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 crown wheel and differential. Compared to normal layout, portal axles enable the vehicle to gain a higher ground clearance, as both 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 l 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, $v = \pi DN / 60 = 5275.2m$
Also $W_t = (\sigma_o \times C_v)\, b.\pi.m.y$ …. (1)
Tangential Tooth load
$= W_t = P/v$ … (2)
= 55*1000/5275.2m = 10.43/m
Where allowable stress =
$\sigma = S_{ut} / 3 = 150$ MPa .. For Steel, $S_{ut} = 450$ MPa
Velocity factor =
$Cv = 6/(6 + v)$ … For hobbed generated Spur Gears
= 6/(6 + 5275.2m)
$Y = 0.175 – (0.841/T)$ … 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
$P/v = (\sigma_o \times C_v)\, b.\pi.m.y$
On Simplifying, we get:
$4125.96m^3 – 55020.336m – 62.58 = 0$
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
$D_2 = D1*1.4$
$D_2 = 144$
$T_2 = 36$
Now,

Minimum number of teeth on smaller Gear to avoid Interference is given by:

$$T_1 \geq \frac{2a_w \frac{1}{T_2} P_d}{\sqrt{1 + \frac{1}{T_2}\left(\frac{1}{T_2} + 2\right) sin^2\phi - 1}}$$

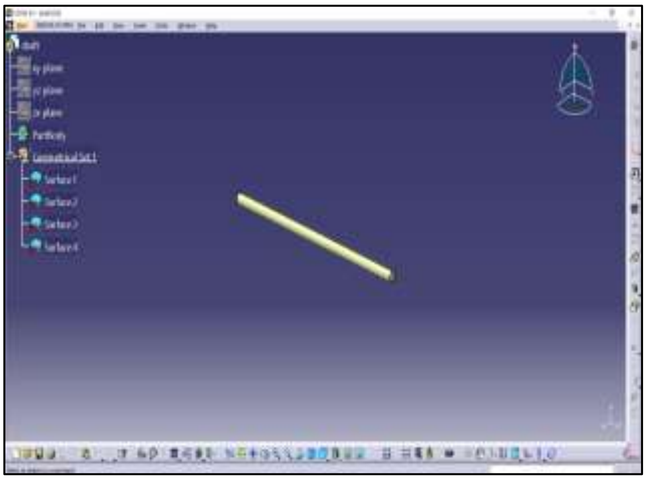
For, $T_2 = 36$ … No. of teeth on driving gear
$T_1 >= 16.01$
Also, for, $T_2 = 2$ … No. of Teeth on Driven Gear T_1
So, Our Assumptions are correct
Gear dimensions are,
$D_1 = 96T_1 = 24$
$D_2 = 144T_2 = 36$
$D_3 = 72T_3 = 18$
h = Length of the tooth, = 2.25*m = 9
Addendum = 1m = 4
Dedendum = 1.25m = 5
Clearance = 0.25m = 1
b = Width of gear face.
Max. = 12.5m to 20m So, let's take
$Sb = m_n.b.\sigma.\pi.y$
Where
Allowable stresses
$\sigma = S_{ut} / 3 = 150$ N/mm2 Tooth form factor or Lewis factor
y = 0.175 – (0.841/Te) … for 20deg Stub teeth
= 0.146
Sb = 10264.032 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 x 1.833 x 2.15 x 280
>= 16.73
$T_1 >= 16.73$
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,
T3/T1 = D3/D1 = 0.75
T2/T3 = D2/D3 = 2.0
T2/T1 = D2/D1 = 1.50
It can be seen that
$T_3/T_1 * T_2/T_3 = T_2/T_1$
$D_1/T_1 = D_2/T_2 = D_3/T_3$
b = 10*m = 40mm
Thickness of tooth,
t = 1.5708m = 6.28



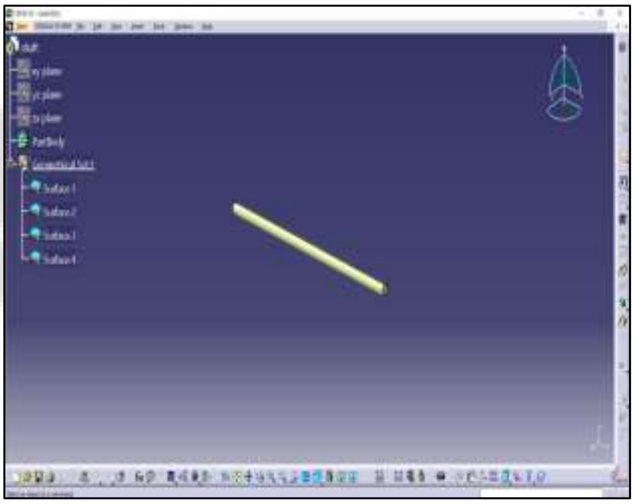
– Strength of gear

$\sigma_w = (Wt.h)*6 / bt2$
$\sigma_w = 356.89$ MPa

– Static Tooth Load

= 2758.665 N-m.

From the design calculation we find that the required external and internal diameter of the half – shaft as per the specified engine parameters and given conditions is 29 mm and 5.6 mm.



