Design, Fabrication and Performance Evaluation of a Hybrid Electric Vehicle

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Abstract: A hybrid vehicle is the one which uses two or more distinct power sources to move the vehicle. The term most commonly refers to hybrid electric vehicles (HEVs), which combine an internal combustion engine and one or more electric motors. The hybrid vehicles should replace regular gas-fuelled cars because they are increasingly popular and are the cars of the future; they consume far less gasoline with a better performance as they are eco-friendly. The objectives of a hybrid drive train are to improve the driving functions of a vehicle, i.e., fuel economy, eco-friendly, emissions, comfort and safety. Hybridization allows performing, downsizing the engine and optimizing the power flows over the different thermal, mechanical and electrical paths between the different power sources.

The main objectives of this project are as listed below:
• To attain a general purpose locomotive which can carry a load of 6.5 KN
• To attain a FOS 2.5-3
• To reduce the pollution as much as possible
• To evaluate engine performance at various load, speeds, and conditions
• Creative design to attain a moderate quality

Index Terms: about four key words or phrases in alphabetical order, separated by commas, for example, energy, conservation, fossil fuels

I. Introduction:

According to Hiroyuki Watanabe, director of Toyota Motor Co., the age of the internal combustion engines over.” (Qtd. in Cochran)

In the last decade automobile technology developed fast, and now on auto market there is a bigger choice of four wheelers, including hybrid four wheeler. Gas Prices have skyrocketed through 2000s (Cochran). As on March 2011, a gallon of regular gasoline cost an average of $3.53 ("Hybrid Vehicles"), and economists predict the price could reach four dollars by the summer of 2012.

With skyrocketing prices of gasoline and uncertain future of oil supply, people are leaning towards buying a hybrid vehicle. It is important to develop alternative vehicles because the oil used to produce gasoline for traditional vehicle is running out. Gas – electric hybrids, and natural gas vehicles, are currently being used to cut oil consumption, and in the future, fuel-cell (hydrogen) vehicles may provide a permanent solution to the oil shortage. In addition, alternative vehicles can bring down the emission of air pollutants (Cochran). That is why it is imperative to say that hybrid vehicles are the future of automotive industry and they should replace gasoline-powered vehicles. Hybrid vehicle require less gasoline, and thus emit fewer greenhouse gases than standard vehicles.

Hybrid Vehicles:

A hybrid vehicle is a vehicle that uses two or more distinct power sources to move the vehicle. The term most commonly refers to hybrid electric vehicles (HEVs), which combine an internal combustion engine and one or more electric motors which fulfill an electric propulsion system. The presence of the electric power train is intended to achieve either better fuel economy than a conventional vehicle, or better performance...
Types of Hybrid Vehicle:
The differing types can be differentiated by:
• How the electric and ICE drive systems of the power train connect
• At what times each drive system is in operation
• What proportion of the power is provided by each propulsion system?

Series Hybrids:
Series-hybrid vehicles are driven by the electric motor with no mechanical connection to the engine. Instead there is an engine tuned for running a generator when the battery pack energy supply isn't sufficient for demands.

Parallel Hybrids:
In a parallel hybrid the single electric motor and the internal combustion engine are installed so that they can both individually or together power the vehicle. In contrast to the power split configuration typically only one electric motor is installed.

Environmental Issues:
The hybrid vehicle typically achieves greater fuel economy and lower emissions than conventional internal combustion engine vehicles (ICEVs), resulting in fewer emissions being generated. These savings are primarily achieved by three elements of a typical hybrid design:

Battery Lead-Acid Batteries:
Is the oldest type of rechargeable battery, despite having a very low energy-to-weight ratio and a low energy-to-volume ratio, their ability to supply high surge currents means that the cells maintain a relatively large power-to-weight ratio. These features, along with their low cost, make them attractive for use in motor vehicles to provide the high current required by automobile starter motors.

Environmental Impact of Hybrid Car Battery:
The Lithium-ion battery has attracted attention due to its potential for use in hybrid electric vehicles. In addition to its smaller size and lighter weight; lithium-ion batteries deliver performance that helps to protect the environment with features such as improved charge efficiency without memory effect. In an environment where motor vehicle requirements including lower exhaust emissions and better fuel economy are prevalent, it is anticipated that the practical use of hybrid, electric, and fuel cell vehicles will continue to increase. The lithium-ion batteries are appealing because they have the highest energy density of any rechargeable batteries and can produce a voltage more than three times that of nickel-metal hydride battery cell while simultaneously storing large quantities of electricity as well. The batteries also produce higher output (boosting vehicle power), higher efficiency (avoiding wasteful use of electricity), and provides excellent durability, compared with the life of the battery being roughly equivalent to the life of the vehicle. Additionally, use of lithium-ion batteries reduces the overall weight of the vehicle and also achieves improved fuel economy of 30% better than gasoline-
powered vehicles with a consequent reduction in CO₂ emissions helping to prevent global warming.

