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Design & Fabrication of Shaft Drive for Bicycle

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Abstract: *This project is developed for the users to rotate the back wheel of a two wheeler using propeller shaft. Usually in two wheelers, chain and sprocket method is used to drive the back wheel. But in this project, the Engine is connected at the front part of the vehicle. The shaft of the engine is connected with a long rod. The other side of the long rod is connected with a set of bevel gears. The bevel gears are used to rotate the shaft in 90 o angle. The back wheel of the vehicle is connected with the bevel gear(driven). Thus the back wheel is rotated in perpendicular to the engine shaft. Thus the two wheeler will move forward. According to the direction of motion of the engine, the wheel will be moved forward or reverse. This avoid the usage of chain and sprocket method*

1. 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 wheel arrangement displayed in the following fig 1. 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. Recently, due to advancements in internal gear technology, a small number of modern shaft-driven bicycles have been introduced. 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 which is shown in fig 1.

Fig.1.1. *Replacement of chain drive bicycle with driveshaft*

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.

Fig2. *Shaft drive for bicycle*

1.1 Use of drive shaft

The torque that is produced from the pedal and transmission must be transferred to the 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 shafts 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 differential and the axles.

2. LITERATURE REVIEW

The first shaft drives for cycles appear to have been invented independently in 1890 in the United States and England. The Drive shafts are carriers of torque; they are subject to torsion and shear stress, which represents the difference between the input force and the load. They thus need to be strong enough to bear the stress, without imposing too great an additional inertia by virtue of the weight of the shaft. Most automobiles today use rigid driveshaft to deliver power from a transmission to the wheels. A pair of short driveshaft is commonly used to send power from a central differential, transmission, or transaxie to the wheels.

3. COMPONENTS OF BICYCLE

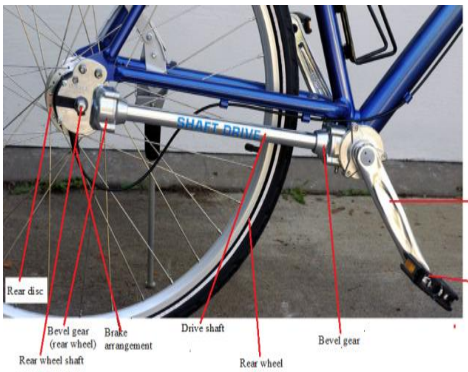

Fig3.1. *components of shaft driven bicycle*

3.1 Paddle

A bicycle pedal is the part of a bicycle that the rider pushes with their foot to propel the bicycle. It provides the connection between the cyclist's foot or shoe and the crank allowing the leg to turn the bottom bracket spindle and propel the bicycle's wheels. Pedals usually consist of a spindle that threads into the end of the crank and a body, on which the foot rests or is attached, that is free to rotate on bearings with respect to the spindle. Part attached to crank that cyclist rotate to provide the bicycle power; it consists of three segments as shown in figure

3.2 Fender

Piece of curved metal covering a part of wheel to protect the cyclist from being splashed.

3.3 Front Brake

Mechanism activated by brake cable compressing a calliper of return springs. It forces a pair of brake pads against the sidewalls to stop the bicycle.

3.4 Hub

Centre part of the wheel from which spoke radiate, inside the hub are ball bearings enabling to rotate around in axle.

3.5 Bevel gear

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.

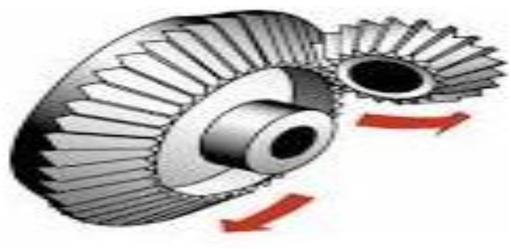

Fig3.2. *Bevel Gear*

3.6 Driven 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 ago, but were mostly supplanted by chain-driven bicycles due to the gear ranges possible with sprockets and derailleurs. Recently, due to advancements in internal gear technology, a small number of modern shaft-driven bicycles have been introduced.

3.7 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 vibration and noise.
5. They have good corrosion resistance.
6. Greater torque capacity than steel or aluminum shaft.
7. Longer fatigue life than steel or aluminum shaft.
8. Lower rotating weight transmits more of available power.

3.8 Selection of Bevel Gear

Bevel gears are gears where the axes of the two shafts intersect and the tooth-bearing faces of the gears themselves are conically shaped. Bevel gears are most often mounted on shafts that are 90 degrees apart, but can be designed to work at other angles as well. The pitch surface of bevel gears is a cone. Two important concepts in gearing are pitch surface and pitch angle. The pitch surface of a gear is the imaginary toothless surface that you would have by averaging out the peaks and valleys of the individual teeth. The pitch surface of an ordinary gear is the shape of a cylinder. The pitch angle of a gear is the angle between the face of the pitch surface and the axis.The most familiar kinds of bevel gears have pitch angles of less than 90 degrees and therefore are cone-shaped. This type of bevel gear is called external because the gear teeth point outward. The pitch surfaces of meshed external bevel gears are coaxial with the gear shafts; the apexes of the two surfaces are at the point of intersection of the shaft axes.

