Design and Manufacturing of Gear Mechanism for Portal Axle

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Abstract:
Portal axles are an off-road technology where the axle tube is above the centre of the wheel hub and the gearbox in the hub, thus ground clearance is increased. The higher ground clearance depends on the arrangement of gear train of portal axle in which input shaft of portal axle is used to receive the power from differential and sends it to the portal axle gear train and output shaft of portal axle transfer the power from portal axle gear train to road wheels. The portal axle is a gearbox unit with minimum two gears i.e. input gear and output gear. Portal axle are commonly installed in four-wheel drive. The main objective of this project is design and analysis of gear mechanism for portal axle.

I. INTRODUCTION

Portal axles are designed for off-road driving conditions. For off road conditions more ground clearance is required since there would be more obstacles on the road than usual road conditions. The torque requirement is also more is more . 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 increases and the vehicle becomes unstable. For this reasons portal axle is a better choice. Specifications of a particular vehicle were considered and portal axle was designed according to requirement. In off-road driving, portal axles are frequently subjected to shock and overloading. It may lead to failure of the gearbox. Therefore, gears in the portal axle must be designed with the extremely high strength to obtain performance. Spur gear is widely used for large power transmission. Since teeth of the spur gear is parallel to the axis, its efficiency and power rating is more. It can be used at vast range of speed ratio. Gear failure can occur in various modes.
Schematic diagram of normal and portal axle is showed in the fig.1

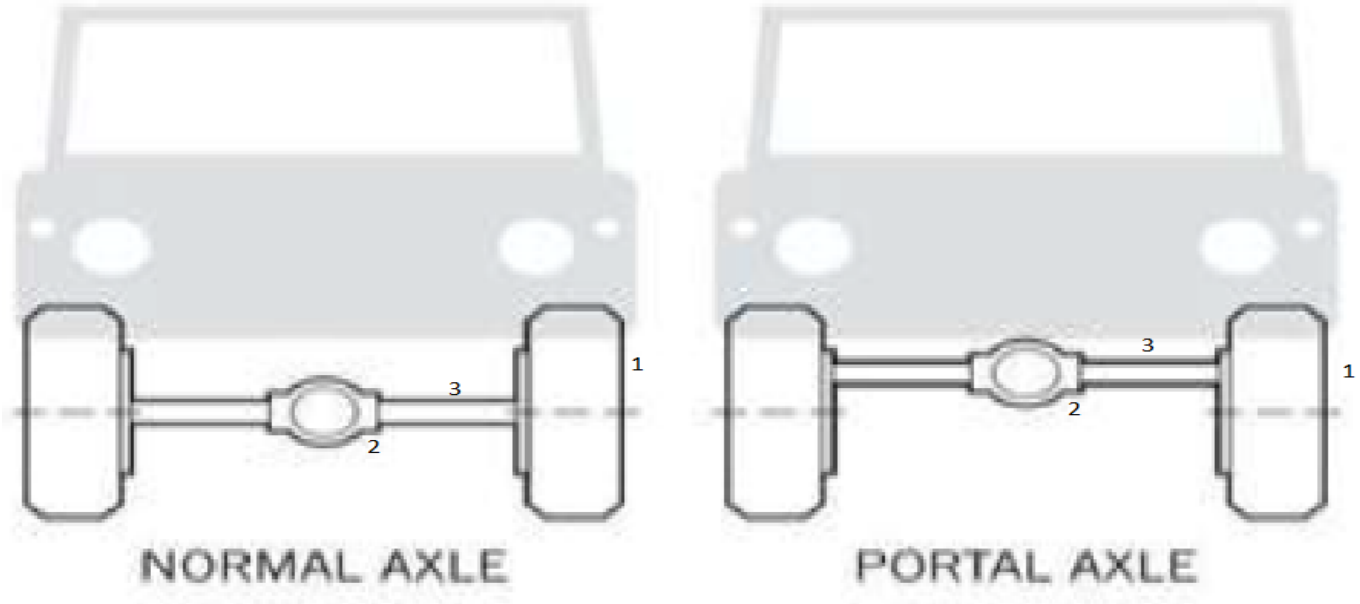


Fig.1 Difference between Normal and Portal axle

1.Wheel
2.Differential
3. Axle of vehicle

RELEVANCE

Portal axle is required for military vehicles and for off-road condition vehicles. For these helical gear mechanism is used. By using Gear mechanism ground clearance is increased. So, chances of vehicle damages are minimized.

II. LITERATURE REVIEW

Umesh Shinde etal[1] , the author serves as a novel approach for gear train design evaluation, and the study of gear stress behavior in gear train which is needed in the small workshop scale industries.
Jong Boon Ooi etal[2] , the author shows optimized model improvement in torsional strength with a slight increase in weight compared to the benchmark mode.
V.B.Math etal[3] , In this paper portal axle shaft analyzed by Finite Element Analysis considering three different composite materials and varying parameters. i.e. rib thickness and hollow shaft thickness are consider.
JongBoon Ooi etal[4] , this methodology serves as a novel approach for gear train design evaluation, and the study of gear stress behavior in gear train which is needed in the small workshop scale industries.
Manjunatha B etal[5] , the main objective of this project is design and analysis of input shaft of a portal axle unit with different thickness of hollow shafts.
E. Jayaram etal[6] , the author represent, structural analysis of portal axle is simulated using Finite Element Method (FEM).
Tejasvi J. Lahoti etal[7] , the design of portal axle elements as input shaft, output shaft, gear train, casing & bearings is to be analyzed.

