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Design and Implementation of Electric Assisted Bicycle with Self Recharging Mechanism

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ABSTRACT: During the revolution for the eco-friendly technologies bicycles were the most depended modes of transportation, along with this the consideration of the increase in fuel price and the environmental factors we must admit that it is far more better to use a bicycle over a motor vehicle for short distance travelling. Imagine how useful would the bicycle be if even the small effort applied by man for climbing slopes and riding on rough terrain is reduced in it. We thought the same way to develop the basics of our project "The e-Bike". The unit developed by us is a combination of the standard geared bicycle with an electric power motor cum alternator that would assist the rider throughout his journey. The system is modified in such a way that the rider can make choice of which mode he prefers i.e. he can either choose the bicycle to be driven completely with the electric motor or he can choose it to be driven manually by himself. The idea of mounting the motor cum alternator assembly onto a geared bicycle was to reduce the effort to-be applied for extra little weight that the rider will have to take along with the bicycle. Detailed study about the gross weight has been mentioned inside the report. The unit has been designed in such a way that people of any age group can depend on it. Our idea of implementation of the project was mainly biased towards providing inter college transportation system and to reduce the use of automobiles inside the campus [5] as a tribute to the "GREEN ENERGY".

KEYWORDS: Hybrid bicycle; PMDC motor cum alternator; flywheel; multi-crank freewheel; sprockets; base plates.

I. INTRODUCTION

Global warming and scarcity of traditional resources are becoming major problems in the current scenario. Due to the economic challenges India is facing in automotive sector the hybrid bicycle [1] market has a huge growth potential. People try to move towards "clean" energies. These facts among others will leverage the electric bicycle industry on the top of the agendas not only in India. Moreover the vision of an electric engine, which supports the muscular strength, became reality. Bicycles with such a supporting electric engine belong to the innovative vehicles, which are wholeheartedly suitable for everyday life. In face of continuous climate discussions and permanent traffic jams, electric bikes have the potential of solving such issues and making a more energy efficient and environment friendly mobility possible. Accordingly a continuous trend towards electric bicycles can be expected simultaneously in whole of India. So it becomes very necessary to manufacture the electric cycles so cheaply that the common people in our country can afford to buy it. The currently existing electric scooters are far more costly and due to budgetary constraints a middle class person cannot afford such a locomotive at his place. Along with the development of technologies the theory must be also implemented to design and manufacture a product that can be sold off at a greater frequency, which has a very low production cost and one that is of good quality. In order to implement all the above ideas, we planned to make the design and product in such a manner that it can be competed with the existing "e-Bikes" [9] in the market.

A. Background

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The basic idea is to attach a motor to the cycle for its motion. A motor that is powered by a battery and that can be switched on during difficult terrains and switched off and pedal to get the battery re-charged during motion in a flat terrain. The idea came into our mind as different stages of project planning, firstly we wanted to implement a simple moving system so the projection of cycle as a system came into our mind, and second stage was adding a necessarily useful component into it that can be beneficial in the future and for common people, falling into the current trend was that of hybrid system so we ended up planning to assemble a motor unit into the cycle drive. There were many issues that came up while making such a system major one of them being the power of the motor to be used, since no such previous systems were made we could not predict the type of motor which we should go for. Second thing being the weight factor, the addition of extra weight on to the system, which can cause discomfort to the rider while normal pedalling. Third was the type of battery to be used, we should go for a battery that has longer life, economically viable, and also has less maintenance issues. Fourth issue was that self-recharging a battery with a motor alternator unit that too with the simple cranking motion of the cycle was not viable, we had to utilize a mechanism that can come in handy here and that was by using the flywheel rotation technique.

B. Mechanical Design and System Integration

The main aim was to fabricate a prototype that would be very light and comfortable for the rider to handle [10]. As the motor and other drive components would take in most of the free space in the system our design challenge was to make the motor-alternator unit as a single system. This was our major challenge, for this purpose we developed the motor cum alternator at its minimum possible size and also at the lowest possible cost. Mounting the battery was another challenge, the location of the mounting could have been anywhere in the rest of the space available near the motor or we could have used up the empty space near the carrier. Keeping in mind the comfort of the rider the battery casing was mounted behind the rider, near the carrier location. Looking at the complicated arrangement of the system one may easily think that the drive arrangement could have been completed in a single step i.e. the direct link from the motor to the drive. But the real fact is that this would make the cranking for self-recharging mechanism difficult, since the speed for alternator recharging cannot be achieved by simple cranking a flywheel has to be used to store the cranking energy and thus the rotation and cranking at normal cycling becomes easier [11].

