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Design and Fabrication of Shaft Driven Bicycle

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Abstract— The normal bicycle is the one of the medium of the travelling. Generally we all are aware of the bicycle and most of us have utilized it. A shaft driven bicycle is a bicycle that uses a shaft drive instead of a chain which contain two set of bevel gear at both the ends to make a new kind of transmission system for bicycle for getting high reliability system, and more safe system. Recently due to advancement in internal gear technology, makes the use of bevel gears for most efficient performance and transmit motion through 90 degrees angle. It replaces the traditional methods.

Key words: Shaft Driven Bicycle, Fabrication

I. INTRODUCTION

A shaft-driven bicycle is a bicycle that uses a drive shaft instead of a chain to transmit power from the pedals to the rear wheel. Shaft drives were introduced over a century ago, but were mostly supplanted by chain-driven bicycles due to the gear ranges possible with sprockets and derailleur. If bevel-gear could be accurately and cheaply cut by machinery, it is possible that gears of this description might supplant, to a great extent. Shaft-driven bikes have a large bevel gear where a conventional bike would have its chain ring. This meshes with another bevel gear mounted on the 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 a 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 or spur-cut gear with the straight teeth. The shaft drives only needs periodic lubrications using a grease gun to keep the gears running quite, smooth and efficient transfer of energy from the pedals to the rear wheel. It is attractive in look compared with chain driven bicycle.

II. LITERATURE SURVEY

Kenneth S. Keyes have performed a patented work or invention related to drive shaft driven bicycle. The object of his invention was to provide a bicycle having a means of linear transmission from the pedal to hub of the bicycle for better efficiency & speed ratios than prior bicycle. A number of problem may be associated with traditional coaster or 3-speed bicycle chains. They are subjected to slippage if the length of the chain is not correctly adjusted.

To overcome above problem, Keyes designed a bicycle which had a driver bevel gear connected to the pedals, a driven bevel gear at the hub of the rear wheel, one or more drive shafts having beveled gears at each end & capable of transmitting the rotation of the driver gear to the driven gear. [1]

Another experimental study to determine the effects of cycle crank length on maximum cycling power, optimal pedaling rate, and optimal pedal speed, and to determine the optimal crank length to leg length ratio for maximal power production. The experiment has been performed using crank lengths of 120, 145, 170, 195, and 220 mm. [2]

An individual idea or any possible combination of different ideas can be used, in order to optimize operating performance of driving mechanism for cycle. The velocity ratio of mechanism, torque generated at drive side, pedal crank length, chain drive efficiency, chainring shape are some important parameters used to optimize performance of drive mechanism of cycle. Also the efficiency of the bicycle chain drive depends on the chain operation as it engages and departs from the sprockets on the high-tension part of the drive. [3]

Fig. 1: Bicycle

Rastogi implemented a FEA approach to design and analyze a composite drive shaft in different conditions. [4]

Improved bicycle infrastructureis positively and significantly correleted with higher rates of commuting bybicycle that could include promotion of folding bicycle. Most people understand the general concept of a folding bicycle but do not recognize the overall value of improved product design givens that few people are willing to pay for additional costs. [5]

III. COMPONENTS

A. Bicycle

It is made up of alloy steel optimize and minimize the weight of bicycle.

B. Bevel Gear

The bevel gears are used for transmitting power at a Constant velocity ratio between two shafts whose axes intersect at a certain angle.

C. Shaft

A shaft is a rotating member, usually of circular cross section, used to transmit power or motion. It provides the axis of rotation, or oscillation, of elements such as gears, pulleys, flywheels, cranks, sprockets, and the like and controls the geometry of their motion.

D. Bearing

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

E. Universal Joint

A universal joint or coupling in a rigid rod that allows the rod to bend in any direction, and is commonly used in shafts that transmit rotary motion.

IV. Working Principle

The job involved is the design for suitable drive shaft and replacement of chain drive smoothly to transmit power from the pedal to the wheel without slip. It needs only a less maintenance. It is cost effective. Propeller shaft strength is more and also propeller shaft diameter is less. It absorbs the shock. Because the propeller shaft center is fitted with the universal joint is a flexible joint. It turns into any angular position. The both end of the shaft are fitted with the bevel pinion, the bevel pinion engaged with the crown and power is transmitted to the rear wheel through the propeller shaft and gear box. With our shaft drive bicycle, there is no more grease on your hands or your clothes; and no more chain and derailleur maintenance.

