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ISSN : 2348 - 5612 | Volume : 04 , Issue : 09 | October - December 2017

Structural Analysis Of Differential Gearbox with Different Grade Of Alumnium Alloys

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***Abstract*— The primarily objective of this research to design CAD model & perform the static structural analysis of differential gear box of three different grades of Aluminum Alloys that are "AA5182, AA6061 & AA7108" iterated at three different magnitude of torque value that are 190N-m, 235N-m & 320N-m to calculate the total deformation & equivalent stress value for each. This paper also shows that among these three alloys which one is the light & helps to reduce the weight of vehicle. To design the CAD model in CATIA v5 & for the static structural analysis ANSYS 15.0 has been used. From result it shows that the total deformation occur less in Aluminum Alloy 6061 grade & it is lightest among three of them.**

Keywords*— Differential Gear Box; Static Structural Analysis; Design and Structural; Aluminum Alloys Grade; Magnitude of Torque.

I. INTRODUCTION

A transmission or gearbox provides speed and torque conversions from a rotating power source to another device using gear ratios the term transmission refers to the whole drive train, including gearbox, clutch, prop shaft (for rear-wheel drive),differential and final drive shafts. In American English, however, the distinction is made that a gear box is any device which converts speed and torque, whereas a transmission is a type of gearbox that can be "shifted" to dynamically change the speed: torque ratio, such as in a vehicle.

Differential gear box is the component in the automobile that have the set of gear arrangement that provide different angular velocity to inner & outer wheels of automobile while taking turn or slippage between ground surface & wheel. This is necessary when the vehicle turns, making the wheel that is traveling around the outside of the turning curve roll farther and faster than the other. The average of the rotational speed of the two driving wheels equals the input rotational speed of the drive shaft. An increase in the speed of one wheel is balanced by a decrease in the speed of the other. When used in this way, a differential couples the input shaft (or propeller shaft) to the pinion, which in turn runs on the ring gear of the differential. This also works as reduction gearing. On rear wheel drive vehicles, the differential may connect to half-shafts inside axle housing, or drive shafts that connect to the rear driving wheels. Front wheel drive vehicles tend to have the pinion on the end of the main-shaft of the gearbox and the differential is enclosed in the same housing as the gearbox. There are individual drive-shafts to each wheel.

ISSN : 2348-5612 © URR
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A. *Types of Differential*

- Epicyclic Differential
- Spur Gear Differential

Epicyclic Differential An epicyclic differential can use epicyclic gearing to split and apportion torque asymmetrically between the front and rear axles. An epicyclic differential is at the heart of the Toyota Prius automotive drive train, where it interconnects the engine, motor generators, and the drive wheels (which have a second differential for splitting torque as usual). It has the advantage of being relatively compact along the length of its axis (that is, the sun gear shaft).

Fig 1 Epicyclical Gear Differential Arrangements

Spur Gear Differential A spur-gear differential has two equal-sized spur gears, one for each half-shaft, with a space between them. Instead of the Bevel gear, also known as a miter gear, assembly (the "spider") at the centre of the differential, there is a rotating carrier on the same axis as the two shafts. Torque from a prime mover or transmission such that the drive shaft of a car rotates this carrier. Mounted in this carrier are one or more pairs of identical pinions, generally longer than their θ diameters, and typically smaller than the spur gears on the individual half-shafts. Each pinion pair rotates freely on pins supported by the carrier. Furthermore, the pinion pairs are displaced axially, such that they mesh only for the part of their length between the two spur gears, and rotate in opposite directions. The remaining length of a given pinion meshes with the nearer spur gear on its axle. Therefore, each pinion couples that spur gear to the other pinion, and in turn, the other spur gear, so that when the drive shaft rotates the carrier, its relationship to the gears for the individual wheel axles is the same as that in a bevel-gear differential.

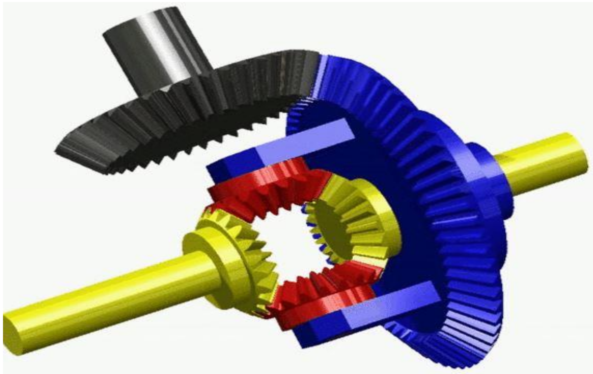

Fig 2 Spur Gear Differential Arrangements

II. OBJECTIVE

- The objective of this research is to analyze the deformation & equivalent stress develops in differential gear box of different grade of aluminum alloy i.e. AA5182, AA6061 & AA7108 by the application of variable torque magnitude i.e. 190N-m, 235N-m & 320N-m on crown gear. For performing this structural analysis was done.
- Another aim is to investigate among three of them which one is lightest in weight & help to reduce the weight of differential gear box & also help to reduce the overall weight of vehicles.

III. MODELING AND ANALYSIS

Differential is used when a vehicle takes a turn, the outer wheel on a longer radius than the inner wheel. The outer wheel turns faster than the inner wheel that is why there is a relative movement between the two rear wheels. This project mainly deals with the objective of the comparative analysis of suitable grade of Aluminium alloy for differential gear box of Ashok Leyland 2156M. To conclude this analysis a 3D CAD model of differential gear is prepared on CATIA v5. Then CAD model converted into STEP format to import in ANSYS 15.0 Static structural workbench for analysis & simulation of geometry before analysis the boundary condition is applied. In this static structural analysis of differential gear box the Total Deformation & Equivalent Stress is calibrated for different grade of aluminium alloy at different magnitude of Torque value.