II. HYBRID SYSTEMS

A. Overview

This section of the paper deals with the mechanical design of the system and the various parts used in the system integration. The power transmission system consists of the motor [2], the chain sprockets, flywheel, housing and the rear wheel. However, before we could select these components, we performed some basic calculations relating energy transfer through the system. Primarily we focused on the current requirements of the system, and a number of torque-speed relationships. Both the acceleration on flat ground and hill climbing ability of the system depend on how much torque can be delivered by the various system components. Before we could size the batteries, we needed to estimate when the motor would demand the most current and the duration that it would draw its peak current. These situations would be at start up (acceleration) and when climbing a gradient. The main components affected by the following calculations are the motor and the battery.

B. Components of Hybrid System

1. PMDC MOTOR (Permanent magnet DC motor): Permanent magnet DC brushed motors (PMDC motors) consist of permanent magnets, located in the stator, and windings, located in the rotor [12]. The ends of the winding coils are connected to commutator segments that make slipping contact with the stationary brushes. Brushes are connected to DC voltage supply across motor terminals. Change of direction of rotation can be achieved by reversal of voltage polarity. The current flow through the coils creates magnetic poles in the rotor that interact with permanent magnet poles. In order to keep the torque generation in same direction, the current flow must be reversed when the rotor north pole passes the stator

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south pole. For this the slipping contacts are segmented. This segmented slip ring is called commutator. Figure 1(a) shows angular position just before commutation of rotor winding current and Figure 1(b) after it.

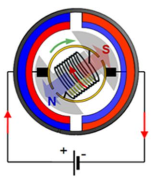

Fig.1 (a) PMDC Motor (Cross-Section)

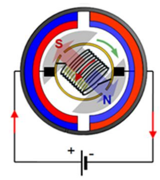

Fig.1 (b) PMDC Motor (Cross-Section)

Motor Specifications:- Power: 150W; Voltage: 12V; Current: 15A; RPM: 1000; Overall length: 0.23m; Mass: 1.5Kg.

2. Flywheel: A flywheel [6] is a rotating mechanical device that is used to store rotational energy. Flywheels have a significant moment of inertia and thus resist changes in rotational speed. The amount of energy stored in a flywheel is proportional to the square of its rotational speed. Energy is transferred to a flywheel by applying torque to it, thereby increasing its rotational speed, and hence its stored energy [3]. Conversely, a flywheel releases stored energy by applying torque to a mechanical load, thereby decreasing its rotational speed. Flywheels are typically made of steel and rotate on conventional bearings; these are generally limited to a revolution rate of a few thousand RPM. Some modern flywheels are made of carbon fiber materials and employ magnetic bearings, enabling them to revolve at speeds up to 60,000 RPM. Our design, due to the simplicity of its application, uses a flywheel which is made up of cast iron having a diameter of 17cm. Carbon-composite flywheel batteries have recently been manufactured and are proving to be viable in real-world tests on mainstream cars. Figure 2 shows the CAD drawing of the flywheel.

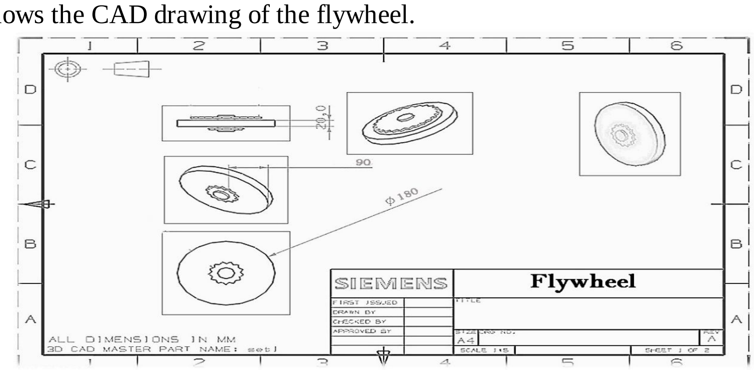

Fig. 2 CAD Drawing of Flywheel

3. Housing: Housing is used for making an interconnection between the rotating flywheel and the sprocket at the other end. It is this sprocket from the rotating flywheel connected to a shaft that drives the multi crank freewheel. The housing is attached with a rubber bush to avoid the shocks. They are normally used in door hinges for making perpendicular movable connections. The ball bearing inside the housing chamber allows the free rotation of the connecting shaft inside the housing.

Design Specifications:- Length: 1m; External Diameter: 0.7m; Internal Diameter: 0.5m; Thread Pitch: 0.024m.