4. Selection Of Methodology

4.1 Selection of bevel gear

4.2 Selection of Drive shaft

4.3 Placing of bevel gear

4.4 Testing and correction

5. Construction And Working Principle

Table4.2. *Mechanical properties of Cast iron*

S. No	Mech.Properties	Symbol	Units	Cast Iron
1.	Youngs Modulus	E	GPa	105.0
2.	Shear Modulus	G	GPa	36.75
3.	Poisson Ratio	v	------	0.23
4.	Density	ρ	Kg/m^3	7209
5.	Yield Strength	S_y	MPa	130
6.	Shear Strength	S_s	MPa	169

The term Drive shaft is used to refer to a shaft, which is used for the transfer of motion from one point to another. Whereas the shafts, which propel is referred to as the propeller shafts. However the drive shaft of the automobile is also referred to as the propeller shaft because apart from transmitting the rotary motion from the front end to the rear end of the vehicle, these

shafts also propel the vehicle forward. The shaft is the primary connection between the front and the rear end, which performs both the jobs of transmitting the motion and propelling the front end. The design of drive shaft as shown in fig.

Thus the terms Drive Shaft and Propeller Shafts are used interchangeably. In other words, a drive shaft is a longitudinal power transmitting, used in vehicle where the pedal is situated at the human feet. A drive shaft is an assembly of one or more tubular shafts connected by universal, constant velocity or flexible joints. The number of tubular pieces and joints depends on the distance between the two wheels.

The job involved is the design for suitable propeller 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 bikes, there is no more grease on your hands or your clothes; and no more chain and derailleur maintenance.

5.1 Specification of drive shaft

The specifications of the composite drive shaft

S.No	Name	Notation	Unit	Value
1.	Ultimate Torque	T_{max}	Nm	3500
2.	Max.Speed of shaft	N_{max}	rpm	6500
3.	Length of Shaft	L	mm	250

rider x g) x the length of the pedal lever. Remember to consider the gearing of the bike though.

5.4 Design Calculations

Inner Diameter of shaft (d_i) = 0.026 m

Outer Diameter of shaft (d_o) = 0.028 m

Length of shaft (L) = 0.335 m

Number of teeth = 16

Gear Pitch (P) = MT/2

of an automotive transmission are same as that of the steel drive shaft for optimal design.

The material properties of the steel (SM45C) are given in Table. The steel drive shaft should satisfy three design specifications such as torque transmission capability, buckling torque capability and bending natural frequency.

5.2 Design Assumptions

1. The shaft rotates at a constant speed about its longitudinal axis.
2. The shaft has a uniform, circular cross section.
3. The shaft is perfectly balanced, i.e., at every cross section, the mass center coincides with the Geometric center.
4. All damping and nonlinear effects are excluded.
5. The stress-strain relationship for composite material is linear & elastic; hence, Hooke's law is Applicable for composite materials.
6. Acoustical fluid interactions are neglected, i.e., the shaft is assumed to be acting in a vacuum.
7. Since lamina is thin and no out-of-plane loads are applied, it is considered as under the plane Stress.

5.3 Transmission of Torque

Action and reaction my friend. If a person does not turn the pedal then he will stand on it and so the maximum torque will = (body mass of the

= 0.008*16/2

= 0.128/2 =0.064 m

Module (m) = 0.008 m

Mass Moment of Inertia (I) $= MR^2/2$

$= 4*0.014^2$

= 0.0039

Polar Moment of Inertia (J)

$= \pi (d_o^4 - d_i^4)/32$

$= \pi (0.028^4 - 0.026^4)/32$

$= (4.953X10^{-7})/32$

$= 1.548 X 10^{-8}$

Maximum Torque on bicycle is given by

T = (Mass of rider x g) L

Where L = Length of pedal crank in 'm'

$g = 9.81 m/sec^2$

(Assume mass of rider = 60 kgs)

= 60 x 9.81 x 0.335

= 197.2 Nm

Power (P) = 2πNT / 60

= (2π x 110 x197.2) / 60

= 2271.5 watts

Shear Stress (г) = Tρ/J

= (197.2)(7209) /1.548 X 10^{-8}

= 9.18 X 10^{13} N/m^4

Max.Shear Stress ($г_{max}$) = TR_o/J

= (197.2)(0.014) / (1.548 x 10^{-8})

= 17.83 X 10^7

Bending moment (M) = EI / R

Where E = Youngs modulus

I = Moment of Inertia

R = Radius (R_o)

M = (105 X 0.0039)/ 0.014

= 29.25

Rate of twist = T/GJ

= 197.2/(36.75)(1.548X10^{-8})

= 3.46 X 10^8

Shear Strain = ρ (rate of twist)

= 7209 X 3.46 X10^8

= 2.49 X 10^{12}

Ɵ = TL/GJ

= (197.2)(0.335)/(36.75)(1.548 X 10^{-8})

= 66.06/(5.68X10^{-7})

= 1.163X10^9

Torsion is the twisting of an object due to an applied torque. It is expressed in newton metres (N·m), In sections perpendicular to the torque axis, the resultant shear stress in this section is perpendicular to the radius.

