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DESIGN, ANALYSIS & FABRICATION OF SHAFT DRIVEN BICYCLE

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ABSTRACT

The conventional bicycle employs the chain drive to transmit power from pedal to the rear wheel and it requires accurate mounting & alignment for proper working. The least misalignment will result in chain dropping. So this problem can be overcome by introducing the shaft drive system. This project includes design and fabrication of shaft driven bicycle. In this project, two spiral bevel gears are used at the pedal side and two straight bevel gears are used at rear wheel side. The drive shaft has two gears mounted one at each end. One is spiral bevel pinion at pedal end and one is straight bevel pinion at the rear wheel end. The use of bevel gears allows the axis of the drive torque from the pedals to be turned through 90 degrees. The bevel gear at the rear end of drive shaft then meshes with a bevel gear rear wheel hub where the rear the flywheel unit would be on a conventional bicycle and canceling out the first drive torque change of axis.

Keywords: Analysis, Bevel gears, drive shaft, shaft driven bicycle.

I. INTRODUCTION

The Shaft driven bicycle has a drive shaft which replaces achaindrive to transmit power from the pedals to the wheel. The arrangement for shaft driven bicycleis as shown in fig 1. Shaft drives were introduced over a century ago but were mostly supplanted by chain-driven bicycle due to the gear ranges possible with sprockets and derailleur. Recently, due to advancements in internal gear technology, a small number of modern shaft-driven bikes have a large bevel gear where a conventional bike would have its chain ring. This meshes another bevel gear mounted on the drive shaft which is shown in fig 1.

Fig.1 Replacement of Chain drive bicycle with drive shaft

The use of bevel gears allows the axis of the drive torque from the pedals to be turned through 90 degrees. The drive shaft then has another bevel gear near the rear wheel hub which meshes with a bevel gear on the hub where the rear sprocket would be on the conventional bike and canceling out the first drive torque change of axis.The design of bevel gear produces less vibration and less noise than conventional straight cut gear.

1.1 Use of drive shaft

The torque that is produced from the pedal and transmission must be transferred to rear wheels to push the vehicle forward and reverse. The drive shaft must provide a smooth, uninterrupted flow of power to the axles. The drive shaft and differential are used to transfer this torque.

1.2 Functions of the drive shaft

1. First, it must transmit torque from the transmission to the foot pedal.
2. During the operation, it is necessary to transmit maximum low-gear torque developed by the pedal.
3. The drive shaft must also be capable of rotating at the very fast speeds required by the vehicle.
4. The drive shaft must also operate through constantly changing angles between the transmission, the differentials and the axle.

II. LITERATURE REVIEW

The first shaft drives for cycles appear to have been invented independently in 1890 in the United States & England. In those days manufacturing of bevel gears was not so precise and cost effective; therefore it was not possible to replace chain drive shaft driven gear system. In shaft drive at both ends of shaft pair of spiral gears is used. Most familiar application of the spiral bevel gear is in automobile differential, in which the direction of drive from the drive shaft must be turned 90 degrees to drive the wheels of the vehicle. The shaft drive bicycle has more efficiency than conventional chain drive bicycle. Moreover, the application of chain drive leads to underutilization of human effort due to the fact the maximum transmission of the bicycle chain remains below 70 per cent due to polygon effect in chain sprocket drives. Thus there is need to replace conventional chain drive using the spiral bevel gear arrangement. In ashaft driven bicycle, a drive shaft is used instead of a chain to transmit power from the pedals to the wheels. The drive shafts carry of torque. The steel drive shaft satisfies three design specifications such as torque transmission capability, buckling torque capability & natural frequency in bending mode. The shaft drive increases power transmission efficiency.

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III. COMPONENTS

3.1 Bevel gear

Fig.3.1 Bevel gears

A kind of gear in which the two wheels working together lie in different planes and have their teeth cut at right angles to the surfaces of two cones whose apices coincide with the point where the axes of the wheels would meet.

3.2 Drive shaft

A shaft- driven bicycle is a bicycle that uses a drive shaft instead of a chain to transmit power from the pedals to the wheel. Shaft drives were introduced over a century agobut were mostly supplanted by chain-driven bicycle due to the gear ranges possible with sprockets and derailleur. Recently, due to advancements in internal gear technology, a small number of modern shaft-driven bicycles have been introduced.

Fig.3.2 Drive shaft & Bearing

3.3 Bearing

For the smooth operation of the shaft, the bearing mechanism is used. To have very less friction loss the two ends of the shaft are pivoted into the same dimensions bearing.

