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Fabrication and Performance Analysis of Shaft Drive Bicycle Without Chain

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Abstract*: 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 derailleur. Recently, due to advancements in internal gear technology, a small number of modern shaft driven bicycles have been introduced. At present, the chain driven bikes have been a great trouble in aspects of maintenance, cleanliness, power transmission etc. So to overcome these effects we have replaced the chain driven bikes by shaft mechanisms. The chain drive eliminated the need to have the cyclist directly above the wheel. Instead the cyclist could be positioned between the two wheels for better balance. More recently bicycles with a shaft drive have been developed and it is slowly changing the bike industry. Both have unique advantages and can produce nearly the same efficiency. This project illustrates the characteristics of the two alternate drive mechanisms, chain drive and shaft drive. After carefully examining the two alternatives, the conventional shaft drive was selected for the project since its cost and flexibility were determined to be better suited for the project. 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 900 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 sprockets would on a conventional bicycle, and canceling out the first drive torque change of axis. Now-a-days it is need to develop shaft drive bicycle to improve better durability and maintenance with mechanical technology.

***Keywords*: Shaft drive bicycle.**

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. 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.

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 90-degree change of the drive plane that occurs at the bottom bracket and again at the rear hub uses bevel gears for the most efficient performance, though other mechanisms could be used, e.g. hob son's joints, worm gears or crossed helical gears.

A. Chain Drive Mechanism

Chain drive is a way of transmitting mechanical power from one place to another. It is often used to convey power to the wheels of a vehicle, particularly bicycles and motorcycles. It is also used in a wide variety of machines besides vehicles.

One of the most power transmitting component in transportation machines like motor- cycles, bicycles, automobiles, conveyors, agriculture machinery and machine tools. Chain drives are flexible and made of number of links and its an intermediate between belts and gears drives. Chains can only be used to transmit power between parallel shafts. Unlike belt drives, chain drives uses special toothed wheels called sprockets.

Sometimes the power is output by simply rotating the chain, which can be used to lift or drag objects. In other situations, a second gear is placed and the power is recovered by attaching shafts or hubs to this gear. Though drive chains are often simple oval loops, they can also go around corners by placing more than two gears along the chain; gears that do not put power into the system or transmit it out are generally known as idler-wheels. By varying the diameter of the input and output gears with respect to each other, the gear ratio can be altered. For example, when the bicycle pedals' gear rotate once, it causes the gear that drives the wheels to rotate more than one revolution.

B. Use of Chain Drive in Bicycle

Chain drive was the main feature which differentiated the safety bicycle introduced in 1885, with its two equal-sized wheels, from the direct-drive penny-farthing or "high wheeler" type of bicycle. The popularity of the chain-driven safety

bicycle brought about the demise of the penny-farthing, and is still a basic feature of bicycle design today.

A bicycle chain is a roller chain that transfers power from the pedals to the drive- wheel of a bicycle, thus propelling it. Most bicycle chains are made from plain carbon or alloy steel, but some are nickel-plated to prevent rust, or simply for aesthetics.

2. Design and analysis of shaft drive bicycle

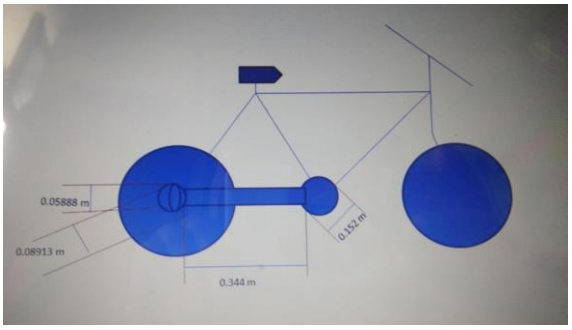

Fig. 1. Design parameters

A. Analysis of Components

The design of components is done in AUTODESK INVENTOR, a designing tool. Autodesk Inventor, developed by U.S. based software company Autodesk, is a computer-aided design application for creating 3D digital prototypes used in the design, visualization and simulation of products. Autodesk Inventor competes directly with SolidWorks.

This software incorporates integrated motion simulation and assembly stress analysis, whereby users are given options to input driving loads, dynamic components, friction loads and further run the dynamic simulation to test how the product will function in a real - world scenario. These simulation tools enable users designing cars or automotive parts, for example, to optimize the strength and weight of a product, identify high-stress areas, identify and reduce unwanted vibrations, and even size motors to reduce their overall energy consumption.

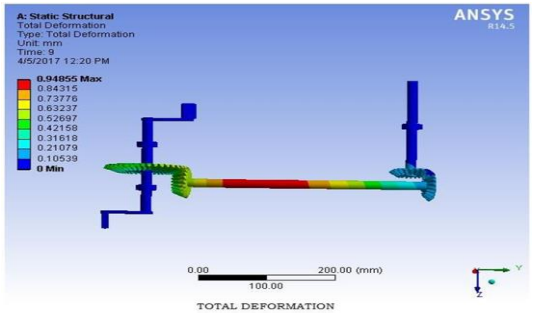

Fig. 2. Deformation

3. Calculation of shaft drive bicycle

A. Readings

External Diameter of Crown Wheel = 0.152 m
External Radius of Crown Wheel = 0.076 m
Length of Crown Wheel = 0.4775 m
Number of Teeth's on Crown Wheel = 44
Number of Teeth's on Pinion = 9
Pitch Circle Diameter = 0.15 m
Length of Shaft Drive = 0.344 m
Diameter of Shaft Drive = 0.018 m
External Diameter of Larger Bevel Gear = 0.08913 m
External Radius of Larger Bevel Gear = 0.044565 m
Number of Teeth's on Larger Bevel Gear = 16
Length of Larger Bevel Gear = 0.28 m
External Diameter of Smaller Bevel Gear = 0.05888 m
External Radius of Smaller Bevel Gear = 0.02944 m
Number of Teeth's on Smaller Bevel Gear = 10
Length of Smaller Bevel Gear = 0.1849 m

