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International Journal for Modern Trends in Science and Technology, *9*(02): 01-10, 2023
Copyright © 2023 International Journal for Modern Trends in Science and Technology
ISSN: 2455-3778 online
DOI: https://doi.org/10.46501/IJMTST0902001
Available online at: http://www.ijmtst.com/vol9issue02.html

Modeling and Structural Analysis of Rear End Differential Gear Box at Different Speeds with Different Materials

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To Cite this Article
B. Subhash, P. Ankith, N. Sandeep, P. Siva Kumar and G. S . R . N. Malleswara Rao. Modeling and Structural Analysis of Rear End Differential Gear Box at Different Speeds with Different Materials. International Journal for Modern Trends in Science and Technology 2023, 9(02), pp. 01-10. https://doi.org/10.46501/IJMTST0902001

Article Info
Received: 28 December 2022; Accepted: 28 January 2023; Published: 31 January 2023.

ABSTRACT

The main aim of this project work is to perform mechanical design & structural analysis of differential gear box. This is necessary when the vehicle turns. The Differential gear is a part for all four wheeler, wheel reserved the power from engine to gear box then by drive shaft to differential gear. A differential is a gear train that transmits an engine's torque to the wheels. During a turn, the outer and inner wheels of the vehicle are forced to travel along paths of different radii. A differential allows the outer driving wheel to rotate at a faster speed when compared to the inner driving wheel during a turn. The analysis is conducted to verify the best material for the gears in the gear box at higher speeds by analyzing stress, strain, total deformation and also by considering weight reduction. Generally, materials used for gears and gear shafts are Cast Iron, magnesium alloy, Cast steel. This project is testing different materials like Aluminum alloy material for reducing the weight of the differential gear box. In this work the differential gear box is designed with Catia V5R20 software. The complete design is imported to ANSYS 14.5 software and analyzed. This analysis is conducted to know the best material for gears in the gearbox at high speed. We consider the factors like stress, strain, total deformation. When comparing the stress, strain total deformation values of the three materials like cast steel, aluminum alloy, magnesium alloy for different speeds at 2400 rpm, 4400 and 115N-m torque. By observing analysis the Result will be displayed and compared to find the most suitable design

KEYWORDS: Differential Gear Box, Structural Analysis, stress, strain, total deformation

1. INTRODUCTION

When a four-wheeler (car) takes a turn, the outer wheel turns faster than the inner wheel. Thus, there is relative movement between the inner and outer wheel. The function of the differential is to permit the relative movement between inner and outer wheels when vehicle negotiates (takes) a turn. The torque transmitted to each rear wheel is equal in this case, although their speed is different. The differential is made up of a system of gears that connect the propeller shaft and rear axles. It is a part of inner axle housing assembly. The assembly consists of differential,rear axles, wheels, and bearings. When a vehicle travels in a straight line, the two rear wheels turn on the road exactlyat the same speed and there is no relative movement between two rear wheels. But when vehicle takes a turn the outer wheel travels on a longer radius than the inner wheel. The outer wheel turns faster than inner wheel i.e. there is relative movement between two rear wheels. If two rear wheels are rigidly fixed to a rear axle, the inner wheel will slip, which will cause rapid tire wear, steering difficulties and poor road holding. Therefore there must be some device, which will divide the input torque of the transmission system between two rear axles. Differential serves this purpose. Location in different types of vehicle layouts. In Front-engine front-wheel-drive layout – differential is located at the front next to gearbox. In Rear engine rear-wheel-drive layout – differential is located at the rear next togearbox. Four wheels drive layout – differential is located at the front as well as rear. Front engine rear-wheel-drive layout – it is located at the rear in between two half shafts. If a vehicle travels in a straight line, the two rear wheels turn exactly at the same speed, and there is no relative movement between them. But when the vehicle takes a turn the outer wheel travels a longer radius than the inner wheel i.e. there is relative movement between the two rear wheels. The outer wheel turns faster and covers a larger distance than the inner wheel. The inner wheel makes a larger angle than the outer wheel. Thus the vehicle negotiates the turn safely.

