ISSN 2395-1621

Design & 3D modeling of double helical gear and its Stress analysis by using FEA software

Mr. Makarand K. Patil, Prof. Dr. V.T. Tale, Prof. Dr. S.N.Khan, Prof. Dr. A.M. Badadhe

mkpatil07@gmail.com
tvithoba@gmail.com
subimkhan3929@gmail.com

Mechanical Engineering Department,
JSPM'S Rajarshi Shahu College of Engineering, Tathawade, Pune, India.

ABSTRACT

This research article presents a investigating procedure for design of double helical gear, CAD modeling of double helical gear by using CATIA, and stress analysis of double helical gear by using FEA software (ANSYS). In this paper, we have done designing of double helical gear for required parameter, which is used for gear modeling and made the static structural analysis of gear by using various material and try to recommend optimum material for double helical gear for heavy torque transmission purpose. This works also focused on selecting a best suitable material for double helical gear.

Keywords: Design, CAD modeling, Static structural analysis, material optimization.

ARTICLE INFO

Article History

Received: 12th May 2021

Received in revised form : 12th May 2021

Accepted: 15th May 2021

Published online : 15th May 2021

I. INTRODUCTION

In this research paper we have done as study on double helical gear design and it cad modeling and its static structural analysis by using FEA software and also we have optimized the material used for manufacturing of double helical gear.A gear is a rotating machine part having cut teeth, or cogs, which mesh with another toothed part in order to transmit torque. Gears are used for a wide range of industrial applications. At least two gear working couple are known as a transmission and can create a mechanical advantage through gear ratio and accordingly might be considered as a basic machine. Gear device can change the speed, magnitude, and direction of a power source. The most common situation is for a gear to mess with another gear; however, a gear can also mess a non-rotating toothed part, called a rack, in this manner producing translation instead of rotation. The gear in a transmission is analogous to the wheels in a pulley. The benefit of gears is that the teeth of a gear forestall slipping. At the point when two gears of unequal number of teeth are combined a mechanical advantage is produced, with both the rotational speed and the torques of the two gears contrasting in a simple relationship.

There are too much importance of double helical gear for transmitting of high capacity torque in marine ship application, sugar factory, heavy duty cranes on sea port, and many more like it. So, for that purpose we have to understand the importance of it. In double helical gears, they have the benefit of exchanging power easily because more than two teeth will be in mess at any moment in time. Along these lines, herringbone gears were a significant advance in the acquaintance of the steam turbine with marine propulsion. Where the oppositely angled teeth meet in the middle of a Double helical gear, the arrangement might be such that tooth tip meets tooth tip, or the alignment might be amazed, so tooth tip meets tooth trough. The latter alignment is the unique defining characteristic of a Wiest type double helical gear, named after its inventor. Gearboxes are key Components of most heavy-duty machines and are extensively used in steel industry. Failure of gears not only results in replacement cost but also in process downtime. This could have exceptional outcomes on productivity and, all the more importantly, on conveyance which could result in perpetual loss of clients.

So, to select proper double helical gear for specific application we have to make its analysis by using FEA software The finite element method is capable to supply this information but the amount of time, a per-processor method that develops the geometry required for finite element analysis might be utilized, instruments, for example, CATIA or Pro/Engineer. These tools can generate 3Dmodels of gears. The model geometry generated using CATIA is saved as an IGES file and then import it to ANSYS for analysis.

Problem Statement

The failure occurred in the heavy-duty gearbox such as marine ships applications, heavy duty cranes equipment's, gas turbines, constructions machineries, heavy torque transmission, is by deformation of tooth of the gear and random fracture and the pitting failure. Pitting is a surface fatigue failure of the gear tooth. It occurs due to of repeated loading of tooth surface the contact stress exceeding the surface fatigue strength of the material, and wear of tooth is also happen due improper material selection for manufacturing of gear.

Objective of Study

1. Material to be changed from gray cast iron to carbon steel alloy in order to increase the load carrying capacity of the machinery.
2. Suggesting a suitable material to be used for designing of double helical gear.
3. Checking out the various stress generated in the contact tooth of gear and total deformation of tooth of double helical gear.
4. To give a proper solution for avoiding of the failure of gear due to the deformation of gear tooth in the heavy torque transmission purpose for industry.

