DESIGN OF DRIVEN ASSEMBLY OF SHAFT DRIVEN BICYCLE

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ABSTRACT

A shaft-driven bicycle is a bicycle that uses a driven shaft. Driven shaft used instead of a chain to transmit power from the pedals to the wheel. We were mostly supplanted by chain-driven bicycles due to the gear ranges possible with sprockets and derailleur. Recently, due to research in internal gear technology, modern shaft-driven bicycles have been introduced. Only periodic lubrication is needed for shaft driven bicycle. For that it uses a grease gun to keep the gears running quiet and smooth. This shaft driven drive system provides smooth, quiet and efficient transfer of energy from the pedals to the rear wheel. It is aesthetically best compare with chain driven bicycle. Chain focused bi-cycle requires accurate mounting and alignment for proper working. Least misalignment will result in chain dropping. Chain drive is not efficient. The concept of shaft driven bicycles can be introduced due to highly developed gear manufacturing technology. The shaft driven system helps to transfer torque from the pedals to the rear wheel. Shaft driven bicycle is remarkable in look compare with chain focused bicycle. This seminar introduces design of shaft drive mode bicycle with shaft drive.

Keyword: *-Bicycle, shaft-driven, Pedals, Chainless, Torque*

1. INTRODUCTION

In structure or machine, cracked parts due to fatigue loading can cause change in a natural frequency. This change 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 arrangement displayed in the following fig 1.

Fig.1 Replacement of chain drive bicycle with driveshaft

Conventional bike would have its chain ring whereas Shaft-driven bikes have a large bevel gear. It also must operate constantly changing angles between the transmission, the differential and the axles. The shaft connected between the pair of spiral bevel gears. The main application of the spiral bevel gear is in a vehicle differential, where the direction of drive from the drive shaft must be turned 90 degrees to drive the wheels. This design produces less vibration and noise. The fact that the teeth of the bevel-wheels cannot be accurately milled is a serious obstacle to their practical success. This meshes with another bevel gear mounted on the drive shaft which is shown in fig 1.

1.1. Use of drive shaft

Fig.2 Shaft drive

1.2. Function of drive shaft

1. First, it must transmit torque from the transmission to the foot pedal.
2. It is necessary to transmit maximum low-gear torque developed by the pedal.
3. The drive shafts must also be capable of rotating at the very fast speeds required by the vehicle.
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2. OBJECTIVE

1. Making system more reliable.
2. To replace the chain drive with shaft drive in two wheeler.
3. Increase durability of bicycle with the help of shaft drive.
4. Reduce maintenance cost of bicycle.
5. Increase power transmission efficiency of the bicycle.
6. Reduce noise pollution using shaft drive

3. CONSTRUCTIONAL FEATURES

The shaft connected between the pair of bevel gears. The main application of the bevel gear is in a vehicle differential, where the direction of drive from the drive shaft must be turned 90 degrees to drive the wheels. Aim of our Project is to make new kind of transmission system for bicycle for getting high reliability system, and more safe system.

3.1 Components of bicycle

- **Paddle**
- **Fender**
- **Brake**
- **Hub**
- **Tire**
- **Wheel rim**
- **Bevel gear**

3.2 Cad Diagram

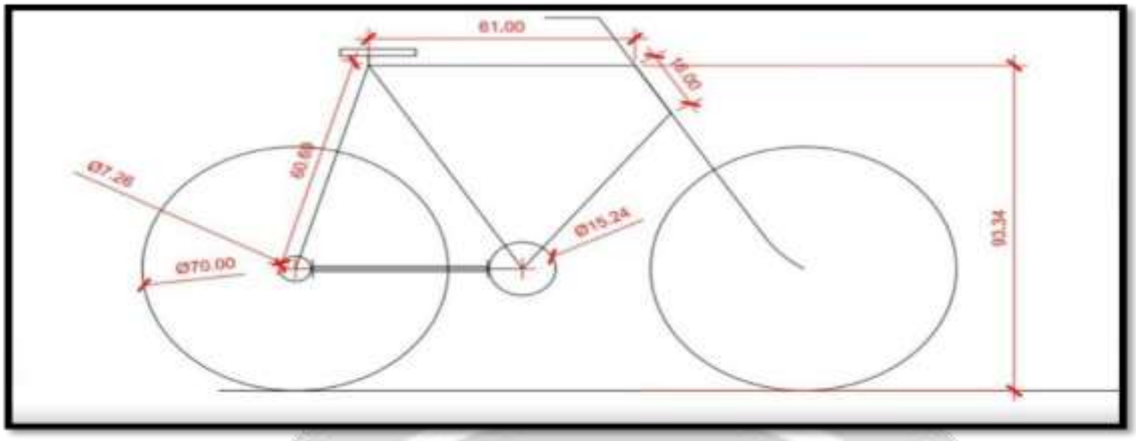

Fig.3.Layout of bicycle

4. DESIGN METHODOLOGY

4.1 Design of pedal shaft

Referred as PSG (1.10 & 1.12) + (1.17) and Machine Design by Khurmi Gupta.