2. LITERATURE REVIEW

K. Dinesh Babu et.al. [1] The main objective of this project is to perform mechanical design of differential gear box and analysis of gears in gear box. We have taken grey cast iron and aluminum alloy materials for conducting the analysis. So, in this paper we are checking as the aluminum can be the other material for the differential gear box for light utility vehicles. We have taken the frictional contact between the mating gears as 0.2 to see does the frictional contact the effect the load or not. From, the above results we found that both grey cast iron and aluminium alloy are preferable for performing the application of differential gearbox in automobiles. But, when it comes to weight for light utility vehicles Aluminium Alloy is preferred. N. Vjaya babu et.al. [2] 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 when there is a relative movement between the two rear wheels. The analysis is conducted to verify the best material for the gears in the gear box at higher speeds by analysing stress, displacement and also by considering weight reduction. Structural analyses are done on the differential gear box to verify the best material by taking in to account stresses, displacements, weight etc. By observing the structural analysis results using Aluminum alloy the stress values are within the permissible stress value.Kunal chitale et.al. [3] A differential allows wheels of a vehicle to rotate at different speeds. The main objective of this paper is to perform mechanical design of differential gear box and analysis of gears in gear box. We have taken grey cast iron and aluminum alloy materials for conducting the analysis. Presently used materials for gears and gears shafts is Cast Iron, Cast Steel. Mayank Bansal et.al. [4] The main aim of the project is to study the structural and dynamic behavior of the gears in the differential gearbox. The composites consider is Aluminum Silicon carbide composite in this we replace the metallic gears of steel alloy with the composites. Cad software and Ansys 14.0 is used the analysis tool to determine the total deformation, von misses stress and the natural frequencies at various mode for the different materials relative to each other when the gears in the gearbox transmit power at different speeds i.e-2400 rpm, 3000 rpm and 4000 rpm. The analysis results shows that the Composite gears offer improved properties over the conventional metallic gear and these can be used as better alternative for replacing metallic gears for the differential gearbox. Prathamesh Patil et.al. [5] The main aim of this paper is to focus on the design and analysis of the assembly of gears in the differential gearbox of LMV. When they transmit power at a speed of 2000 RPM and 4400 RPM. The analysis is also conducted by different materials for gears i.e. Cast Iron, Cast Steels and Aluminum Alloy. Generally, materials used for gears and gear shafts are Cast Iron, Cast steel. This paper testing different materials like Aluminum alloy and Nickel Chromium Alloy material for reducing the weight of the differential gearbox. Stress and displacement are analyzed by considering weight reduction in the gearbox at a higher speed. The analysis is done in Ansys software. Modeling and assembly are done in Solid Work.K. Jhansi Rani et.al. [6] The main objective of this project is to developed parametric model of differential Gearbox by using CATIA- V5 under various design stages. It is observed that Glass filled polyamide composite material is selected as best material for differential gearbox and is found to suitable when apply moment 200 N/m under static loading conditions. Comparisons of various stress and deformation, shear stress results using ANSYS-14.5 with Glass filled polyamide composite and metallicmaterial (grey cast iron) are also being performed and found to be lower for composite material. R. Karthick et.al. [7] 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 when there is a relative movement between the two rear wheels. Differential is a part of inner axle housing assembly, which includes the differential rear axles, wheels and bearings. The differential consists of a system of gears arranged in such a way that connects the propeller shaft with the rear axles. The main objective of this paper is toper form mechanical design of differential gear box and analysis of gears in gear box. We have taken Stainless steel, aluminium alloy, magnesium alloy, structural steel materials for conducting the analysis. Ketan Kale et.al. [8] The main aim of this project work is to perform mechanical design & analysis of differential gear box. Presently used materials for gears and gears shafts is Cast Iron, Cast Steel. So, in this paper we are checking as the aluminum 7475can be the other material for the differential gear box for light utility vehicles so, we can reduce the weight this project contains the design and material selection of the gearbox for different type of vehicles also. For better efficiency, improvement of power transmit rate is important phenomenon Hlae yi myo et.al. [9] The main aim of this paper is to focus on the mechanical design and analysis on assembly of gears in gear box when they transmit various powers at different speeds. In this paper, the tangential load and torque are applied with speeds of 3600rpm, 4000 rpm and 4500 rpm Presently used materials for gears and gears shafts is Cast Iron, Cast Steel. So, in this paper to replace the materials with Cast Iron material for reducing weight of the product.Daniel Das.A et.al. [10] The main aim of this paper is to focus on the mechanical design and analysis on assembly of gears in gear box when they transmit power at different speeds. Analysis is also conducted by varying the materials for gears, Cast Iron, Cast Steels and Aluminum Alloy etc., presently used materials for gears and gear shafts is cast-iron, cast steel. In this work to replace the materials with Aluminum material for reducing weight of the product. Stress, displacement is analyzed by considering weight reduction in the gear box at higher speed.

By using these literature surveys, we can say that there are different types of speeds are acting on the differential gear box and different types of materials are used. These journals helps us to design, modelling and analyse the different RPM and torque applied on differential gear box and increase the efficiency for different materials to use it conveniently

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3. METHODOLOGY

1.Define materials and parameters of the rear end differential

gearbox:Designing For

A. Car Model: Maruti Suzukiswift

B. Engine: 4cylinder-4stroke dieselEngine 1.2L

C. Max power: 88.50 bhp@6000RPM

D. Maxtorque: 115 Nm@4400 RPM

E. Max speed: 121mph/180 mph

To determine the design of differential Gearbox. First, we have to create the Differential model using modeling software. Here we used CATIA V5R21 for constructing our 3D geometry of Differential Assembly. The Assembly consists of 1) ring gear 2) pinion gear 3) two bevel gears or side gears 4) two spider gear.

4. MODELING AND ANALYSIS

Design of differential gearbox: Open Catia v5 software. Start- mechanical design –part design – enter the part name. First we can draw a sketch select with using sketch tool. Firstly, we need to select the plane on which sketch is needed to draw. Then, we draw thepart with the help of dimensions required for designing. By using profile we have created the dimensional view we can use shaft toolThis figure represents the modeling of crown gear in catia v5. It is created by drawing the bevel gear profile from prerequisites and removing the faces of bevel gear. After creating base of the crown then we can draw a line select xy plane Then we can use rib option to create gear tooth. After we draw gear tooth select the rib and select circular pattern give the number of teeth

39After creating gear tooth then we can draw a sketch to take top surface of the gear and thenwe can use pad tool to draw bars after completing crown gear at last we can use fillet and pocket option. After complete the crown gear to create side gear or spider gear. It is the second bevel side gear. This figure represents the modeling of second side gear in catia v5. It is created by drawing the bevel gear profile from prerequisites and removing the faces of bevel gear tooth for 45 deg mating of other gears for assembly. And adding an extrude stub axles to it Pinion and side gear is also a same pattern to draw same condition! We can use the same procedure for the pinion and side gear also. After complete the side gear to draw a new pinion gear To determine the structural analysis on the differential gear box. represents the modeling of ring gear in catia v5. It is created by drawing the bevel gear profile from prerequisites and removing the faces of bevel gear tooth for 45 deg mating of other gears for assembly. And adding an extrude stub axles to it. The ring rotates while the vehicle is taking a turn. It rotates in its own axis.First, we have to create a model of differential gear box in modeling software's. We have the assembly of differential gear box in catia V5. Construct a three-dimensional representation of the bevel gears in CATIA V5. The assembly consists of 2 side gears, 2 ring gears and on sun gear. After doing the assembly in CATIA V5 software. Save the file in. IGES format continuing the further work in ANSYS Mechanical.