Scope of study

Now a days in global industrial scenario there is a need to optimize the design as well as material for gear, due to that we can save our time for maintenance, as well as cost saving also can be done for replacement of new gear. We can give the coating of titanium or other suitable material coating to the double helical gear tooth due to that failure due to the wear and failure due to pitting can be reduce in large percentage, it will indirectly improves productivity of industry. So, ultimately we can recommend optimum material for with respect to the design of double helical gear.

Also the on of the scope for this study is, we can find out the stress, strain and deformation values before manufacturing of actual gear by selecting proper suitable material we can also optimize suitable material for actual manufacturing. Due to that economical loss can be avoided and time saving also can be done by this way.

II. LITERATURE REVIEW

1. D. Ramakrishna. V.S. Parameswara, S. Siva Naga, MalleswarRao

In this research paper author has done work of the static examination, modular investigation and weariness investigation was completed on 3 distinct materials. The examination results, i.e., ANSYS answer for CFRP material has been introduced. Amid the investigation, it very well may be discovered that the miss happening of the apparatus wheel for carbon strengthened plastic material is littler when contrasted with that of alternate materials. The pressure actuated is relatively the same as that of the other two. Despite the fact that the dynamic disfigurement is minimal more, the life of the rigging is any longer at a similar load.

2. S. Vijayrangan, N. Ganeshan.

In this paper author has done his work on conventional (steel-like) material helical gears can be replaced by helical gears made of composite materials. This results in light-weight helical gears, which add to the existing list of advantages of helical gears, such as smooth and silent operation and larger load carrying capacity, while at the same time maintaining higher strengths, which is an important requirement in applications like spacecraft and aircraft. In the present work, the performance of Kevlar/epoxy and graphite/epoxy material helical gears has been compared with that of carbon steel helical gears using a three-dimensional finite element method. From the present it may be concluded that composite material helical gears behave similarly to carbon steel helical gears and graphite/epoxy helical gear behavior is very close to that of carbon steel helical gears,except for the slightly larger displacements at the tip. The safety factor obtained based on the root stress values for the two orthotropic material helical gears is very favorable.

3. A.Y Gidado, I. Muhammad, A. A. Umar.

In this research paper the author has workout on gear stresses, there are two kinds of stresses in gear teeth, root bending stresses and tooth contact stresses. These two stresses results in the failure of gear teeth, root bending stress results in fatigue fracture and contact stresses results in pitting failure at the contact surface. So, both these stresses are to be considered when designing gears. Usually heavily loaded gears are made of ferrous materials that have infinite life for bending loads. But it is impossible to design gears with infinite life against surface failure. In this paper one of the principal failure modes are studied based on the calculation of bending stress. Helical gears are widely used in industry where the power transmission is required at heavy loads with smoother and noiseless operation. To estimate the bending stress, three-dimensional solid models for different face width are generated by Pro/Engineer that is a powerful and modern solid modeling software and the numerical solution is done by ANSYS, which is a finite element analysis package. The analytical investigation is based on Lewis's stress formula. In this paper a helical gear was modeled on Pro engineer wildfire 4.0 and stress analysis part is done on ANSYS 11.0. The results are then compared with both AGMA and FEM procedures.

4. Govind T Sarkar, Yogesh L Yenarkar, and Dipak V Bhope

One of the best methods of transmitting power between the shafts is gears. Gears are mostly used to transmit torque and angular velocity. The rapid development of industries such as vehicle, shipbuilding and aircraft require advanced application of gear technology. Customers prefer cars with highly efficient engine. This needed up a demand for quite power transmission. Automobile sectors are one of the largest manufacturers of gears. Higher reliability and lighter weight gears necessary to make automobile light in weight as lighter automobiles continue to be in demand. The success in engine noise reduction promotes the production of quieter gear pairs for further noise reduction. The best way of gear noise reduction is attained by decreasing the vibration related with them. In this paper real in-volute gear pair with transmission ratio is analyzed.