III. CONCLUDING REMARK FROM LITERATURE REVIEW

The portal axle is the system which increases the ground clearance of the vehicle. It is commonly installed on four wheel-drive vehicles. Because of portal axle in vehicles gain additional ground clearance to protect underneath components from damage. Due to portal axle increases torque transmission capacity of vehicle.

IV. PROBLEM STATEMENT

Normal cars other than off-road vehicles its suspension gets damaged due to low ground clearance which decreases the life of vehicle. Suspension of normal vehicle gets damage due to low ground clearance. This decreases life of vehicles also while driving vehicles on off-road conditions also obstacle may damage vehicle.
To avoid this design the gear mechanism for certain vehicle SUV like Scorpio which are having low ground clearance. So design the gear mechanism for portal axle with Helical gear which are mount on wheel hub to increase ground clearance.

V. SCOPE OF WORK

The investigation of work is based on numerical analysis and experimental validation of spur gear train system of portal axle unit. For numerical analysis the FEA approach carried on ANSYS Is used to study detailed stress analysis. The experimental torque transmission ability is also to be investigated to get better results.

VI. DESIGN AND MANUFACTURING OF GEAR MECHANISM

The project designing will start by sketching some rough models and selecting suitable design from it. After sketching start with calculation part in which select various forces acting on it and most essential that is material are going to choose for it. The calculation part will contain design of helical gear, shaft, bearing , and casing. 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.
SELECTION OF MATERIAL: The gear material should have the following properties:

1. High tensile strength to prevent failure against static loads
2. High endurance strength to withstand dynamic loads
3. Low coefficient of friction
4. Good manufacturability

Cast steel was used to manufacturing the gears of the portal axle because it has high melting point. Melting allowed other element, such as nickel to be mixed into the metal, thus strengthening the steel Cast steel has a rough finish.

Table 1

Youngs modulus	$2\times 10^5 Mpa$
Poissons ratio	0.29
Density	$7.85\times 10^{-6} kg/mm^3$
Tensile strength	518.8Mpa
Yield tensile strength	415Mpa
Ultimate Tensile strength	540Mpa

DESIGN CALCULATION
Helical gear design- Given:

Power = 55 kW
N2 = 2800 rpm
Gear Ratio = 1.5 Standard value of Speed ratio for High speed Helical Gear is 1:1 to 10:1

∴ N1 = 4200 rpm
Centre Distance:
C = 150 mm = 0.15 m
DESIGN OF INPUT SHAFT

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

Stresses in Shafts The following stresses are induced in the shafts:
1. Shear stresses due to the transmission of torque (i.e. due to torsional load).
2. Bending stresses (tensile or compressive) due to the forces acting upon machine elements like gears, pulleys etc. as well as due to the weight of the shaft itself.
3. Stresses due to combined torsional and bending loads.

As this Shaft is subjected to Combined Twisting Moment and Bending Moment, the shaft must be designed on the basis of the two moments simultaneously.

Now,

Using Maximum normal stress theory or Rankine's theory.

… As EN 24 is brittle material.

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

Ultimate Tensile/Compressive Strength = 850 N/mm^2

So,

Allowable maximum bending stresses,

σ_b = 850/3 = 283.33 N/mm^2 = 283.33*10^6 N/m^2 … Taking FoS = 3

Torque is given by:

T = P*60 / 2πN = **125.11 Nm**

Tangential force on gear

F_t = 2T/D = 2606.46 N

The normal load acting on the tooth of the gear

W = F_t/cos∝= 2774.01 N

Since gear is mounted at the end of the shaft,

Bending moment is:

M = WL = **1387.00 Nm**

So from equation (1)

d = 0.037 m = **37 mm**

So,

Diameter of Input Shaft is 40 mm.

DESIGN OF OUTPUT SHAFT

Given:

Speed = 2800 rpm

Power = 55 kW

Diameter, D = 144mm

Length of shaft = 300mm

Now Shaft material is EN-8 …. Tough, hard material containing such elements as nickel, chromium and molybdenum

Stresses in Shafts The following stresses are induced in the shafts:
1. Shear stresses due to the transmission of torque (i.e. due to torsional load).
2. Bending stresses (tensile or compressive) due to the forces acting upon machine elements like gears, pulleys etc. as well as due to the weight of the shaft itself.
3. Stresses due to combined torsional and bending loads.

As this Shaft is subjected to Combined Twisting Moment and Bending Moment, the shaft must be designed on the basis of the two moments simultaneously.

Now,

Using Maximum normal stress theory or Rankine's theory.

… As EN 8 is brittle material.