Build geometry:

Construct a three-dimensional representation of the bevel gears in CATIA V5. The assembly consists of 2 side gears, 2 ring gears and on sun gear. After doing the assembly in CATIA V5 software. Save the file in. IGES format continuing the further work in ANSYS Mechanical. the assembly of differential gear box. As shown in below figure 1, 2, 3 and 4.

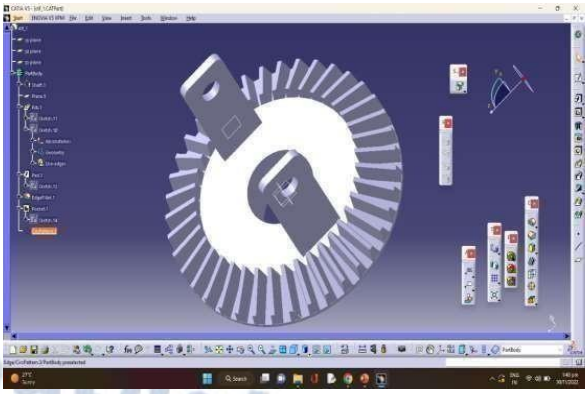

Fig: 1 crown gear

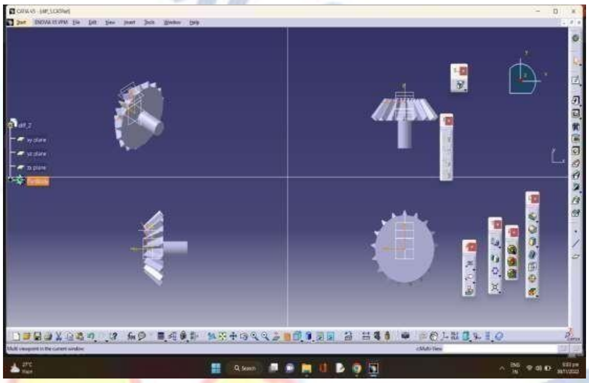

Fig: 2 spider gear

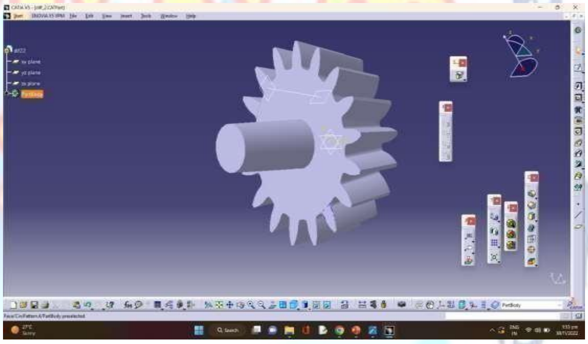

Fig: 3 pinion gear

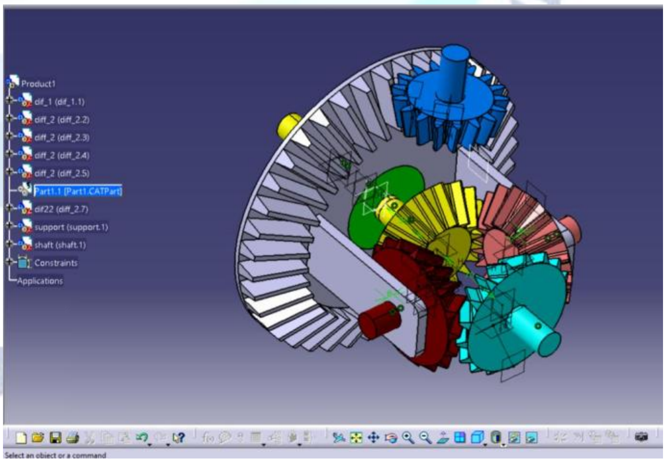

Fig : 4 rear end differential

Static analysis:

The static structural analysis calculates the stresses, displacements, shear stress and forces in structures caused by a load that does not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that the loads and the structure's response are assumed to change slowly with respect to time. A static structural load can be performed using the Ansys work bench solver. The types of loading that can be applied in a static analysis include

Meshing of differential gear box:

Meshing of differential gear box: Gear box are representing the fine meshing on the differential gear box. By meshing we can do the analysis properly and perfectly to know the load values on the differential gear box as shown in below figure 5

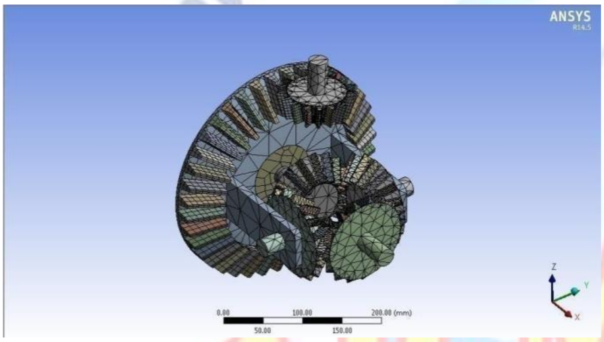

Fig: 5 meshing of differential gear

Fixed support of differential gear box:

The fixed supports because while doing the structural analysis we can't do it without giving the fixed supports so we have the fixed supports to the crown gear hand because it doesn't imply any forces on the analysis as shown in below figure : 6