V. Design Assumption

1) The shaft rotates at constant speed about its longitudinal axis.
2) The shaft has a uniform, circular cross section.
3) The shaft is perfectly balanced.
4) All damping and nonlinear effect are excluded.
5) The stress-strain relationship for composite material is linear and elastic.

VI. Calculations

A. Design calculation for gear

Speed of gear (N_g) = 100 rpm
Velocity ratio = 2
Teeth of pinion (t_p) = 16
Mass of rider (m) = 60 kg
Length of the pedal lever (L) = 190 mm

1) Step 1) Maximum torque applied on bicycle

= (Mass of rider x g) x Length of the pedal lever
= 60 x 9.81 x 0.19
= 111.83 N-m

2) Step 2) Calculate Rated power

$P_R = 2\pi NT / 60$
$= (2\pi \times 100 \times 111.83) / 60$
= 1.172 KW

3) Step 3) Select suitable teeth of pinion

$t_p = 16$
$V.R. = t_g / t_p$
$V.R. = N_p / N_g$
$2 = t_g / 16$
$2 = N_p / 100$
$t_g = 32$
$N_p = 200$ rpm

4) Step 4) Pitch angle

For pinion, $\tan \gamma_p = t_p / t_g$
For gear, $\tan \gamma_g = t_g / t_p$
$\gamma_p = \tan^{-1} (16/32)$
$\gamma_g = \tan^{-1}(32 / 16)$
$\gamma_p = 26.56$
$\gamma_g = 63.43$

5) Step 5) Module

m = D / t
D = m x t
D_P = m x tp
$D_g = m \times t_g$
$D_p = m \times 16$
$D_g = m \times 32$
Cone distance
$L = 0.5 \times \sqrt{Dp^2 + Dg^2}$
$L = 0.5 \times \sqrt{(16\,x\,m)^2 + (32\,x\,m)^2}$
L = 17.88 x module

6) Step 6) Formative number of teeth

$(t_f)_p = t_p / \cos\gamma_p$ $(t_f)_g = t_g / \cos\gamma_g$
$(t_f)_p = 16 / \cos (26.56)$ $(t_f)_g = 32 / \cos(63.43)$
$(t_f)_p = 17.88 \approx 18$ $(t_f)_p = 71.54 \approx 72$

7) Step 7) Design power

$P_d = P_R \times K_L$
Where, Load factor $K_L = 1.25$
$P_d = 1.172 \times 1.25$
$P_d = 1.465$ kW

8) Step 8) Tangential or tooth load

$F_t = P_d / V_p$
Where, $V_p = (\pi \times D_p \times N_P / 60000)$
$= (\pi \times 16m \times 200 / 60000)$
= 0.167 x m
Therefore
$F_t = (1.465 \times 10^3) / (0.167 \times m)$
$F_t = (8.772 \times 10^3) / (m)$ (1)

9) Step 9) Beam strength

F_B = So x C.V. x Y x b x m (1– b/L)
Where,
So = beam strength
For pinion, So = 105 mPa --- (Gear material-Cast Iron, high grade)
For gear, So = 105 mPa
C.V. = Velocity factor
C.V. = 0.5 --- (Speed N<1000)
Y = Lewis Factor
For pinion,
$Y_p = 0.45- (2.87 / (t_f)_p)$
$Y_p = 0.45- (2.87 / 18)$
$Y_p = 0.3255$
For gear, $Y_g = 0.45- (2.87 / (t_f)_g)$
$Y_g = 0.45- (2.87 / 72)$
$Y_g = 0.4451$
B = Face width of gear
B = 7 x m
Now,
For pinion $(So \times Y)_P = (105 \times 0.3255) = 34.17$
For gear $(So \times Y)_g = (105 \times 0.4451) = 46.73$
Therefore, $F_B = 34.17 \times 0.5 \times 7m \times m \times (1 – 7m/17.88m)$
$F_B = 72.53 \times m^2$ (2)
by limiting condition from equation (1) and (2),
$F_B = F_t$
$72.56 \times m^2 = (8.772 \times 10^3) / (m)$

