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Design and Manufacturing of Portal Axle Gear Box

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Abstract – *Portal axles are an off-road technology where the axle tube is above the center of the wheel hub and where there is a gearbox in the hub. Because of that ground clearance is increased. This reduces load on the axle crown wheel and differential. In this project the design of portal axle elements as input shaft, output shaft, gear train, casing & bearings is to be analyzed. The performance of spur gear train is determined. The objective of project is the comparative study of spur gears is analyzed with the analytical as well as experimental results.*

Key Words: Gear, Pinion, Input Shaft, Output Shaft, Bearing, Casing.

1. INTRODUCTION

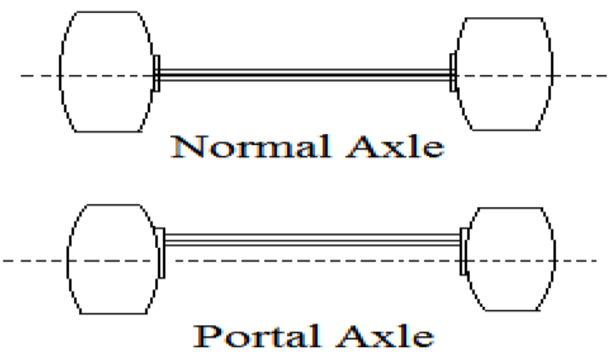


Figure 1

The output shaft, input shaft, bearing, casing and gear train is mainly design for portal shaft. With the help of CAD model (CATIA, UNI GRAPHICS) and ANSYS software we can do the analysis by FEA method. For better result experimental analysis can be performs. When the spur gear is compare with helical gear the advantages are follows:
Spur gear can withstand at more stress and vibrations.

- Reliability of Spur Gear is more.
- Spur gears are easily manufactured & compact.
- Helical gears engage more gradually than do spur gear.
- Helical gears are highly durable & transmit more torque.
- In helical gear wearing capacity is less.

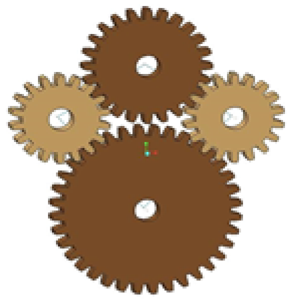
Material Selection:

Cast steel was use to manufacturing the gears of the portal axel because it has high melting point. Melting allowed other elements, such as nickel, to be mixed into the metal, thus strengthening the steel Cast steel has a rough finish. In future work different composite materials can be used for analysis of input and output shaft of portal axle unit.

Table -1: Properties of Cast Steel

Cast Steel	
Density	7870 kg/m^3
Young modulus	200 GPa
Poisson's ratio	0.29
Tensile strength	518.8 MPa
Ultimate Tensile Strength	540 MPa
Yield Tensile Strength	415 MPa

2. Layout and Design of the Setup -



Problem statement

Design study of Portal Axle Gear box with the help following information,

PAIR 1

20 degree full depth involute system
Gear ratio is = 1/2
Input RPM N_1 = 1440 rpm
Output RPM = 2880 rpm
Power = 746W approx. 1000 W
No. of teeth Z2 = 20
Z1 = 40
Material,
For both gear and pinion
- 40 C8 / 1040 (AISI)
- Syt = 374 Mpa
- BHN=170
- Sut = 590 Mpa
- 28% elongation in 50mm
- E = 200 GPA
- Factor of safety = 2

a) Beam strength, Fb = σmby* ∏

Yp = $0.154 - \frac{0.912}{Zp} = 0.154 - \frac{0.912}{20} = 0.1084$
Yg = $0.154 - \frac{0.912}{Zg} = 0.154 - \frac{0.912}{40} = 0.1312$
Here the material of pinion & gear is same
So pinion is Weaker than gear
So design the pinion,
σbp = $\frac{Syt}{3} = \frac{374}{3}$ = 124.667 Mpa
m = module (mm)
b = 10*m (mm)
Yp = 0.1084
Fbp = 124.667 * 10* m*m*0.1084*π
Fbp = 424.55 mm^2

b) Wear strength, Fwp = dp*b*Q*k

dp = m*Zp
b = 10m
Q = $\frac{2Zg}{Zg+Zp} = \frac{2*40}{40+20}$ = 1.333
K = $\frac{(\sigma)^2 Sin\varphi}{1.4} * (\frac{1}{Ep} + \frac{1}{Eg})$
(σ)= (2.8*BHN-70) N/mm^2
(σ)= (2.8*170-70) = 406 N/mm^2
K = $\frac{(406)^2 \sin 20}{1.4} * (\frac{2}{200*1000})$
= 0.4027
Fwp = 20* m* 10* m * 1.333* 0.4027
Fwp = 107.36 N
So the pinion is weaker in bending

