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Static Structural Analysis of Chainless Bicycle

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Abstract - *This project is developed amid the petroleum crisis to develop an eco-friendly mode of transportation that can be used for transportation for shorter distances. The most common method to drive the rear wheels is chain and sprocket method . But in this project, the rear wheel is connected to the front part of the vehicle using a shaft that is meshed with the pedal using a bevel gear. The bevel gears are used to change the axis of rotation by 90 degrees. On application of force on the pedal it rotates and it then rotates the gear which is meshed with the bevel gear attached to the propeller shaft the rotation is hence transferred to the shaft the shaft is placed inside a sleeve. The sleeve is attached to the body of the bicycle through arc welding. The other end of the shaft is meshed with the rear gear which is attached to the rear wheel using bevel gears. The rotating shaft then rotates the rear wheel. This paper illustrates the characteristics of an alternate drive mechanism, against the chain drive. After carefully examining the two alternatives, the shaft drive was selected for the project since its cost and flexibility were determined to be better suited for the project and then it out stood chain drive in many aspects in terms of reliability.*

Key Words: Gears meshing, Chainless bicycle, Shaft Drive Ansys, Design, Design methodology, Analysis

1.INTRODUCTION

A shaft driven bicycle uses a chainless mechanism using drive shafts to transmit the power generated by the rider's foot from the pedal to the rear wheel (Driving wheel) in this project rear wheel is used as driving wheel. Introduction of shaft drive took place over 100 years ago, but were very rarely used because of availability of number of gear ratios in chain drive due to the presence of sprocket and derailleurs.

In due course of time the technology has taken many large leaps which has resulted in the advancement of shaft drive and recently many shafts driven bicycle have been introduced in the market in recent times. Shaft driven bicycle use bevel gears for transmission of torque. There is large bevel gear attached with the pedal as the rider provides torque to the pedal the bevel gear attached with pedal rotates this bevel gear is meshed with another bevel gear attached with the shaft. The shaft rotates and the bevel gear attached at the other end is used to rotate the rear wheel as the rear wheel is also attached with another bevel gear. The bevel gear provides us with the flexibility of transmitting torque at an angle of 90 degrees. If we compare it with the conventional cycles, we have two bevel gears in the front instead of sprocket and chain. Similarly, we have a pair of bevel gear in the rear instead of rear sprocket and chain. So, we are making a new generation of cycle which is multipurpose and has sufficient mechanical advantage. The number of shaft drive manufacturers is increasing and public interests are growing as well. It is slowly changing the bike industry.

Fig -1: **Shaft drive assembly**

1.1 Use of Drive Shaft

A drive shaft can be defined as a rod-like component that is used to transmits torque from the engine of the vehicle to the wheels. In our project engine is the rider as in this project as in case of cycle rider provides the torque to drive the vehicle. The shaft must be flexible as it must be able to tolerate the vibrations when the cycle moves along a rough road. The torque that is produced from the pedal is transferred to the rear wheels to move the vehicle forward or reverse. The drive shaft supplies uninterrupted power in a smooth and continuous manner. The power is transferred by the bevel gears and shaft. The shaft drive has no free play as in chain drive hence the transmission of power is instantaneous.

1.2 Types of Drive Shaft

- **Single Piece Shaft: -** These types of shafts find application in four-wheel drive where the distance between axle and engine is small. It uses only a single shaft to transmit power. The durability, quality, and strength of the single-piece drive shaft is improved by friction welding.

- **Two or Three Piece Shaft**: - These shafts are used in vehicle where the distance between the axle and engine is large to avoid bending stress. There are some instances where number of shafts are used for gear reduction.

2. COMPONENTS OF SHAFT DRIVEN BICYCLE

2.1. Pedal Assembly

The basic function of a pedal is to use the provide a surface to the rider's foot/shoe so as to facilitate the rider to apply force. The pedal harnesses the force applied by the rider. The essential component of a pedal includes a spindle which is attached with a shaft and on the other end there is another pedal which is at 180 degrees angle with the first one.

Pedal has three types namely.