m = 4.61

10) Step 10) Value calculated

Tangential or tooth load

$F_t = (8.772 \times 10^3) / (m)$

$= (8.772 \times 10^3) / (4.61)$

= 1902.81 N

Pitch velocity

Vp = 0.167 x m

= 0.167 x 4.61

= 0.7698 m/sec

Beam strength

$F_B = 72.53 \times m^2$

$= 72.53 \times 4.61^2$

= 1541.41 N

Diameter of pinion

$D_P = 16 \times m$

= 16 x 4.61

= 73.76 mm

Diameter of gear

$D_g = 32 \times m$

= 32 x 4.61

= 147.52 mm

B. *Design Calculation for Shaft*

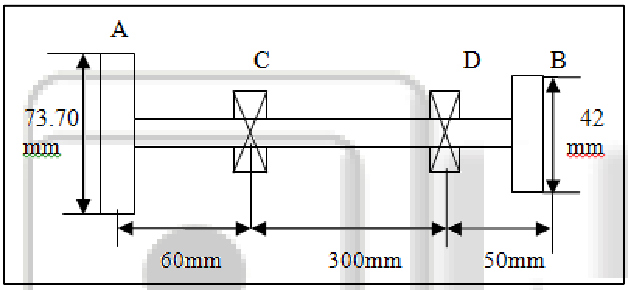

Fig. 2: Design Calculations

Power (P) = 2.34 kW = 2.34×10^3 W

Speed (N) = 200 rpm

Mass (m) = 50 kg

Weight of 1st pinion (W_A) = 9 N

Weight of 2nd pinion (W_B) = 5 N

R_B = 24 mm

Tensile stress (S_{yt}) = 296 mPa

Shear stress (τ) = 0.35 x S_{yt}

= 103.2 mPa

Assume,

Fatigue factor, $K_m = 1$ $K_t = 0.5$

Torque applied,

T = (P x 60) / (2π x N)

$= (2.34 \times 10^3 \times 60) / (2\pi \times 200)$

T = 111.72 N-m

$= 111.72 \times 10^3$ N-mm

Total vertical load acting downward on the shaft at A,

$F_{t\,A} = (T / R_A)$

$= (111.72 \times 10^3) / (36.85)$

= 3031.74N

Since the weight of gear A at vertically downward therefore the total vertically acting upward of the same shaft at A

$= F_{t\,A} - WA$

= 3031.74 – 9

= 3022.74 N

Assuming that the torque on the gear B in same as that of the shaft therefore the tangential force acting vertically upward on the same gear B,

$F_{t\,B} = (T / R_B)$

$= (111.72 \times 10^3) / (24)$

$F_{t\,B}$ = 4655 N

Since the weight of gear B at vertically downward therefore the total vertically acting upward of the same shaft at B

$= F_{t\,B} - WB$

= 4655 – 5

= 4650 N

Taking moment about D we get,

R_C x 300 = 3022.74 x 360 + 4650 x 50 - 14x 155

R_C = 4395.05 N

For the equilibrium of the shaft,

3022.74 + R_D = R_C + 4650 + 14

R_D + 3022.74 = 4395.05 + 4650 + 14

R_D = 6036.31 N

SFD calculation,

A_L = 0 N

A_R = 3022.74 N

C_L = 3022.74 N

C_R = 3022.74 – 4395.05

= -1372.31 N

E_L = -1372.31 N

E_R = -1372.31 – 14

= -1386.31 N

D_L = -1386.31 N

D_R = -1386.31 + 6036.31

= 4650 N

B_L = 4650 N

B_R = 4650 – 4650

= 0 N

We know that bending moment at A and B = 0

BM at C = 3022.74 x 60

$= 181.36 \times 10^3$ N-mm

BM at E = 3022.74 x 205 – 4395.05 x 145

$= -17.62 \times 10^3$ N-mm

BM at D = -4650 x 50

$= -232.5 \times 10^3$ N-mm

We see that the bending moment is maximum at C

Maximum Bending Moment = M = M_C = 181.36×10^3 N-mm

We know that the equivalent twisting moment

$$Te = \sqrt{(Km * M)^2 + (Kt * T)^2}$$

$$Te = \sqrt{(1 * 181.36 * 10^3)^2 + (0.5 * 111.72 * 10^3)^2}$$

$Te = 189.76 \times 10^3$ N-mm

Also, we know that the equivalent twisting moment (Te)

$Te = (\pi / 16) \times \tau \times d^3$

$189.76 \times 10^3 = (\pi / 16) \times 103.2 \times d^3$

d = 21.07 mm

Therefore, Diameter of shaft = 21.07 mm

Now consider mass (m) acting on shaft = mass of shaft (1.3 kg) + mass of two bearing (0.8+0.6 kg) = 2.7 kg

