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DESIGN AND STRUCTURAL ANALYSIS OF PORTAL AXLE OF VECHICLE USING FINITE ELEMENT METHOD

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***Abstract:** Gear is one of the most commonly used component in power transmission between two parallel shafts, they are widely used in mechanical power transmission. Engineering components made of composite materials have find increasing applications ranging from space craft to small instruments. Portal axle is gearbox designed to increase the ground clearance of the vehicle for off-road driving conditions. The higher ground clearance depends on the arrangement of gear train of the portal axle. The gear train and shafts are the most critical part in the portal axle as they transmit and withstand very high loads. They should be designed to withstand overloading and lightweight for greater durability and performance of the portal axle. The Design and Structural Analaysis of helical gears in portal axle is important to predict the actual motion behavior. However, gear train design in portal axle is difficult to study comprehensively due to their relatively low cost and short product life cycle. The main objective of this project is design and analysis of portal axle for Scorpio S2(SUV) having helical gear train with two idler gear. In this study, 3D Model is created in catia software and Structural analysis of portal axle is simulated using finite element method (FEM) with four different materials Structural steel, Grey cast iron, 15Ni5Cr4Mo1, Aluminum alloy Finally observe the Von-misses stresses and Total deformation and conclude the which material is the suitable for the Axle portal gears .*

***Keywords:** Portal axle, Gear train, Helical gear, FEM, Catia, Ansys*

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I INTRODUCTION

Gears are one of the most critical components in mechanical power transmission systems. They are generally used to transmit power and torque. The efficiency of power transmission through gears is very high when compared to other kind of transmission. Portal axles (or portal gear train) are an off-road technology where the axle tube is above the center of the wheel hub and where there is reduction gearbox in the hub. Portal axle in vehicle gives two advantages, firstly ground clearance is increased and secondly axle shaft drive with same power but reduced torque. This reduces load on axle crown wheel and

differential. The Portal Axle is a gearbox unit at least two gears (input and output gear) combined to give greater offset between the input gear and output gear. portal axle and normal vehicle with portal axle.

Figure 1Portal gear box

In actual mounting of shaft in vehicle the input shaft of portal axle is used to receive the power from differential unit and sends it to portal axle unit and the output shaft transfer the power from portal axle unit to road wheels.

II LITERATURE REVIEW

"Manjunatha B, Malthesha P. J., Somashekar Hiremath", June 2014, "Design and Analysis of Input Shaft of a Portal Axle." The main objective of this project is design and analysis of input shaft of a portal axle unit with different thickness of hollow shafts. The portal axle input shaft models were modeled and analyzed using ANSYS software and validated through comparison of results with the analytical results.

"E. Jayaram, M. Rambabu", April 2013, "Structural Analysis of Gear Train Design in Portal Axle Using Finite Element." The paper states that the portal axle is a gearbox that is specially designed for off-road driving conditions. It is installed between the wheel and the axle shaft to give higher ground clearance to the vehicle.

"JongBoon Ooi1, Xin Wang1, ChingSeong Tan2", October 2014, "Modal And Stress Analysis Of Gear Train Design In Portal Axle Using FEM And Simulation." It investigated modal analysis on three different gear trains of the portal axle unit was studied using FEM simulation under free-stress state and pre-stressed state. The gear tooth maximum bending stress and contact stress were calculated using FEM for three different gear trains with respect to varying angular position involving single and double tooth contact.

"Umesh Shinde, Deepak C Patil", June 2015, "Finite Element Analysis Of A Portal Axle Gear Train Using Metallic And Composite Spur Gears." In this paper the cast steel which used in is the first type of steel that allowed alloys to be added to the iron. Prior to this method, manufacturers had not been able to get steel hot enough to melt. By heating blister steel in a clay crucible placed directly into a fire, Huntsman allowed the metal to reach up to 1600°C. Melting allowed other elements, such as nickel, to be mixed into the metal, thus strengthening the steel. Cast steel has a rough finish. It often has surface holes created by gas bubbling during heating process. Elastic metal, this type of steel is very tough, having 4 times tensile strength of cast iron. Literature Gap From above literature it is found that the gear train design is the main part for portal axle but it is available for spur gear train. For helical gear train for portal axle there is no such analysis done. Also very few data is available for experimentation of portal axle unit. There is no such research on total stress analysis of portal axle with casings and bearings.

