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DESIGN AND ANALYSIS OF A COMPOSITE BEVEL GEAR IN AN AUTOMOBILE DIFFERENTIAL GEAR BOX

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ABSTRACT

In automotive Industry,the differential gear plays an important role in power transmission as well as in the handling of the automobile.It transmits torque through three different shafts. This project deals with the design and optimization of the differential gear box through use of composite material. The solid modelling is done by using SOLIDWORKS. Static analysis is performed on the gear using Ni-CR steel, malleable cast iron, aluminium alloy and glass filled polyamide using ANSYS 14.5 The results are tabulated for Von- Misesstress, strain and deformation and compared against the composite material. The composite differential gear box is compared against the other currently used materials and the reults are concluded accordingly.

KEYWORDS: Differential, Von Mises stress, Bevel gear, Composite, Solidworks.

INTRODUCTION

The differential gear is a one of the important component in the transmission system. Hence being at the axle the effective weight of the differential directly affects the performance and efficiency of the vehicle. The efficiency of a drive train solely depends on the efficiency of the gear used in the system. This makes scope for alternate materials to be used for gear manufacture. The main considerations while selecting a gear is its ability to withstand the high stresses and temperatures during continuous operation. It should have high wear resistance and thermal stability while being ant fade in its characteristic. In the current scenario the thirst for efficient materials has increased drastically. This brought forward the use of composites in gear manufacture. Over the past few years the use of composite has increased which bring in the scope of using composites in gear manufacture. The main aim in any efficient system is to reduce the overall weight without compromising on the mechanical properties. Here composites fits in well as they inherit the properties such as lower density with high specific stiffness and strength, corrosion resistant, high impact energy absorption and so on. These factors make composites to be considered as a suitable alternate for gear manufacture. Here the gear is subjected to a peak torque of 130 N.m and the results are obtained.

LITERATURE REVIEW

B. Venkatesh , had gotten Von-Mises stress by hypothetical and ANSYS programming for Aluminium compound, values acquired from ANSYS are less than the hypothetical estimations. The normal frequencies and mode shapes are essential parameters in the design of a structure for element stacking conditions, which are lower compared to alternate materials like steel. Aluminium compound diminishes the weight up to 55% contrasted with alternate materials. Aluminium is having remarkable property (i.e.. corrosion resistance), great surface finish, thus it promotes quite operation. Weight reduction is an essential paradigm, keeping in mind the end goal to minimize the unbalanced forces in the marine framework, there by enhances the framework execution.

C. Veeranjaneyulu, had demonstrated that the basic investigation results utilizing Aluminium combination shows stress values within allowable limits. So utilizing Aluminium Alloy is good for differential apparatus. At the point when looking at the stress values of the three materials for all velocities 2400rpm, 5000rpm and 6400 rpm, the values are lower for Aluminium alloy than Alloy Steel and Cast Iron. By observing the frequency, the Aluminum Alloy has lower vibration than other two materials since its natural frequency is less. Furthermore weight of the Aluminum alloy decreases just about 3 times when contrasted with Alloy Steel and Cast Iron since its density is less.hence from the results, Aluminum Alloy is best material for Differential.

S H Gawande , In this paper design of MFWD (FWA) Axle (of TAFE MF 455) differential gear box crown wheel and pinion is done. Through modeling, assembly and analysis of tooth of crown gear and pinion is done in Pro-E. Finite element analysis is done to analyse the crown gear tooth for working loads. The induced equivalent stress is lower than the allowable stress. From this it is concluded that the design is safe.

Anoop Lega, the main objective of the paper is to develop the composite material gear box using computer aided Engineering. Parametric methodology has been used here; 3D family is generated by set of variables which controls other gear dimensions related gear design laws. Product Design Specification sheet was developed for the gearbox and simultaneously material selection was carried out through detailed study and past performance of composite materials. Gearbox assembly is imported in Ansys software package and evaluated for equivalent (von-Misses) stress and equivalent (von-Mises) elastic strain for both composite material and existing metallic material. Results revealed the creditibility of composite material gearbox with approximately 60% weight reduction and lower stresses than metallic gearbox with other composite material advantages.