This analysis is performed with Aluminium alloy of different grade are mention below

- Aluminium Alloy 5182
- Aluminium Alloy 6061
- Aluminium Alloy 7108

Dimension of the differential gear box geometry is taken from K. Dinesh Babu, M. Siva Nagendra, Ch. Phanideep, J. Sai Trinadh et al.” Design And Analysis Of Differential Gearbox In Automobiles”

IV. GEARS DIMENSION

A. Dimensions for crown gear

Bevel gearing arrangement = 90°
Diameter of crown wheel = D_G = 475mm
Number of teeth on gear = T_G =5 0
Number of teeth on pinion= T_P = 8
Module = m=D_G/T_G=475/50= 9.5 = 10 (according to standards)
Diameter of pinion = m x T_P=10x8 = 80mm
Module = m = D_G/T_G = 475/50 = 9.5 = 10 (according to standards)
Pressure angle of teeth is 20° involutes system Ø=20°

B. Dimensions for sun & planet gears

Diameter of sun gear =D_{SG}=150mm
Diameter of pinion =D_{PG}=70mm
Number of teeth on gear = T_{SG} =18
Number of teeth on pinion = T_P = 15
$D=D_{SG}+D_{PG}$=220
$T=T_{SG}+T_{PG}$ = 33
Module = m = D/T = 220/33 = 6.66 = 7(according to standards)

V. MODELLING IN CATIA V5

The CATIA v5 is 3D modelling software package enables the creation of 3D parts, from 3D sketches, sheet metal, composites, moulded, forged or tooling parts up to the definition of mechanical assemblies. The software provides advanced technologies for mechanical surfacing & BIW.

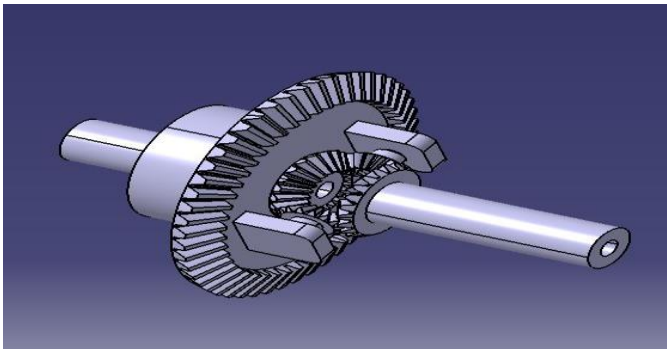

Fig 3 Differential Assembly

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ISSN : 2348 - 5612 | Volume : 04 , Issue : 09 | October - December 2017

The solid modelling of differential gear box is done on CATIA v5 platform and converted into STEP format for further use in ANSYS software for simulation & analysis.

Components of differential gear box are shown below in the figure.

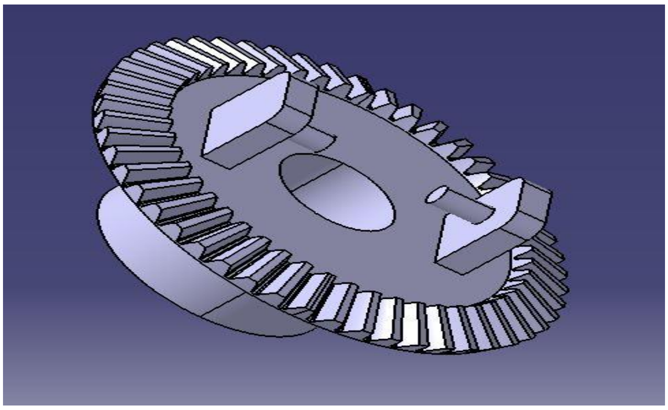


Fig.4 Crown Gear

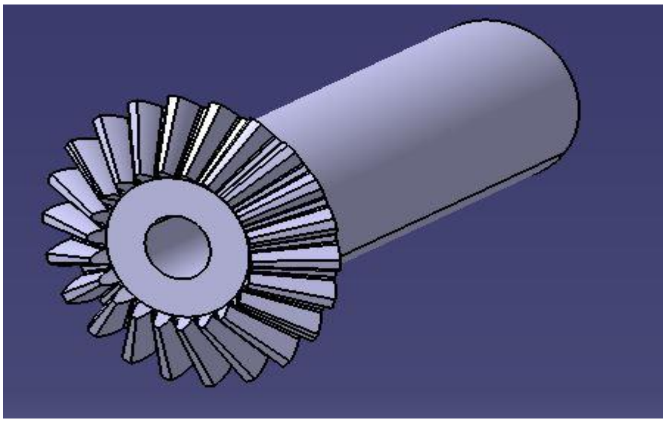
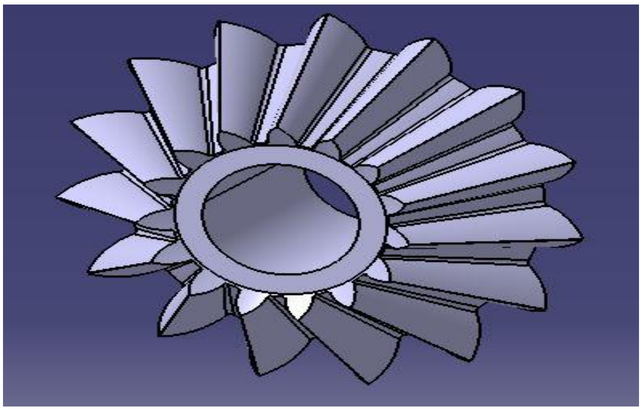