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

Ultimate Tensile/Compressive Strength = 850 N/mm^2

So,

Allowable maximum bending stresses,

σ_b = 850/3 = 283.33 N/mm^2 = 283.33*10^6 N/m^2 … Taking FoS = 3

Torque is given by:

Torque due to rotation:

T_1 = P*60 / 2πN = 187.67 Nm

Torque due to frictional force:

T_2 = Frictional force * radius of tyre
= (0.5*200)*0.254
= 25 Nm

Torque due to Braking:

T_3 = T_1 = 187.67 Nm

So, Equivalent torque is:

$T = T_1 + T_2 + T_3$
= **400.34 Nm**

Tangential force on gear

F_t = 2T/D = 5560.28 N

The normal load acting on the tooth of the gear

W = F_t/cos∝= 5917.71 N

Since gear is mounted at the end of the shaft,
Bending moment is:

M = WL = **1775.31 Nm**

So from equation (1)

d = 0.0401 m = **40 mm**

Diameter of Output Shaft is 40 mm.

Syt=300N/mm^2,Sut=550N/mm^2

Combined Shock (Kb)=1.5, Fatigue Factor (Kt)= 1.0

Allowable shear stress

According A.S.M.E. code, the allowable shear stress for shaft keyway effect is

τ_s= 0.75 (0.18 X Sut)
= 0.75 (0.18*550)
= 74.15 N/mm^2
τ_s= 0.75 (0.18 X Syt)
= 0.75 (0.18*300)
= 67.5 N/mm^2
$\therefore \tau s = 67.5 N/mm^2$

} smaller of two values

Step (2)

Torque on shaft $P = \frac{2\pi NT}{60}$

$$P = \frac{2\pi 1400T}{60} = 0.746 = \frac{2\pi 1400T}{60X1000X1000}$$

$T = 5088.41\ N.mm$

Now,

$T = F_{T1}\frac{C}{2}$

$5088.41 = F_{T1}\frac{150}{2}$

$F_{T1} = 67.845\ N$

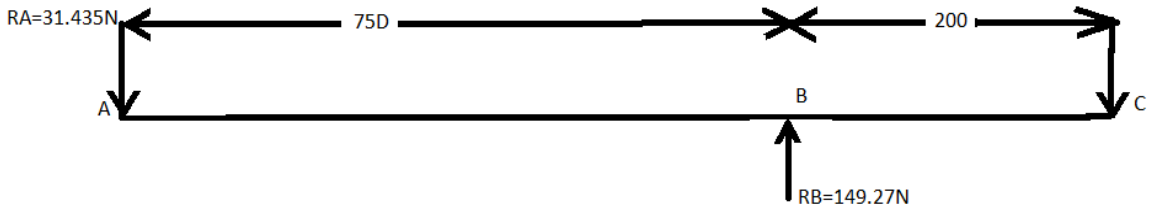
Total Vertical Load on Gear box

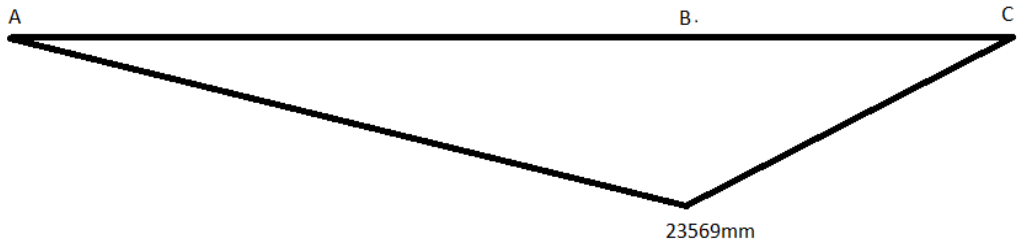
$$F_T = F_{T1} + W = F_T = 67.845 + 50$$

$F_T = 117.845\ N$

Step (3)

Taking moment on Shaft





Taking moment about point B,

-R_A X 550 + F_T X 550 = 0
-R_A X 550 + 117.845X 550 = 0
$\therefore$ -R_A = 31.425 N

Now, $\Sigma f = 0$

-R_A + R_B – 117.845 = 0
-31.425+ R_B – 117.845 = 0
R_B = 149.27 N
M_B = F_T X 200 = 117.845.200 = 23569 N.mm
Max.Bending Moment
M=23569 N.mm

Hence diameter of the shaft : ·
Equivalent Torque ,

$T_e = \sqrt{(K_b M)^2 + (K_t M)^2}$

$T_e = \sqrt{(1.5 * 23569)^2 + (1 * 5088.41)^2}$

$T_e = 35717.80 N.mm$

$$\mathcal{T} \max = \frac{16 * 35717.80}{\pi d^3}$$

$$67.5 = \frac{16 T_e}{\pi d^3}$$

d = 13.91 ≈ 14 mm

or to make it more reliable taking,

d = 15 mm

VII. CONCLUSION

Portal axle is designed using helical gear train. for designing portal axle classical approach is used, designing of input shaft, output shaft and gear loading condition is calculated for fabrication

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