A Bensely ,In this paper the crown wheel and pinion failure has been studied. using standard metallurgical techniques a fractured gear was subjected to detailed analysis to pinpoint the cause for failure. The study concludes that the failure is due to the manufacturer compromise made in raw material composition, which is understood by the presence of high manganese percentage and absence of nickel and molybdenum. This resulted in high core hardness (458 HV) leading to premature failure of the pinion.

Robert F Handschuh, in this paper the thermal behaviour of the spiral bevel gear has been studied. The experiment was conducted on aerospace spiral bevel gears at rotational speeds of 14400 rpm and 537 kW (720 hp). The experimental results showed that load, jet location, flow rate, and oil inlet temperature all can affect the steady state operating temperature of the spiral bevel gear. An analytical model was also developed to study and analyse the thermal behaviour using finite element method.

MATERIALS AND METHODS

Material Selection

Engineering data represents the material properties. Composite materials made from two or more different materials with different physical or chemical properties. These constituent materials combined to produce a material with characteristics different from the parent individual components. The composite material selection for gearbox is done using if –then approach, using product design specification sheet. Glass filled polyamide in particulate form is used for differential gear box(bevel and spur gears)having better tensile strength (38.1 Mpa), recyclability, low density (840 Kg/m 3), high creep resistance, fatigue strength, low Von-MisesStress, high impact strength,, less friction and low cost. Table gives the properties of glass filled polyamide and E-glass/Epoxy.
The material properties to be considered are

Table 1 . Product Design Specification of Composite material Gearbox

Density	< 2700 Kg/m 3
Creep resistance	good
Fatigue strength	good
Corrosion resistance	good
Impact strength	good
Manufacturing method associated with material must be high volume production The component made from this material must be dimensionally stable and provides internal damping. The material should have low friction coefficient	

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Table 2 . The various materials considered for analysis

Properties	Ni-Cr steel	Malleable Cast Iron	Aluminium alloy	Glass Filled Polyamide
Model type	Linear elastic isotropic	Linear elastic isotropic	Linear elastic isotropic	Linear elastic isotropic
Failure criteria	Max Von Misesstress	Max Von Misesstress	Max Von Misesstress	Max Von Mises stress
Yield strength	1.72339×10^8 N/m^2	2.75742×10^8 N/m^2	1.65×10^8 N/m^2	5.91×10^8 N/m^2
Tensile strength	4.13613×10^8 N/m^2	4.1631×10^8 N/m^2	3×10^7 N/m^2	3.81×10^7 N/m^2
Elastic Modulus	2×10^{11} N/m^2	1.9×10^{11} N/m^2	7×10^{11} N/m^2	5×10^{11} N/m^2
Poisson's ratio	0.28	0.27	0.33	0.314
Mass density	7800 Kg/$\boldsymbol{m^3}$	7300 Kg/$\boldsymbol{m^3}$	2600Kg/$\boldsymbol{m^3}$	1840 Kg/$\boldsymbol{m^3}$

The selected composite material is glass filled polyamide. The material is supplied by Dura Form. It has glass filling 20% by volume with 0.30% of moisture absorption. It has good creep and corrosion resistance and chemically resistant against alkalis, hydrocarbons, fuels and solvents.

Modelling of the differential gear box

The design of the automobile taken here is of FSO Caro pickup and the design parameters are taken and the assembly is made.