Fig.5 Sun Gear



. Fig..6 Planet Gear

VI. BOUNDARY CONDITIONS

A. Contact

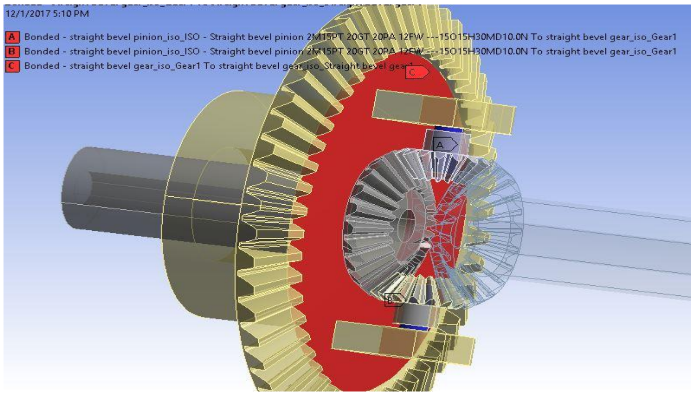


Fig.7 Bonded Contacts

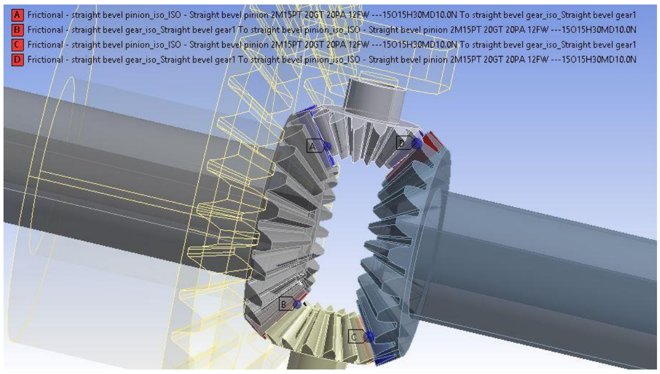


Fig.8 Frictional Contacts with Friction Coefficient 0.2 As Considered

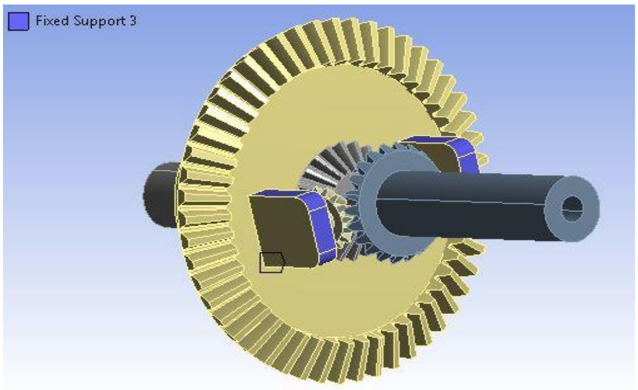


Fig.9 Fixed Contacts

B. Meshing of differential gearbox

Meshing is defined as the process of dividing the whole component into number of elements so that whenever the boundary conditions are applied on the component it distributes the inputs uniformly called as meshing. The mesh created in this work is shown in figure no.46 the total node is generated 111141& total no. Of elements is 63521 for differential gear box.