III. REQUIRED DESIGN CALCULATION OF DOUBLE HELICAL GEAR FOR 3D MODELING.

[All standard values are taken from V.B. Bhandari Std. Book]

Considering the module = 4mm.
Pitch Circle Diameter = 342 mm.
1. Module (m)
m=4 **(**reference from V.B. Bhandari text book.)
2. Number of teeth on gear
for 20-degree full depth involute system the number of teeth on pinion is =20 from that assuming gear ratio is 4
(reference from V.B. Bhandari text book)

$$i=\frac{Zg}{Zp}$$

$Zg=i\times Zp= 4\times 20=80$
Number of teeth t= 80.
3. pitch circle diameter of gear

$$Dg=\frac{Zg\times Mn}{\cos\varphi}$$

Dg=342mm.
4.Addendum=1×Mn=4mm
5.Dedendum=1.25×Mn=5mm
6. Torque (τ)

Let Power = 20KW
N = 900 rpm

$$P=\frac{2\pi NT}{60}\ ,\ T=\frac{P*60}{2\pi N}$$

T= 212.2065 NM.

7.. Forces applied of Gear tooth

1) Tangential component force (Pt)

$$P_t=\frac{2(Mt)}{dp}$$

Pt = 4985.23 N.

2) Thrust component force (Pa)

$Pa= Pt\times\tan\alpha$
Pa=1814.47 N.

3) Radial component force (Pr)

$$P_r=[\frac{\tan\alpha n}{\cos\psi}]$$

Pr = 1930.92 N.

IV. Figure AND TABLE

TABLE.1. PARAMETERS OF DOUBLE HELICAL GEAR

Sr.no	Variable Name	Description	Values	units
1	Zg	Number of teeth on gear	80	–
2	Dg	Gear pitch circle diameter	342	mm
3	m	Module	4	mm
4	α	Helix angle	20	degree
5	b	Face Width	52	mm
6	D	Diameter of Shaft	50	mm
7	ψ	Pressure Angle	20	degree
8	P	Power	20	KW
9	N	Speed	900	RPM
10	A	Addendum	4	mm
11	B	Dedendum	5	mm

V. CAD MODELING OF DOUBLE HELICAL GEAR

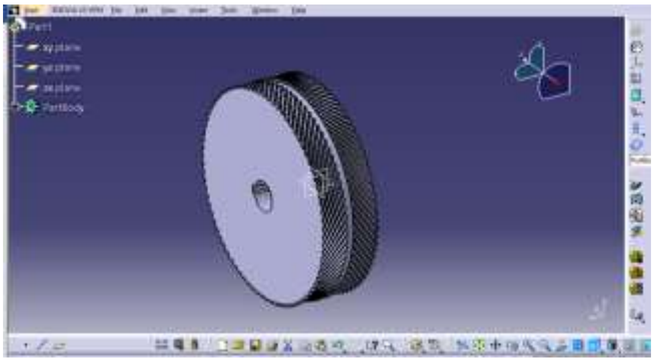

Fig.1.CAD modeling of Double Helical Gear

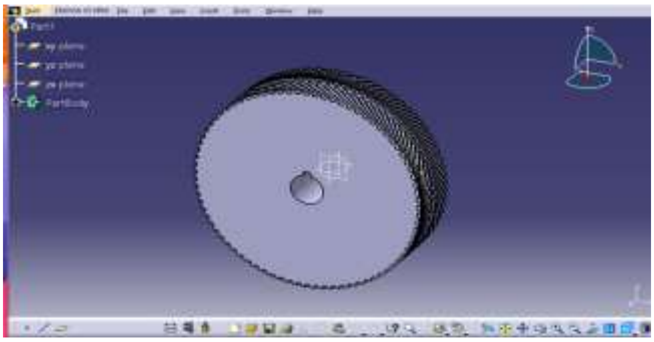

Fig.2.CAD Modeling of Double Helical Gear

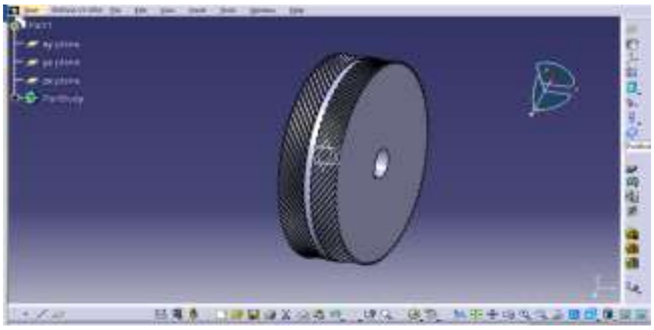

Fig.3.CAD Modeling of Double Helical Gear

VI.FEA ANALYSIS OF DOUBLE HELICAL GEAR

FEA Analysis of Double Helical Gear is the widest method is used for analysis of double helical gear as well as all the types of gear analysis in industry.
Finite element analysis (FEA) is use for stress, deformation analysis. The Complete procedure of analysis has been done using ANSYS workbench 21. To conduct finite element Analysis, the general process of FEA is divided into three main phases. Preprocessor, Solutions & Post-processor.