3.3 Merits of drive shaft

1) They have high specific modulus and strength.
2) Reduced weight.
3) Due to the weight reduction, energy consumption will be reduced.
4) They have high damping capacity hence they produce less noise and vibration.

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5) They have good corrosion resistance.
6) Lower rotating weight transmits more of available power.

IV. WORKING PRINCIPLE

The job involved is the design for the suitable drive shaft and replacement of chain drive smoothly to transmit power from pedal to the wheel without slip. It needs only a less maintenance. It is cost effective. Drive shaft strength is more and also its diameter is less. The both ends of the shaft are fitted with a bevel pinion, the bevel pinion is engaged with a crown and power is transmitted to the rear wheel through the drive shaft.

V. DESIGN METHODOLOGY

5.1 Design assumption

A. The shaft rotates at constant speed about its longitudinal axis.
B. The shaft has a uniform, circular cross section.
C. The shaft is perfectly balanced, i.e. at every cross section, the mass center coincides with the Geometric center.
D. All damping and nonlinear effects are executed.
E. The stress-strain relationship for thecomposite material is linear & elastic; hence, Hooke's law is applicable for composite materials.
F. Acoustical fluid interactions are neglected, i.e. the shaft is assumed to be acting in a vacuum.
G. Since lamina is thin and no out-of-plane loads are applied, it is considered as under the plane stress.

5.2 Design calculation

5.2.1For Drive Shaft

Diameter of shaft (d) = 0.025 m

Length of shaft (L) = 0.35 m

Length of pedal crank (l) = 0.175 m

Speed of pedal gear = 120 rpm

If person does not turn the pedal then he will stand on it and so the maximum torque will be,

T = (body mass of the rider) x (g) x (length of pedal crank)

T = 80 x 9.81 x 0.175

$\therefore$ T = 137.34 N-m

Power (P) = $2\pi NT / 60$

P = 2π x 120 x 137.34 / 60

= 1725.86 watts

$J = \pi d^4 / 32$

$= \pi \times 0.025^4 / 32$

$= 3.835 \times 10^{-8}\ m^4$

Shear stress (τ) = TR / J

$=137.34 \times 0.0125 / 3.835 \times 10^{-8}$

$= 44.76 \times 10^{6}$ N/ m^{2}

$I = \pi d^{4} / 64$

$= \pi \times 0.025^{4} / 64$

$= 1.917 \times 10^{-8}\ m^{4}$

Bending moment,

$M = EI / R$

$=2.06 \times 10^{11} \times 1.917 \times 10^{-8} / 0.0125$

= 315921.6 N-m

Rate of twist = T /GJ

$= 137.34 / (0.84 \times 10^{11} \times 3.835 \times 10^{-8})$

= 0.0426 rad / m

ϴ = TL / GJ = Rate of twist x Length of shaft

= 0.0426 x 0.35

= 0.0149 rad

5.2.2. For bevel gears

Speed of gear (N_g) = 120 rpm

Velocity ratio (i) = 4.33

Teeth of pinion (Z_p) = 9

Diameter of crown = 0.15 m

Diameter of pinion = 0.045 m

Select suitable teeth on crown,

$i = Z_c / Z_p = N_p / N_c$

$4.33 = Z_c / 9 = N_p / 120$

$Z_c = 39$

$N_p = 520$ rpm

Pitch angle,

For pinion

$\tan\gamma_p = Z_p / Z_c$

$= 9 / 39$

$\gamma_p = 13$

for crown

$\tan\gamma_c = 39 / 9$

$= 77$

Module (m)

Diameter = module x teeth

150 = m x 39

m = 3.589 mm

Normal module (m_n) = 3.5 mm

$m_n = m \times \cos\beta$

$3.5 = 3.589 \times \cos\beta$

$\beta = 12.78°$

Cone distance,

$A = 0.5 \times \sqrt{(150 * 150 + 45 * 45)}$

A = 78.30 mm

Pitch circle diameter

$P_c = \pi m$

$= \pi \times 3.589$

= 11.27 mm

Virtual number of teeth,

For crown

$Z_{vc} = Z_c / \cos\delta \times \cos^3\beta$

$= 39 / \cos(77) \times \cos^3(12.78)$

= 187

$Z_{pc} = Z_p / \cos\delta \times \cos^3\beta$

$= 9 / \cos(77) \times \cos^3(12.78)$

= 43

Tangential force (F_t)