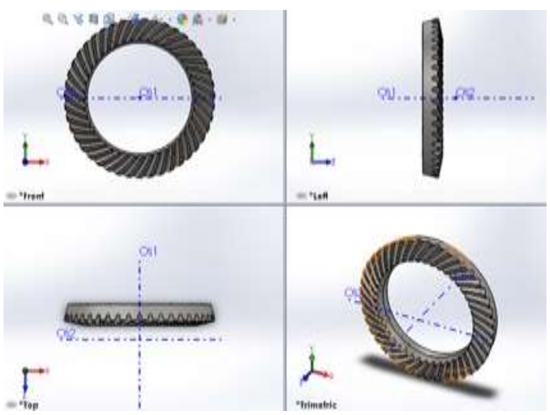

Figure 1. Crown gear

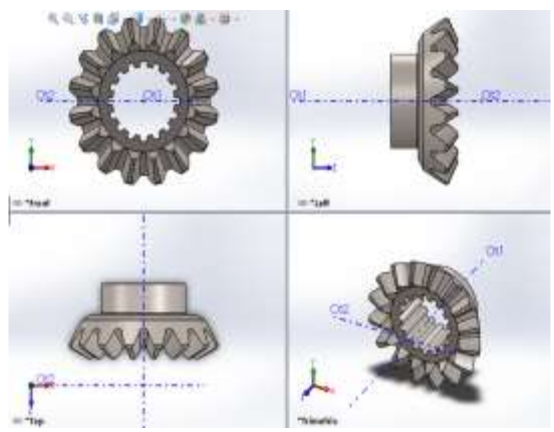

Figure 2. Axle side shaft gear

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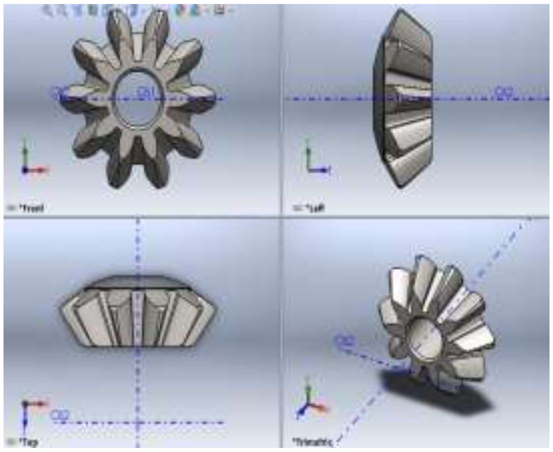

Figure 3. Planet gear

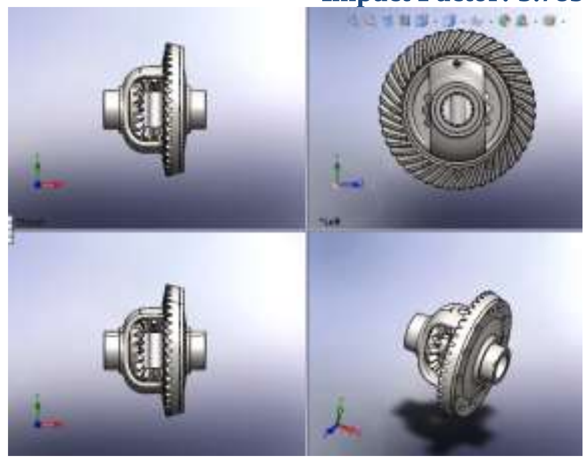

Figure 4. Assembly of the differential gear box

Table 3. Specifications of the differential gear box

Gear	Name	No. of teeth	Peak torque	Material
gear 1	Crown gear	43	130Nm @5000 RPM	Ni- Cr steel
gear 2	Axle side shaft gear	16		
gear 3	planet gear	10		

Adding boundry condition : fixed support

The left pinion is fixed and the whole apparatus rotates about the pinion. Assuming the left wheel to be stationary and torque being given on to the crown gear, the torque is transmitted to the other right wheel.