B. Calculation of shaft drive mechanism

1) Speed

N_1= speed of input drive
N_2 = speed of output drive
N_1 = 80 rpm (Assume)
N_2 =?
T_1 = 44, T_2 = 16
$N_1T_1 = N_2T_2$

$$N_2 = \frac{N_1T_1}{T_2}$$

$$N_2 = \frac{80\times44}{16}$$

N_2 = 220 rpm

2) Velocity

d_1 = 0.152 m
d_2 = 0.08913 m
N_1 = 80 rpm
N_2 = 220 rpm

$$v = \frac{\pi d N}{60}$$

$$\upsilon_{min} = \frac{\pi d1N1}{60}$$

$$\upsilon_{min} = \frac{\pi \times 0.152 \times 80}{60}$$

v_{min} =0.6366 m/s

$$\upsilon_{max} = \frac{\pi d2N2}{60}$$

$$\upsilon_{max} = \frac{\pi \times 0.08913 \times 220}{60}$$

v_{max} = 1.0267 m/s

3) Velocity Ratio (Speed Ratio)

$$V.R = \frac{N1}{N2}$$

$$V.R = \frac{80}{220}$$

V.R = 0.3636

Circular Pitch for Crown Wheel Gear Set

$$P_{c1} = \frac{\pi d1}{T1}$$

$$P_{c1} = \frac{\pi \times 0.152}{44}$$

$$P_{c1} = 0.01085 \text{ m}$$

Circular Pitch for Bevel Gear Set

$$P_{c2} = \frac{\pi d2}{T2}$$

$$P_{c2} = \frac{\pi \times 0.08913}{16}$$

$$P_{c2} = 0.0175$$

Module

$$m = Picth\ circle\ diameter\ no.of\ teeh's = D/T$$

$$m = 0.15 / 44$$

$$m = 0.0034 \text{ m}$$

Torque

T = (mass of the rider) × g × L

Assume mass of the rider=70 kg

g = 9.81 m/s^2

Length of the shaft = 0.344 m

T =70×9.81×0.344

T= 236.23 Nm

Power

$$P = \frac{2\pi NT}{60}$$

Input Power

$$P = \frac{2\pi N1T}{60}$$

$$P = \frac{2 \times \pi \times 80 \times 236.23}{60}$$

P = 1978.97 Watts

Output Power

$$P = \frac{2\pi N2T}{60}$$

$$P = \frac{2 \times \pi \times 220 \times 236.23}{60}$$

P = 5442.348 Watts

Shear Stress of Shaft Drive

$$\tau = \frac{T}{J} \times R$$

$$\tau = \frac{236.23}{1.03 \times 10^{-8}} \times 0.009$$

$$\tau = 206414.563 \text{ KPa}$$

Angle of Twist

$$\frac{\tau}{R} = \frac{C\theta}{L}$$

$$\theta = \frac{\tau}{R} \times \frac{L}{C}$$

$$\theta = \frac{206414563}{0.009} \times \frac{0.344}{78 \times 10}$$

$$\theta = 0.1011 \text{ rad}$$

$$\theta = 5.795°$$

Centrifugal Force

$$F_c = \frac{mv1^2}{r1}$$

$$F_c = \frac{70 \times 0.6366^2}{0.076}$$

Fc=373.26 N

4. Results and Discussions

Comparison of parameters of shaft drive and chain drive table.

Parameters of shaft drive and chain drive

Parameters	Shaft drive	Chain drive
Torque	236.23 Nm	236.23 Nm
Input speed	80 rpm	80 rpm
Output speed	220 rpm	195.55 rpm
Minimum velocity	0.6386 m/s	0.6534 m/s
Maximum velocity	1.0267 m/s	0.7986 m/s
Velocity ratio	0.3636	0.4091
Efficiency	95%	98%
Input power	1978.97 W	1978.97 W
Output power	5442.348 W	4837.5 W
Tangential driving force	3108.65 N	3028.72 N
Centrifugal force	373.26 N	383.14 N

Parameters of Shaft Drive

Polar moment of inertia (J) = 1.03× 10^{-8} m^4

Shear stress (τ) = 206414.563 K Pa

Bending moment (M) = 114488.8 Nm

Angle of twist (θ) = 5.795°

Trouble Detected with Shaft Drive

Causes and remedies of shaft drive

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

Shaft drive bicycle produce more output power when comparing chain drive bicycle. The maintenance of shaft drive bicycle is very easy than chain drive. Shaft drive bicycle gives more output velocity than chain drive bicycle.

5. Conclusion

The bicycle works efficiently and transmits the power from pedal to rear wheel smoothly, but it is requiring slightly more initial torque compare to chain 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.

The shaft driven bicycle would replace the existing conventional bicycle which runs by means of chain and sprocket arrangement. As the manual load given by the rider results in increased displacement of the bicycle, the human effort is reduced. It would be very advantageous for off road racing. It also requires less maintenance with a comparatively longer life. The shaft driven bicycle is designed successfully.

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