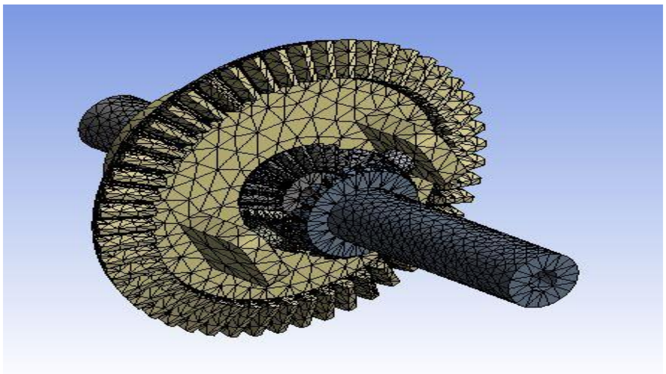


Fig.10 Mesh Geometry of Differential Gear Box

C. Torque Acting On Differential gear box

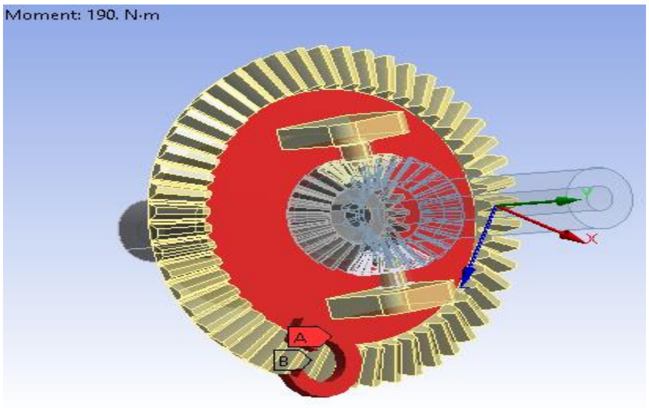


Fig.11 **190** N-m

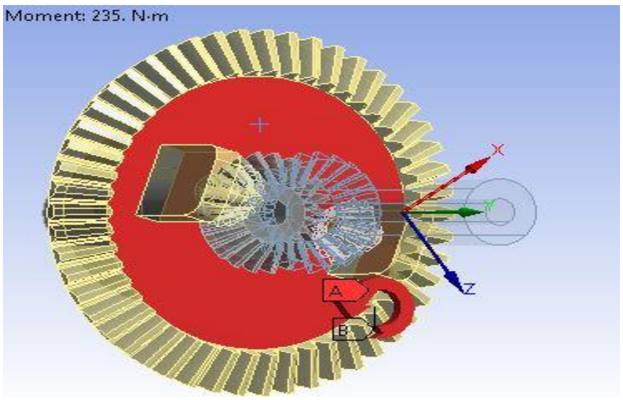


Fig.12 **235** N-m Torque

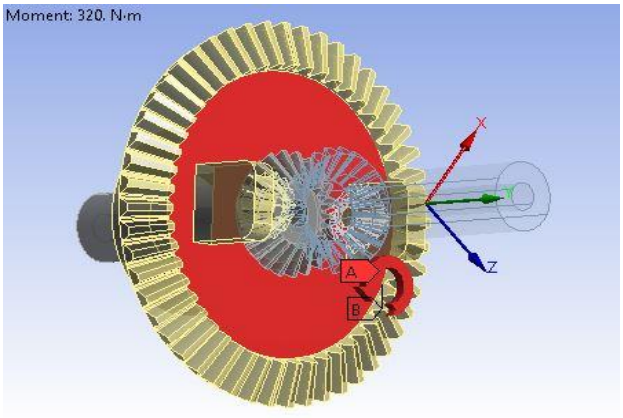


Fig.13 **320** N-m Torque

VII. MATERIAL PROPERTIES

Table No.1 Material used for static structural design analysis of Ashok Leyland 2156M differential gear box are

Material	Young's modulus of Elasticity (Gpa)	Density Kg/m^3	Poisson's Ratio	Tensile Yield Strength (Mpa)	Ultimate Tensile Strength (Mpa)
Aluminum Alloy 5128	68	2730	.33	130	280
Aluminum Alloy 6061	70	2700	.32	276	310
Aluminum Alloy 7108	69	2900	.33	290	350

CURRENTLY USED MATERIAL FOR DIFFERENTIAL GEARS IN AUTOMOTIVE INDUSTRIES:

In the current scenario Cast Iron is commonly used in the automotive industries for manufacturing differential gear box system. Cast iron being the heavy material increases the weight of complete automotive assembly. Various researches have compared cast iron with other materials like Aluminum alloys and magnesium alloys. Among all the three materials magnesium is very light in nature but increases the cost of complete system at the same time. Whereas aluminum shows comparative behaviour like magnesium alloy. So a study using different aluminum alloys is performed in this study to have the best selection of aluminum grade.

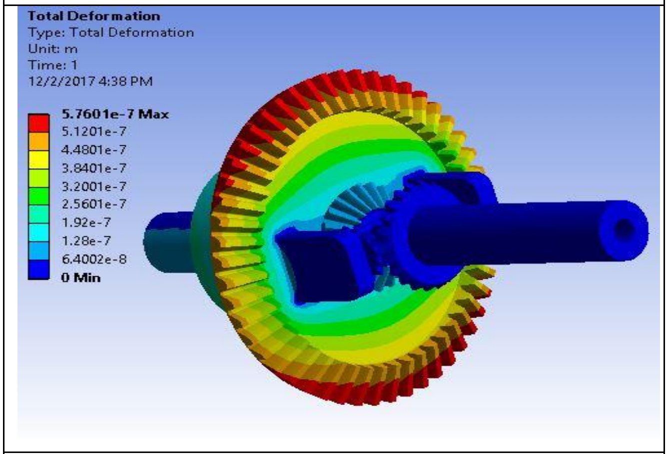
VIII. STATIC STRUCTURAL ANALYSIS

A. Total Deformation

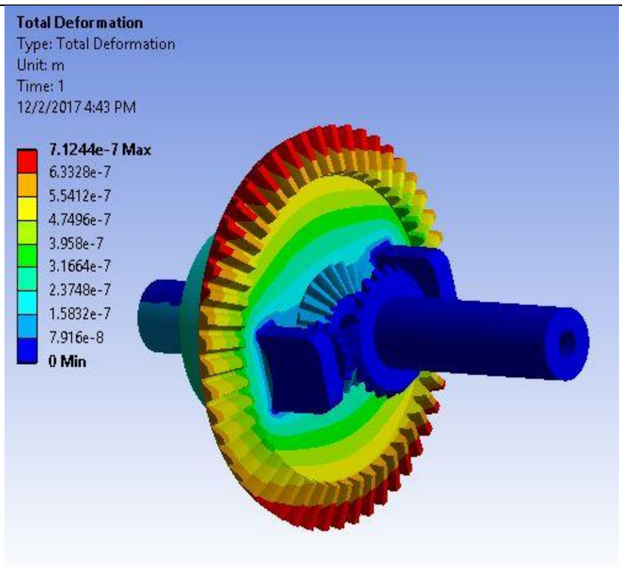
The total deformations (In meters) were analyzed by using ANSYS 15.0 Static structural For different Aluminium Alloys at different magnitude of torque.