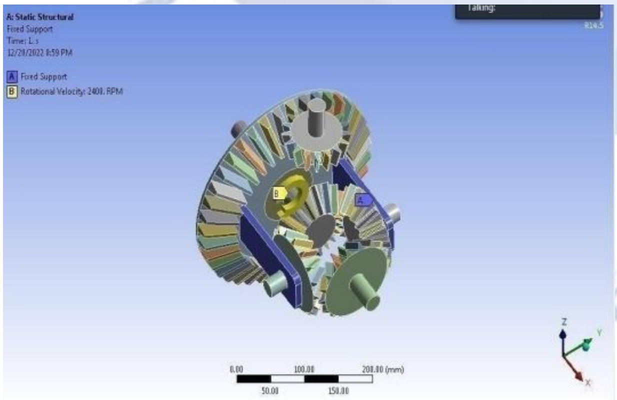

Fig : 6 fixed support of differential gear box

Rotational velocity acting on differential gear box:

In this below figure : 7 shows the rotational velocity acting on differential gear box. The rotational velocity is 4400 rpm

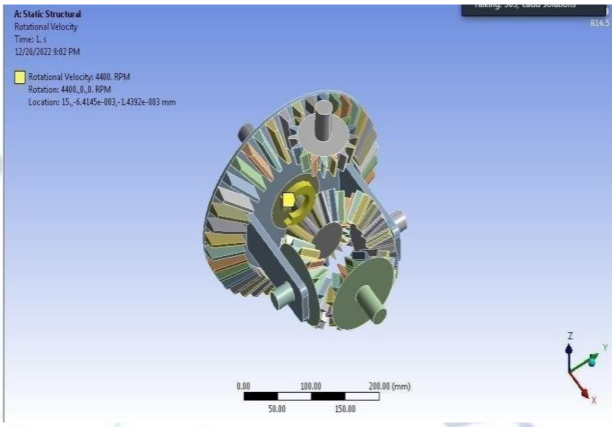

Fig : 7 rotational velocity acting on differential gear box

Static Structural Analysis of cast steel at 2400 rpm :

The below fig 8,9,10 shows equivalent stress, total deformation, equivalent strain of cast steel at 2400 rpm

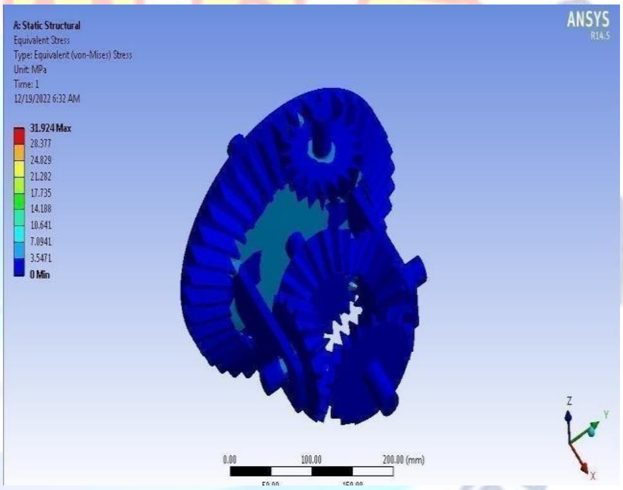

Fig: 8 equivalent stress analysis of cast steel

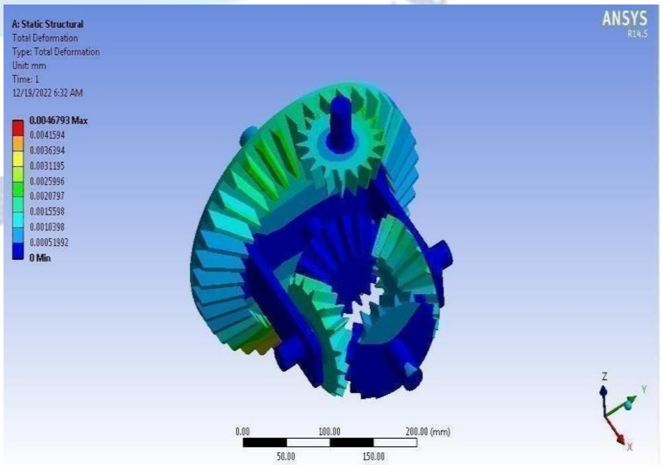

Fig: 9 total deformation of cast steel

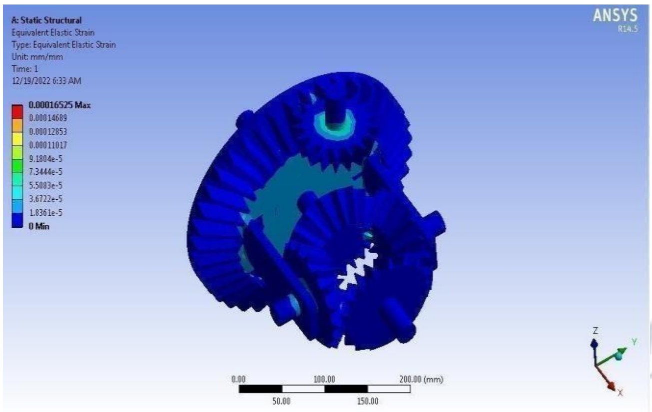

Fig : 10 equivalent strain analysis of cast steel

Analysis of aluminum alloy at 2400 rpm

The below fig 11, 12, 13 shows equivalent stress, total deformation, equivalent strain of aluminum alloy at 2400 rpm

