Design and Analysis of Parallel Hybrid Two Wheeler

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***Abstract*:- The project work deals with the design and analysis of parallel hybrid two wheelers. The term "hybrid" denotes the vehicle using more than one power source. Today, the world is facing problems due to depletion of fossil fuels and the emission problems of two wheelers. The goal of the hybrid vehicle development is to combine different drive components, such as batteries and SI engines. To overcome the emission problems of two-wheeler, the hybrid concept is introduced in two wheelers which is running successfully in four wheelers. The gasoline powered SI engine is combined with the electric motor. The front wheel is driven by electric motor and the rear wheel of the vehicle is powered by IC engine. Initially, the vehicle is run on electric motor purely powered by battery up to the speed of 30kmph in the city covering the maximum range of 53km. If the battery is drained, then the vehicle switches over to the IC engine to reach the destination. When the vehicle reaches the highway, then it operates on hybrid mode, i.e., the spark ignition engine is used to run the IC engine for fast and smooth driving. It is noted that the vehicle can be operated in either battery or IC engine mode. And also during grading the vehicle can be driven by both modes to get the sufficient torque. A sealed lead acid battery of 48volt, 18amps and a brushless DC hub motor have been selected for the electrical drive mode..**

Keywords: Parallel hybrid, DC hub motor, SI Engine, Battery, Fuels, Emission.

CHAPTER 1

1.1. Introduction

A hybrid vehicle uses more than one propulsion systems to provide power for driving the vehicle. The most familiar type of hybrid vehicle is the gasoline-electric hybrid vehicles, which uses gasoline and electric batteries to power the internal combustion engine and electric motor respectively.

Integrated Motor Assist (commonly abbreviated as IMA) is Honda's hybrid car technology, introduced in 1999 on the INSIGHT. It uses both gasoline engine and a thin, compact permanent magnet electric motor/generator mounted between the engine and transmission to act as a starter motor, engine balancer, and assist traction motor. The theory behind IMA is to use Regenerative Braking to recapture some of the energy lost through deceleration, and reuse that energy later on to help accelerates the vehicle. They also have a conventional starter as a backup, making it the only production hybrid system which can operate with its high voltage electric system disabled, using only its ICE like a traditional vehicle.

For developing a hybrid electric two-wheeler the electric motor is a key component and the use of a high starting torque motor with good speed range is essential for an efficient hybrid concept. The size of the motor has to be smaller for space savings. For an entry level vehicle of interest, a performance equivalent of nearly a 100cc motorcycle suits the need. As it is necessary for any modern vehicle to have some flexibility in usage it should be capable of long highway hauls as well as challenging city driving conditions which can be fulfilled by having separate modes of operation for different terrains and different conditions. An improvement in acceleration of the vehicle is one thing that can be achieved with a hybrid vehicle with good starting torque and it helps a lot in city traffic conditions. A detailed control strategy has to be developed for fulfilling these conditions. An advanced power transmission system strategy is a key factor in the development of a vehicle combining more than one powertrains. It all depends on the hybrid transmission system that how fast and how efficient both the powertrains can be either combined or isolated to deal with different driving requirements. Cost consideration is another important aspect. Using low cost manufacturing techniques wherever possible, making some trade-offs to the desired parameters, a well-planned cost effective designing etc. can be considered to achieve this. The design can then consider using conventional battery and conventional metal parts to be made use of for cost savings, though the same might result in a lower life cycle of the storage system. Procedure for transmission and control system design can affect the cost factor and time factor. The ideas like parallel hybrid architecture can be thought of if there's a correct methodology for that. Since hybrid vehicles usually have more no: of components and complex construction, emphasis on reliability and safety is necessary. The complex electrical and electronics in HEVs shall be carefully designed for functional safety.

1.2. Formulation of control strategy

The integration of conventional vehicle components with electric propulsion components results in a vast number of potential hybrid electric configurations. The series hybrid electric configuration is an interesting solution for driving in urban areas with passenger cars, light duty vehicles as well as with heavy-duty vehicles like city buses. On the other hand, parallel hybrid electric powertrain configuration is more suitable for the family or higher class vehicle segment, while driving on highway and long distances. In addition, a series-parallel hybrid powertrain system has a complex transmission and increase in the number of components also makes the integration more complicated.

As the complexity of the vehicle configuration increases, so do the demands for control. As people may expect, there is no universal architecture that can be considered superior in all practical aspects such as energy efficiency, vehicle performance and range, driver comfort, manufacturing complexity, and production cost. Therefore, in practice, automakers may choose different architectures to achieve different goals and meet distinct transport segment requirements. Besides the powertrain configuration, a suitable power and energy distribution system is also important. The control strategy plays a basic role. A control strategy is an algorithm that manages the power split between the IC engine and the electrical machine in order to reduce fuel consumption and pollutant emissions. In a plug-in hybrid electric vehicle, the strategy will attempt to use most of the energy from the battery pack. However, majority of global two-wheelers population utilizes small displacement engines, generally in the order of 50-150 cc. Hence, for two-wheelers of simple architecture with low cost operation, there is a need to develop a simple powertrain design with a simple control strategy which is less complex.