Alternatively, FEA is used extensively in studying the stresses and vibrations in the gear train. With the advent of FEA and Computer Aided Design (CAD), the ability to simulate various gear design have been improved (Wei, 2004; Ooi, 2012). However, the model and the solutions in CAD and FEA must be evaluated carefully to ensure that the results are accurate. There are a number of research works done in investigating the gear tooth parameters and also validating the gear train models

(Draca, 2006; Xu, 2008; Stoker, 2009). However, the gear train models were simplified and limited to the analysis of a gear tooth model in two-dimensional (2D). For a more comprehensive study on the gear train stress and vibration characteristics, a 3D gear train model should be modelled and analysed to predict the actual motion behaviour of the gear train (Bruns 2007).

J.L. Moya, et al. (2007) they have performed a theoretical analysis of a procedure to determine the Lewis Factor and also performed the contact analysis of spur gears to find the stress distribution between gear teeth.

V. Siva Prasad et al. (2012) analyzed design of spur gear and proposed a gear for sugarcane juice machine. They created a model in PRO-E and analyzed in ANSYS10.0. From the analysis they found the Nylon gear is suitable for the application of sugarcane juice machine under limited load condition compared with cast iron spur gear.

N.Lenin Rakesh et al. (2018) investigated a spur gear is modeled using a modeling software Pro-E and using software ANSYS. The theoretical stresses of both bending and contact stress is found manually and then analyzed in ANSYS software. The readings are shown in the tabular column. It is found that comparing with manual results, results are approximate or closer to it.

Nitin kapoor et al. (2019) analyzed parametric model of differential Gearbox by using CATIA-V5.Glass filled polyamide composite and metallic materials (Aluminum alloy, Alloy Steel and Cast Iron) are also being performed and analyses using ANSYS for equivalent (Von-Misses) stress, displacement and maximum shear elastic strain for different revolutions under static conditions. A comparison gives Glass Filled Polyamide composite material is selected as a best material for Differential gear box.

III PROJECT OVERVIEW

SCOPE OF THE PROJECT:

1. Study the different Journals Related to the Axle portal gear assembly
2. Study the complete design analysis concepts about the axle portal of Scorpio car
3. Study the different materials Structural steel, Grey cast iron, 15Ni5Cr4Mo1, Aluminum alloy
4. To design portal axle with two idler gear for helical gear using the catia v5 software.
5. Create Finite element model of the axle portal using ANSYS software.

6. Perform Structural analysis (Pre processor ,solution, post processor)
7. Perform static analysis to calculate the von-misses stress, Total deformation
8. Finally concluded the suitable material of the Axle portal gear assembly based on the stress, and total deformation values

METHODOLOGY:

• Problem identification.

• Project literature study.

• Methodology.

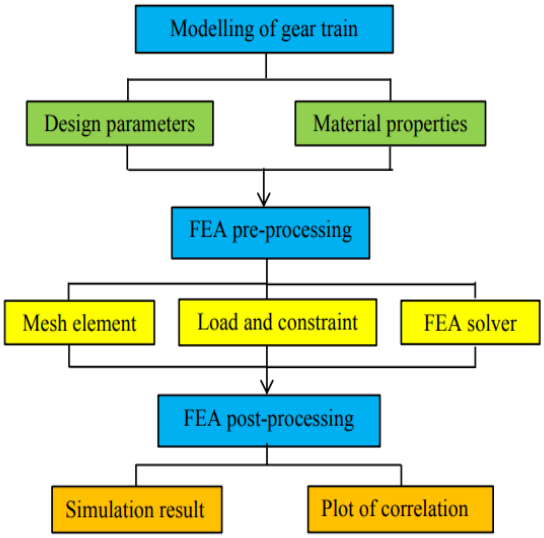
• Selection of design parameters for design stage.

