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Design and Fabrication of Shaft Driven Electric Bicycle

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Abstract:- Shaft driven Bi-cycles were introduced decades ago, but the prevalence of the chain drive dominated the Shaft drive in both Bi-cycles and Motor Bikes. Recently shaft driven Bi-cycles started drawing interest among the mountain riders because of its ease in driving and maintenance. To make this even more comfortable, we are coupling the shaft drive mechanism with a Brushless D.C motor, which helps to drive the Bi-cycle with ease like an E- bike; by coupling the shaft drive mechanism with a brushless D.C motor we can enjoy the perks of both. This way people can use this shaft driven E- bicycle, for travelling short distance. Approximately 2.5 metric tons of Carbon-di-oxide is released by a bike in a year, this may look like a small number; but when we consider the amount of emission from all the bikes, it's definitely a huge number. The addition of D.C motor not only eases the ride but also reduces the amount of pollution being generated. With the rise in fuel price and air pollution, this kind of a bicycle will be ideal for covering short distances. People can use this bicycle, for travelling to schools, colleges or even to purchase groceries.

Keywords:- *Brushless D.C Motor, Shaft, Multispeed, Chailess.*

I. INTRODUCTION

In our everyday life, vehicles are playing a major role in transportation and two wheelers have a lion's share in this. 76% of the total vehicles in India are two wheelers. In such a scenario two wheelers are responsible for majority of fuel need in India. The extensive use of two wheelers also causes air pollution. A two wheeler emits, 2.5 metric tons of Carbon-di-oxide every year. Moreover price of fuel has sky rocketed and has never been so high since the Indian Independence.

With these kinds of short comings we have to find a better alternative for two wheelers. The shaft driven E-bicycle will serve this purpose. Shaft Bi-cycles were first introduced in the year 1880, but it didn't grab the attention as chain bicycles were getting very popular and was being used in bi-cycles as well as motor bikes.

But in the past few years, shaft driven bi-cycles has started to gain attraction, because of its advantages. In this case to make the drive even more comfortable and luxurious we are coupling it with a brushless D.C motor. The brushless D.C motor helps to drive the Bi-cycle like an E-bike. So with the addition of D.C motor we are making use of the perks of both the shaft drive and motor drive mechanisms.

E-bikes are also getting attention now a days, because of the rise in fuel price, in such a situation this kind of a bicycle will definitely be useful in covering short distances. Moreover the government is also giving a lot of subsidies for electric vehicles.

1.2 PROBLEMS IDENTIFIES:

1. Increasing Pollution: The level of pollution in metro cities are increasing every year (New Delhi is a best example). This has led to several health issues and it degrades the environment.

2. Rise in fuel price: As everyone know globally fuel price are increasing and in India the fuel price is sky rocketing. The fuel price has reached approximately Rs. 100 per liter in few states, as a result of which the price of essential commodities have increased and people are facing severe issues.

3. Wear and Tear problems in chain drive: The chain drive cycles are more conventionally used in India but the chain and roller are subjected to wear which leads to cutting a part of chain or replacing it periodically

II. COMPONENTS OF BICYCLE:

2.1 Bevel Gear

In this system, bevel gear's plays a major role in transmission of power from the pedal to the rear wheel of the bicycle. Bevel gears are mechanical elements that are used in transmitting power between other gears connected to it. Other than transferring power bevel gears are also used in increasing the torquw output . They are mostly mounted at 90 degrees apart and can also work at different angles to. The efficiency of this gear varies from 94% - 98% with low gear ratios. Bevel gears are differentiated based on the type of tooth and shape of the teeth in the bevel gear. The types of bevel gears are straight, spiral, zirol, miter and hypoid.

2.2 Brushless D.C motor

This version works with Brushless direct modern-day motor also known as BLDC motor. These BLDC have significantly high performance and better efficiency that the other type brushed dc motor and induction motors. BLDC offer high weight to torque ratio and increased torque per watt to power input. BLDC motor works with the aid of alternating the polarity of the copper windings on the interior of the motor. When the magnetic fields are created on the coil they exert a push/pull force on the everlasting magnet arranged around the casing. In BLDC it's the Outer case or bell which rotates not the shaft inside the stator.

