Design and Analysis of Portal Axle

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Abstract— This project is related to the ground clearance and its toughness. Increased ground clearance is probably the main reason why serious off-roaders choose to fit portal axles to their vehicles. Hence we studied various gear arrangement for portal axle. Keywords: portal axle, Design of portal Axle, gear train design, Portal axle with spur & helical gear train

I. INTRODUCTION
Portal axles (or portal gear) are an off-road technology where the axle tube is above the center of the wheel hub and where there is a reduction gearbox in the hub. This gives two advantages: ground clearance is increased, particularly beneath the low-slung differential housing of the main axles; and secondly the hub gearing allows the axle half shafts to drive the same power but at reduced torque (by using higher shaft speed). This reduces load on the axle tube and differential casing are tucked up higher under the vehicle. The size of the differential casing can be reduced to gain even more ground clearance. Additionally, all drivetrain elements, in particular the transfer gearbox and drive shafts can be built lighter. This can be of use in lowering the center of gravity for a given ground clearance. To be able to drive off the pavement, off-road vehicles need several characteristics. They need to have a low ground pressure, so as not to sink into soft ground, they need ground clearance to not get hung up on obstacles, and they need to keep their wheels or tracks on the ground so as not to lose traction.

II. PROBLEM STATEMENT
Design study of spur gears is analyzed with the analytical as well as experimental results such that it can transmits the Power through engine to wheel

III. OBJECTIVE
1) To design a machine which can overcome all problems should occurs during off roading of the vehicle.
2) Increase the ground clearance of the vehicle as much as possible without changing its Centre of gravity.
3) Test a portal axle on maximum engine speed with various acting 1 soad.

IV. METHODOLOGY
Steps to be considered while analysis the portal axle:
- Design inputs from vehicle for portal axle analysis with spur gear train.
- Analytical study of gear trains with ANSYS interface.
- Comparative study of gear trains by FEA approach.
- Manufacturing of portal axle as input shaft, output shaft & gear train with spur gear trains
- Results.

V. CALCULATION
A. Design- Since both gear are of same material, pinion is Weaker.

1) Design for Pinion
Let,
Number of teeth T1 = 24 ... Available standard
So, module = m
Diameter, D = T × m
Velocity, v = πDN / 60 = 527.52m
Also W_t = (σ_o × C_v) b × π × m × y .... (1)
Tangential Tooth load
P/v = W_t
... (2)

Where allowable stress = σ = S_u / 3 = 150 MPa
.. For Steel, S_u = 450 MPa
Velocity factor = C_v = 6/(6 + v)
... For hobbed generated Spur Gears
Y = 0.175 – (0.841/T) ... for 20deg Stub teeth
So,
y = 0.139
Width of gear face = Max. = 12.5m to 20m
So, b = 10*m
Equating equations 1 & 2
P/v = (σ_o × C_v) b × π × m × y
On Simplifying, we get:
4125.96 × 3 – 55020.336 × 62.58 = 0
On solving, we get positive value of m is: m = 3.65
So, Module = 4

Now,

Diameter,
D1= 4 × 24
D1= 96

For Driven Gear
Also, Diameter of driven gear
D2 = D1 × 1.4
D2 = 144
T2 = 36
Now,
Minimum number of teeth on smaller Gear to avoid Interference is given by:

$$T_1 \geq \frac{2\sigma_w 1^2 P_d}{\sqrt{1 + \frac{1}{T_2^2} + \frac{1}{T_2^2} + 2 sin^2\phi - 1}}$$

For,  $T_2 = 36$  … No. of teeth on driving gear $T_1 \geq 16.01$

Also, for,  $T_2 = 2$  … No. of Teeth on Driven Gear $T_1$

So, Our Assumptions are correct

Gear dimensions are,

$D_1 = 96T_1 = 24$

$D_2 = 144T_2 = 36$

$D_3 = 72T_3 = 18$

$h = Length \text{ of the tooth, } = 2.25*m = 9$

Addendum = 1m = 4

Dedendum = 1.25m = 5

Clearance = 0.25m = 1

$b = Width \text{ of gear face.}$

Max. $= 12.5m \text{ to } 20m$ So, let’s take $S_b = m \cdot b \cdot \sigma \cdot \pi \cdot y$

Where

Allowable stresses

$\sigma = S_{ut}/3 = 150 \text{ N/mm}^2$

Tooth form factor or Lewis factor

$y = 0.175 - (0.841/Te)$  … for 20deg Stub teeth

$\sigma = 0.146$

$S_b = 10264.032 \text{ N}$

Since, Static tooth load is much more than the tangential load on the tooth, therefore the design is satisfactory in static load.

− Half – Shaft:

The half-shaft connects the differential gear box to the gear arrangement of portal axle. We can assume this shaft as an input of the portal axle arrangement.