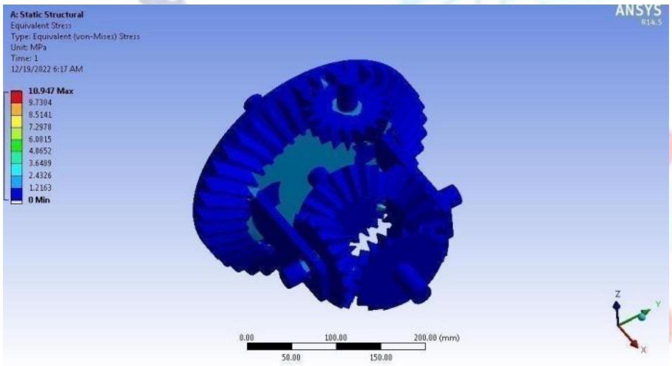

Fig : 11 equivalent stress of aluminum alloy

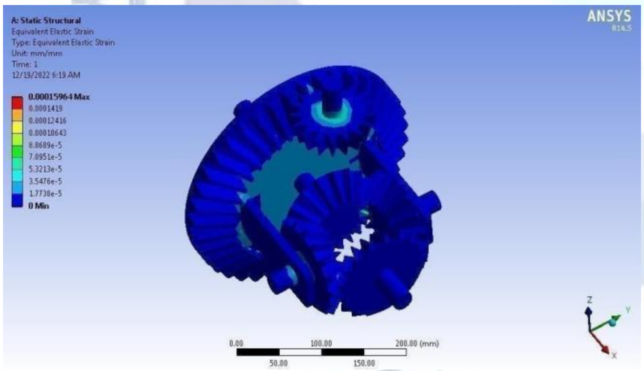

Fig : 12 equivalent strain of aluminum

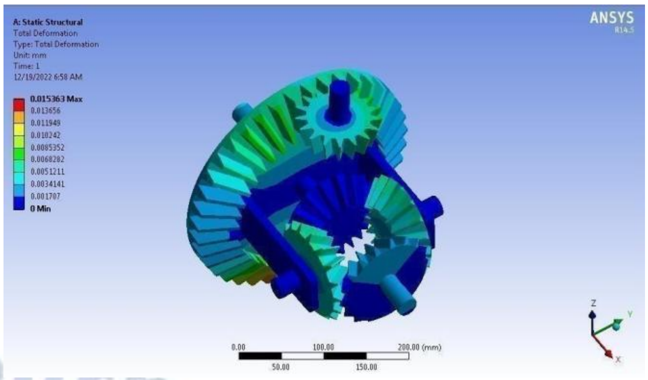

Fig : 13 total deformation of aluminum alloy

Analysis of magnesium at 2400 rpm:

The below fig 14, 15 shows equivalent stress, total deformation, equivalent strain of aluminum alloy at 2400 rpm

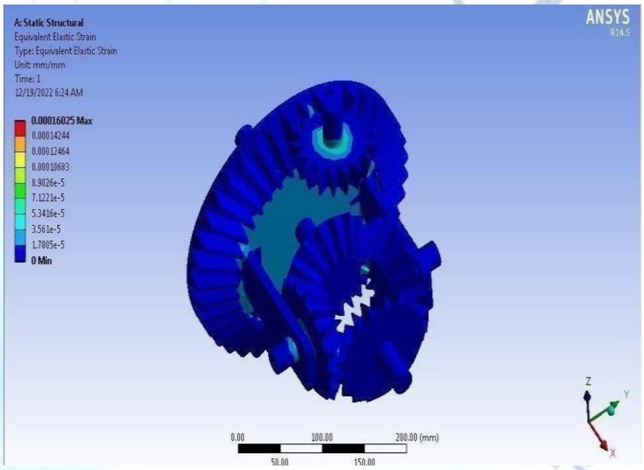

Fig : 14 equivalent strain of magnesium alloy

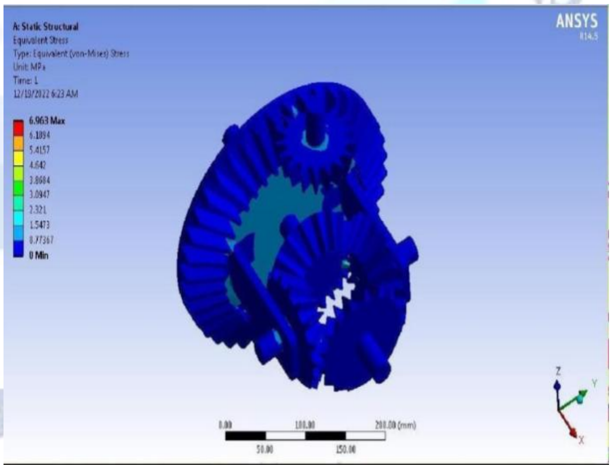

Fig : 15 equivalent stress of magnesium alloy

Analysis of cast steel at 4400 rpm:

The below fig 16, 17, 18 shows equivalent stress, total deformation, equivalent strain of cast steel at 4400 rpm

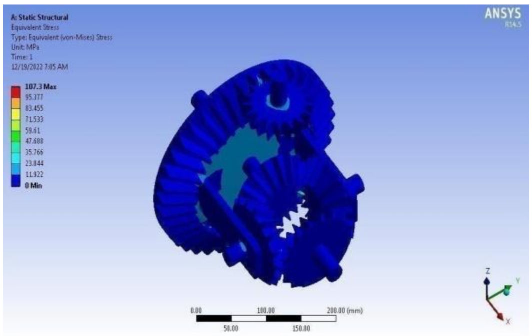

Fig : 16 equivalent stress of cast steel

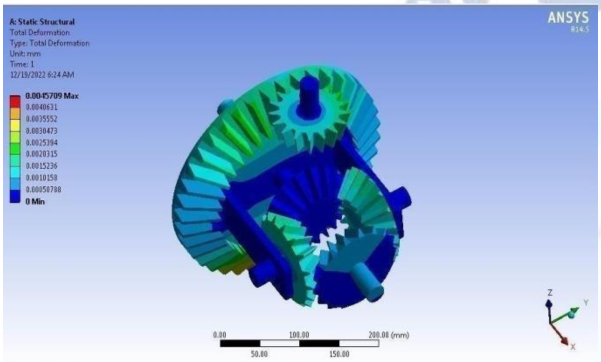

Fig : 17 total deformation of cast steel

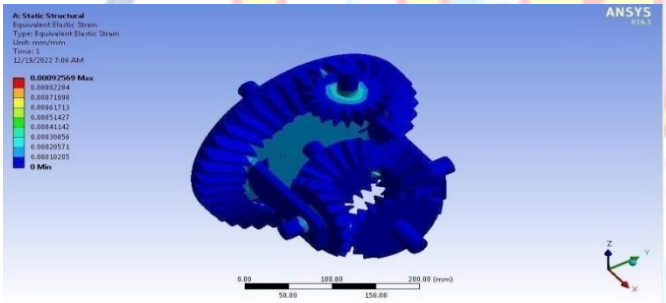

Fig : 18 equivalent strain of cast steel

Analysis of aluminum alloy at 4400 rpm:

The below fig 19, 20, 21 shows equivalent stress, total deformation, equivalent strain of aluminum alloy at 4400 rpm

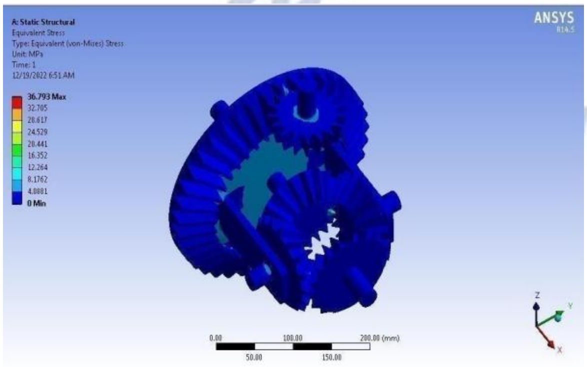

Fig : 19 equivalent stress of aluminum alloy

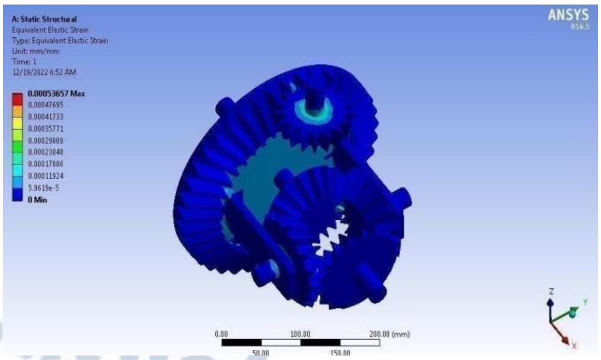

Fig : 20 equivalent strain of aluminum alloy

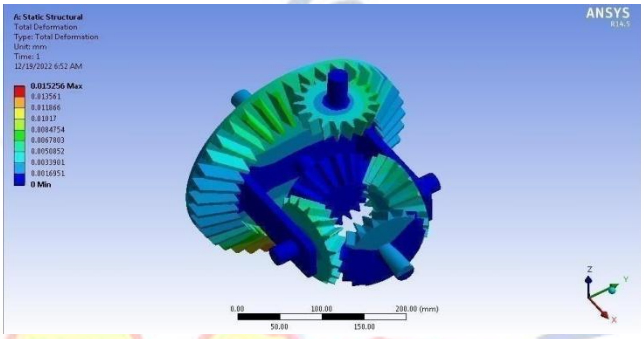

Fig : 21 total deformation of aluminum alloy

Analysis of magnesium alloy at 4400 rpm:

The below fig 22, 23, 24 shows equivalent stress, total deformation, equivalent strain of magnesium alloy at 4400 rpm

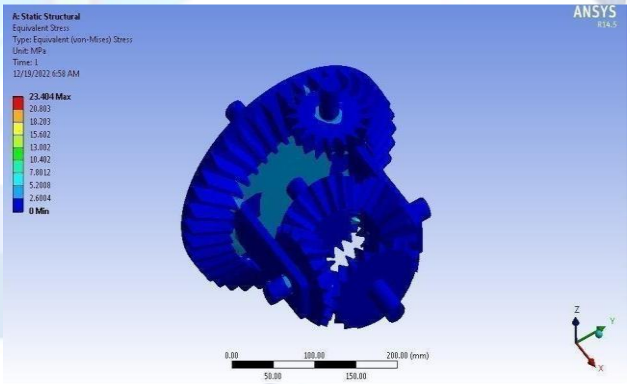

Fig : 22 equivalent stress of magnesiuum alloy

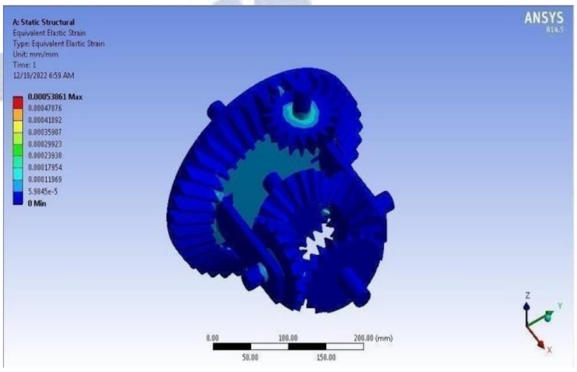

Fig : 23 equivalent strain of magnesium alloy

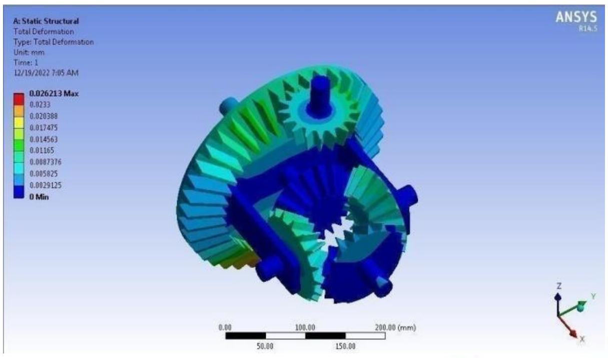

Fig : 24 total deformation of magnesium alloy

Analysis of aluminum alloy at torque 115N-m:

the below fig 25, 26, 27 shows torque at 115N-m and total deformation, equivalent stress, equivalent strain of aluminum alloy

