International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161

Available at http://inpressco.com/category/ijcet

Research Article

Design and Analysis of Portal Axle of vehicle

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Accepted 04 May 2017, Available online 06 May 2017, **Vol.7, No.3 (June 2017)**

Abstract

While driving vehicles on countryside road or off road conditions, obstacles in the road may cause damage to vehicle. To avoid that portal axle is designed to increase ground clearance of the vehicle. In this work a vehicle model was considered and portal axle was designed for it. The high ground clearance depends on the arrangement of gear train of the portal axle. The gear train and shafts are the most critical part of 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. Stress analysis of the gear train and shafts are necessary in evaluating the design for gear train and shaft. The characteristics of the gear train of the portal axle were investigated by analyzing the gear contact stresses, bending stresses of the gears by using finite element analysis (FEA) software such as ANSYS.

Keywords: *Portal axle, Torque calculation of vehicle, FEA analysis of gear train, off road vehicles, Design of gear train.*

1. Introduction

Portal axles are designed for off-road driving conditions. For off road conditions the ground clearance required is more since there would be more obstacles on the road than usual road conditions, also the torque requirement is more because of road conditions do not provide much coefficient of friction than usual roads. The axle tube is above the center of the wheel hub where there is a reduction in the gearbox. Portal axle is fitted in between the wheel and axle. Another method of increasing ground clearance is to increase the wheel dimensions, but since it also increases the C.G. of the vehicle and thus turning radius is more and the vehicle becomes unstable. So that's why portal axle is a better choice. Specifications of a particular vehicle were considered and portal axle was designed according to requirement. Testing was done on any commercial software like ANSYS. To understand the actual behavior of the system and to analyze the torque model of portal axle was prepared. The modeling & simulation of spur gears in portal axle was important to predict the actual motion behavior. In this study, static analysis of portal axle was simulated using finite element method (FEM).

2. Literature Review

Previous work done on this topic proposed the modal stress analysis of gear train design in portal axle using finite element modeling and simulation by Jong Boon Ooi *et.al.* (1). Another study stated that the parametric optimization of the output shaft of portal axle using FEA by Xin Wang *et.al.* (4). Static analysis of portal axle output shaft using composite material by Bhaskar K. *et.al.* suggested the use of composite materials in portal axle in output shaft so that the weight of the system is reduced with more strong and tough shaft, in this study different parameters were considered and by varying those best solution was selected (3). Structural Analysis of Gear Train Design in Portal Axle Using Finite Element Modeling by E. Jayaram, M. Rambabu., in this FEM static stress analysis is simulated on three different gear trains to study the gear teeth bending stress and contact stress behaviour of the gear trains. The single and double pair gear teeth contact are also considered (2). Drive Wheel Motor Torque Calculations provided the basis for design of portal axle with the help of which the torque was found for required vehicle and portal axle designed according to it(5). The aim of this work was to design a portal axle unit for selected vehicle and analyze using FEA.

3. Problem Statement

While driving vehicles on off road conditions, obstacles may damage vehicle to avoid that we propose the design of portal axle for a certain vehicle model that would modify ground clearance of it then finally validate the design by testing model prepared.

4. Methodology

Previous method used for power transmission of a vehicle includes differential gear box and the half

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shafts connected to the wheels. New proposed method adds an additional gear box (portal axle) which takes input power from half shafts and then through reduced speed ratio transmits it to the wheels. Ground clearance was increased equal to the central distance between input and output shaft.

This gear train consists of simple gear train with two idler gears and input, output gear. The centre distance between them was required to increase the ground clearance and the requirement of increased torque decides gear ratio between them.

This study consists of following chronological step of working:

Project literature study

Project literature studies include the study of previously done work on this portal axle and understand the basic concept and working of portal axle. Literature studied was helpful for selecting best suited system structure. Also study provides a base for our design and analysis. The FEA study stated type of analysis to be done, boundary conditions, constraints considered in the analysis.

Design stage

At the design stage of the project, considered a vehicle model was Mahindra Scorpio S2 for which portal axle was designed. According to considered specifications of the vehicle and assumed off road conditions, difficulties faced by vehicles on these off road conditions various parameters of portal axle were found that would solve the problem.

System drawing

In this step CAD model of portal axle was created as per designed dimensions. A model was created in CATIA which was an input for the analysis stage.