Total Deformations in Aluminum Alloys

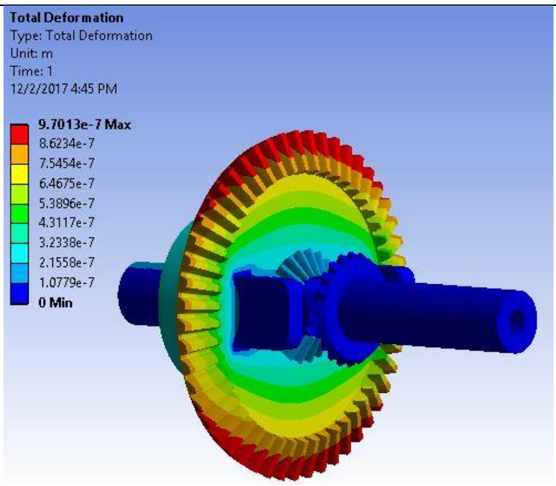
ALUMINUM ALLOY 5182



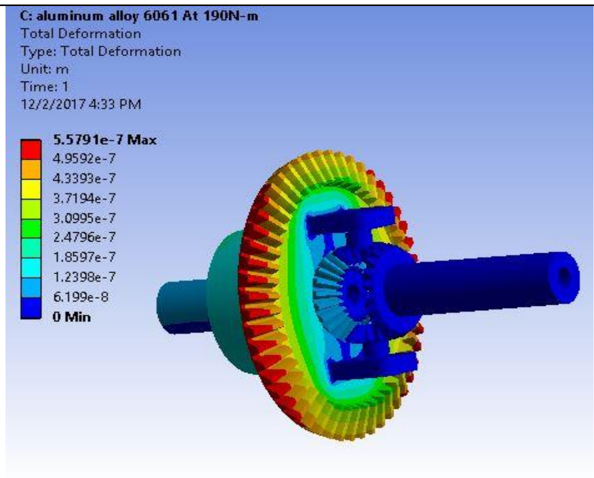
At 190N-m



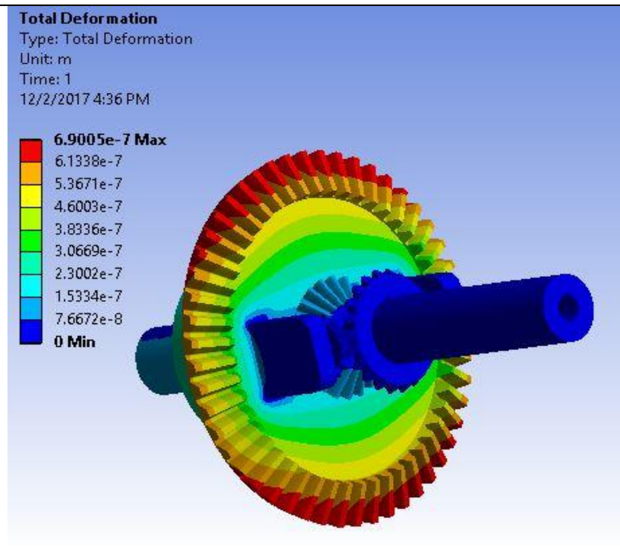
At 235 N-m



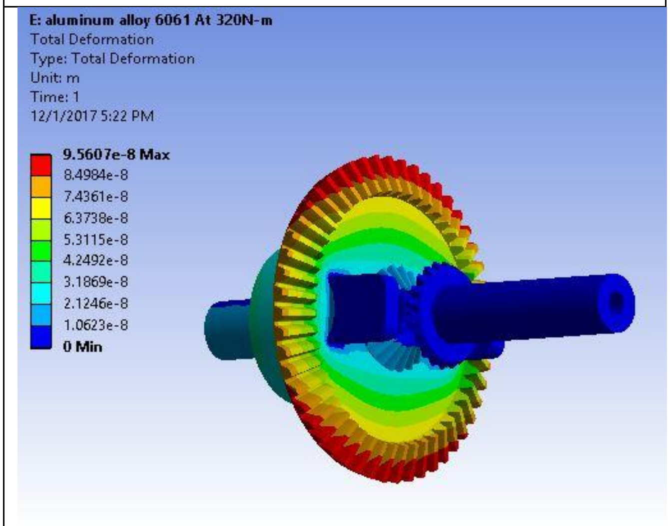
At 320 N-m



At 190N-m



At 235 N-m



At 320 N-m

ALUMINUM ALLOY 6061

ALUMINUM ALLOY 7108