Design and Fabrication:

Structural Design:

Structure/ Chassis/Frame:

There are three main designs for frame rails. Their cross-sections include:
1. C-shaped
2. Boxed
3. Hat

The first step in the design of this project was the basic structural design; Basic structural design itself was a challenging task. So it was proposed 3 different designs to choose among the best.

Design Calculation (Structural/Chassis):

Figure: Mild Steel Semi Bright Square Tube

Why Square Tube:

The advantages of square tube are excellent flexibility in mounting options, greater loading capacity over U-channel, and L angle with better strength to weight ratio which leads for a light weight

Material Properties:
Material Density = 7.85 g/cm³
Young’s modulus = 210,000 MPa
Ultimate tensile strength = 505 Mpa
Ultimate bending stress = 9.32 Mpa

Beam Analysis:

By considering the total structure as two beams, which supports the entire structure
Span = 1320 mm
Y = a/2 = 19mm
Bending moment (M) = W*L*L/8
M/I = F/Y
M = (F/Y)*I
  = 9.4*74934/19
  = 37072.6 N-MM
M=2W
W = 37072.6/2
  = 18536.30 N
  = 1890 Kg
Since 2 beams are used Total weight carrying capacity will be 2 times, around 3780.28 kg.

Figure: Proposed Chasis Design

A chassis consists of an internal framework that supports a man-made object. It is analogous to an animal's skeleton. An example of a chassis is the under part of a motor vehicle, consisting of the frame (on which the body is mounted) with the wheels and machinery. Above shown is the optimum design, modeled using solid edge-v19, the analysis that done on this particular model lead to some conclusion as follows: Since the advantage is that it bears is much as compared to the other two, where the disadvantages it bears can be eliminated by alternative fabricating process. So this is preferred.
Fabrication of Chassis Power Transmission:

Design:

Above shown fig is the design modeled using solid edge-v19, the analysis that done on this particular model leads to some conclusion as follows; can attain a perfect steering mechanism because of introducing differential mechanism, speed control is possible ,less wearing of tyres ,more effective

Differential Mechanism:

A differential is a device, usually but not necessarily employing gears, capable of transmitting torque and rotation through three shafts, almost always used in one of two ways: in one way, it receives one input and provides two outputs—other way, it combines two inputs to create an output that is the sum, difference, or average, of the inputs. Automobiles and other wheeled vehicles, the differential allows each of the driving road wheels to rotate at different speeds.

Rear Shaft Design:

Here also we are looking for beam analysis, where we are taking the rear shaft as a beam
Span  = 889.0 mm
Y  = a/2  = 25mm
Bending moment (M) = W*L*L/8
M/I  = F/Y
M  = (F/Y)*I
  = 9.4*105319.375/25
  = 39600N-MM
M  =2W
W  =39600/2
  = 19800 N
=2018.36KG

Total weight carrying capacity will be Around 2018.8kg

Fabrication of Driving Mechanism:

For an under-damped system, the value of $\zeta$ can be found by examining the logarithm of the ratio of succeeding amplitudes of a system. This is called the logarithmic decrement.

Damping Analysis (Calculation):

Free length of spring  = 255mm
Wire diameter   = 7 mm
Applied load   = 4954 N (505 kg)
Deflection obtained   =4.5 mm
Velocity   =0.96m/s
Damping resistance force = 44N
Stiffness(K) = applied load / deflection  
  = 4954/4.5  
  = 1100.9 N/mm
Critical damping coefficient
Natural frequency (Nf) = (k/m)/\ 0.5
  =2.18rad/second
Critical damping coefficient (Cc)= 2*M*Nf  
  =2201 N-sec/m
Damping coefficient (C) = applied load / velocity
  =526.04 N-sec/m
Damping factor (Df) = C/Cc
  =0.23

Fabrication of Damping System:

Steering Mechanism:

The basic aim of steering is to ensure that the wheels are pointing in the desired directions. This is typically achieved by a series of linkages, rods, pivots and gears .It is proposed to use ackermann steering mechanism

Braking System:

It is proposed to have drum / shoe brake system.