- Clipless
- Clip
- Platform

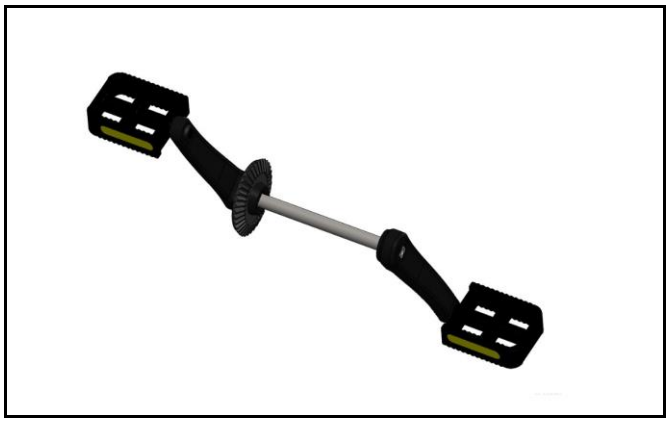

Fig -2: **CAD of platform type pedal used in the project**

2.2. Hub

Hub is the cylindrical like part which is at the center of the wheel. It has three components

- Axle
- Bearing
- Hub shell

The hub shell typically has two circular surfaces which spokes can be attached. Hub helps the wheel to rotate on the shaft.

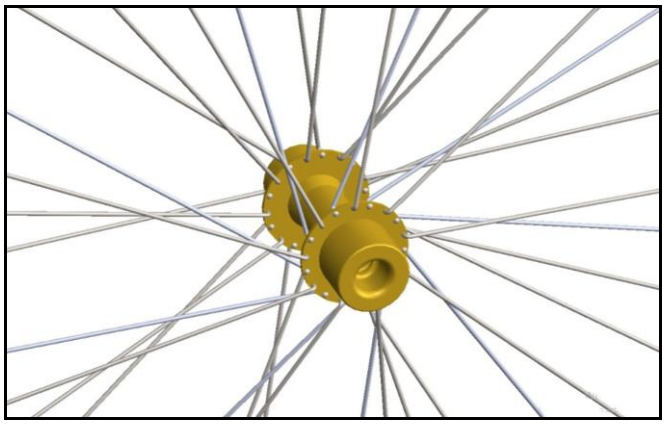

Fig -3: **CAD of hub used in the project**

2.3. Bevel Gear

A kind of gear in which the two wheels working together lie in different planes and 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. Bevel gears are used to connect shafts whose axes lie perpendicular to each other, The tooth profile is similar to spur gears except that the tooth gets progressively smaller as it approaches the apex of the projected cone.

Bevel gears are used at two locations for two different purposes.

- Connecting the pedal with the transmission shaft.
- Meshing the shaft with the rear wheel so as to transmit rotational motion to the rear wheel.

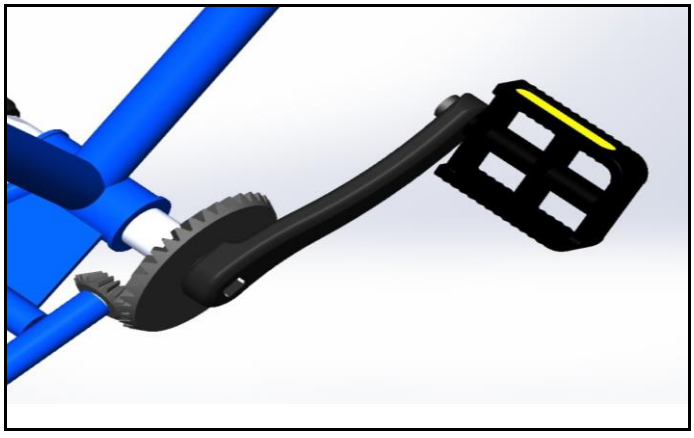

Fig -4: **CAD of bevel gear used to mesh pedal with transmission shaft**

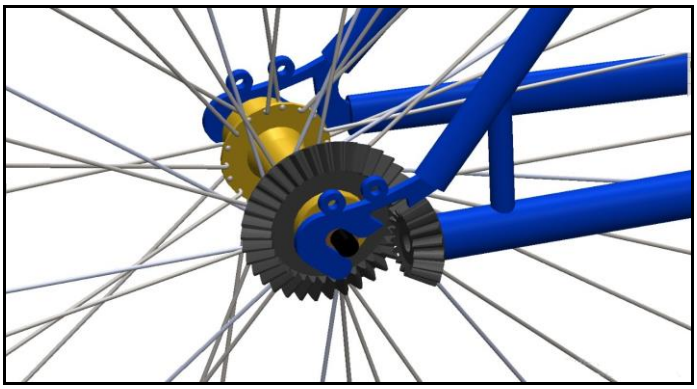

Fig -5: CAD of bevel gear used to mesh transmission shaft with rear wheel

2.4 Driven Shaft

A driven shaft is a cylindrical rod which is used to transmit torque between two points. It has gears on either of its ends which is used to transmit the rotary motion from the prime mover to the shaft and then from the shaft to the wheel. The major advantage of the shaft is instantaneous power transmission because of absence of free play in the shaft which is present in chain drives.