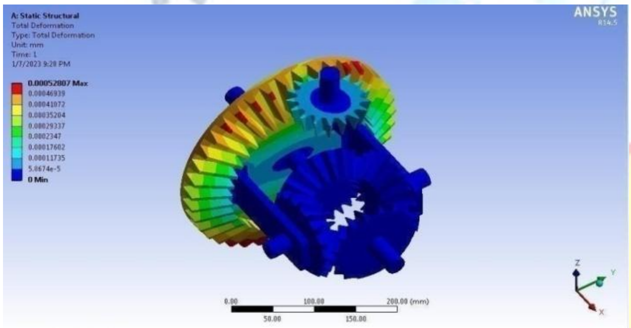

Fig : 25 total deformation of aluminum alloy

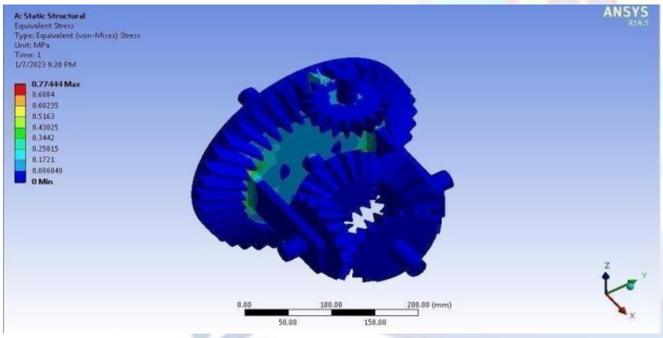

Fig : 26 equivalent stress of aluminum alloy

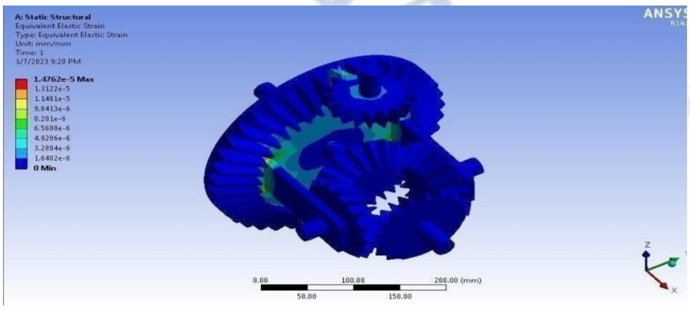

Fig : 27 equivalent strain of aluminum alloy

Analysis of magnesium alloy at torque 115 N-m:

the below fig 28, 29, 30 shows torque at 115N-m and total deformation, equivalent stress, equivalent strain of magnesium alloy

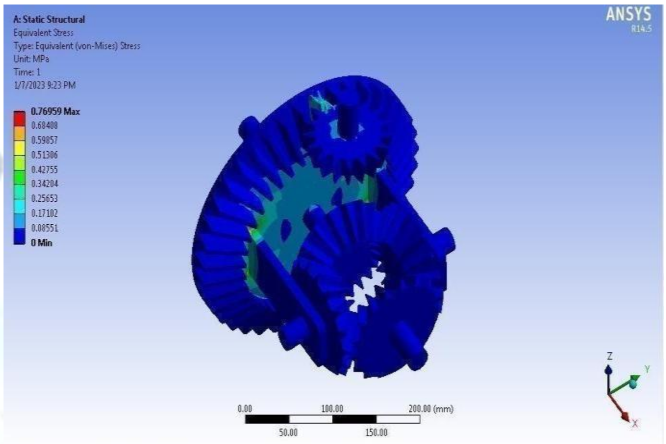

Fig : 28 equivalent stress of magnesium alloy

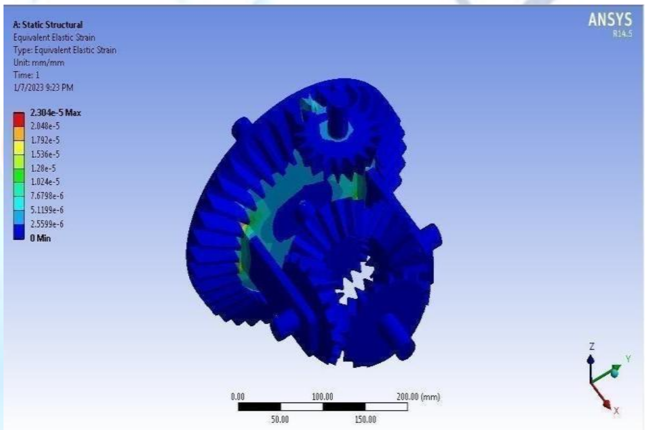

Fig : 29 equivalent strain of magnesium

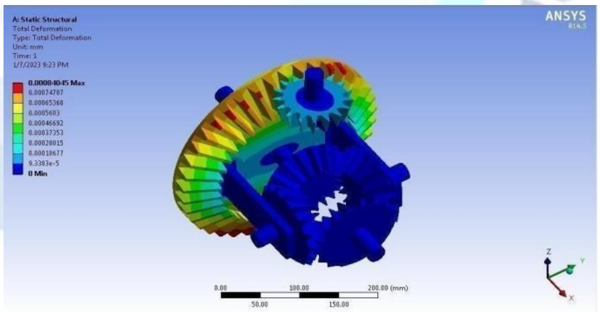

Fig : 30 total deformaton of magnesium alloy

Analysis of cast steel at torque 115 N-m:

the below fig:31, 32, 33 shows torque at 115N-m and total deformation, equivalent stress, equivalent strain of cast steel