4. Multi-crank Freewheel: Multi crank freewheel is developed as alternate mechanism to drive the rear wheel from the motor power the crank is developed in such a way that the ball bearing has a special effect when rotation on one direction through motor happens the ball bearing external lock holds the moving pedal thus restricting its motion, on the other hand when the rotation with pedal happens the bearing engages with the pedal and thus the drive through cranking happens. For developing, the crank was attached with another crank of the same diameter so that there will not be any difference in the pedaling effect to the rider.

Design Specifications:- Crank Diameter: 0.18m; Number of Teeth: 52

Figure 3 shows the CAD drawing of multi-crank freewheel

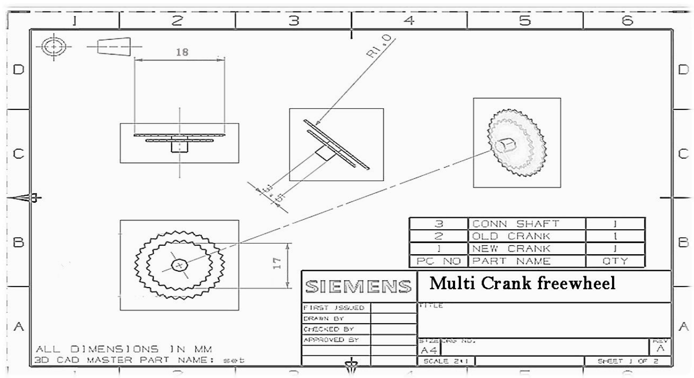

Fig.3 CAD Drawing of Multi-Crank Freewheel

5. Sprockets: A sprocket or sprocket-wheel is a profile wheel with teeth, cogs, or even sprockets that mesh with a chain, track or other perforated or indented material. The name 'sprocket' applies generally to any wheel upon which are radial projections that engage a chain passing over it. It is distinguished from a gear in that sprockets are never meshed together directly, and differs from a pulley in that sprockets have teeth and pulleys are smooth. Sprockets are used in bicycles, motorcycles, cars, tracked vehicles, and other machinery to transmit rotary motion between two shafts where gears are unsuitable or to impart linear motion to a track, tape etc. Perhaps the most common form of sprocket may be found in the bicycle, in which the pedal shaft carries a large sprocket-wheel, which drives a chain, which, in turn, drives a small sprocket on the axle of the rear wheel. Early automobiles were also largely driven by sprocket and chain mechanism, a practice largely copied from bicycles. Sprockets are of various designs, a maximum of efficiency being claimed for each by its originator. Sprockets typically do not have a flange. Some sprockets used with timing belts have flanges to keep the timing belt centered. Sprockets and chains are also used for power transmission from one shaft to another where slippage is not admissible, sprocket chains being used instead of belts or ropes and sprocket-wheels instead of pulleys. They can be run at high speed and some forms of chain are so constructed as to be noiseless even at high speed. Figure 4 shows the front and side views of the designed sprockets and Figure 5 show the manufactured one.

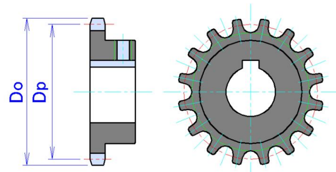

Fig.4 Sprockets (Front and Side Views)

Fig: 5 Manufactured Sprocket

<u>Design Specifications</u>:- Sprocket 1 (connected with the motor) Number of Teeth: 16; Diameter: 70mm
Sprocket 2 (connected with housing) Number of Teeth: 16; Diameter: 70mm

Figure 6 shows the CAD drawing of multi-crank freewheel

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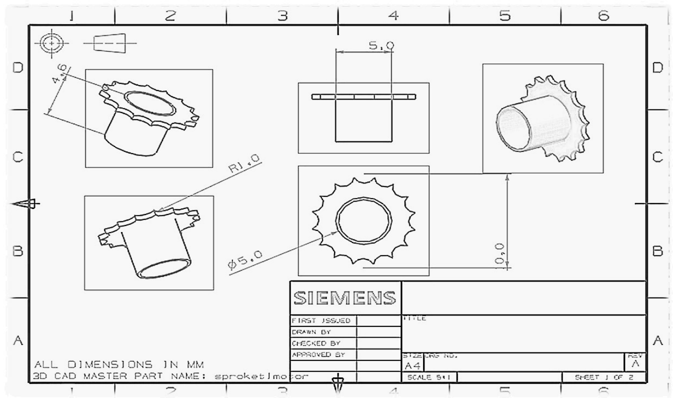

Fig.6 CAD Drawing of Sprockets

6. Rear Sprockets (Gear Mechanism): A number of sprockets have been provided at the rear drive in order to attain variety of speeds as well as facilitating slope climbing. We have 7 different sprockets at the rear drive that provide 7 different speed and torque. Each of them is used whenever they are required. Shifting the gear is by conventional tension shift mechanism using a derailleur that would loosen the chain in order to shift the gear. When the rider wants to attain maximum speed from the system he can shift the gear arrangement to the lowest gear (i.e 7th gear) and similarly when he wants the easiness in riding or get higher torque for slope climbing the he can shift the gear to highest number (i.e 1st gear).because of the added weight of the system a rider may wish to cycle at the highest gear that would provide him the easiness to ride.