Finite Element Analysis is one of several numerical methods that can be used to solve complex problems and is the dominant method used today. As the name implies, it takes a complex problem and breaks it down into a finite number of simple problems. A continuous structure theoretically has an infinite number of simple problems, but finite element analysis approximates the behaviour of a continuous structure by analyzing a finite number of simple problems. Each element in a finite element analysis is one of these simple problems. Each element in a finite element model will have a fixed number of nodes that define the element boundaries to which loads and boundary conditions can be applied. The finer the mesh, the closer we can approximate the geometry of the structure, the load application, as well as the stress,strains and deformations gradients.

ANSYS WORKBENCH PLATFORM

Fig.4. User Interface of ANSYS Workbench

CASE -1 ANALYSIS OF DOUBLE HELICAL GEAR FOR GRAY CAST IRON

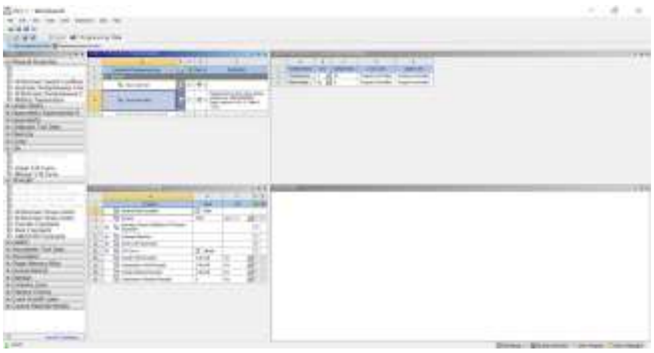

Fig.5. Material selection of Gray Cast Iron

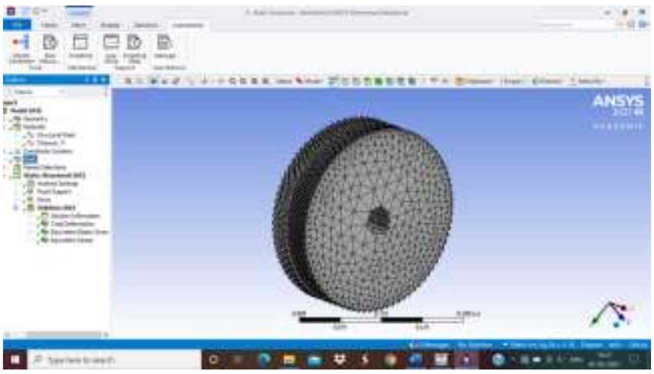

Fig.6. Meshing of Double helical gear in ANSYS

	A	B	C
1	Property	Value	Unit
2	Density	7200	kg m^-3
3	Isotropic Secant Coefficient of Thermal Expansion		
4	Coefficient of Thermal Expansion	1.1E-05	C^-1
5	Reference Temperature	22	C
6	Isotropic Elasticity		
16	Tensile Yield Strength	0	Pa
17	Compressive Yield Strength	0	Pa
18	Tensile Ultimate Strength	2.4E+08	Pa
19	Compressive Ultimate Strength	8.2E+08	Pa

Fig.7. Material Properties of Gray Cast Iron.

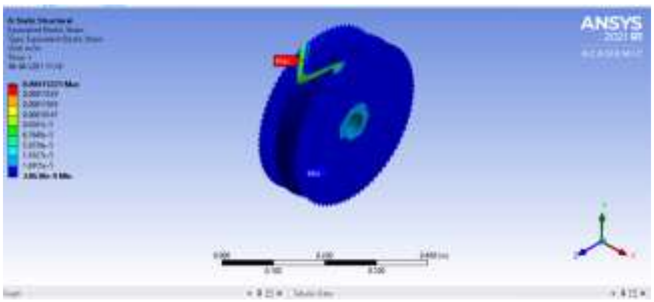

Fig.8. Equivalent Strain Analysis of Gray C.I.