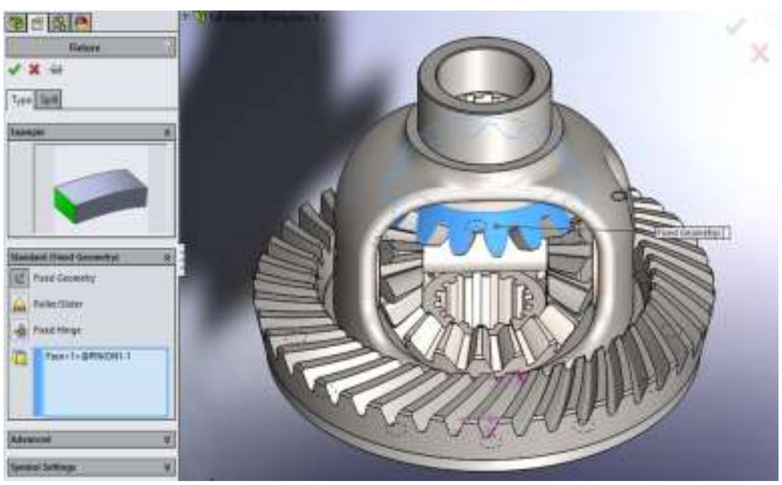

Figure 5. The pinion of the left axle is fixed

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Now toque is to be added on to the crown gear where it receives the power and is transmitted to the other gears. Since the left pinion is fixed the whole gear along with the planets would rotate around the pinion.

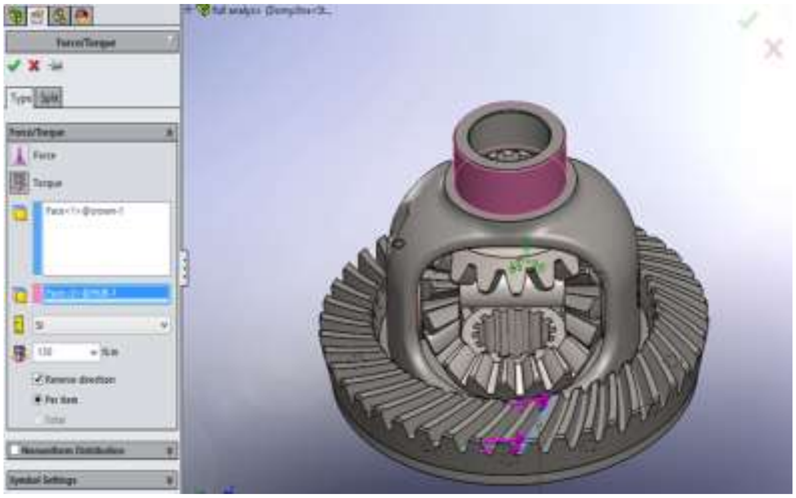

Figure 6. Torque application on the crown gear (130 Nm)

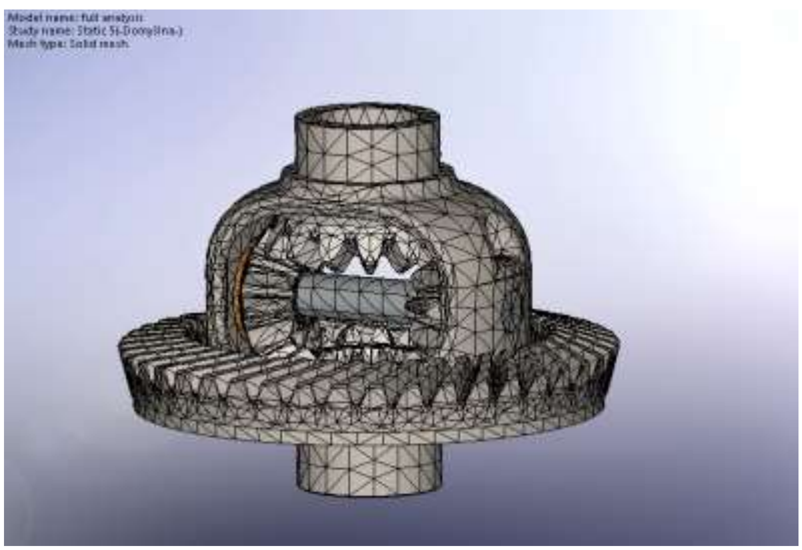

Figure 7. Meshed differential gear assembly

RESULTS AND DISCUSSION

Now the forces and boundary conditions being applied the following results are calculated using finite element analysis.Von Mises stress- this is used to evaluate a design whether it can withstand the given loading condition. It is based on distortion energy failure theory, the Deformation / displacement and Strain are also calculated.