Specifications:- Type: Tension Shift Mechanism; Number of Speed: 7 Speed

7. Batteries: Desirable attributes of dry cell batteries are providing clean energy and sufficient discharge, economically viable and long calendar and cycle life. Lead acid batteries, used currently in many electric vehicles, are potentially usable in hybrid applications. Lead acid batteries can be designed to be high power and are inexpensive, safe, and reliable. A recycling infrastructure is in place for them. But low specific energy, poor cold temperature performance, and short calendar and cycle life are still impediments to their use. Due to leakage issues and low safety in an open system like cycle we did not use lead acid batteries over dry cell ones.

Technical Specifications of the chosen battery:- Type : Dry cell (lead gel type); Rated voltage : 12V; Rated current: 15Ah; Number of batteries:2; Battery Rating = 12 V * 14 Ah = 168 W

8. Control System: The control system consist of two basic PCB’s, one of them is the driver motor whereas the other is the Arduino board. The driver motor is directly linked with the motor and the power source. The specification of these boards will be clearly specified in the upcoming sections. The main purpose of using the control system is to regulate the system speed. The other major components in the system are the potentiometer and the PWM controller, the PWM controller is the programmable Arduino board. The potentiometer acts as a regulator, on moving clockwise and anti-clockwise the analog signals are sent to the PWM from where it gets converted to the digital signals in the form of pulses which are received by the driver unit and the speed is adjusted as per the variations in the system.

The Arduino Uno is a microcontroller board based on the ATmega328 . It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the micro controller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.

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Specifications of Driver unit:-Rated voltage: 24V; Rated current: 20A; Type: DC motor driver pin type; Manufacturer: Robokits India pvt ltd.
Specifications of Arduino Uno board:- Manufacturer: Ardour labs; Microcontroller: ATmega328; Operating Voltage :5V; Input Voltage (recommended) :7-12V; Input Voltage (limits) :6-20V; Digital I/O Pins :14 (of which 6 provide PWM output); Analog Input Pins: 6; DC Current per I/O Pin :40 mA; DC Current for 3.3V Pin: 50 mA; SRAM: 2 KB (ATmega328); EEPROM:1 KB (ATmega328); Clock Speed: 16 MHz.

III. ELECTRICAL SYSTEM DESIGN

A.Overview

The PMDC motor had to be regulated by a mechanism which involved a DC motor driver [7]. This driver had specifications able to withstand upto 20A which was key to this project as varying loads would undoubtedly draw more current. So the rated current rating had to be high enough to withstand this. The driver is controlled by an Arduino Board which receives input signals via. a potentiometer (variable resistance). The Arduino board was programmed in such a way that varying the resistance in the potentiometer would result in an equivalent value of bytes which the program could comprehend and translate to proportional DC motor speeds.

B.Programming

The programming was done on the software accompanied with the Arduino Board. When the "initialise motor" command is used charge starts flowing to the motor through the driver. When the program enters the loop, the potentiometer values (read as resistance pulse values) gets translated to equivalent bytes that lets the Board allow charge to pass through the motor thus increasing/decreasing the speed. Once the loop is exited, the program goes back to initial value.

C .Electrical Connections

There are different approaches to driving a motor [4] when it comes to driving a motor with Arduino. If a simple relay is used to drive a motor it can only turn the motor on and off. In case a single transistor like TIP120 (BJT) or IRF510 (MOSFET) is used, it is possible to control the speed of the rotation. There exist smarter DC motor drivers (so called H-bridge) that can control the direction of rotation and even brake. An example of such a driver is MC33887 Motor Driver which is affordable and versatile. This driver can control a single DC motor with maximum consumption of 2.5A and peaks of 5A. Motor voltage can range from 5-28V which makes it an excellent general purpose motor driver. Figure 7 shows the circuit diagram and Figure 8 shows the electrical connection.