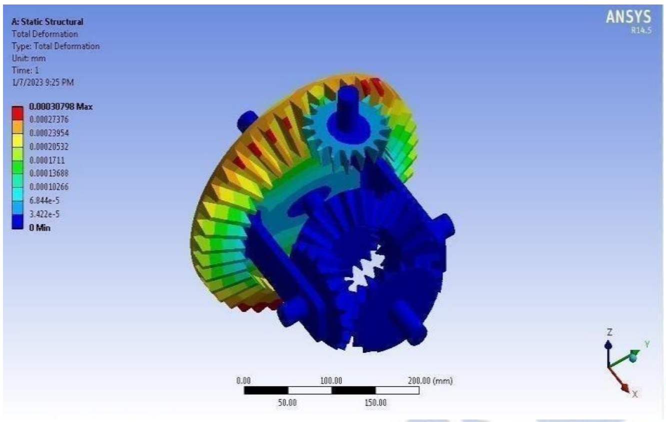

Fig : 31 total deformation of cast steel

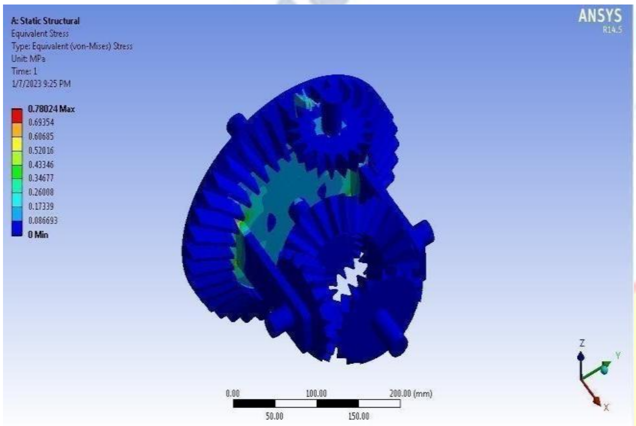

Fig : 32 stress of cast steel

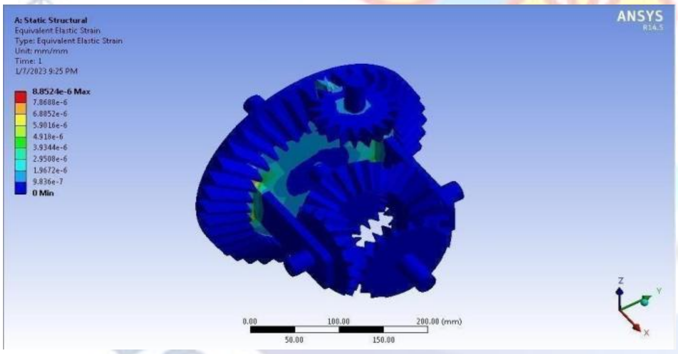

Fig : 33 equivalent strain of cast steel

5. Result and Discussion

The values obtained are noted in table 1, table 2 and table 3 and compared with cast steel, aluminum alloy and magnesium alloy. In the below table-1 shows the Different Maximum stress values, elastic strain values, total deformation values in different materials like cast steel, aluminum alloy and magnesium alloy at speed 4400 rpm, 2400 rpm and at torque 115N-m

Table :1 values obtained in analysis at 4400 RPM

Speed Consideration	**Speed at 4400 rpm**		
MATERIALS	CAST STEEL	ALUMINUM ALLOY	MAGNESIUM ALLOY
VON-MISES STRESS (MPa)	107.3	36.793	23.404
TOTAL DEFORMATION (mm)	2.6213e-2	1.5256 e-2	1.5363e-2
ELASTIC STRAIN (mm/mm)	9.2569e-4	5.3657e-4	5.3861e-4

Table : 2 values obtained in analysis at 2400 rpm

Speed Consideration	**Speed at 2400 rpm**		
MATERIALS	CAST STEEL	ALUMINUM ALLOY	MAGNESIUM ALLOY
VON-MISES STRESS (MPa)	31.924	10.947	6.963
TOTAL DEFORMATION (mm)	4.6793e-3	4.5389e-3	4.5709e-3
ELASTIC STRAIN (mm/mm)	1.6525e-4	1.5964e-4	1.6025e-4

Table : 3 values obtained in analysis at torque 115 n-m

Torque Consideration	**Torque at 115 N-m**		
MATERIALS	CAST STEEL	ALUMINUM ALLOY	MAGNESIUM ALLOY
VON-MISES STRESS (MPa)	7.8024e-1	7.7444e-1	7.6959e-1
TOTAL DEFORMATION (mm)	8.8524e-5	1.4762e-5	2.304e-5
ELASTIC STRAIN (mm/mm)	3.0798e-4	5.2809e-4	8.4045e-4

In This analysis is performed to find Structural parameters such as Total Deformation and von–mise stress Here we observed results on three materials namely aluminum alloy, grey cast steel and magnesium alloy. In this analysis are performed different speeds at 2400 rpm and 4400 rpm and torque 115N-m we obsereved to compare the different total deformation values, von-mise stress and equivalent elastic strain values in different materials, aluminum alloy material has least deformation, equivalent strain and von-mise stress values compared to cast steel and magnesium alloy.

6. CONCLUSION

The following conclusion can be drawn from the analysis conducted in this study. In this Project, we have successfully done analysis on differential with varying different speeds at 4400rpm and 2400rpm. Analysis is done to verify the best material for the Differential taking into account stress development, strain and deformation. This project is compare the different von mises stress values, total deformation values and elastic strain values for different materials like aluminum alloy, cast steel and magnesium alloy by comparing these three materials aluminum alloy has least values. In our Analysis, We Observe that All Three material are Good for the gear design but when it's come to weight reduction The aluminum alloys perform the as the best Option

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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