2.3 Lithium ion Battery

Lithium ion or Li ion are certain kind of rechargeable Batteries. These are commonly used on portable electronics and electric vehicles and slowly expanding its presence in military and aerospace application for its Constant power, longest life, fast and safe charging and light in weight when compared to Other lead-acid batteries. The typical life span of a li-ion battery is 24-36 months or 300-500 charging cycle. The main difference between LITHIUM batteries and LITHIUM-ION are ION batteries are secondary cell construction so they can be recharged and used again, where as in LITHIUM batteries they are primary cell construction so can't be used more than once.

2.4 Shaft

A shaft is a reliable machine component, which transmits mechanical power and torque and rotation by tensile-forces, and is mainly used in transmitting power between mechanical components. The shaft functions similar to a chain drive but has more advantage than a chain driven cycle.

2.5 Controller

Most of the BLDC motor controller in the market works by using HALL EFFECT sensors to provide accurate positioning of the rotor, but this results in higher cost and complication. To overcome this issue Sensorless Brusheless DC motor cuts the necessity for "HALL-EFFECT" sensor and makes use of the back 'Electromotive-Force' of the motor to determine location of the stator with the help of rotor.The back- Electromotive-force are expressed as differential emf that opposes driving motor. It is zero when the motor is non-functional, and increase according to motor's angular velocity. Back-Electromotive Force an output of the motor.

2.6 Throttle

A throttle is a device which is used to control the speed of the vehicle. When the throttle is engaged, power is produced from motor and the bike moves forward.

2.7 Chain Sprocket

A chain and sprocket drive is a type of transmission system in which a chain engages with toothed sprockets. These are the more common and widely used drive system in two wheelers.

III. PRINCIPLE

The working principle of a BLDC motor is "when a current carrying conductor is placed on a magnetic field, it experiences a mechanical force." Also known as "Lorentz Force". The direction of force is given by "Flemings Left Hand Rule".

3.1 FLEMING'S LEFT HAND RULE:

Stretch your thumb, index finger and middle finger perpendicular to each other. In this Thumb denotes the "force", the index finger denotes direction of the "magnetic field", the middle finger denotes the direction of "current" passing through the conductor.

IV. METHODOLOGY

- The following methodology was followed for completing this project
- The problem identified in conventional cycles is that the chain setup in the cycle tends to get loose over a period of time and it would be a problem whenever we ride a cycle. So to reduce this problem we came up with shaft drive which will be coupled with a Brushless DC motor to drive the cycle, so that we can also reduce the pollution. This cycle can used as a manual drive as well as an electric cycle.
- We took surveys from many college students regarding their usage of cycles. The result came out as over 69.3% of student who owned a cycle were not using it because of laziness.
- Before the design was made we did some calculations for the following, Pitch circle diameter, cone angle of the bevel gear, Gear tooth thickness, face width, Maximum Torque, Tangential load, effective load on gear tooth and the strength. Then we did the 3d designs of the shaft drive mechanism, cycle and the Brushless DC motor drive mechanisms in Solidworks software.
- For the fabrication we initially fabricated two pairs of bevel gears. The material for bevel gear is cast iron. We fabricated the gears in a gear hobbing machine. Then the shaft was fabricated with help of a lathe. After the fabrication of gears and the shaft, 2 small bevel gears were place on the ends of the shaft and the two larger gears were placed on the rear wheel and pedal respectively. After arranging the shaft setup a brushless dc motor was

coupled with the shaft drive mechanism. The DC motor, the key, throttle, are 16 connected to the motor control unit which is powered with two lead acid batteries (since this is a prototype we are using a lead acid battery instead of lithium ion)