For shafts of uniform cross-section the torsion is:

$$T = \frac{J_T}{r}\tau = \frac{J_T}{\ell}G\theta$$

- T is the applied torque Nm.
- τ is the maximum shear stress at the outer surface
- $J_T = J_{zz}$ for concentric circular tubes
- r is the distance between the rotational axis
- ℓ is the length of the object the torque is being applied to or over.
- θ is the angle of twist in radians.
- G is the shear modulus or more commonly the modulus of rigidity (GPa),
- r_o outer radius

Torsion (T) = J_T.GƟ/L

= (1.548 X 10^{-8})(36.75)(1.163 X 10^9) / 0.335

Torsion (T) = 1974.9 Nm

Deflection (Y_{Max}) = ML^2 /2EI

= (29.25 X 0.335^2) / (2 X 105 X 0.0039)

= 4.008 m

Max.Deflection = [T X d_o / 2] / I

= [29.25 X 0.014] / 0.0039

= 105 Max.Shear Stress ($Г_{max}$) = (29.25 X 0.014) / (1.548 X 10^{-8})

= 26.45 X 10^7 Pa

Torque Transmission Capacity (T) is given by

T = S_s x π [(d_o^4 – d_i^4)d_o] / 16

(Assume shear strength (S_s) = 360 to 1200 Mpa)

T = 360 X π [(0.028^4 – 0.026^4)0.028] / 16

= 3.120 X 10^{-7} N-m

Tensional buckling capacity = $\frac{1}{\sqrt{1-\upsilon 2}}\frac{L^2 t}{2r3}$

Tensional Buckling Capacity = (t x L^2t) / $\sqrt{1-\mu 2}$.2r^3

= (0.003 x 0.335^2 x 0.003) / √(1 – 0.23^2).2x0.014^3

= (1.01 x 10^{-6}) /(√0.947(5.48 x 10^{-6})

= 3.71 X 10^{-4} m

Bending Vibration Frequency is given by

F_{vb} = (πp^2 / $2L^2$)√(EI_x / m_i)

= [(7.73 X 10^{-3})/(2 X 0.335^2)].√(105 X 0.0039)/0.204

= (0.0344).√2.007

= 1.4166 X 0.0344

= 0.0487

6. RESULT

S.no	Parameter	Symbol	Units	Value
1.	Gear Pitch	P	m	0.064
2.	Moment of Inertia	I	$Kg.m^2$	0.0039
3.	Polar Moment of Inertia	J	m^4	$1.548 X 10^{-8}$
4.	Torque	T	Nm	197.2
5	Power	P	Watts	2271.5
6	Shear Stress	τ	Pa	$9.18 X 10^{13}$
7	Max.Shear Stress	τ_{max}	Pa	$17.83 X 10^{7}$
8	Bending Moment	M	N-m	29.25
9	Shear Strain	Ø	----	$2.49 X 10^{12}$
10	Angle of twist	ϴ	^{o}c	66.63
11	Torsion	ϴ	Nm	1974.9
12	Deflection	У	m	4.008
13	Max.Deflection	$У_{max}$	m	105
14	Torque Transmission Capacity	T	N/m	$3.12 X 10^{-7}$
15	Tensional Buckling Capacity	T_C	m	$3.71 X 10^{-4}$

7. CONCLUSION

Firstly the project were unable to be completed with the drive shaft due to various problems around circumference of the bicycle ,later on this was realized to run successfully with two bevel gears at both end of the drive shaft.

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 i.e converting rotary motion in 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 drive shaft with the objective of minimization of weight of shaft which was subjected to the constraints such as torque transmission , torsion buckling capacity , stress, strain , etc

The torque transmission capacity of the bicycle drive shaft has been calculated by neglecting and considering the effect of centrifugal forces and it has been observed that centrifugal force will reduce the torque transmission capacity of the shaft.

The stress distribution and the maximum deformation in the drive shaft are the functions of the stacking of material. The optimum stacking of material layers can be used as the effective tool to reduce weight and stress acting on the drive shaft.

The design of drive shaft is critical as it is subjected to combined loads. The designer has two options for designing the drive shaft whether to select solid or hollow shaft. The solid shaft gives a maximum value of torque transmission but at same time due to increase in weight of shaft, For a given weight, the hollow shaft is stronger because it has a bigger diameter due to less weight & less bending moment

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

The drive shaft has served as an alternative to a chain-drive in bicycles for the past century, never becoming very popular

8. TROUBLESHOOTING

When abnormal vibrations or noises are detected in the driveshaft area, this chart can be used to help diagnose possible causes. Remember that other components such as wheels, tires, rear axle

Problem	**Caused by**	**What to do**
As bicycle is accelerated from stop	torque is required	Apply more torque at starting
when gears are not shifting	rusting	Clean with fluids
Vibration at speed	High speed	Maintain low speed
Noise at low speed	Universal joint	Apply grease
Gears pitch circle is not coincide	Vibrations	Adjust the position of gears
Gear backlash	Noise, Overloading, Overheating	Follow design characteristics

and suspension can also produce similar conditions.

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