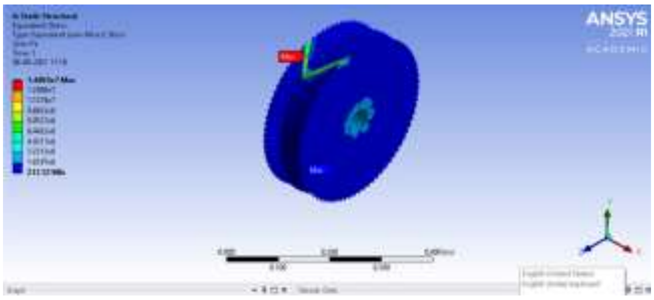

Fig.9. Equivalent Von-mises Stress analysis of Gray C.I.

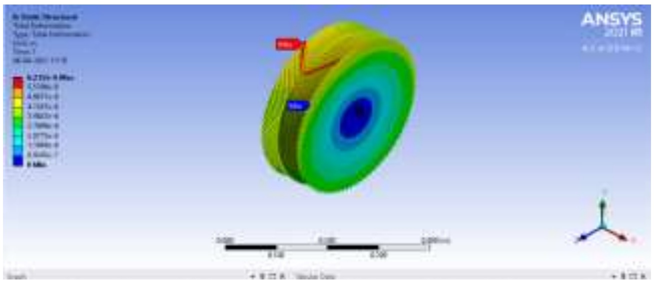

Fig.10.Total deformation of Gray C.I.

CASE 2 - ANALYSIS OF DOUBLE HELICAL GEAR FOR ALUMINIUM

Material Properties of Aluminum

Density	2705kg/m3
Young's modulus	6.895e+10pa
Poisson ratio	0.33
Bulk Modulus	6.7598e+10pa
Shear Modulus	2.5921e+10pa
Ultimate Tensile Strength	8.274e+07pa