Table1. Standard values

Designation	**Ultimate tensile strength (N/mm^2) (σ_{ut})**	**Yield Strength (N/mm^2) (τ_{max})**
EN24	800	680

Specifications of EN24

Table 2. Specification of EN24

Carbon	0.36 – 0.44 %
Silicon	0.10 – 0.35 %
Manganese	0.45 – 0.70 %
Sulphur	0.040 Max %
Phosphorus	0.035 Max %
Chromium	1.00 – 1.40 %

$\tau_{max} = 0.18\sigma_{ut}$------------------------------(1)
$= 0.18 \times 800$
$= 144 \quad N/mm^2$

$\tau_{max} = 0.3\sigma_{yt}$ **------------------------------(2)**
$= 0.3 \times 680$

= 204 N/mm^2

Considering minimum of above values,

$\tau max=144$ N/mm^2

Reducing above value of allowable stress by 25%.

$\tau max = 108$ N/mm^2

This is allowable shear stress limit of the shaft material for safe operation.

Torque at pedal shaft = $(P\times60) / (2\pi N)$ ---------------------------- (3)

$= (1.5\times10^3\times60) / (2\pi\, 300)$

$= 47.74\times10^3$ N-mm

Check for torsional shear failure of shaft.

d= 15mm

$T_{design} = (\pi/16) \times d^3\times \tau act$ --------------------------------- (4)

$\tau act = (47074\times10^3\times16) / (\pi\times15^3)$

$\tau act = 72.04$ N/mm^2

As, $\tau act < \tau max$; the input pedal shaft is safe.

4.2 Design of bevel gear

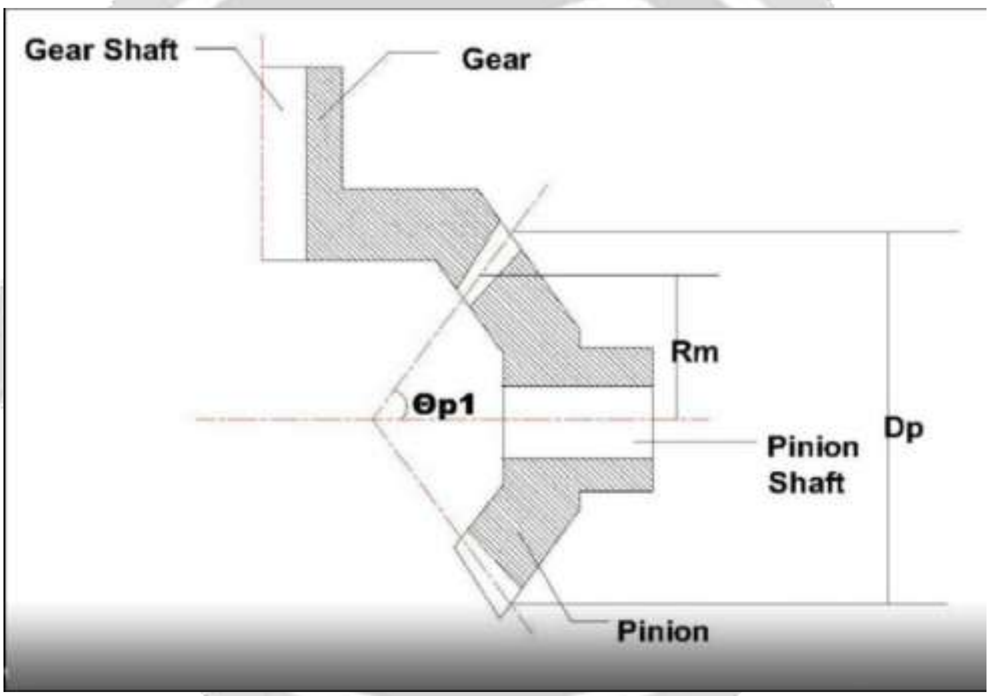

Fig.3 Gear design terms

1. For big gear and small pinion meshed with it :-

Let, m = required module in mm.