c) Effective load Feff = $\frac{Ka*Km}{Kv} * \frac{p}{v}$

KA = Applications Factor = 1
Km = Service factor = 1.5
Kv = velocity factor = $\frac{6}{6+v} = \frac{6}{6+3.0159m}$
P = 1000W
v = $\frac{\pi*dp*np}{60000} = \frac{\pi*2880*20m}{60000}$ = 3.0159m m/s
Therefore,
Feff = $\frac{Ka*Km}{Kv} * \frac{p}{v} = \frac{(6+3.0159m)*1.5*1000}{6*3.0159m}$
= $\frac{9000+4523.85m}{18.095m}$
So that to calculate the module,
Fbp = FOS * Feff
424.55m^2 = 2* $\frac{9000+4523.85m}{18.095m}$
After calculations of Equations,
m = 2mm
So that for the module m=2mm
m = 2mm
dp = 2*20 = 40mm
Zg = 20
b = 10*2 = 20mm
v = $\frac{\pi*dp*np}{60000}$ = 6.0318 m/s
Ft = $\frac{p}{v} = \frac{1000}{6.0318} = 165.79N$

d) Dynamic load, Fd= ft+$\frac{21v(bc+ft)}{21v+(bc+ft)^{(1/2)}}$

b= 20mm
Ft = 165.79
v = 6.0318
error e= 2+0.16φ
φ= m+0.25(d)^(1/2)
e= 0.05 mm
e= 114

Fd = 165.79+ $\frac{21*6.0348*(20*114+165.79)}{21*6.0318+(20*114+165.79)^{(1/2)}}$
Fd = 1924.817m
Fb = 424.55m^2
= 424.55*4
=1689.2 N
Here, Fd > Fb Design is unsafe
For next m = 3mm
b =10*m= 30mm
dp = 60mm
V = 9.04 m/s
Ft = 110.619
c = 114
Fd = $\frac{21v(bc+ft)}{21v+(bc+ft)^{(1/2)}} = \frac{21*9.04*(30*114+110.619)}{21*9.04+(30*114+110.619)^{(1/2)}}$.
= 2799.69 N
Fbp = 424.55*9 = 3820.95 N
so, Fbp > Fd Design is safe

e) GEAR DIMENSIONS –

module = 3 mm
dp = 3*20 = 60mm
dg = 3*40 = 120 mm
Zp= 20
Zg = 40
Addendum = 1m = 3 mm
Dedundum = 1.25m = 3.75mm
Working depth = 2 m = 6mm
Minimum total depth = 2.25 m = 6.75mm
Tooth thickness = 1.5708 m = 4.7124mm
Minimum clearance = 0.25m = 0.75mm
Fillet radius at tooth = 0.4m = 1.2mm

DESIGN OF SHAFT FOR GEAR 1

Material
EN8/45C8/1040
Syt = 374 Mpa
Fos = 3

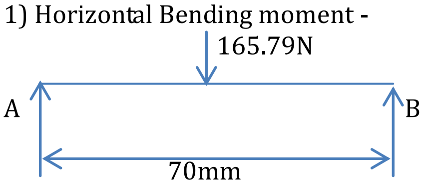
So using ASME design

Tmax = $\frac{16}{\Pi d^3}((KbMb)^2 + (KtMt)^2)^{(1/2)}$

For suddenly applied load minor shock
Kb = 1.7, Kt = 1.3
Length of shaft
Taking the clearance between the gear face & housing is 10 mm
So gear for analysis
Ft = $\frac{P}{V}$= 165.79 N
Fr = Ft tanα
= 165.79 tan 20
= 60.34 N

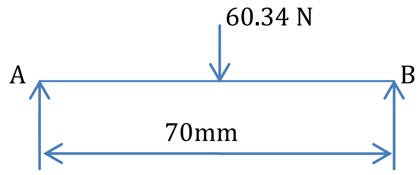
Bending Moment calculations

1) Horizontal Bending moment -



(Mb)H = (165.79/ 2) * (70/2)
= 2901.325 N-mm

2) Vertical Bending moment –



(Mb)v = (60.34/2) * (70/2)
= 1055.95 N-mm

3) Resultant bending moment -

Mb = $\sqrt{(MbH)^2 + (Mbv)^2}$ = $\sqrt{(MbH)^2 + (Mbv)^2}$
= 3087.51

Torsional moment calculation
Mt = Ft * r
= Ft * (dg/2)
= 165.79 * (120/2)
Mt = 9947.4 N-mm

so finally according to max. Shear stress theory,

Tmax = $\frac{0.5Syt}{Fs}$= $\sqrt{(KbMb)^2 + (KtMt)^2}$* $\frac{16}{\Pi d^3}$

62.333 = $\frac{16}{\Pi d^3}$* (13956.23)
d^3 = 1140.302
d = 10.44 mm
For safe working
Taking shaft diameter is,
(d = 15 mm)