The torque applied at the crown gear is to be transmitted to the planet gear via the hub and stress is induced within the teeth meshand the results are obtained as shown in the following pictures.

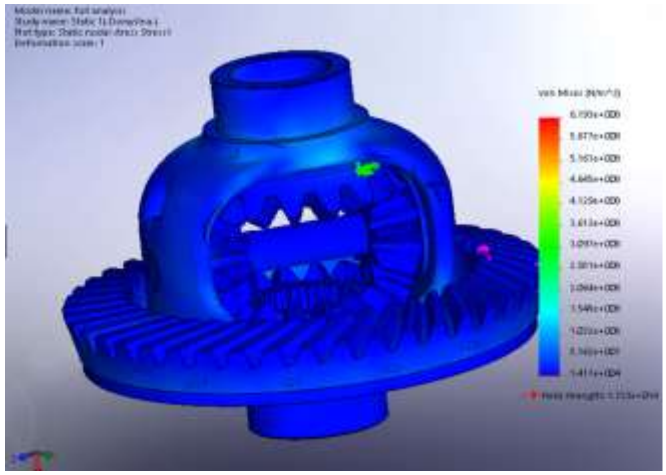

Figure 8. Maximum Von Mises Stress for Ni-Cr steel = 6.193×10^8 N/m^2

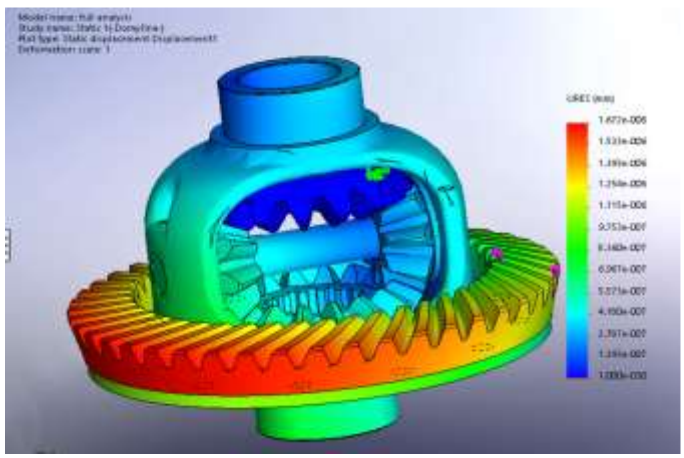

Figure 9. Max Displacement for Ni-Cr steel = 1.67×10^{-6}mm