V. DESIGN CALCULATION:

5.1 DESIGN CALCULATION FOR FRONT GEAR SET.

Module (m) = 3
Pressure angle = 20 degree
No. of tooth in pinion (Zp) = 23
No. of tooth in gear (Zg) = 46
1. Pitch circle diameter of pinion = m(Zp) = 3 (23) = 69mm
2. Pitch circle diameter of gear = m(Zg) = 3(46) = 138mm
3. Cone angle of pinion (Dp) = Tan -1[(sin 90)/(Zg/Zd) + cos90]
Dp = Tan-1[(sin90)/(46/23) + cos90]
Dp = 26.57 degree
4. Cone angle of gear (Dg) = 90 – Dp
Dg = 90 – 26.47
Dg = 63.43 degree
5. Cone distance (R) = D/2sind Dp
R = 69/2sin(26.57)
R = 77.13 mm
6. Face width b <= R/3
b = 77.13/3 = 25.71
7. Addendum = m = 3
8. Dedendum = 1.3 x m = 1.3(3) = 3.9 mm
9. Clearance = 0.25 x (m) = 0.75mm
10. Working Depth = 2(m) = 6mm
11. Whole Depth = 2.3(m) = 2.3(3) = 6.9 mm
12. Tooth Thickness = 1.57(m) = 1.57(3) = 4.70 mm
14. Tooth space = 1.57(m) = 1.57(3) = 4.70 mm

5.2 DESIGN CALCULATIONS FOR REAR GEAR SET.

Module (m) = 3
Pressure angle = 20 degree
No. of tooth in pinion (Zp) = 23
No. of tooth in gear (Zg) = 23
1. Pitch circle diameter of pinion = m(Zp) = 3 (23) = 69mm
2. Pitch circle diameter of gear = m(Zg) = 3(23) = 69mm
3. Cone angle of pinion (Dp) = Tan -1[(sin 90)/(Zg/Zd) + cos90]
Dp = Tan-1[(sin90)/(23/23) + cos90]
Dp = 45 degree
4. Cone angle of gear (Dg) = 90 – Dp
Dg = 90 – 45

Dg = 45 degree
5. Cone distance (R) = D/2sind Dp
R = 69/2sin(45)
R = 48.79 mm

6. Face width b <= R/3
b = 48.79/3 = 16.26
7. Addendum = m = 3
8. Dedendum = 1.3 x m = 1.3(3) = 3.9 mm
9. Clearance = 0.25 x (m) = 0.75mm
10. Working Depth = 2(m) = 6mm
11. Whole Depth = 2.3(m) = 2.3(3) = 6.9 mm
12. Tooth Thickness = 1.57(m) = 1.57(3) = 4.70 mm

5.3 ANALYSIS OF GEAR.

1. Max Torque (T) = mass of rider*g*length of pedal
T = 80*9.81*0.2
T = 156.96Nm or 156960 Nmm

2. Power (P) = 2(Pi)NT/60
= 2(3.14) 50*156.96/60
P = 821.84 W
3. Tangential load on pinion (Pt) = 2T/Zp*m
= 2*156960/ 2*23
Pt = 6824.3 N
4. Effective load on gear tooth = Cs*Pt + Pd
Cs = Service factor = 1
Pd = Dynamic load (N)
Pd = (21v (Ceb + Pt)/ (12v+(Ceb + Pt)^-2)
Where C = Dynamic factor = 5930e, for cast iron e = 0.05
Ce = 296.5
v = Pitch line velocity (m/s)
v = (Pi * Dp * Np)/ 60*10^3
v = (3.14*69*100) /60* 10^3
Pd = [21*0.361(296.5*22.36+ 6824.3)]/[(21*0.361+(296.5*22.36+6824.3)^-2)]
Pd = 825.38
Effective load on gear tooth = (Cs*Pt)+Pd
= (1*6824.3) + 825.38
= 7649.68
5. Maximum bending stress (б) = (Pt/b) * (6h/t^2)
= (6824.3/22.36) (6*6.75/4.7122)
Maximum bending stress = 472.626 N/mm^2
6. Y = Lewis factor = 0.352
7. Beam Strength of tooth, Sb = mbбbY(1-(b/R)) N
= 3(22.36) (472.62)
Sb = 8439.713
Since load on teeth is less than beam strength of the tooth the design is safe.