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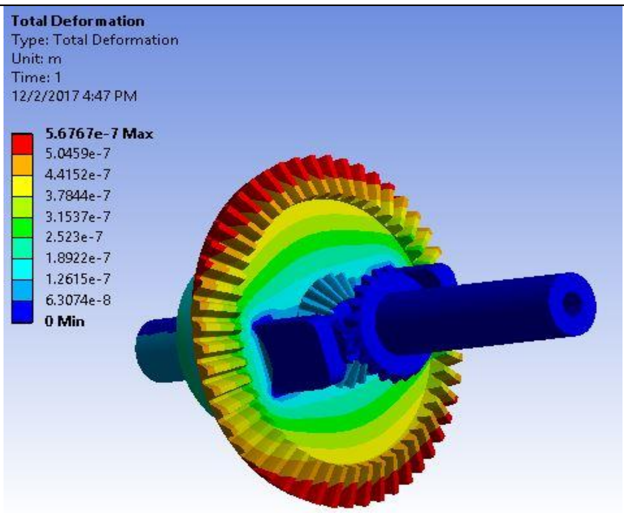
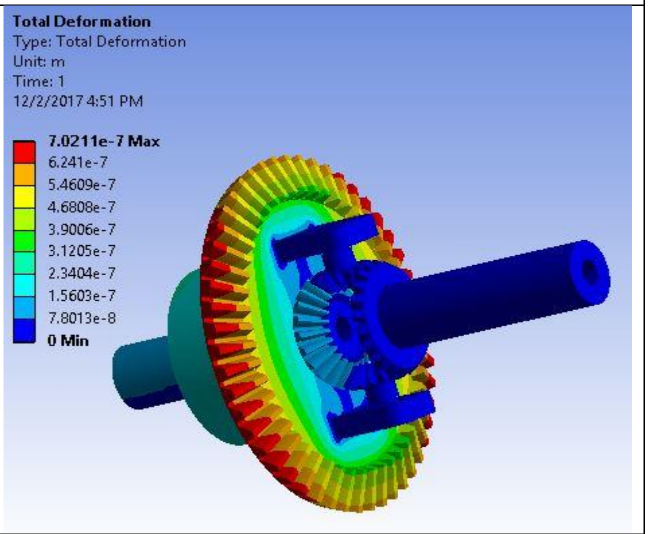
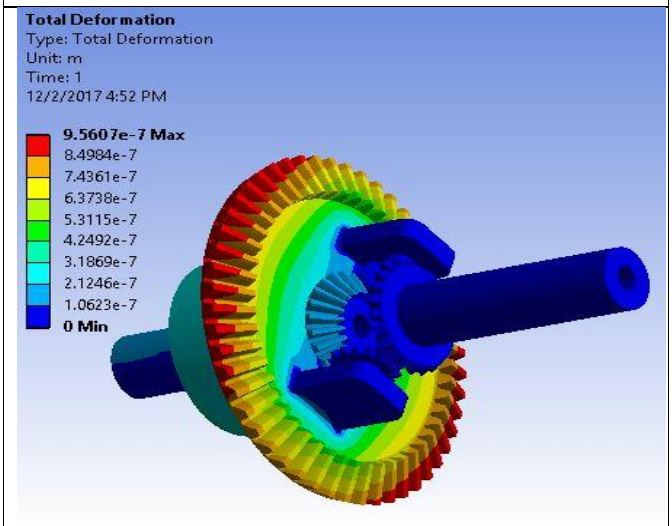


At 190N-m



At 235 N-m

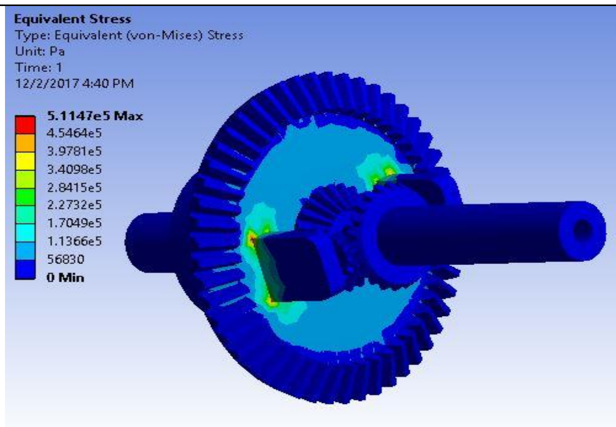


At 320 N-m

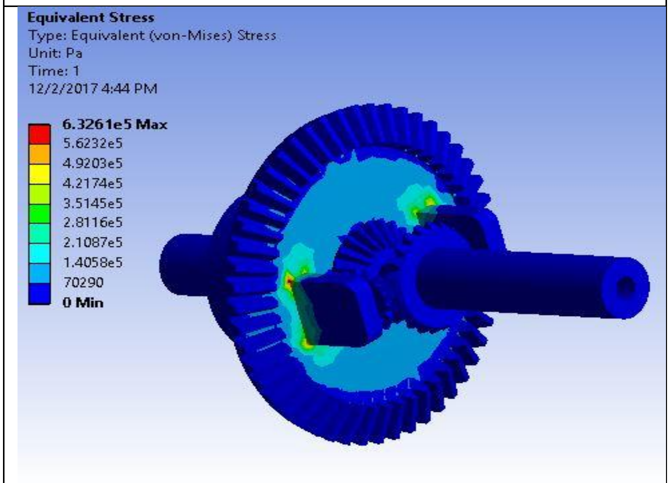
B. Equivalent Stresses

Von misses Stress (In Mpa) were determined for different aluminium alloys at different torque value.