− Calculation of Torque at Half-Shafts:

Shock torque = factor of safety x first gear ratio x final drive x maximum engine torque $= 2.5 \times 1.833 \times 2.15 \times 280 >= 16.73$

$T_1 \geq 16.73$

Let,

No. of teeth on Intermediate Gear is $T_3 = 18$

$D_3 = 18*4$

$D_3 = 72$  … As this is greater than 30 mm, our assumption is correct

Now, $T_3/T_1 = D_3/D_1 = 0.75$

$T_2/T_3 = D_2/D_3 = 2.0$

$T_2/T_1 = D_2/D_1 = 1.50$

It can be seen that $T_3/T_1 * T_2/T_3 = T_2/T_1$

$D_2/T_1 = D_2/T_3$

$b = 10*m = 40mm$

Thickness of tooth, $t = 1.5708 m = 6.28$

VI. SIMULATION WORK

A. Analysis

Gears are the most important members of mechanical power transmission systems. For power transmission spur gears have become the subject of attention. The main factors responsible for the failure of a gear set are torsional stress and vibrational analysis of a gear tooth. Therefore stress analysis becomes an important area of research which deals with minimization or reduction of the stresses and also with optimal design of gears. For analysis of spur gears the stress & vibrational analysis are essential.

B. Spur Gear Train:

<table>
<thead>
<tr>
<th>Gear</th>
<th>Diameter (mm)</th>
<th>Teeth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driving</td>
<td>96</td>
<td>24</td>
</tr>
<tr>
<td>Intermediate</td>
<td>72</td>
<td>18</td>
</tr>
<tr>
<td>Driven</td>
<td>144</td>
<td>36</td>
</tr>
</tbody>
</table>
C. Bearing:

<table>
<thead>
<tr>
<th>Actual radial load</th>
<th>650233.02 N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load rating</td>
<td>7175774.397 N/m²</td>
</tr>
<tr>
<td>Selected bearing</td>
<td>Ball bearing 208</td>
</tr>
</tbody>
</table>

D. Stress Analysis

The CAD model is considered with specified geometry approach with given input data. The meshing is hence done for selected size and nodes. Finally the structural behavior of given portal axle is analyzed with spur gear train.

E. Equivalent Stress

VII. DESIGN AND SELECTION OF MATERIAL

A. Shaft

EN8 carbon steel is a common medium carbon and medium tensile steel, with improved strength over mild steel, through-hardening medium carbon steel.

B. Plate (Casing):

C. Spur Gears:

The gears made of cast iron have low cost of manufacture, are easy to machine with high damping. Cast iron has good machining characteristics like dry cutting, better dimensional stability, longer cutter life, and superb surface finish.

D. Design Assembly Model
E. Actual Model

VIII. EXPERIMENTAL ANALYSIS AND TESTING

A. Procedure:
1) First the output shaft is connected to the rope brake dynamometer with the help of another coupler.
2) Then start the motor and record the initial rpm of the motor without any load acting on it.
3) Now with help of spring balance increase the load one by one on the motor.
4) Note down the motor speed for various acting load on to the motor.

B. Observations:

<table>
<thead>
<tr>
<th>Load (Kg)</th>
<th>Input Speed (rpm)</th>
<th>Output Speed (rpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case1</td>
<td>0</td>
<td>1500</td>
</tr>
<tr>
<td>Case2</td>
<td>15</td>
<td>1500</td>
</tr>
<tr>
<td>Case3</td>
<td>20</td>
<td>1500</td>
</tr>
<tr>
<td>Case4</td>
<td>25</td>
<td>1500</td>
</tr>
</tbody>
</table>

C. Result:

IX. CONCLUSION

Increased ground clearance is probably the main reason why serious off-roaders choose to fit portal axles to their vehicles. The second is toughness. If you’re going to be tackling grade five trails on a regular basis, breakdowns are inevitable, but they happen less often when you’re running portal axles with reduction gears. These are not the only benefits, however. There are a few others, too. As you’ve probably seen on vehicles like the Unimog and the G63 AMG 6x6, portal axles allow for the installation of central tyre- inflation systems.

You can’t put an airline through a CV joint, but once the joint is above the wheel spindle, it becomes possible.

Hence we studied various gear arrangement for portal axle, and we can conclude that the portal axle is necessary for the modern cars. Now a day we can see almost all off road cars having a portal axle. It provides good handling to the driver, clearance is increased. Material selection and design of gears is studied too.

REFERENCE

[1] JongBoon Ooi1, Xin Wang1,*, ChingSeong Tan2, Jee-Hou Ho3 and Ying Pio Lim[1]: Modal and stress analysis of gear train design in portal axle using finite element modeling and simulation