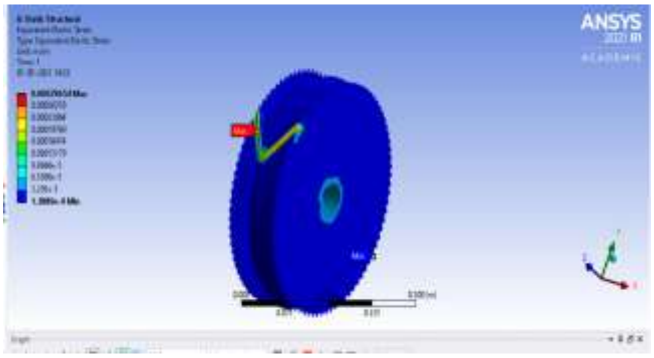

Fig.11.Equivalent Strain Analysis for Aluminum

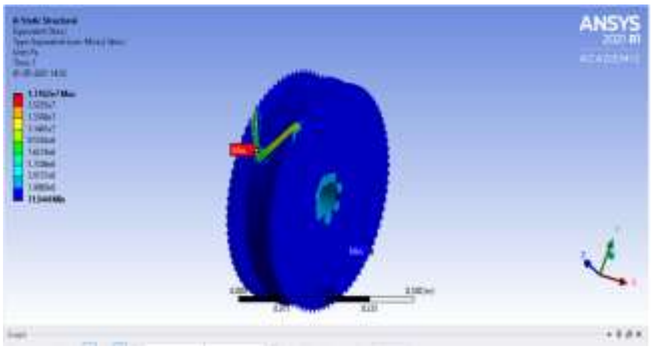

Fig.12.Equivalent (Von-Mises) Stress Analysis for Aluminum

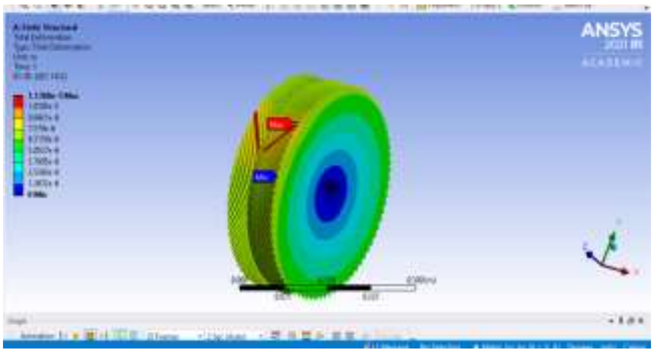

Fig.13.Total Deformation for Aluminum

CASE 3 - ANALYSIS OF DOUBLE HELICAL GEAR FOR CARBON STEEL ALLOY

Material Properties of Carbon Steel

Density	7850 kg/m3
Youngs Modulus	2.124e+11 pa
Poisson's Ratio	0.29
Bulk Modulus	1.6857e+11 pa
Shear Modulus	8.2326e+10 pa
Ultimate Tensile Strength	3.93e+08 pa
Yield Strength	2.935e+08 pa

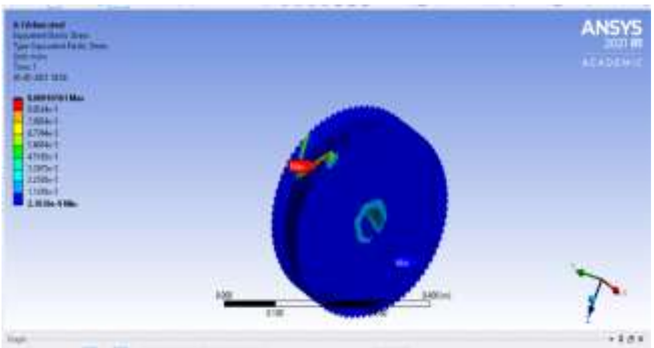

Fig.14.Equivalent Elastic Strain Analysis for Carbon Steel Alloy

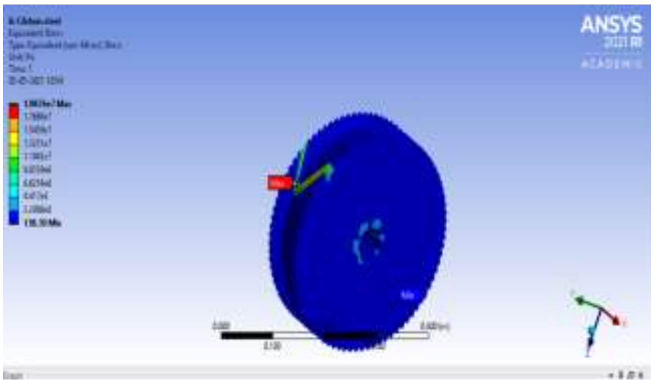

Fig.15. Equivalent (Von-Mises) Stress Analysis for Carbon Steel alloy.

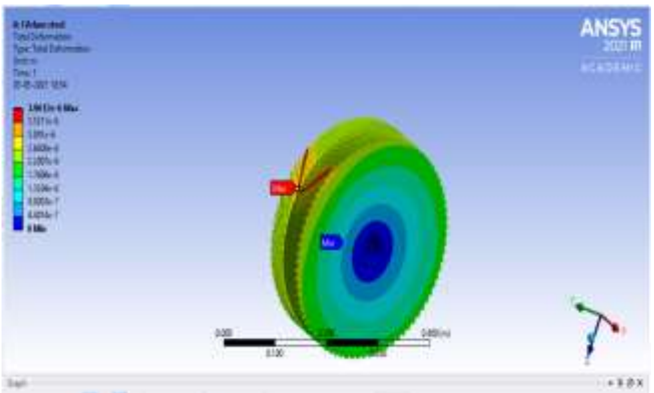

Fig.16.Total Deformation for Carbon Steel Alloy.

VII.RESULTS

The static analysis was carried out on 3 different materials. The analysis results, of Gray cast iron, Aluminum alloy and Carbon steel alloy has been carried out and we obtained the results are as follows. In this analysis we have obtained equivalent strain, equivalent von-mises stress, and total deformation for gray cast iron, aluminum alloy and carbon steel alloy. Form all three we have observed the equivalent strain, equivalent stress and total deformation of aluminum of higher than gray cast iron and carbon steel alloy. Following is the comparison table and chart for all three materials.