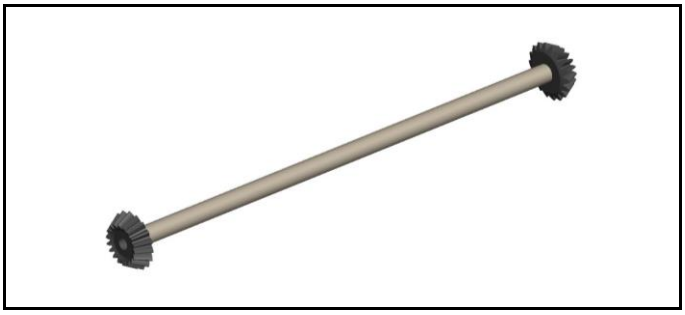

Fig -6: Drive shaft used in our bicycle

2.5 Wheel

A wheel is one among six simple machines. It is circular in shape and it rotates on an axle hence providing us with rotary motion. The tire is connected to the hub with the help of spokes. The whole assemble of tire, hub and axle is responsible for the forward motion of the bicycle. There are two tires in a bicycle one at the front and the other at the rear. These two tires bear the total load of the bicycle and support the other components of the bicycle.

Fig -6: CAD of rear wheel

2.6 Frame

It is almost like skeleton of a body it supports the components of the vehicle. The main functions of a frame a vehicle are:

1. It provides support to the other component of the vehicle
2. It primarily deals with distortion and deflection which arises because of dynamic loads on the vehicle.

There are many types of frames which include ladder frame, Unibody. X frame, Tubular frame etc

We have used a tubular sort of frame.

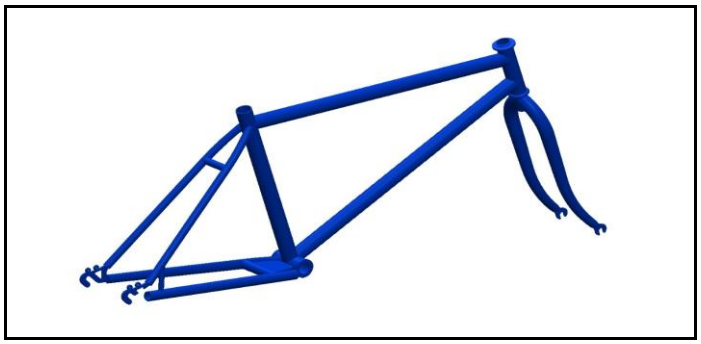

Fig -7: CAD of frame used in our bicycle

3. FULL ASSEMBLY OF THE BICYCLE

Fig -8: Isometric view of full assembly of bicycle

4. DESIGN CALCULATION OF SHAFT DRIVEN BICYCLE

4.1. Design Assumptions

● The shaft rotates at a constant speed about its longitudinal axis.

● The shaft has a uniform, circular cross section.

● The shaft is perfectly balanced, i.e., at every cross section, the mass center coincides with the Geometric center.

● All damping and nonlinear effects are excluded.

4.2 Design Calculation of Front and Rear Gear Set

Module, m = 3

Pressure Angle, $\alpha = 20°$

No. of teeth on Pinion, Zp = 18

No. of teeth on Gear, Zg = 36

Pitch Circle Diameter, D = m*Z

Pitch Circle Diameter of Pinion, Dp = 3*20 = 54 mm

Pitch Circle Diameter of Gear, Dg = 3*40 = 108 mm

Circle Diameter of Gear, Dg = 3*40 = 108 mm

Cone Angle (Pitch Angle) of Pinion,

$\partial P = \text{Tan-1}\ ((\sin 90^0)/(ZG/ZP) + \cos(90^0)$

$\Rightarrow \partial P = \text{Tan-1}\ ((\sin 90^0)/(40/20) + \cos(90^0) = 26.56^0$

Cone Angle (Pitch Angle) of Gear, $\partial G = 90^0 - \partial P = 63.435^0$

Cone Distance, $R = D/2\sin\partial P = 60/2 \sin 26.560 = 67.09$ mm

Face Width, $b \le R/3 = 67.09 / 3 = 22.36$ mm

Addendum, ha = m = 3 mm

Dedendum, hf = 1.25*m = 1.25*3 = 3.75 mm

Clearance, c = 0.25*m = 0.25*3 = 0.75 mm

Working Depth, hk = 2*m = 2*3 = 6 mm

Whole Depth, h = 2.25*m = 2.25*3 = 6.75 mm

Tooth Thickness, s = 1.5708*m = 1.5708*3 = 4.71 mm

Tooth Space = 1.5708*m = 1.5708*3 = 4.71 mm

Fillet Radius = 0.4m = 1.2 mm

4.3 Design Calculation of Shaft

(Assume mass of the rider = 70kg = 260.946 N, $g = 9.81 m/s^2$)