$F_t = P_d \times C_v / V$

Where, $P_d = 1.25 \times 1725.86$

= 2.157 KN-m / sec

For medium shock of service factor

$C_s = 1.50$

$V = \pi dN / 60$

$= \pi \times 0.045 \times 520 / 60$

= 1.225 m/s

$F_t = 1000 \times 2.157 \times 1.50 / 1.225$

= 2.641 KN

Dynamic load calculation

$F_d = C_v N_{sf}\, k_m\, F_t$

Where, $C_v = [(5.5 + V_m^{0.5}) / 5.5]^{0.5}$

$= [(5.5 + 5^{0.5}) / 5.5]^{0.5}$

= 1.18

$N_{sf} = 1.5$

$k_m = 1.1$

$F_d = 1.18 \times 1.5 \times 1.1 \times 2.641$

= 7.011 KN

Beam strength calculation,

Lewis equation

$F_s = ([\sigma_b]\, b\, Y_v\, (1- b/A)) / P_d$

= 720 x 25 x 0.4686 x (1 – 25 / 78.30) /0.2

= 28.708 KN

Hence, $F_s > F_d$

Wear strength calculation,

$F_w = dbQK$

Where, $Q = 2Z_c/(Z_p + Z_c)$

= 2 x 39 / (9+39)

= 1.625

$K = \sigma_{es}^2 \sin\alpha\, (1/E_p + 1/E_c) / 1.4$

σ_{es} = 2.75 x (BHN) – 70

= 2.75 x 265 – 70

= 658.75 N/mm^2

K = 658.75^2 x sin (20) x (2/ 540) / 1.4

K = 392.64

F_w = 45 x 25 x 1.625 x 392.64

= 717.8 KN Hence $F_w > F_d$

VI. Result

Sr. no.	Parameter	Symbol	Unit	Value
1	Moment of inertia	I	m^4	1.917 x 10^{-8}
2	Polar moment of inertia	J	m^4	3.835 x 10^{-8}
3	Torque	T	N-m	137.34
4	Power	P	W	1725.86
5	Shear stress	τ	N/m^2	44.76 x 10^6
6	Bending moment	M	N-m	315921.6
7	Angle of twist	θ	rad	0.0149

Table 6.1 result

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VII. ANALYSIS OF SPIRAL BEVEL GEAR

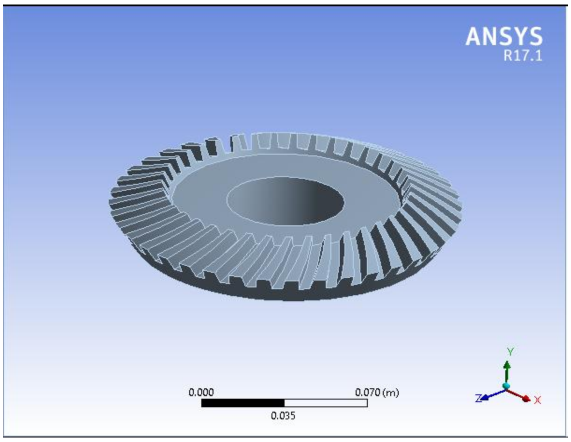

Fig.7.1 CAD Model of spiral bevel gear

The CAD geometry is created by using SOLIDWORKS and used for finite elemental analysis in ANSYS.

FE model is created using ANSYS. Second order tetrahedral elements are used to capture bevel geometry for better accuracy.

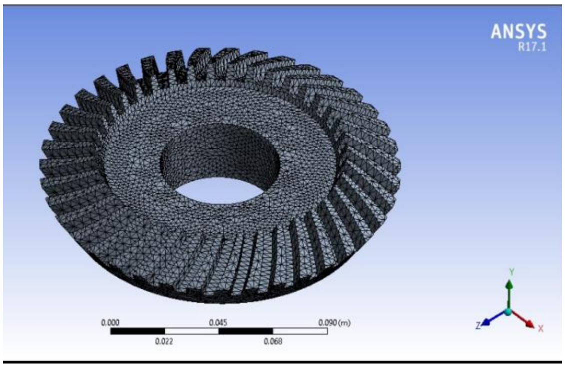

Fig.7.2 FE Model of spiral bevel gear

All translational degrees of freedom and rotation about bevel gear is fixed for FE analysis. These are minimum required boundary condition to get proper convergence of the model. Tangential load is applied on the four teeth of the bevel gear.

Equivalent von Mises stress and deformations within gear are plotted. Stress observed in gear is well within acceptable limit.