Table.2. Result Table

Sr. No.	Parameter	Grey Cast Iron	Aluminum Alloy	Carbon steel Alloy
1	Equivalent Strain (mm/mm) ×10^5	15.221	26.74	10.161
2	Equivalent Stress (MPa)	14.495	17.116	19.8
3	Total Deformation(m)10^-6	6.232	11.368	3.96

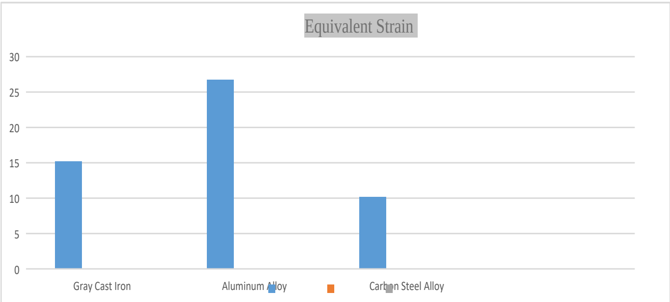

Fig.17. Comparison Chart for Equivalent Strain Analysis

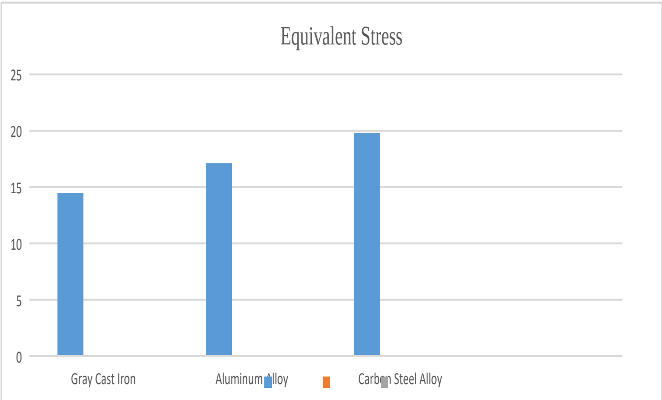

Fig.18. Comparison Chart for Equivalent (von-mises) stress Analysis

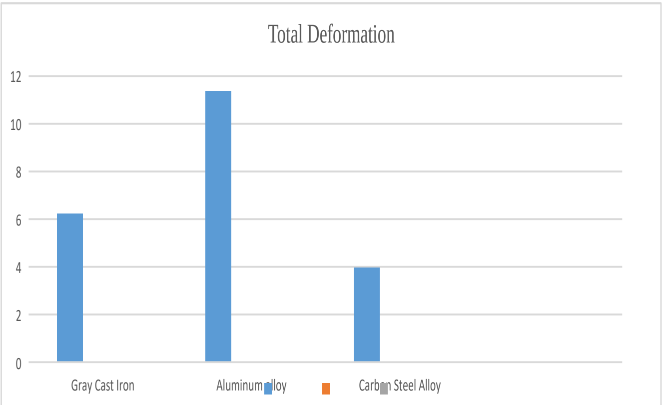

Fig.19. Comparison Chart for Total deformation Analysis

VIII. CONCLUSION

During the analysis, it can be learned that the deformation of the gear wheel for carbon steel material is smaller I.e.,3.96 when compared to that of the Grey Cast iron and Aluminum alloy 6.232 and 11.368 respectively. As well as the equivalent von-mises stress is generated also comparatively less for carbon steel I.e., 14.495 Mpa as compared to Aluminum alloy is little more I.e.,17.116 and Grey cast iron is 19.8 respectively. And equivalent strain is also lower as compared to other two materials. So, considering all the above factors the carbon steel alloy ia a best suitable material for manufacturing of double helical gear.

The cost of the carbon Steel material is compared to lower-than Gray cast iron and aluminum alloy. The strength which we obtained from carbon steel alloy is much better than the other two material and the availability of material and its manufacturing process is quite easier than other two material. Also, the mechanical, physical, and thermal properties is very good of carbon steel alloy compared to other material.it ultimate tensile strength, compressive strength is very high compared to other material. Due to that we had select it for manufacturing of double helical gear.

The added advantage of this analysis is we can design a required size of gear which will utilize for heavy torque transmission purpose, with selecting a different material like carbon steel alloy. Magnesium alloy, brass alloys, nickel alloy etc. Or if we look specific material like as 20Mncr5, 16Mncr5, SAE8620 etc. So, finally we would like to conclude this study on the following edge of point. From the design,3D modeling and analysis, it is found that the Double helical gears can be made with carbon steel alloy material for better performance and results.

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