DESIGN OF SHAFT FOR GEAR 2 -

Material
EN8/45C8/1040
Syt = 374 Mpa
Fos = 3
So using ASME design

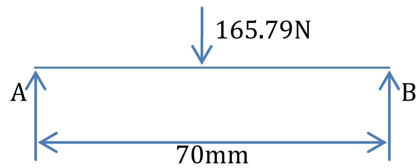
Tmax = $\frac{16}{\Pi d^3}((KbMb)^2 + (KtMt)^2)^{(1/2)}$

For suddenly applied load minor shock
Kb = 1.7, Kt = 1.3
Length of shaft
Taking the clearance between the gear face & housing is 10 mm

So gear for analysis,
Ft = $\frac{P}{V}$= 165.79 N
Fr = Ft tanα
= 165.79 tan 20
= 60.34 N

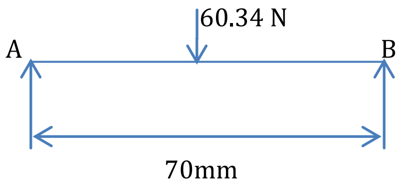
Bending Moment calculations

1) Horizontal Bending moment



(Mb)H = (165.79/ 2) * (70/2)
= 2901.325 N-mm

2) Vertical Bending moment-



(Mb)v = (60.34/2) * (70/2)
= 1055.95 N-mm

3) Resultant bending moment -

Mb = $\sqrt{(MbH)^2 + (Mbv)^2}$

= $\sqrt{(MbH)^2 + (Mbv)^2}$

= 3087.51

Torsional moment calculation

Mt = Ft * r
= Ft * (dp/2)
= 165.79 * (60/2)
Mt = 4973.7 N-mm

so finally according to max. Shear stress theory,

Tmax = $\frac{0.5Syt}{Fs} = \sqrt{(KbMb)^2 + (KtMt)^2} * \frac{16}{\Pi d^3}$

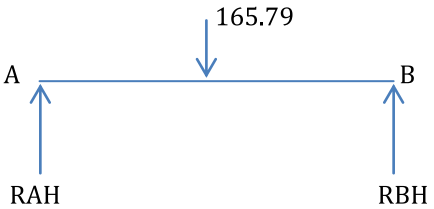
62.333 = $\frac{133248.643}{\Pi d^3}$

d^3 = 680.44
d = 8.79 mm
For safe working
Taking shaft diameter is ,
(d = 12 mm)

BEARING DESIGN,

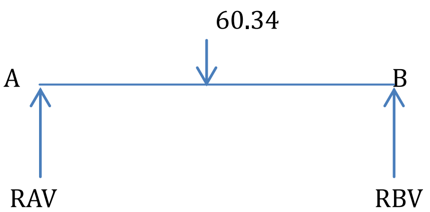
1) Bearing for shaft of gear 1
Radial force on bearing –

Horizontal force diagram



(R)AH = (R)BH = $\frac{165.79}{2}$= 82.895 N

Vertical force diagram



(R)Av = (R)Bv = $\frac{60.34}{2}$= 30.17 N

Resultant radial force on point A

RA = $\sqrt{((R)AH)^2 + ((R)Av)^2}$

= $\sqrt{(82.895)^2 + (30.17)^2}$

= 88.21 N

Resultant radial force on point B
(R)B = 88.21 N
Axial forces on bearing are zero.

EQUIVALANT DYNAMIC LOAD

P= V* Fr+ Y *Fa
V = 1
X = 1
P = Fr = RA= RB= 88.21 N
Taking life of bearing = 16000 hrs.
For the application of 8 hrs. Per day working for general purpose gears,
Lh = 16000hrs

Lh = $\frac{60N*\ln}{10000000} = \frac{60*1440*16000}{10000000}$

L = 1382.4 millions
Using load life relations,

L= $(\frac{C}{P})^3$ for ball bearing

Here putting values,

1382.4 = $(\frac{C}{88.21})^3$

C = 982.64 N
From manufacturer cat log

Bearing no.- 6002 selected has the following specifications
Inner dia. = 15mm
Outer dia. = 32 mm
Basic load rating
C = 5590 N
C0= 2500 N

BEARING FOR SHAFT OF GEAR 2

Reaction forces on shaft 2 is same as shaft 1 only the diameter of shaft is taken as 12 mm
Bearing no.- 6001
Inner dia. = 12mm
Outer dia. = 20 mm
Basic load rating
C = 2240 N
C0= 5070 N
Design Calculations' for Pair 2 is Identical as Pair 1 Since, The Geometrical Parameters and Power Transmitted is same.

CONCLUSION

We have successfully Design and manufactured of Portal axle gear box.

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