FEA analysis

In the FEA analysis stage designed model is analyzed in ANSYS 14.5. this analysis involved 3 steps preprocessing, solution and post processing. Static structural analysis preprocessing had following steps

- CAD model is imported in ANSYS created in the previous stage
- Element type was defined
- Fine meshing was done
- Material properties were assigned
- Contact types of gear meshing were selected as no separation
- Frictionless support applied at every gear's internal bore.
- Moment was applied to gear equivalent to the torque

In solution step applied boundary conditions and constrains were solved to find results of analysis.

In post processing results in, deformation, stresses, 3D model to facilitate viewing of internal stress pattern were defined and interpreted. Factor of safety was also found to validate design.

Material procurement

In this stage, according to design criteria and FEA results, proper materials were selected among which readily available and economical.

Manufacturing stage

This stage includes preparing a process chart which has all the production processes to be done on raw material for manufacturing model components. Criteria for selecting a manufacturing process was accuracy required economic consideration.

Fabrication of assembly

After all components were manufactured next stage was to assemble all components. Gears were mounted on a shaft; selected bearings were installed in casing all this mounted in frame. Selected motor was mounted on the frame and connected to the input shaft of portal axle. Welding, laser cutting, boring were the processes done in assembly of the unit.

Trials and troubleshooting

After assembly a trial run was done for understanding troubles occurring in the unit. Then these problems were solved. For ex. The noise of meshing gears could be reduced by grinding and finishing gear teeth, stuck gears, over heating are some problems that may occur which solved by understanding the root cause of it.

Testing

In testing phase model was tested for various loads applied on output shaft by using belt dynamometer. Results were then compared with the required tractive effort for off road conditions.

Conclusion

Conclusion stage involved confronting results which achieve our final aim.

5. Design

In design stage vehicle specification was decided on which portal axle was to be installed and then according to that required torque was calculated considering vehicle and passenger weight. This was the input given to the design process. Torque is calculated by,

Total Torque = Tractive effort * Radius of Tyre * Resistance factor
In which total tractive effort was given by
Total tractive effort = RR + GW+ FA
Where RR- rolling resistance
GR- Grade resistance and FA – acceleration momentum [6]
According to Lewis form factor method considering dynamic load on gear module and other dimensions of gears were checked. (8)

$$F_b = \sigma_b b\, m\, y \quad (1)$$

Where F_b- bending load
σ_b- bending stress
m- module of gear
b- face width of gear
Y- lewis form factor
Then for wear stress

$$F_w = b\ k\ Q\ D_p \quad (2)$$

b – face width
k- load stress factor
Q- ratio factor
D_P- diameter of pinion
Then these loads were checked against P_{eff} which was an effective load includes tangential load and the dynamic load

Buckingham dynamic load equation (7)

$$P_d = \frac{21 \times v(b \times ce + F_t)}{21v + \sqrt{(bce + F_t)}} \quad (3)$$

Finally Factor of safety was found (7)

$$FOS = \frac{Fw}{Peff} \quad (4)$$

Shafts were designed according to principal shear stress theory (7)

$$\frac{1}{2}\left[M + \sqrt{M^2 + T^2} \right] = \frac{\pi}{32}\sigma_b d^3 \quad (5)$$

Appropriate bearing was selected considering static and dynamic tangential and radial load.

6. System drawing

CATIA V5 is a complex engineering design software used , among many others , in parametric 3D modeling surface modeling and structural simulation, it contained comprehensive libraries for standard parts and had the possibility to create user defined libraries for repetitive content. As gears were not included as accessible parametric parts gave a simple yet complete solution for integration of gear repetitive content as accessible function embedded in the program platform. The geometry of a spur gear was controlled by well-known parameters so the generic gear would be controlled by those parameters while mounting would be considered with single keyway for key mounting on the shaft for involute spline joints on shaft Spur spline, Helical spline

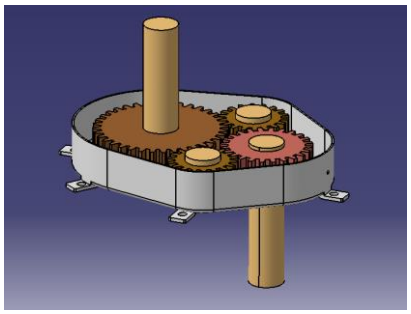

Fig 1 CAD Model of portal axle

7. Finite Element Analysis

In the analysis section design was checked which confirmed the design is safe. A three dimensional model of system was created and meshed in the software package. Available constraints were given to the model like material properties and load acting on it. Solution of the problem gave the stresses both contact and bending on gear tooth and suggest if any modification was required or not.

