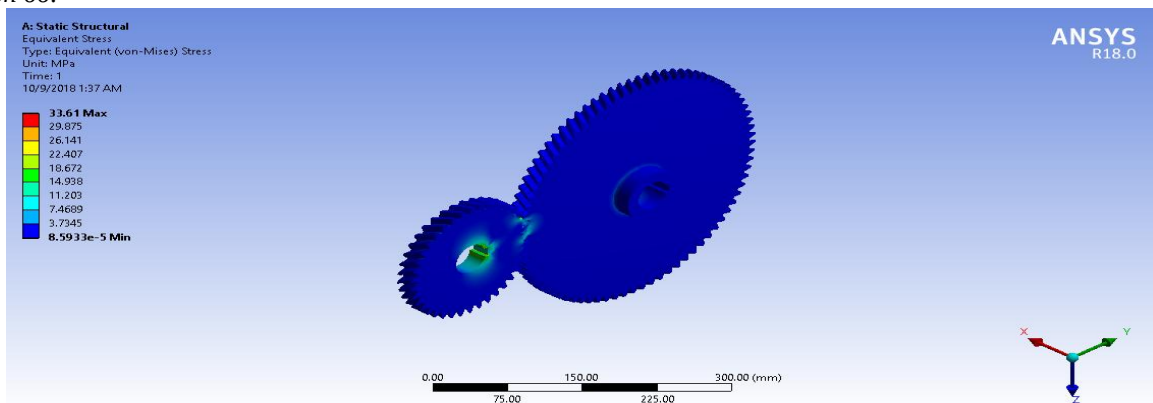


Figure 10 Equivalent Stress of Nylon 66

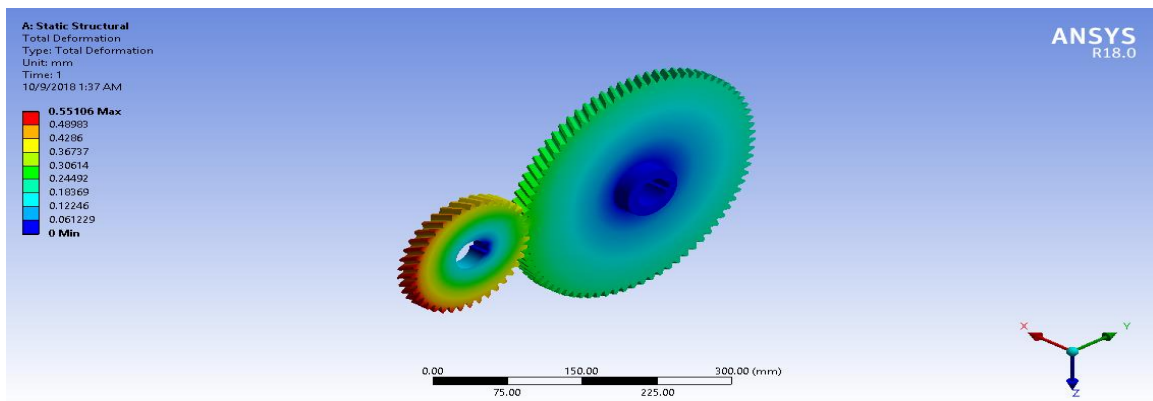


Figure 11 Total Deformation of Nylon 66

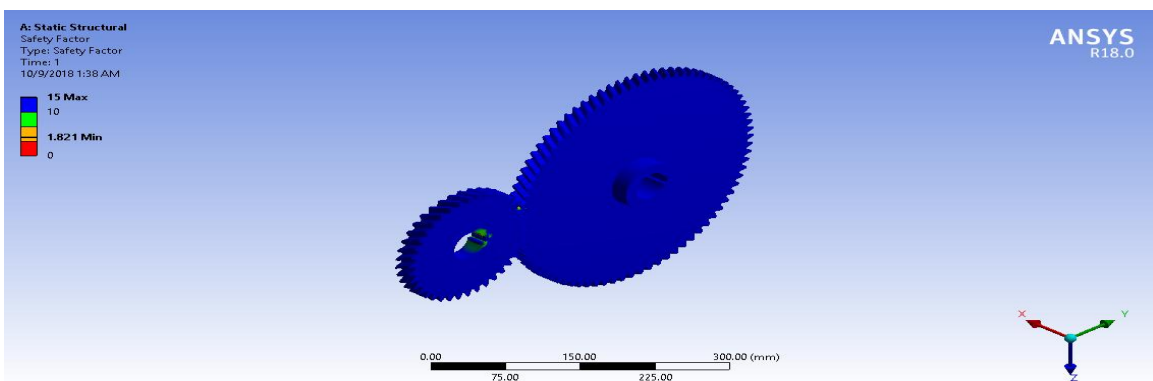


Figure 12 Safety Factor of Nylon 66

IX. RESULT

A. Comparison

By obtaining all value from the analysis a comparison table is made, which is as follow:

		Gray Cast Iron	Alumina Silicon Carbide	Nylon 66
Maximum Equivalent Stress	MPa	32.273 MPa	32.249 MPa	33.61 MPa
Total Deformation	mm	1.1686e-002 mm	1.0875e-002 mm	0.55106 mm
Safety Factor		3.3774	6.1735	1.821
Gear Weight	Kg	11.972 kg	3.7911 kg	1.9122 kg
Pinion Weight	Kg	2.4653 kg	0.78066 kg	0.39376 kg
Total Weight	Kg	14.437 kg	4.5717 kg	2.3059 kg

B. Result Analysis

The objective of this thesis is to reduce the stress, deformation acting on the helical gear by make it lighter and more compact by using composites materials. For these purposes, the model was made in SolidWorks 2016 and a software-based finite element analysis was carried using ANSYS 18.0, to find out Maximum equivalent stress, Total deformation, Safety factor and the weight of the helical gear assembly.

By analyzing the result which is obtained from the work done some conclusion is made, which are as follow:

- Maximum equivalent stress is similar and below the maximum allowable stress in all three materials. Therefore, all the three material are safe to use.
- The lightest gear assembly is of material nylon 66, were as lowest total deformation is observed in alumina silicon carbide
- More over the safety factor is highest in alumina silicon carbide and it is safest material to used among this three, were as for weight constrained nylon 66 will be more preferred material.

X. REFERENCES

- [1] Sarth Shah, Krupal Shah, "Design and Analysis of Helical Gear: A Review", International Journal of Research and Analytical Reviews (IJRAR), Volume.5, Issue 4, Page No 594-599, December 2018
- [2] A.S. Chavan, B.B. Deshmukh, P.V. Pawar, S.V. Wagh, S.S. Pardeshi, "Investigating the Effect of Material Change on Strength of Helical Gear", IOSR Journal of Mechanical and Civil Engineering. March 2017, Page 19-22

- [3] Hlwan Htet San, Htay Win, Myint Thein, “Design and Contact Stress Analysis of Helical Gear for Light-Weight Car”, International Journal of Mechanical and Production Engineering, Volume-5 Issue-8, August 2017, Page 7-12
- [4] Mohit Singh, Waris Khan, Sanjeev Kumar, “Structural Analysis of Composite Material Helical Gear Under Different Loading Condition”, International Journal of Engineering Sciences & Research Technology, 5. (6): June 2016, Page 593-607
- [5] K. Naresh and C. Chandrudhu, “Design and Analysis of Helical Gear”, International Journal of Professional Engineering Studies, Volume-6 Issue-4, August 2016, Page 194-203
- [6] J. Venkatesh, Mr. P. B. G. S. N. Murthy, “Design and Structural Analysis of High-Speed Helical Gear Using Ansys”, Int. Journal of Engineering Research and Applications, Volume-4 Issue-3, March 2014, Page 1-5
- [7] Abhishek Kulkarni, Shubham Lonkar, Prafull Pachare, Prof. S. J. Gulhane, “Review Paper on Design and Stress Analysis of Helical Gear and Manufacturing Through Rapid Prototyping Method”, International Research Journal of Engineering and Technology, Volume-5 Issue-4, April 2018, Page 479-482
- [8] Modi Prashant, “A Review Paper on Design and Analysis of Helical Gear Using ANSYS, FEM & AGMA Standards”, International Research Journal of Engineering and Technology, Volume-4 Issue-1, January 2017, Page 1129-1131
- [9] Sharad J. Chauhan, Parth K. Patel, Abhishek Dubey, Deepkumar K. Patel, “A Review Paper on Design and Development of Helical Gear by using ANSYS and AGMA Standards”, International Journal of Engineering Research and Technology, Volume-6 Issue-4, April 2017, Page 1056-1058
- [10] Govind T Sarkar, Yogesh L Yenarkar, Dipak V Bhoje, “Stress Analysis of Helical Gear By Finite Element Method”, International Journal of Mechanical Engineering And Robotics Research, Volume-2 Issue-4, October 2013, Page 322-329
- [11] R.S. Khurmi, J.K. Gupta “A Textbook of Machine Design”, S.Chand, 2013, Chapter 29