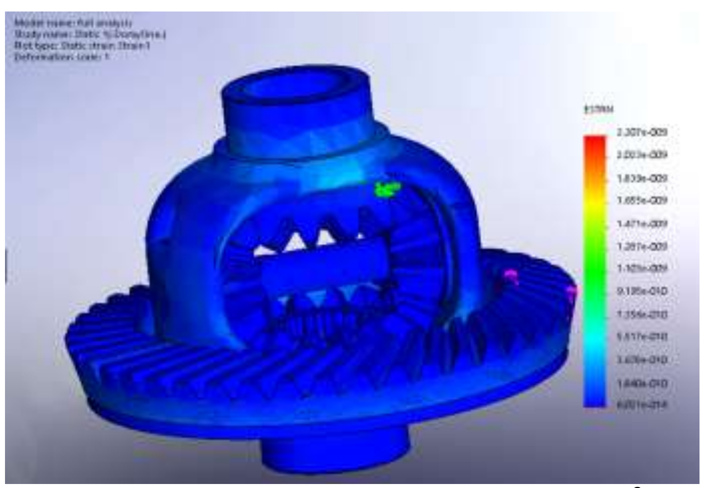

Figure 10. Maximum Strain for Ni-Cr steel = 2.207×10^{-9}

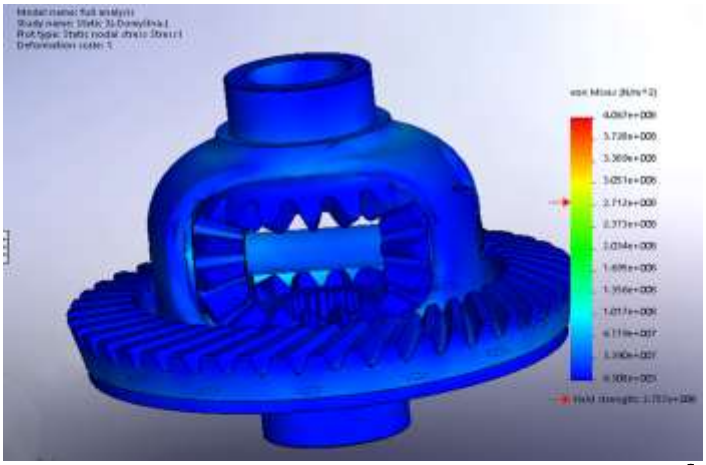

Figure 11. Maximum Von Mises Stress for malleable cast iron = 4.067×10^8 N/m^2

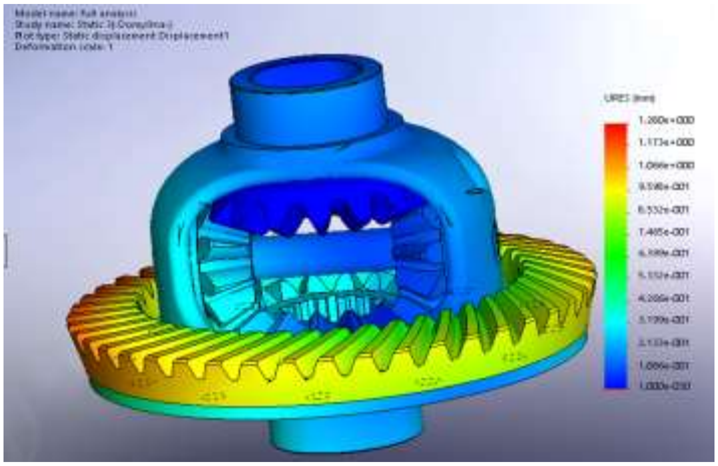

Figure 12. Max Displacement for malleable cast iron = 1.280 mm

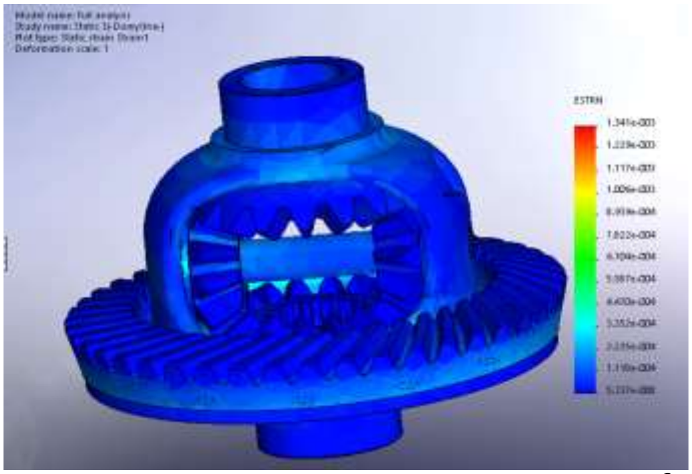

Figure 13. Maximum Strain for malleable cast iron = 1.341×10^{-3}