1) Mass moment of inertia (I) $= m \times R^2$
$= 2.7 \times (0.01053)^2$
$= 0.00299$ kg-m^2
2) Polar movement of inertia (J) $= (\pi / 32) \times d^4$
$= (\pi / 32) \times 0.02107^4$
$= 2.6344 \times 10^{-8}$ m^4

3) Natural frequency (Fn) $= \frac{\pi \times p^2}{2 \times L^2} \times \sqrt{\frac{E \times I_x}{m_i}}$

$= \frac{\pi \times (0.2)^2}{2 \times (0.41)^2} \times \sqrt{\frac{204 \times 10^3 \times 0.00299}{2.7}}$

= 5.35 Hz

4) Whirling speed (N_ω) = Fn x 60

= 5.35 x 60

= 321 rpm

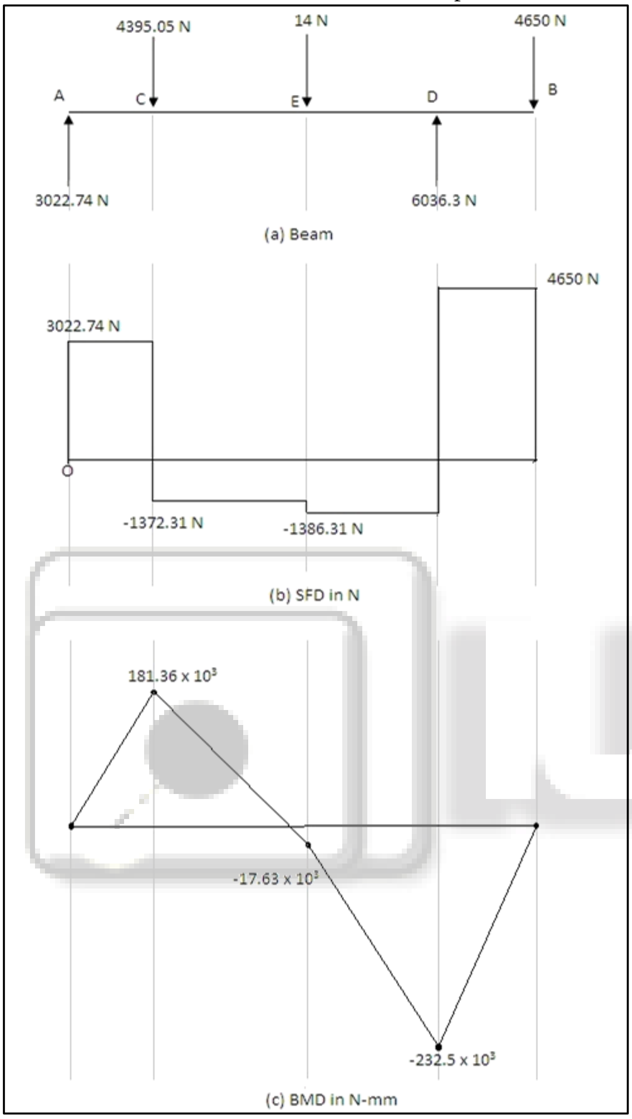

Fig. 3: Calculations

VII. Advantages and Applications

A. *Advantages*

- Drive system is less likely to become jammed.
- The use of a gear system creates a smoother and more consistent pedaling motion.
- Lower maintenance.
- Efficiency is more as compared to conventional bicycle design.
- High durability.
- Low cost of ownership when manufactured in large scale.

B. *Applications*

- It is used for racing purpose.
- Also used for Off-road riding.
- For Cycling.
- For public and bicycle rental purpose.

VIII. Result and Conclusion

- The presented work was aimed to reduce the wastage of human power on bicycle riding.
- The presented work also deals with optimization i.e. converting rotary motion into the linear motion with aid of two bevel gears.
- Instead of chain drive one piece drive shaft for rear wheel drive bicycle have been optimally designed and manufactured for easily power transmission.
- The result obtained from this work is a useful approximation to help in the earlier stage of the development, saving development time and helping in the decision making process to optimize a design.
- Hence we are trying to make the transmission smooth and easy by applying the bevel gears and shaft attachment instead of chain, chain sprocket.

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