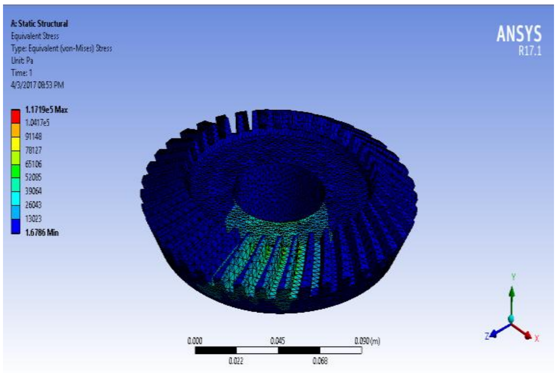

Fig.7.3 Von Mises stresses

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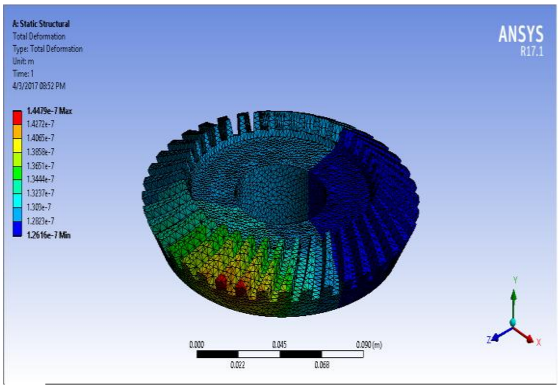

Fig. 7.4 Tooth deformation

1) Maximum stress induced in the gear is1.17 x 10^5 N/m^2< allowable stress 44.76 x 10^6.

2) Maximum deformation is 1.447 x 10^{-7} m.

VIII. CONCLUSION

The shaft driven bicycle is designed successfully. The bicycle works efficiently and transmits the power from pedal to rear wheel smoothly, but it is requiring slightly more initial torque compare to drive torque. The noise and the vibration of the gear pair are considerably reduced.

This bicycle can be used for racing purpose and off-road riding. As the speed of the shaft driven bicycle is more enough, it can be utilized for generating pedal work.

The result obtained from this work is a useful approximation to help in the earlier stages of the development, saving development time and helping the decision-making process to optimize the design.

The drive shaft with the objective of minimization of the weight of shaft which was subjected to the constraints such as torque transmission, torsion buckling capacity, stress-strain etc. The stress distribution and maximum deformation in the drive shaft are the functions of stacking of the material. The optimum stacking of material layers can be used as the effective tool to reduce weight and stress acting on the drive shaft.

IX. TROUBLESHOOTING

When abnormal vibrations and noise are detected in drive shaft area, following chart can be used to help to diagnose possible causes.

Problem	Caused by	Remedy
Gear slip at rear side	More load on pedal	Precise alignment of gear and sufficient lubrication
More torque required	Large gear ratio	Reduce gear ratio
Noise	Insufficient lubrication	Provide sufficient lubrication
Gear pitch circle not coincides	Vibrations	Precise alignment of gear
Jamming of gears	Foreign dust particles	Provide casing

Table 9.1 Trobleshooting

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XI. REFERENCES

- **Journal Paper**

[1] Prasad G. H., Marurthi S., Ganapathi R., Janardhan M., Madhusudhan M.P., 2014,"Design & fabrication of shaft drive for bicycle", International Journal Of Emerging Engineering Research And Technology, Volume 2, Issue 2, pp.43-49

[2] BhajantriV. S., Bajantri S. C., Shindolkar A. M., Amarapure S. S,2014,"Design and analysis of composite drive shaft"., International Journal Of Research In Engineering And Technology, Volume 03 Special Issue 03,pp.738-745

[3] Parashar A., Purohit S., Malviya S., Pande, 2016,"Design and fabrication of shaft driven bicycle", International Journal Of Science Technology And Engineering, Volume 2,Issue 11,pp.23-31.

[4] Gawande A. S., Gedam A. E., Pipre A. G., Bajait N. C.,2015,"Design and fabrication of shaft driven bicycle", International Journal for Scientific Research &Development, Volume 3, Issue 02, pp.2526-2529

- **Proceeding paper**

[5] Durgude J.A, Gawade S. R., 2015,"Design development and analysis of dual mode bicycle." FIRSTMECHPGCON, University Of Pune, Pune, India.

- **Website references**

[6] www.dynamicbicycles.com

[7] www.webbicycle.netpaths.net/technology.php

Books

[8] "Design data"- Data book of engineering

[9] Machine design by V. B. Bhandari