Pitch angle for pinion,

$\theta_{p1} = \tan^{-1} (T_P/T_G)$-----------------------(4)

$\theta_{p1} = \tan^{-1} (15/76)$

$\theta_{p1} = 11.16^o$

Where, T_P = Teeth on pinion = 15

T_G = Teeth on gear = 76

θ_{p1} = pitch angle for pinion,

Pitch angle for gear,

$\theta_{p2} = \theta_s - \theta_{p1} = 90^o - 11.16^o = 78.84^o$

Formative number of teeth on pinion:-

$T_{EP} = T_P \times \mathrm{Sec}\ \theta_{p1} = 15\mathrm{Sec}\ 11.13^o = 15.23 \approx 15$ ------------------------- (5)

Formative number of teeth on gear:-

$T_{EG} = T_G \times \mathrm{Sec} = 76 \times \mathrm{Sec}\ 78.84 = 232.98$ ----------------------- (6)

We know that tooth form factor fpr the pinion

$Y'P = 0.124 - (0.684/ T_{EP})$

$= 0.124 - (0.684/ 15.23)$

$= 0.079$

And tooth form factor for gear,

$Y'G = 0.124 - (0.684 / T_{EG})$

$= 0.124 - (0.684/ 232.98)$

$= 0.12$

Now, σ_{op} and σ_{OG} is 350 N/mm2 for both pinion and gear as they are made up of mild steel.

$\sigma_{op} \times Y'P = 350 \times 0.079 = 27.65$

$\sigma_{OG} \times Y'G = 350 \times 0.12 = 42$

Since, product $\sigma_{op} \times Y'P$ is greater than $\sigma_{OG} \times Y'G$; Therefore, gear is strong enough to bear all the force acting on it.

Now, rpm on gear = 75 rpm

P = 5 KW

Torque on gear,

$T_G = (P \times 60) / (2\pi N_G)$

$= (5 \times 10^3 \times 60) / (2\pi \times 75)$

$T_G = 636.61$ N-mm

Tangential load on gear,

$W_T = T / (D_G/2)$

$= 2T/ (m \times T_G)$

$= (2 \times 636.61) / (m \times 76)$

$= 16.75/m$ N

Pitch line velocity,

$V = (\pi \times m \times T_G \times N_G) / 60$ ---------------------------------- (7)

$V = (\pi \times m \times 76 \times 75) / 60$

$V = 298.45 \approx 298$ mm/s

$V = 0.298$ mm/s

Taking Velocity Factor,

$C_V = 6 / (6 +V)$ -- (8)

$= 6 / (6+0.298m)$

Length of pitch cone element,

$L = (m.T_G) / (2.\mathrm{Sin}\ \theta_{P2})$----------------------------(9)

$L = (m \times 76) / (2 \times \mathrm{Sin}\ 78.84^o)$

$L = 38.73m$ mm

Assume face width (b) as 1/3 rd of length,

$b= L/3$

$b= 38.73m / 3$

$b= 12.91m$ mm

We know that tangential load on gear,

$W_T = (\sigma_{OG} \times C_V) b \times \pi \times m \times Y'G \times ((L-b)/L)$----------------(10)

$16.75 / m = (350 \times 6/ (6 + 0.298m) \times 12.91m \times \pi \times m \times 0.12 \times ((38.73m - 12.91m) / (38.73m))$

$16.75 / m = 350 \times (6 / (6+0.298m)) \times 12.91m \times \pi \times m \times 0.12 \times 0.66$

$16.75 / m = 6745.6m^2 / (6+0.298m)$

$100.5 + 4.99m = 6745.6\ m^3$

M = 1.7 $\approx$ 2 mm
Now,
$D_P = m \times T_P$--------------------------(11)
$D_P = 2\times15$
$D_P = 30$mm

$D_G = m\ T_G$ --------------------------- (12)
$D_G = 2\times76$
$D_G = 152$ mm

V = pitch line velocity = 0.298 ×m
V = 0.298×2
V = 0.596 m/s
Tangential load on gear :-
$W_T = 16.75 / m$
$W_T = 16.75 / 2$
$W_T = 8.375$ N

Dynamic load on gear,
$W_D = [W_T + 21V\times (B\times C + W_T)] / (21V + \sqrt{b \times C \times WT}$)------------------(13)