5.4 CALCULATION FOR MOTOR DRIVE:

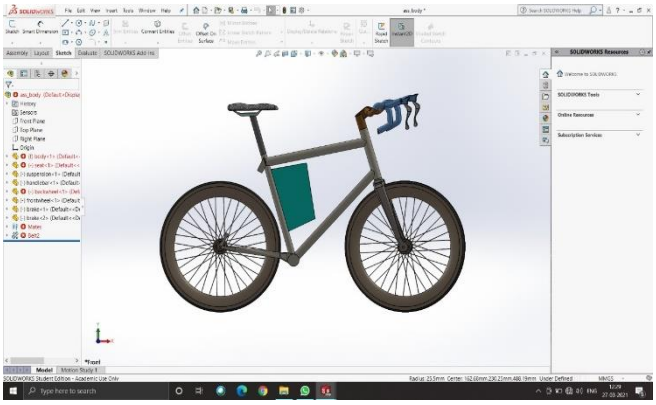
1. Torque = Fc*r
Fc = Circumferential force
Fc = Tc (Tc = tension in chain)
Tc = mv^2
v = velocity
m = b*t*l*ρ
b = breath of chain = 0.017 m
t = thickness of chain = 0.008 m
l = length = 0.9 m
ρ = Mass density = 1130 kg/m^3
m = 0.1383 kg
v = (Pi*d*n)/60
= (3.14*0.2284*3000)/60
= 35.86 m/s
Tc = m*v^2
T = Fc*r
T = Fc*r
= 177.84 * 0.1142
= 20.30 Nm

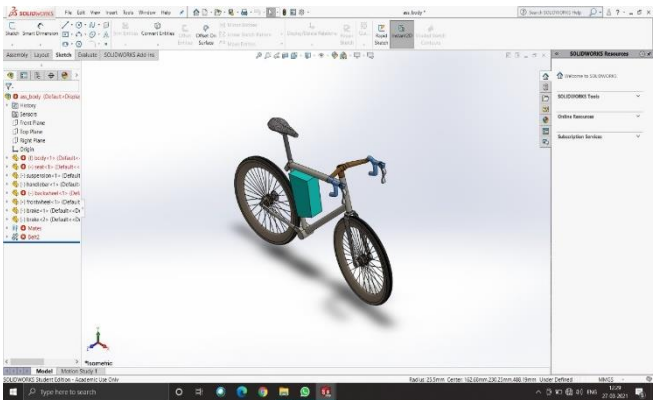
Speed of the cycle:
Motor sprocket Diameter (D1) = 80mm
Motor speed (N1) = 900
Cycle drive sprocket Diameter = 180 mm
R.P.M of wheel (N2) = (D1/D2)*N1
= (80/180) * 900
= 400 RPM

Speed of vehicle:
Engine RPM = 1800
Drive train transmission ratio = 4.5
Wheel RPM = 400
Tire diameter = 587 mm
Vehicle speed = 30.3 Km/Hr

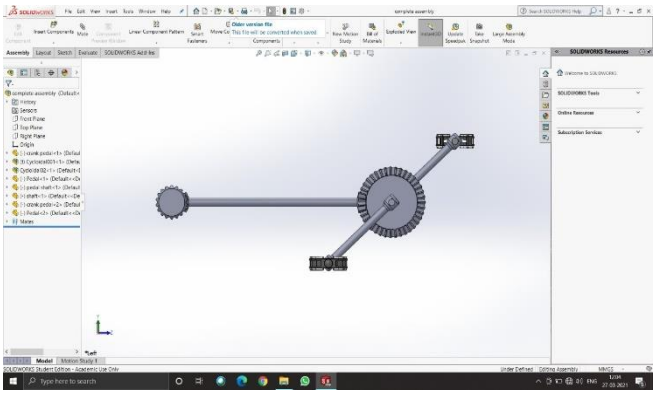
VI. DESIGN:

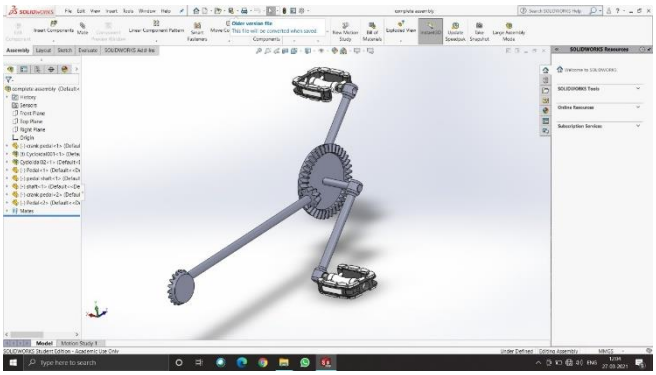
6.1 CYCLE



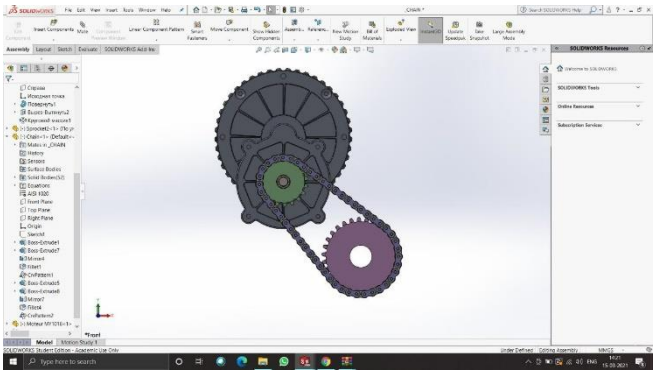


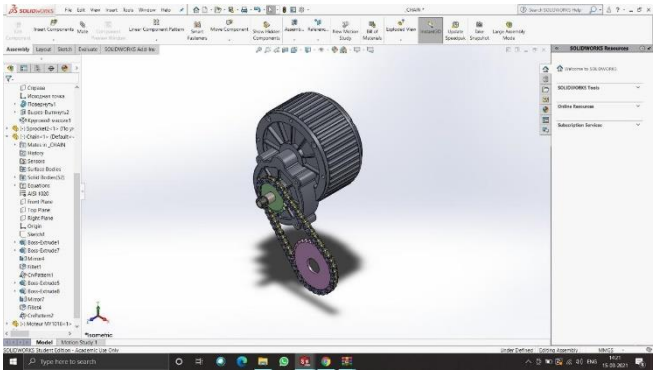
6.2 SHAFT DRIVE SYSTEM:





6.3 MOTOR DRIVE SYSTEM:





VII. ADVANTAGE, DISADVANTAGE AND FUTURE SCOPE:

7.1 ADVANTAGES:

1. Jamming of drive system is less likely.
2. Comparatively low maintenance than a chain drive system.
3. Improved efficiency, it's claimed that shaft driven bicycles are 94% efficient by Dynamic Bicycles.
4. Easy to drive, due to the addition of D.C motor.
5. Environmental friendly
6. Could be used as an alternative for motor bikes.

7.2 DISADVANTAGES:

1. Increased weight.
2. Removal of wheel can be complicated.

7.3 FUTURE SCOPE:

1. The system can be implemented in motor bikes too, with a high powered motor such as 1Kw.
2. The bicycles can be introduced as a start up in countries like China, Malaysia, and Japan etc. where the number of people using cycles are very high. Besides this the cost of lithium ion batteries are cheaper in these countries.
3. These kind of bicycles would be a perfect alternative for motor bikes.
4. These kind of bicycles have started to gain interest among young mountain rides.

VIII. CONCLUSION:

Our aim is to reduce the amount of pollutants injected into our environment. From the results seen above it is clear that the shaft driven e-bicycle would be very helpful for youngsters and for the mountain riders. The Shaft driven mechanism reduces the pedaling force greatly and helps us drive the cycle for a long distance, and whenever the rider feels tired he can switch the motor ON and ride it like a bike. This way we can reduce the usage of Motor bikes for travelling short distance. This reduces the amount of pollutants injected into the air and at the same time we can maintain our fitness too.

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