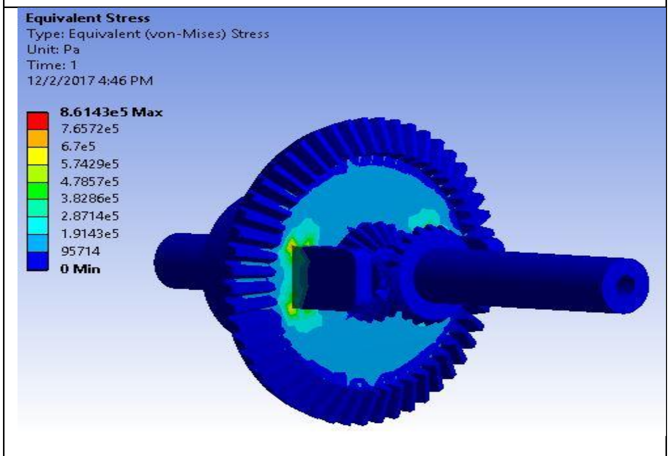
ALUMINUM ALLOY 5182



At 190N-m

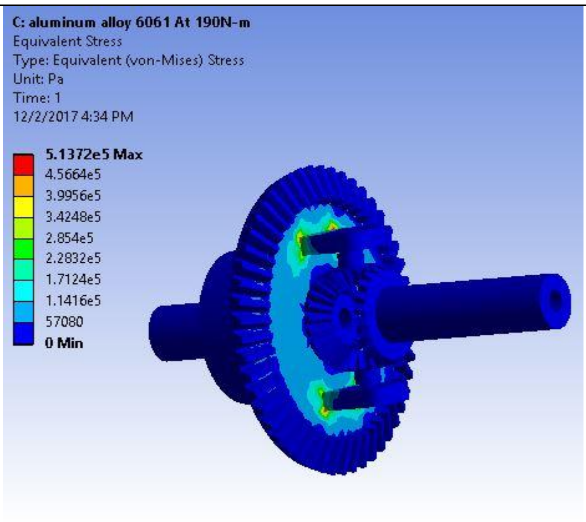


At 235 N-m

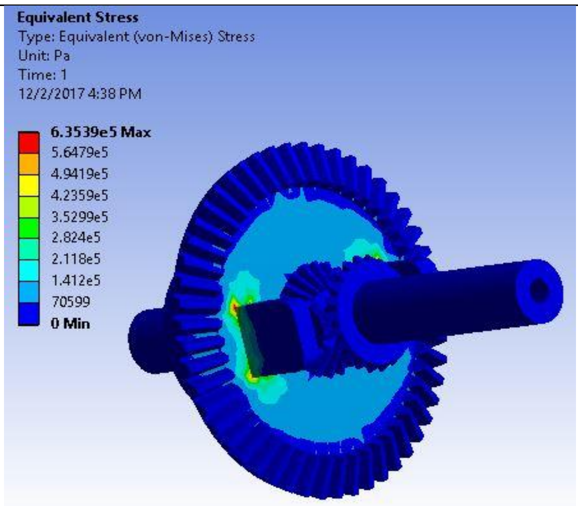


At 320 N-m

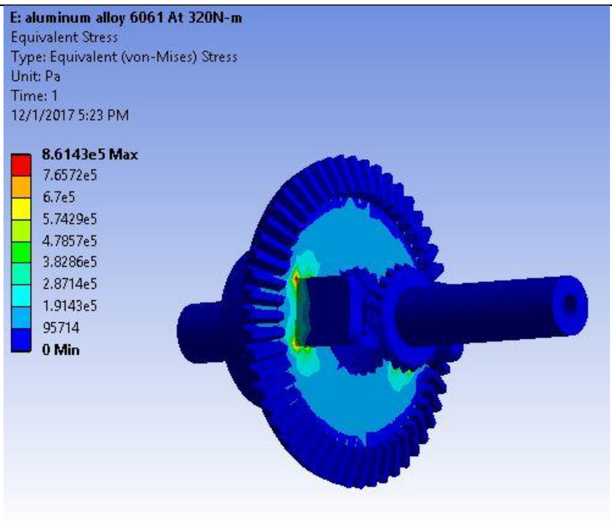
ALUMINUM ALLOY 6061



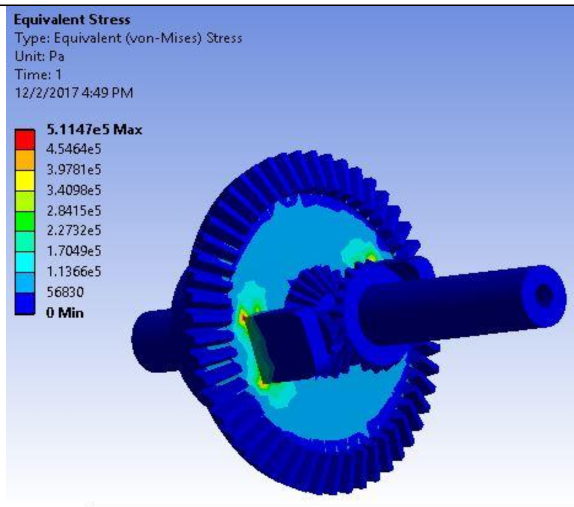
At 190N-m



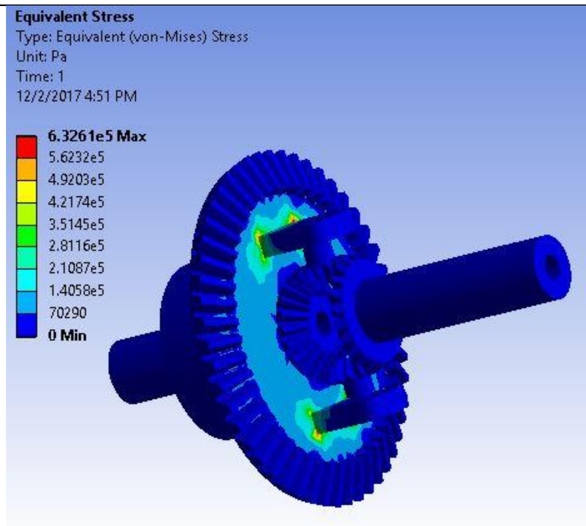
At 235 N-m



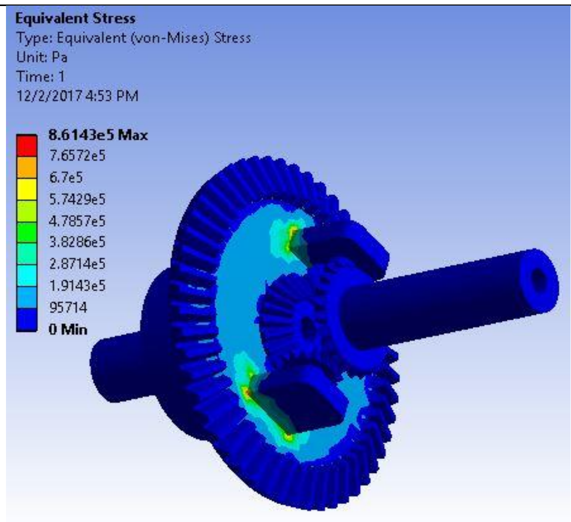
At 320 N-m



At 190N-m



At 235 N-m



At 320 N-m

ALUMINUM ALLOY 7108

IX. RESULTS & DISCUSSIONS

A. Total Deformation

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Table No .2 Total Deformations in Aluminum Alloys