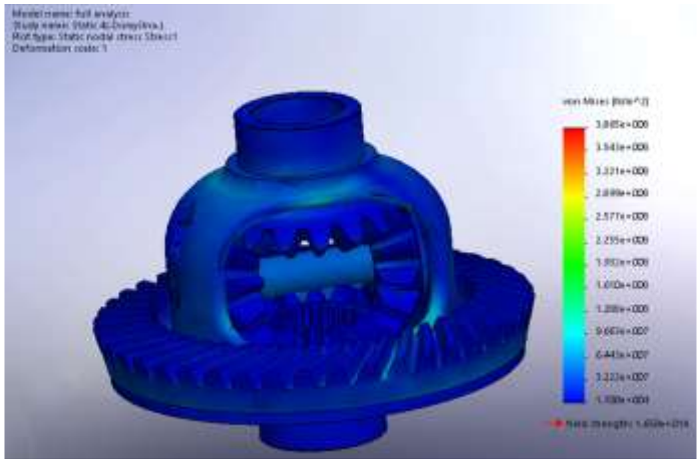

Figure 14. Maximum Von Mises Stress for Aluminium Alloy = 3.865×10^8 N/m^2

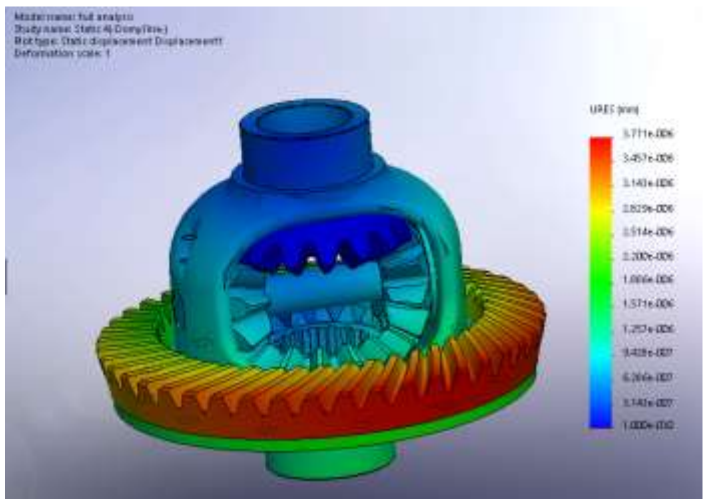

Figure 15. Max Displacement for Aluminium Alloy = 3.771×10^{-6} mm

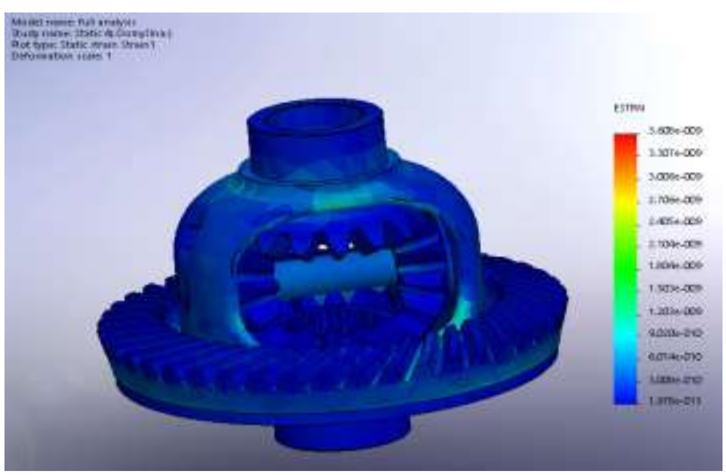

Figure 16. Maximum Strain for Aluminium Alloy = 3.608×10^{-9}

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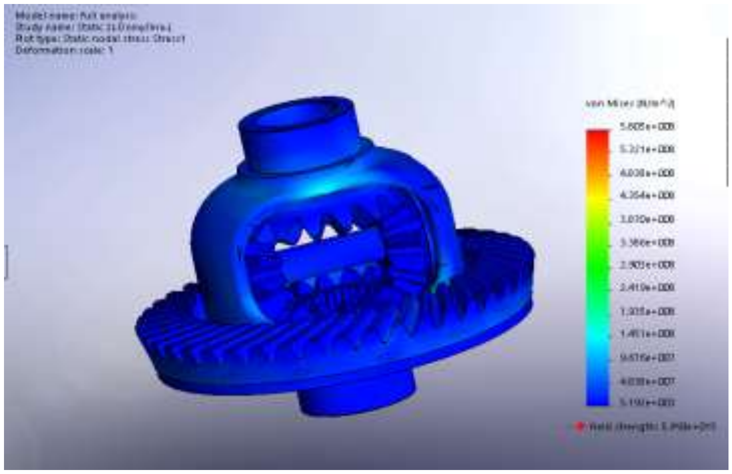