• Create system model by using CAD.

• Finite element analysis by using ANASYS 16.

• Material procurement for gear.

• Results and discussion



PROBLEM STATEMENT

Improper material leads to the failure generally using Grey cast iron materials are using Portal axle unit is a special gearbox unit designed to increase the vehicle's ground clearance. Normal cars other than off-road vehicles its suspension gets damage due to low ground clearance which decreases the life of vehicle. Portal axle unit is a special gearbox unit designed to increase the vehicle's ground clearance. This gearbox can also be regarded as off-road technology where the axle tube is above the centre of the wheel hub. It allows driving on off-road so that the vehicle can go over high terrains and obstacles. Portal axle is normally designed for spur gear train system. In this project work it is proposed to substitute the Metallic gear Scorpio vehicle Advanced material.

MATERIAL PROPERTIES:

MATERIAL PROPERTIES	Density Kg/m³	Possion's ratio (u)	Youngs modulus (Gpa)	Ultimate Tensile strength (Mpa)
STRUCTURAL STEEL	7850	0.3	200	460
GREY CAST IRON	7200	0.28	110	430
15Ni5Cr4Mo1	7850	0.3	210	1350
ALUMINIUM ALLOY	2700	0.33	71	310

VEHICLE SPECIFICATIONS DIMENSIONS:

- Body type = SUV(Sport utility vehicle)
- Number of gears = 5
- Length = 4456 mm
- Height =1930 mm
- Ground Clearance = 180 mm
- Width =1820 mm
- Drive train= rear wheel drive
- Mileage = 16.7 kmpl
- Max Power = 75 bhp @ 3200 RPM
- Max Torque = 200 Nm @ 1400 RPM

IV DESIGN PROCEDURE IN CATIA WORK BENCH:

The input shaft is designed on given input specifications of Mahindra Scorpio as:

Given:

Speed = 4200 rpm Power = 55 kW Diameter, D = 96mm Length of shaft = 500mm

D1 = 96mm T1 = 24

D2 =144mm T2 = 36

D3= 72mm T3 = 18

INPUT GEAR:

Go to the sketcher workbench create the 96mm diameter by using circles after create the multiple teeths by using the rotate option as shown below figure. Go to the planes and create the offset plane after go to the rotate the object now apply multi section as shown below figure

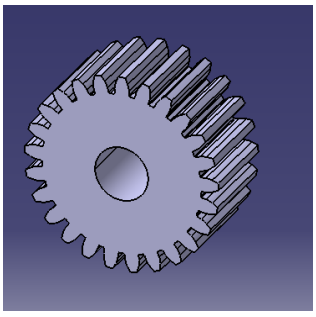


Figure 2 Input

Centre distance= 150mm Design of shaft:

Diameter of output shaft= 15mm

Diameter of input shaft= 15mm

The design of portal axle is based on following systems from both gear-train units as:

Input shaft

Output shaft

Spur gear train unit

Helical gear train unit

Bearing

Casing

The Input shaft, output shaft, bearings & casing are common design systems for both gear trains as spur & helical. The total ground clearance has to increase by 6 inch for both the spur and helical gear train as per the given input

OUTPUT GEAR:

Go to the sketcher work bench create the circle diameter 144mm as per dimensions after create the teeth profile after now create the teeth profile around the circle no of teeths is 36 after apply pad option as shown the figure.