The energy consumed to propel the vehicle based on the test cycle is equal to the energy produced by the I.C Engine and decreased by the energy consumed by brake.

Power of the brake is defined as the difference between the power required to the engine at a particular speed and the negative torque imposed by the test cycle. In parallel hybrid powertrains, electric energy is never produced and consumed simultaneously. The energy should be balance on parallel hybrid powertrain.

CHAPTER 2

2.1. *Methodology*

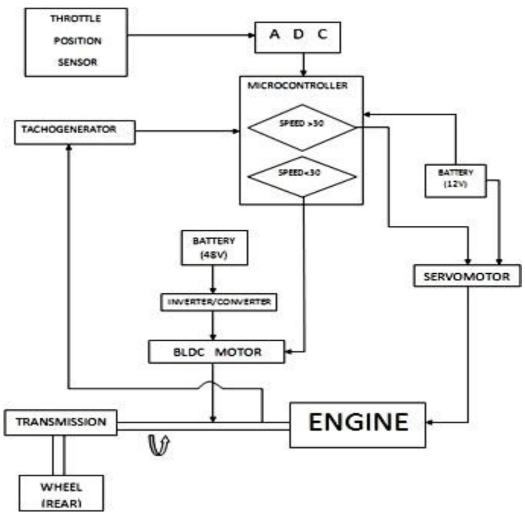

Fig.1. Schematic of Experimental setup

Parallel hybrid is suitable, the single motor and the internal combustion engine are installed such that they can power the vehicle either individually or together. We are using one electric motor in our system. The internal combustion engine, the electric motor, and transmission are coupled by clutches

The frame of the two wheelers has to be modified accordingly to suit the power assisting system, its battery and electronic control unit. The Batteries and the Electronic Control Unit are to be installed on the bike by proper clamping and attachments.

Typical brushless DC Motor use a rotating permanent magnet in the rotor, and stationary electrical current/coil magnets on the housing for the rotor, but the symmetrical opposite is also possible. A motor controller converts DC to AC. This design is simpler than that of brushed motors because it eliminates the complication of transferring power from outside the motor to the spinning rotor. We are about to choose a BLDC motor of 48V, 600W which can provide 3000 rpm to the wheel.

- Inverter
- Microcontroller
- Throttle position sensor
- Servo motor
- Tach generator

2.2. *Design*

Theoretical calculations and verifications for selecting the motor should be done. The motor and its speed controller should be selected with respect to the engine specifications. The selected BLDC motor should be coupled with the IC Engine by using chain drive. The designing of the control unit is to control and synchronies the functioning of the ICE and the BLDC motor. Selection of sensors, relay circuits, PCB boards and micro-controllers suitable for the application. An electronic control circuit is to be designed incorporating with a Microcontroller, Analog Digital Converter (ADC), required resistors and capacitors according to the components used in the whole system in a PCB on which the microcontroller is kept. A throttle position sensor is to be installed on the throttle where it detects the angle of throttling. When the rider accelerates the bike, a magnetic field will be generated and corresponding voltage will be generated by the throttle with respect to the angle of throttling. This voltage signal is converted into digital signal with the help of ADC and is fed to the Microcontroller.

Fig 2.2 Design of Hub

CHAPTER 3

3.1 MOTOR POWER CALCULATION

3.1.1 TRACTIVE EFFORT

The first stage of the design process involved in measuring the tractive force requirement of the two wheeler are mentioned below

The formulae for calculating tractive resistance is

Ftotal = Faero + Froll + Fla + Fgrad (N) F_{aero} = Cd * A * ρ * V^2 * 0.5 (N) F_{roll} = m * g * C_{rr} (N)

F_{la} = m * a (N)

F_{grad} = m * g * sine (θ) (N)

Tractive effort required at the wheels to accelerate the vehicle to the maximum velocity is given by,

F tr = F res + F la

Where

F_{la} is the acceleration force required F_{aero} is the aerodynamic force induced F_{roll} is the rolling resistance encountered