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:

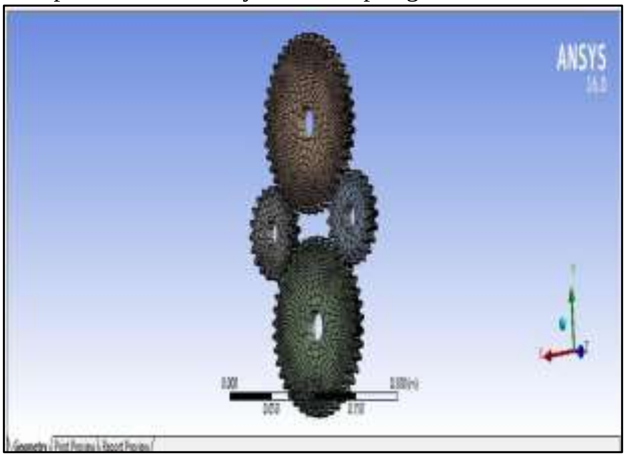
Gear	Diameter (mm)	Teeth
Driving	96	24
Intermediate	72	18
Driven	144	36

C. Bearing:

Actual radial load	650233.02 N
Load rating	7175774.397 N/m2
Selected bearing	Ball bearing 208

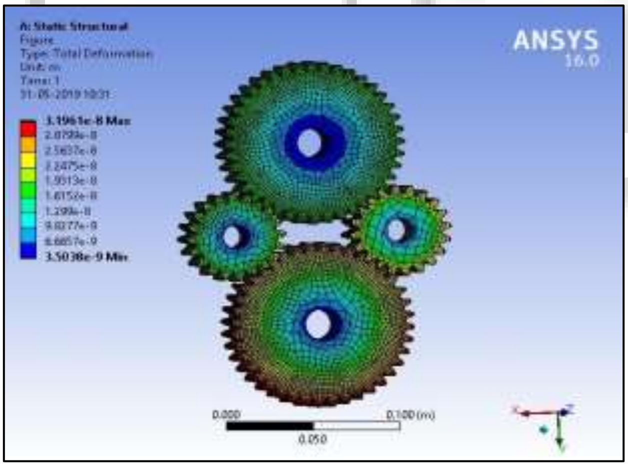
D. Stress Analysis

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.

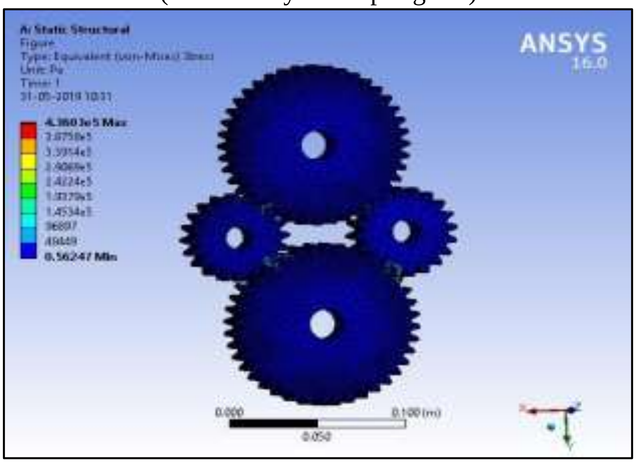


(Meshing of spur gear.)

E. Equivalent Stress



(Stress analysis of spur gears)



(Equivalent (Von Mises) stress on FEA software)

VII. DESIGN AND SELECTION OF MATERIAL

A. Shaft

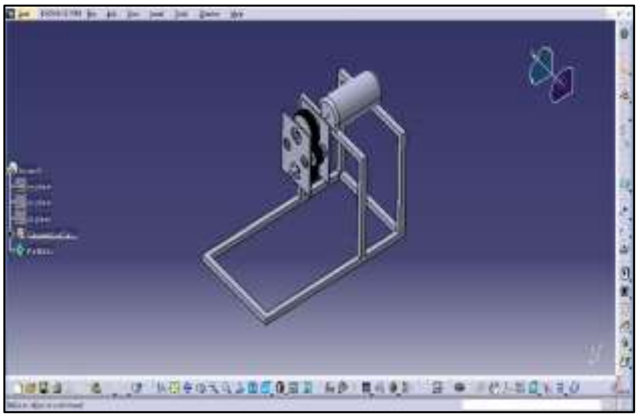
EN8 carbon steel is a common medium carbon and medium tensile steel, with improved strength over mild steel, through-hardening medium carbon steel.

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

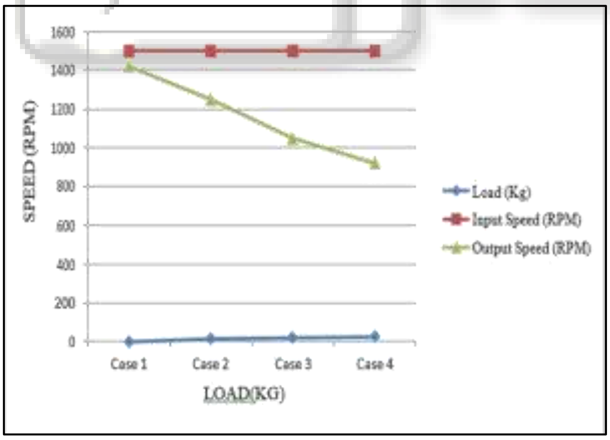
A. Procedure:

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

B. Observations:

	Load	Input Speed	Output Speed
Case1	0	1500	1420
Case2	15	1500	1250
Case3	20	1500	1050
Case4	25	1500	920

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 6×6, 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.

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