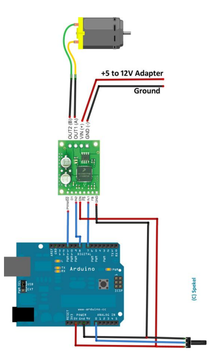

Fig. 7 Circuit Diagram

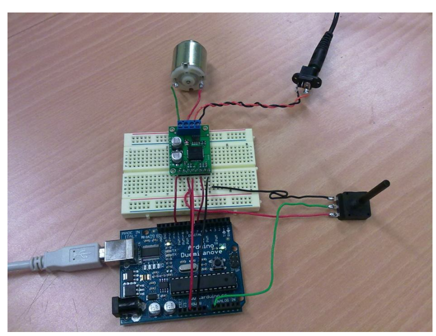
Fig.8 Electrical Connections

IV. CALCULATIONS

A.Maximum current drawn from the cycles at two stages:- 1. During Acceleration; 2. During Hill Climbing

1. During Acceleration the forces acting on the system are: Drag force; Friction from tires; Force due to gravity.
There is a major change of energy from electrical to K.E+P.E
K.E = ½.m.v^2 Where the value of 'v' keeps varying.
Electrical energy = V.I.T
Final K.E = voltage rating x current required x time to accelerate
Voltage provided=36v
Maximum mass = 120Kg(value taken is considering mass of man 100 kg+unit wt. 20kg)
K.E = ½ x 120 x $(25)^2$ = 375500 W. (POWER CONSUMED)
375=36 x I x20(s), **I=0.52A**; 375=36 x Ix 40(s), **I=0.26A**; 375=36 x Ix 60(s), **I=0.17A**
[These values shows the current drawn when unit reaches 25Km/hr. at various intervals]
Current drawn from the unit is more when time taken is less and vice versa. Considering that the cyclist can achieve the 25km/hr. mark in 60(s), the current drawn will be 0.17A. But practically the values varies from person to person hence an average value is calculated to be about = 0.3166 ≈ 0.32 A.
2. Gradient ascent requirements (During hill climbing) Gradient is given by, SinΘ=ΔH/Δx
Maximum power drawn during hill climbing based on the calculation is 600W; hence the motor of that rating or more than that rating must be used.

B. Selection of Speed and Gear Reduction

For a desired top speed of 25Km/hr. Gear Ratio = **1:9** (drive: driven)
Speed (motor) = 3100 rev/min x 27p/rev x 60 minutes/hr. x 1ft/12 inches x 1 mi/5280ft = **24.9 KM/Hr**.
Desired speed = 25km/hr. Therefore speed of motor/ desired wheel speed = 24.9/25 = **0.996~0.9**(taking the lower limit).

C. Motor Starting Current

Motor starting current (from dead start) =**3.44A**.
Motor starting current (cont. motion) =**1.05A**.

V. WORKING OF THE PROTOTYPE

The 150 watt PMDC motor which gives a 1000 RPM at 12V and 15A rating was linked with a flywheel using the sprocket ratio at 16:40 (motor : flywheel) teeth ratio, the shaft from the flywheel was then linked to the sprocket on the other side with a housing. The drive from this sprocket to the multi crank freewheel is attached again at 16:52(sprocket: crank freewheel) teeth ratio. These ratios were selected for maximum efficient power transmission with minimal loss. The drive from this crank is directly linked with rear wheel sprocket that facilitates its motion. When the motor is switched ON, the motor draws current from the two dry cell batteries connected in parallel that would give an effective discharge of 12V and 14A. Since the motor uses maximum current (11 amp) during starting a battery of that specification was used. Later on as the effective speed increases the current drawn reduces to 1.77A. Figure 9 shows the final assembled prototype of the hybrid bicycle.

Fig.9 Final Assembled Prototype

The motion of the motor actuates the flywheel whose rotation in turn drives the shaft through the housing and make the sprockets at the other end move which would drive the multi crank and thus the rear wheel.it should be noted that while the motor is in working mode the pedals won't rotate which would otherwise cause discomfort to the rider [8]. For this to work we have added a ball bearing at the crank spot that would disengage the inner ring while motor is in rotation and engage them when the motor is switched off.

V. CONCLUSION

It is clearly seen that hybrid economy ensures a cleaner and more economical solution to the energy crisis. People use bikes and fuelled vehicles for even travelling short distances without making use of cycles and other non –fuelled vehicles. Most number of people from the list have been those which think riding a cycle is equivalent to providing extra effort for cycling.in order to avoid this an electric assistance has been provided to the cycle that will ease the user to ride the unit with the help of a motor. Even the hardship of climbing slopes and riding on rough terrains has been reduced. All these aspects are available keeping in mind the factor of pollution being affected at all.

The factors that our prototype provides to the market are:

1. Simplified riding with minimal effort on flat as well as gradients.
2. Easiness of riding on rough terrains.

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