Figure 17. Maximum Von Mises Stress for glass filled polyamide= 5.805×10^8 N/m^2

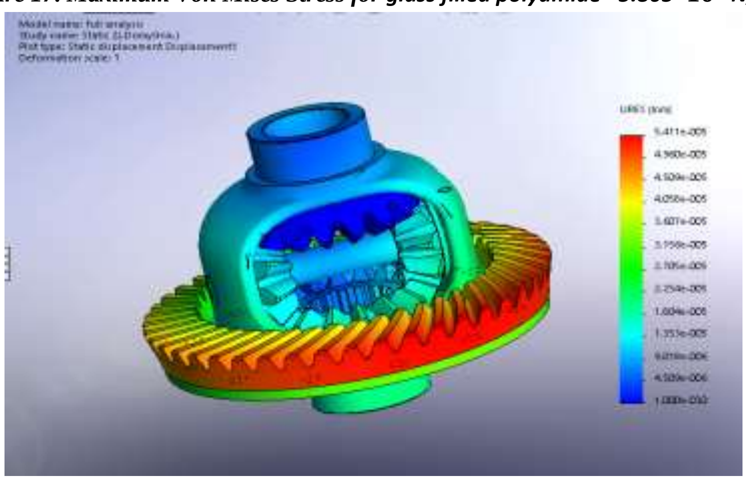

Figure 18. Maximum displacement for glass filled polyamide = 5.411×10^{-5}mm

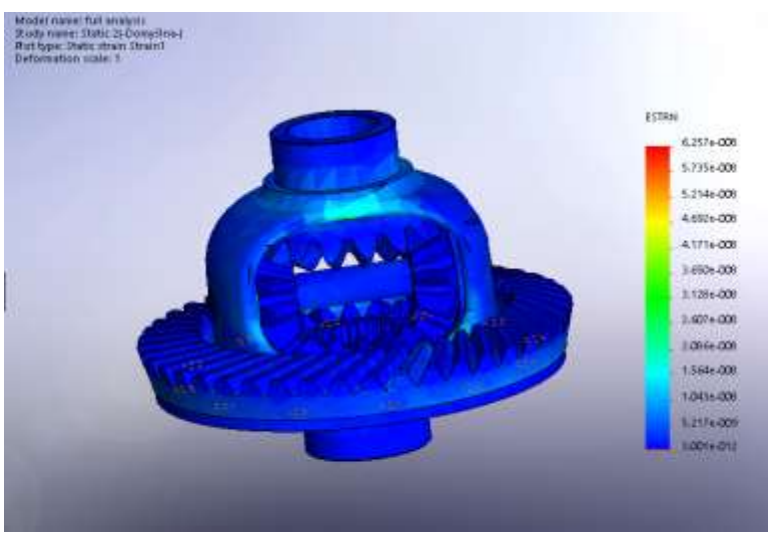

***Figure* 19. Maximum strain for glass filled polyamide = 6.257×10^{-8}**

Table 4. comparison table for materials considered

Materials	Stress (N/m^2)	Strain	Displacement (mm)	Density (Kg/m^3)
Ni-Cr steel	6.193×10^{8}	2.207×10^{-9}	1.67×10^{-6}	**7800**
Malleable Cast Iron	4.067×10^{8}	1.341×10^{-3}	**1.280**	**7300**
Aluminium alloy	3.865×10^{8}	3.608×10^{-9}	3.771×10^{-6}	**2600**
Glass Filled Polyamide	5.805×10^{8}	6.257×10^{-8}	5.411×10^{-5}	**1840**

CONCLUSION

1. The designed Bevel Gear is compared with the existing gear material, which is Ni-Cr steel Bevel Gear. In this analysis of the torque loading at 130Nm under static loading condition.
2. The analysis shows the composite is suitable material for differential gear with lower stress and density
3. This reduces the weight of the differential gear box, hence increasing efficiency.

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