Diameter of shaft, d = 18 mm

Length of the main shaft, L = 375 mm

Torque to be transmitted,

T = mass of the rider * g * length of the main shaft

$\Rightarrow T = 70 * 9.81 * 375 = 257512.5$ N mm

Modulus of rigidity, G = 41 GPa

Polar moment of inertia, $J = \pi(d^4)/2$

$\Rightarrow J = \pi(0.018^4)/2 = 164895.922\ mm^4$

Angle of twist, $\theta = TL/GJ$ Degrees

$\Rightarrow \theta = (260.946*0.380)/(41000*164895.922) = 0.84^0$

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

$\Rightarrow P = (2\pi*100*260.946)/60 = 2732.62$ W

Shear stress, $\tau = T\rho/J$

$\Rightarrow \tau = (260.946*7800)/164895.922 = 12.343415$ N/mm

5. ANALYSIS OF FRAME OF SHAFT DRIVEN BICYCLE

The analysis and simulation are performed on the designed model of the frame using the simulation tool ANSYS R19.2. It is found initially that the design is safe with respect to the given load, based on the theoretical analysis performed. From the Static Structural simulation report it was found out that the design is safe. Hence, the designed shaft driven bicycle can sustain the loads at the predefined RPM. On comparing the theoretical and simulated values it was found that they were approximately closer.

Fig -9: Equivalent Stress in Static Structural

Analysis of Frame

Fig -10: Equivalent Elastic Strain in Static Structural Analysis of Frame

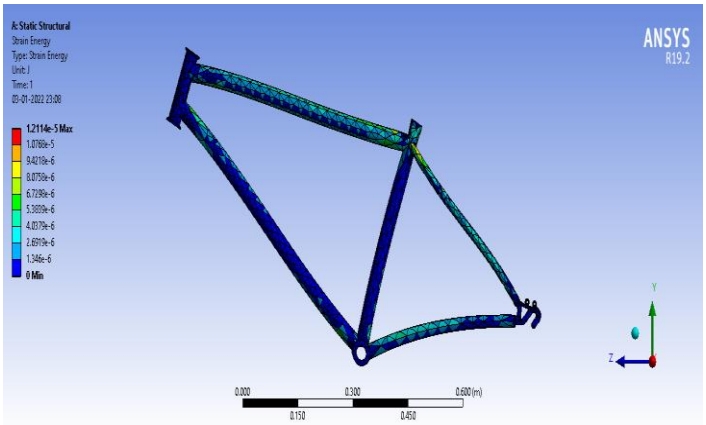

Fig -11: Strain Energy in Static Structural

Analysis of Frame

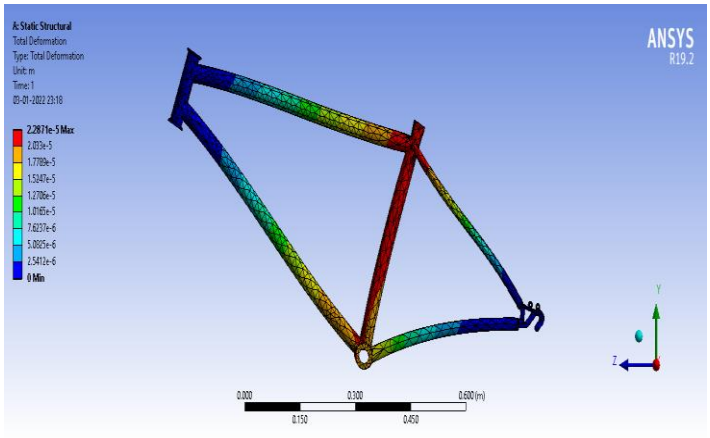

Fig -12: Total Deformation in Static Structural Analysis of Frame

6. CONCLUSIONS

In this project we have aimed to reduce the wastage of energy supplied on bicycle riding or any machine, which employs drive shafts. It is generally achieved by using light-weight drive shafts with bevel gears on both sides designed on replacing chain transmission.

The presented work also deals with optimization of design i.e., converting rotary motion in linear motion with the help of bevel gear and shaft assembly.

The maximum torque transmission capacity of the bicycle drive shaft has been calculated by neglecting centrifugal effects through numerical methods and has been verified through analytical methods and it was observed that centrifugal force reduces the torque transmission capacity of the shaft. The stress distribution and the maximum deformation in the drive shaft depends on the way of stacking of material.

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