F_{grad} is the gradient resistance F_{res} is the total resistance

F_{tr} is the tractive effort required at the wheels

- m is the mass of the vehicle = 280kg
- g is the acceleration due to gravity = 9.81 m/sec^2
- ρ is the density of the air = 1.25 kg/m3
- V is the velocity of the vehicle = 11.11 m/sec
- A is the projected frontal area of the vehicle = 0.02
- Cd is the coefficient of drag = 0.5
- C_{rr} is the coefficient of rolling resistance = 0.02
- θ is the gradient angle = 0
- Final Velocity of the vehicle at the end of time period, V = 40 kmph
- Time to accelerate to the final velocity, t = 25 secs
- This acceleration corresponds to 40 kmph in 25 secs, which is very suitable for a plug-in hybrid two wheeler, which will act as primarily an electric vehicle. We have to bear in mind the fact that the acceleration for pug-in hybrid two wheeler may be even slower than electric vehicles, because of the fact that they have to carry an engine which will not assist in propulsion during part of the journey the speedometer reaches 40 kmph in 20 seconds implies a constant acceleration,

a = 0.44m/sec^2

3.1.1. Rolling Resistance Force

F_{rr} = C_{rr} * mass * g

= 0.02 * 280 * 9.81

= 54.93 N

3.1.1. Linear Acceleration Force

F_{la} = mass * acceleration

= 280 * 0.44

= 123.2 N

3.1.3 Gradient Resistant Force

Angle of grade of the road considering level road conditions θ=0 degree

Sin (θ) = 0 degree

Force to overcome grade F_{grad} = m * g * sin (θ)

= 0 N

3.1.4 Air Drag Force

F_{areo} = 0.5*C_d*A*ρ*V^2

= 0.5*0.5*0.33*1.25*$(11.11)^2$

= 12.72 N

3.1.5 Total tractive force needed

Ftr = Ftotal +Fla

Fres = Faero + Froll + Fgrad F_{res} = 12.72 + 54.93

= 67.65 N

F_{tr} = 67.65 + 123.2

= 190.85 N

Thus the total tractive force requirement at the wheels is 190.85N

3.2 CALCULATING THE MOTOR POWER REQUIREMENTS

Since our vehicle is a plug-in HEV, the motor should be capable of supplying the total power requirement of the vehicle without overheating

Wheel radius r = 0.21m is selected based on vehicle manual

Final drive ratio (fixed gear ratio) G = 1.0 N_{wheel} = v * 60 / (2p * r)

= 505.2rpm Nmotor = Nwheel * G

= 505.2 * 1.0

= 505.2rpm

Torque at wheel = F_{res} * r

=14.21 Nm

Torque at motor = F_{tr} * r / G

=14.21 Nm

Motor Power = (2*π*N_{motor}*T) /60

=(2*π*505.2*14.21) /60

= 751.8W

CHAPTER 4

4.1Working

Our Power Assisting System works on a predefined level of speed of the bike. In city traffic areas, low speed restricted areas, congested roads, etc. the normal speed in which the bike runs is less than 30km/hr. While driving the bike on this speed levels, the IC Engines consumes more fuel and the level of emission is also high due to the presence of unburnt fuel particles.

The Microcontroller should be programmed in such a way that if the speed corresponding to the angle deviation of the throttle is less than 25km/hr, then the electric motor would be switched on by opening the circuit from the Li-ion Battery. If the speed is greater than 25km/hr then the vehicle would be driven by IC Engine. Thereby the bike runs on electric power when it is in low speeds, say <25km/hr. Since at higher speeds, and at elevated slopes the electric motor is not efficient, IC Engine is used to drive the vehicle, say>25km/hr. A Tach generator is installed on the electric motor which senses the speed of the motor and gives the signal to the microcontroller. A servomotor is also attached in the circuit to control the fuel inlet to the IC Engine, when the bike has to be driven by IC Engine, the relay circuit to the electric motor closes and the circuit to the servomotor and engine opens. Thus electric current is passed to the servomotor and it opens the fuel inlet valve. For starting of an IC Engine, few seconds of time is required. Thus the microcontroller should be programmed with a delay of 2 seconds for the electric motor. Thereby when the throttling increases to more than 25km/hr, the IC Engine turns on and till the IC Engine comes in action the electric motor will be driving the vehicle for additional two seconds. This is the working procedure of our Power Assisting System.

4.2. FUTURE WORKS

We'll be designing our power assisting system by using Computer aided design software's. The simulations would be obtained by using software's. Feasibility study is conducting various surveys in order to find the peoples who are best to utilise this system.

By installing this Power Assisting System, the rider's pleasure as well as efficiency of the vehicle can be maintained.

This system is best for those who uses bike in traffic congested areas more time such as pizza delivery bikes, sales representatives, etc. The cost for installing this system can be easily recovered within 1 or 2 years of duration.

CHAPTER 5

5.1. Conclusion

By coupling the motor to the gearbox the torque and speed of the motor can be varied. BLDC motor has higher starting torque when compared to IC engine. In the first two gears the vehicle runs on the DC motor and so mileage can be increased. By integrating the motor and the engine, power can be increased without alteration in the speed. Therefore by the installation of this Power Assisting System the rider's pleasure as well as efficiency of the bike is maintained in an effective manner.

CHAPTER 6

6.1.References

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