From machine design book, tooth error action for precision gear having module 2 is
e = 0.125
For e = 0.125
K = 0.111

Now, $C = (K\times e) / [(1/E_P) + (1/E_G)]$----------------------------(14)
$C = (0.111\times0.125) / / [(1/210\times10^3) + (1/84\times10^3)]$
$C = (0.111\times0.125) / (1.666\times10^{-5})$
C = 832.833
Now,
$W_D\ [8.375 +21\times0.596\times (25.82\times832.83 + 8.375)] / (2/0.596 + \sqrt{25.85 \times 832.83 \times 8.375}$)

$W_D = 8.375 + (21512.045/ 155.016)$
$W_D = 147.148$ N

For precision gear,
Brinell hardness number (BHN) = 160
σe = 525

WS = $\sigma e\times b\times\pi\times m\times Y'G$ ------------------------------ (15)
= $525\times25.82\times\pi\times2\times0.12$
= 10220.60 N

As, Ws >WD
Design is safe for Dynamic load.

4.3 Design of Drive Shaft :
Mild Steel shaft,
W = m×g
W = 150×9.81
W = 1471.5 N
P = 5Kw
N = 150rpm

τ max = 420 N/mm2
Assume T_1 = 2.5 T2

Fig.4 FBD of shaft

$T = (T_1 - T_2) \times R_A$ -------------------------------------- (16)
$T = 2.5T_2 - T_2 \times 25.65$
$138.30\times10^3 = 1.5\times T_2 \times 25.65$

T_2 = 3594.54 N-mm

T_1 = 8986.35 N-mm

$T_1 = F_t \times R_B$
$F_t = (138.30\times10^3) / 25.65$
F_t = 5391.8128 N

Net load acting on small gear at first and second end,
$W_A - W_B = 138.30 \times 10^3 - 25.65$
$W_A - W_B = 138.27 \times 10^3$ N

Now bending moment at C and D,
$M_C = M_D = 138.27 \times 103 \times 50$
$M_C = M_D = 69.13\times 10^5$ N-mm

$T_e = \sqrt{2 \times 69.13 \times 10^5} + \sqrt{1.5 \times 138.30 \times 10^3}$
3746.12 N-mm
$T_e = \pi/16 \times \tau max \times d_3$----------------------(17)
$(3746.12 \times 16) / (\pi \times 420) = d_3$
d = 16.7 mm

5. SHAFT DRIVE OVER CHAIN DRIVE

Table 3. Comparison between shaft drive and chain drive

Sr. No.	Features	Shaft Driven bicycles	Sprocket- chain bicycles
1.	**Frame construction**	Aluminum Alloy	Aluminum Alloy
2.	**Maintenance**	No Scheduled Maintenance on Hub; Periodic Grease added to Shaft Drive -fast and easy	Requires adjustment of derailleur's by trained bike mechanic; periodic chain cleaning, lubrication and tensioning
3.	**Durability**	All moving parts fully enclosed to prevents damage and corrosion.	All moving parts fully exposed and susceptible to damage, misalignment and corrosion.
4.	**Ground Clearance**	13+ inches to shaft drive	~ 8 inches to derailleur, chain and sprocket
5.	**Safety**	Gears fully enclosed in shaft-drive, nothing to catch on hands or clothing; no more "chain bite"	Chain, sprockets and derailleur's can tear and soil clothing and cut hands
6.	**Noise**	Low	Can vary depending on condition of chain and alignment of derailleur
7.	**Efficiency**	90%+ efficient (consistently with minimum maintenance)	75% - 90% efficient (varies depending on condition and upkeep)

5.1 Advantages

1. Increase the durability of bicycle.
2. Fluctuations are absent.
3. Elongation of chain is overcome.
4. As there is no need of chain, chain adjuster is not needed.
5. Reduce the human power wastage.
6. Lower maintenance than a chain system when the drive shaft is enclosed in a tube.

5.2 Applications

1. Cross road bicycles.
2. Racing bicycles.

6. CONCLUSION

The presented work was aimed to reduce the wastage of human power (energy) on bicycle riding or any machine, which employs drive shafts; in general it is achieved by using light weight drive shaft with bevel gears on both sides designed on replacing chain transmission. The presented work also deals with design optimization. Instead of chain drive one piece drive shaft for rear wheel drive bicycle have been optimally designed and manufactured for easily power transmission. The drive shaft has served as an alternative to a chain-drive in bicycles for the past century, never becoming very popular.

7. REFERENCES

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