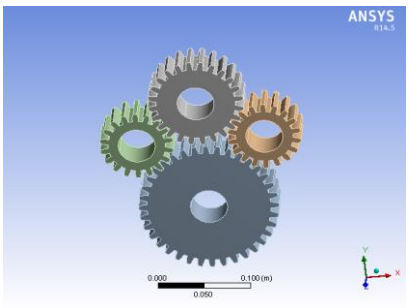

Fig 2 Model of portal axle

The meshing of the spur gear train is as shown in above figure Standard element size were used for meshing of a gear pair to obtain the best results in the analysis . Fig .(3) shows mesh model of portal axle.

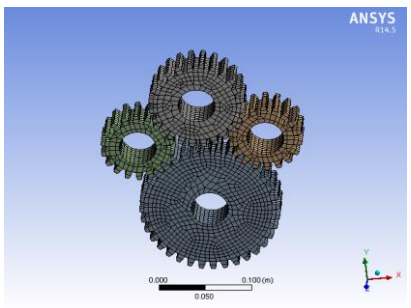

Fig 3 Meshing of portal axle

Then frictionless support and no separation contact were applied to each gear for smooth rotation of a gear pair as shown in fig.(4)

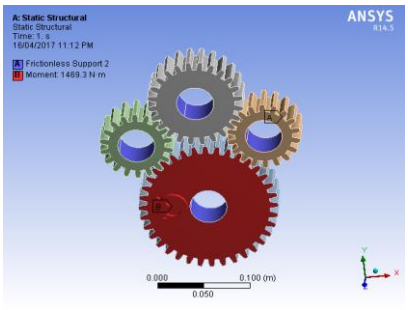

Fig 4 Support and moment applied on model

According to analytical solutions, it has been calculated that the torque applied was 1462 Nm. Thus after applied moment of 1462 Nm to one gear gave the results. Figure (4) shows the boundary condition for the static analysis.

Interpretation: The maximum stress was (57.14) MPa at the contact of two mating gear.

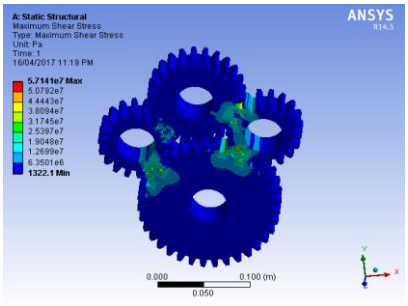

Fig 4 Stress on gear pair

Interpretation: The maximum deformation of Gear pair was (3.03e-5) mm.

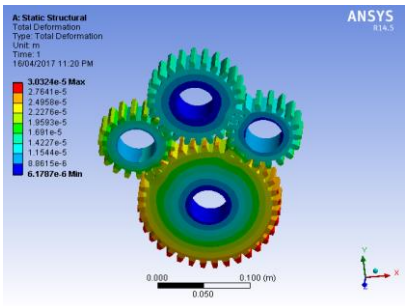

Fig 6 Deformation of gear pair

Future scope

- As we have seen portal axle being used in off road conditions in the same way it can be used in buses and trucks for reducing ground clearance so that it allows ease of boarding on buses or other passenger vehicles.
- Portal axle using various gear trains and other gears can be implemented for better results
- Composite material can also be effective to improvise the portal axle
- Since adding gear system in a vehicle we have reduced power at the wheels so need to consider various losses in portal axle and reduce those we have to find a suitable solution for this.
- And finally adjustable ground clearance can also be implemented in vehicles using various gear mechanisms.
- We developed this gear system for on road vehicles also, so while designing we do not consider the parameters that on road vehicles have influences such as an extra load on the engine, vibration analysis, and also we have to consider the amount which can we raise the ground clearance considering human ergonomics

Conclusion

Increase in ground clearance, reduced damage to the differential gearbox casing and enable to drive a vehicle in off road conditions. Provided that C.G. was unaltered, vehicle was more stable, turning radius of the vehicle was also less. FEA analysis helped in material selection, optimization of design. Torque measurement helped in determining torque provided by portal axle compared with the required tractive effort for various driving conditions.

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