IC Engines:

The internal combustion engines are usually classified on the basic of cylinder arrangement, cycle of operation, type of fuel used, method of charging the engine cylinder, type of ignition and type of cooling. TYPE OF IC ENGINE USED

Single cylinder, two stroke petrol engine
Engine Specifications:

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Displacement:</td>
<td>109cc</td>
</tr>
<tr>
<td>Engine:</td>
<td>2-stroke, Single cylinder</td>
</tr>
<tr>
<td>Maximum Power:</td>
<td>8.9bhp@5600 rpm</td>
</tr>
<tr>
<td>Maximum Torque:</td>
<td>1.0kgm@5000 rpm</td>
</tr>
<tr>
<td>Gears:</td>
<td>Automatic</td>
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</tbody>
</table>

DIMENSIONS:

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Value</th>
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<tbody>
<tr>
<td>Length:</td>
<td>1761.00 mm</td>
</tr>
<tr>
<td>Width:</td>
<td>710.00 mm</td>
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<tr>
<td>Height:</td>
<td>1147.00 mm</td>
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</table>

OTHER SPECIFICATIONS:

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
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<tbody>
<tr>
<td>Weight:</td>
<td>110.00 kg</td>
</tr>
<tr>
<td>Ground Clearance</td>
<td>145.00 mm</td>
</tr>
<tr>
<td>Fuel Tank:</td>
<td>5.30 liters</td>
</tr>
<tr>
<td>Wheelbase:</td>
<td>1238.00 mm</td>
</tr>
</tbody>
</table>

Electric Motor:

It is proposed to have brushless variable speed dc motor D.C. Motors are a torque source, and so are able to operate well under high transient load conditions. At low speed, the D.C. motor is able to deliver a high torque.

Motor Specification:

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Input Voltage:</td>
<td>115 VAC</td>
</tr>
<tr>
<td>Input Current:</td>
<td>1:00 AM</td>
</tr>
<tr>
<td>Output Voltage:</td>
<td>Variable 0-90 VDC</td>
</tr>
<tr>
<td>Speed:</td>
<td>1200 rpm</td>
</tr>
<tr>
<td>Output Current:</td>
<td>0.50 A</td>
</tr>
<tr>
<td>Temperature Range</td>
<td>-20°C to 85°C</td>
</tr>
<tr>
<td>Weight:</td>
<td>2 lb</td>
</tr>
<tr>
<td>Dimensions:</td>
<td>6.75x5.80x2.85</td>
</tr>
</tbody>
</table>

Final Assembly:

Figure: Final Assembly

Performance Evaluation:

The performance of the project has been evaluated in different stages, by using simple techniques.

Turn Radius:

Turn radius refers to the extent that the edge of a commercial driveway is “rounded” to permit easier entry and exit by turning vehicles. Driveway entrances with longer turn radii help slower, turning traffic move off the arterial more quickly. While evaluating it is concluded that the truing radius of the hybrid four wheeler is 1.9 m.

Results and Discussions:

Evaluation on Load Carrying Capacity:

Using Engine (Keeping Motor Idle):

The data obtained from the test carried out by keeping electric motor idle, gives graph as shown below. Minimum load with a driver is taken as 285 kg.

Figure: Fuel Efficiency vs Load
Using Motor (Keeping Engine Idle):
The data obtained from the test carried out by keeping petrol engine idle, gives a curve as shown below. Here the battery charged for every 10 minutes to obtain the kilometer covered with different load. Minimum load with a driver is taken as 285 kg.

Using Engine and Motor (Starting Using Petrol Engine):
Here the battery is charged for every 10 minutes to obtain the kilometer covered with different load. The minimum load with a driver is taken as 285 kg.

Evaluation on Maximum Speed:
Here it is looking to derive the maximum speed the vehicle attain in different condition, different weights.

Using Engine (Keeping Motor Idle):
The data obtained from the test carried out by keeping electric motor idle, gives a curve as shown below. The minimum load with a driver is taken as 285 kg.

Using Motor (Keeping Engine Idle):
The data obtained from the test done by keeping petrol engine idle, gives a curve as shown below. Here the battery charged for every 10 minutes to obtain the kilometer covered with different load. The minimum load with a driver is taken as 285 kg.
Using Engine and Motor (Starting Using Petrol Engine):

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![Graph: Speed vs Load (Starting with Petrol Engine)]

**Figure:** Speed vs Load (Starting with Petrol Engine)

**Conclusion:**

The vehicle designed and fabricated is maneuverable. This utilizes a 100cc 2-stroke automatic petrol engine as one source of energy and DC powered motor (solar powered) as the other source. The vehicle has a very small turning radius of 1.9m. The engine performance is evaluated at various loads, speeds and observed that it gives an optimum mileage of 45kmpl with a pay load of 480kgs at 40kmph. The vehicle has a maximum speed of 55kmph and can carry pay load of 900kg, which is suitable for both load carrying and passenger vehicle as well. It is observed that while hybridizing, it yields more performance and power output.

**References:**


[2] “Preliminary experimental evaluation of a four wheel motors” by Rambaldi, LorenzoBocci, Enrico Orecchini, Fabio