D2 =144mm T2 = 36

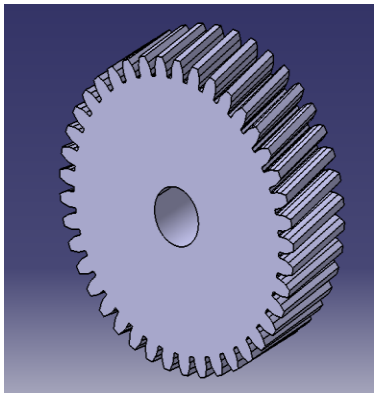


Figure 3 output gear

IDEAL GEAR:

Create the Spur gear radius is 36 in sketcher workbench by using circle after create the tooth profile again go to the operation tool bar apply rotate option 18 no's as shown below figure.

D3= 72mm T3 = 18

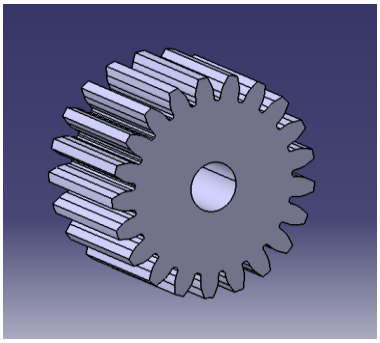


Figure 4 IDLE GEAR

ASSEMBLY WORK BENCH:

After create the parts all Gears Assembly in assembly workbench using product structure toolbars and constraints as shown below figures.

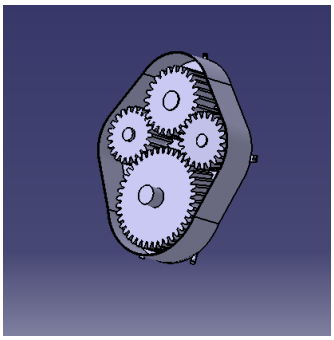


Figure 5ASSEMBLY WORKBENCH

V STRUCTURAL STATIC ANALYSIS*:*

A static analysis calculates the effects of study loading conditions on a structure, while ignoring inertia and damping effects, such as those caused by time varying loads. A static analysis can however include steady inertia loads and time varying loads that can be approximated as static equivalent loads. Static analysis is used to determine the displacements, stresses, strains and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady loading and response conditions are assumed, i.e. the loads and the structure's responses are assumed to vary slowly with respect to time. The kinds of loading that can be applied in static analysis include:

- Externally applied forces and pressures.
- Steady state inertial forces
- Imposed displacement
- Temperatures

Fluences (for nuclear swelling)

- Imposed displacement

PROCEDURE OF STATIC ANALYSIS ANALYSIS:

Create the geomentry in catia workbench and save the file in igs format and open ansys workbench apply engineering data(material properties), create or import the geomentry, apply model(meshing),applyboundaryconditions(setup)shown the results(stress,deformation,strain).

MESHING AND BOUNDARY CONDITIONS:

The stress analysis of helical gear train is carried out on ANSYS software. The fine meshing is done in a preprocessing of gear train model. The given generated mesh model of the gear train consisting of hexahedron elements, tetrahedrons elements and prism elements. From the mesh

model, the number of elements , nodes are 192652 and 331284 respectively.

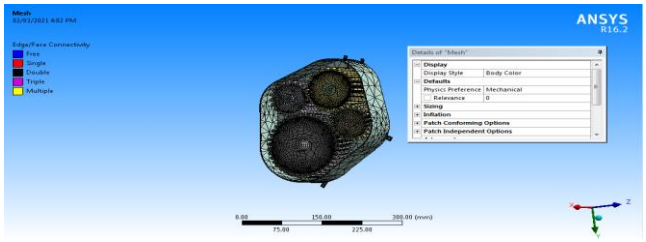


Figure 6MESH NODES: 192652 ELEMENTS :331284

BOUNDARY CONDITIONS

In the static structural approach the boundary conditions are set on the gear train in ANSYS setup. The load and surface constraints set in the ANSYS setup for simulating the static bending stress. Torque load of 25000Nmm