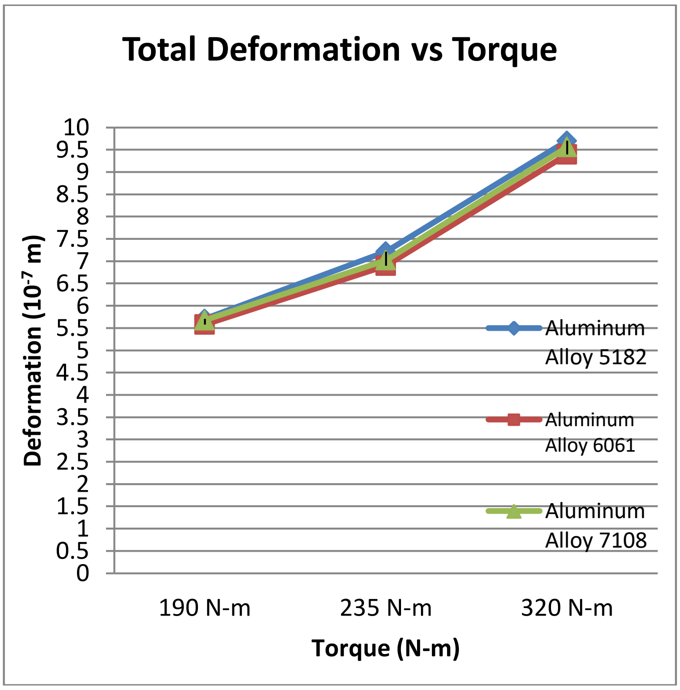
Magnitude of Torque (N-m)	Aluminum Alloy 5182	Aluminum Alloy 6061	Aluminum Alloy 7108
190N-m	5.7061E-7	5.5791E-7	5.6767E-7
235N-m	7.2144E-7	6.9005E-7	7.0211E-7
320N-m	9.7013E-7	9.3965E-7	9.5607E-7

B. Equivalent Stresses

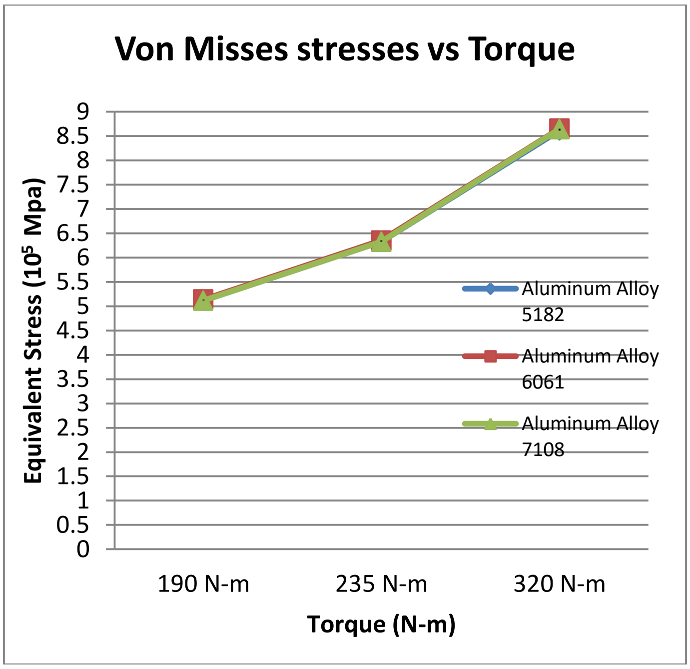
Table No .3 Von Misses stresses in Aluminum Alloys

Magnitude of Torque(N-m)	Aluminum Alloy 5182	Aluminum Alloy 6061	Aluminum Alloy 7108
190N-m	5.1147E5	5.1372E5	5.1147E5
235N-m	6.3261E5	6.3539E5	6.3261E5
320N-m	8.6143E5	8.6521E5	8.6413E5

C. Graphs



Graph no. 5.1 Total Deformations in Aluminum Alloys



Graph no. 5.2 Von Misses stresses in Aluminum Alloys

X. CONCLUSION

In this thesis "Design analysis of differential gear box of Ashok Leyland 2156M on different grade of Aluminum Alloys" is concluded. From the results mentioned in the previous chapter following conclusion can be drawn:

- From the result this is concluded that on increase in the torque magnitude, the magnitude of total deformation is also increases in the alloys
- The result shows that the total deformation occur less in Aluminum Alloys 6061 compared 5182 & 7108 grades in all three cases of different torque magnitudes.
- The result also shows that the equivalent stresses developed less in Aluminum Alloys 5182 & 7108, while the stress in the 6061 grade have slightly more compared to 5182 & 7108 grade
- The overall weight of differential 3D model of 6061 grade aluminum alloys is less compared to 5182 & 7108 grade.

A. Future scope

1. The results provided in this work can be experimentally verified.
2. Further more research should be continuing on different sub grade of Aluminum alloy 6061 for further reduction of overall weight differential of vehicle & other application.

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