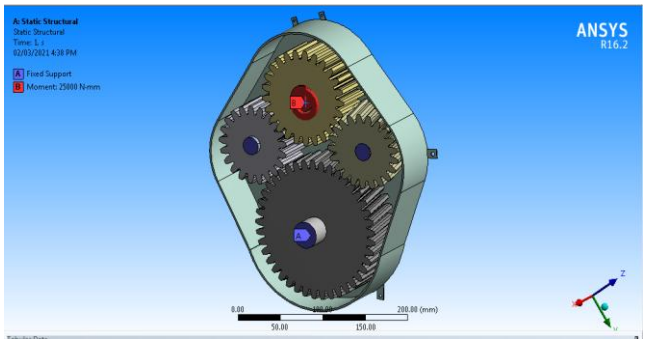


Figure 7BOUNDARY CONDITION

VI RESULTS AND DISCUSSION

In the static structural approach the boundary conditions are set on the gear train in ANSYS setup. The load and surface constraints set in the ANSYS setup for simulating the structural anlaysis. Torque load of 25000Nmm and tangential cylindrical support are applied on the hub surface of the input gear. In the tangential cylindrical support, the surface is rigid and restricts the input gear to rotate about its axis. The driven gear's inner surface is fixed at hub surface to load at the gear teeth With various materials Structural steel, Grey cast iron, 15Ni5Cr4Mo1, Aluminum alloy Finally findout the Von-misses stresses and Total deformation as shown below figures.

STRUCTURAL STEEL:

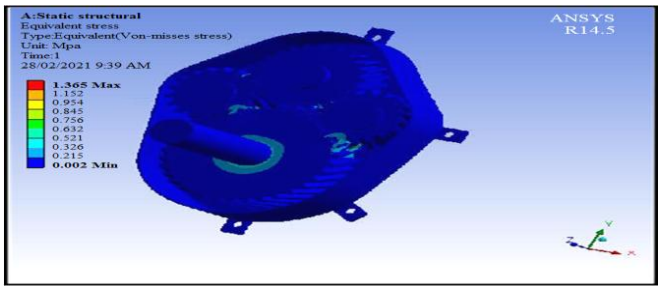


Figure 8Von-misses stress of structural steel

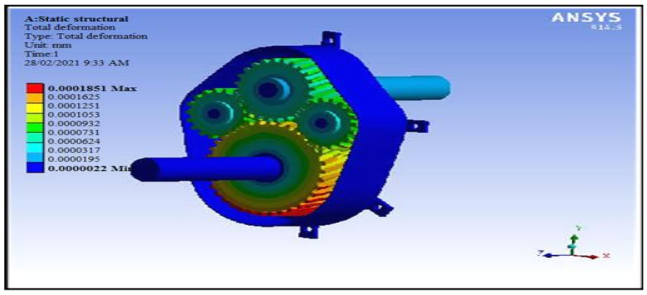


Figure 9Total deformation of structural steel

GREY CAST IRON:

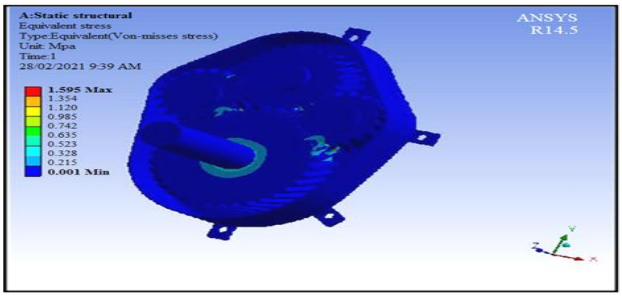


Figure 10Von-misses stress of grey cast iron

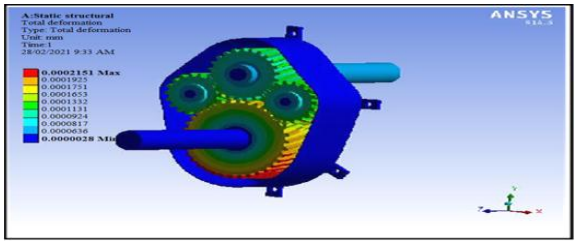


Figure 11Total deformation of grey cast iron

15Ni5Cr4Mo1Steel Material:

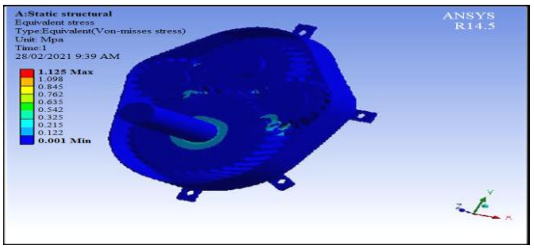


Figure 12Von-misses stress of 15Ni5Cr4Mo1

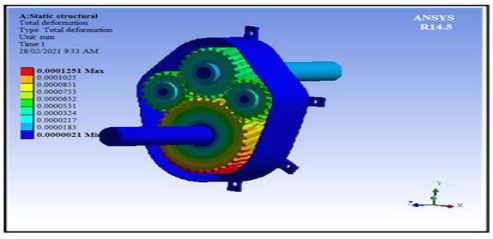


Figure 13Total deformation of 15Ni5Cr4Mo1

EQUIVALENT VON-MISES STRESS:

Here we compared equivalent von-misses stresses of 4 different materials . Finally we observe 15Ni5Cr4Mo1 Steel material is the low von-misses stress

VON-MISSES STRESS GRAPH

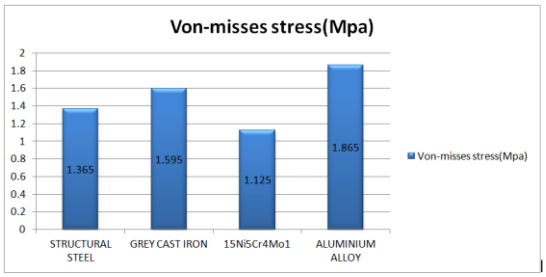


Figure 14VON-MISSES STRESS GRAPH

TOTAL DEFORMATION:

Here we compared Total deformation of 4 different materials of axle portal gear box . Finally we observed 15Ni5Cr4Mo1 Steel material have Low Total deformation.

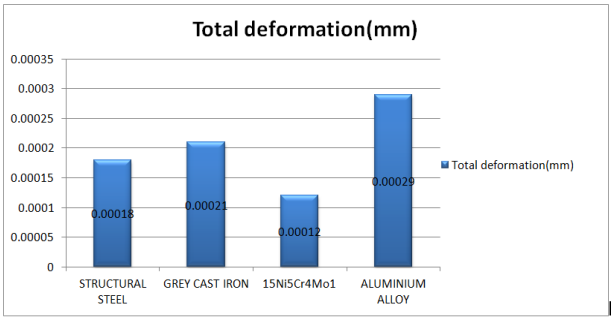


Figure 15TOTAL DEFORMATION

VII CONCLUSION

Design and Analysis of Portal axle is completed using with various materials are The portal axle is the system which increases the ground clearance of the vehicle. It is mainly beneficial for off-road driving conditions. The Portal Axle is a gearbox unit at least two gears (input and output gear) combined to give greater off-set between the input gear and output gear. Gear train with Helical gear provides more ground clearance than spur gear train for the same number of the teeth, module and pressure angle. 3D Model Design process using in catia software assembly the all parts Input gear, output Gear and 2 Idle gears with frame after export in ansys workbench using finite element method .In general, helical gears have more load carrying capacity and also produce less noise during power transmission compared with spur gear using various materials Structural steel, Grey cast iron, 15Ni5cr4Mo1,Aluminium alloy using the structural analysis in ansys software finally concluded the 15Ni5cr4Mo1 Material based on the von-misses stress and Total deformation values so it is suitable for manufacturing purpose in real time.

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