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Design Of An Electric Motor For Internal Combustion Engine Vehicles

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Abstract: The work deals with the design and development of an Electric Drive-Line for an Electric vehicle that aims to achieve less emission than conventional gasoline powered vehicles. This work has been developed with two concepts. One is to develop an electric drive-line for a given vehicle with less emission compared to fuel driven vehicles and the other one is to re-design the above vehicle for a specific purpose and run it with a low effect towards pollution. Through calculations, a motor is selected to run a 500 kg vehicle. To match the motors configuration a vehicle is selected is re-designed to suit the motor and for the particular application. An electronic controller is used to control the speed of the vehicle and direction of the motor (forward and reverse).An existing vehicle is taken for this work. The gasoline engine is to be replaced by an electric motor which obtains power from a controller and controls its speed. The controller gets its power from an array of rechargeable batteries.

1. INTRODUCTION

The increasing population worldwide has caused an increase in the number of vehicle users. The usage of vehicles is increasing in all the developing countries. This has further increased the traffic density thereby causes accumulation of pollutants locally in the high traffic zones causing various health hazards. Also fuel consumption at this rate will deplete the fossil fuel reserve and may cause a global havoc.

It is high time to think about energy efficient vehicles that consume less fuel and pollute less. Because of the unpredictable market pricing and the potential of limited fuel supplies, electric vehicles have received extraordinary attention. Electric vehicles have become an appealing alternative, particularly for short-distance commuting, thanks to advancements in battery technology and major increases in electrical motor efficiency. This work describes the application of DC motor in an electric vehicle. Because of their excellent efficiency and ruggedness, DC motors are becoming more used in electric vehicles.

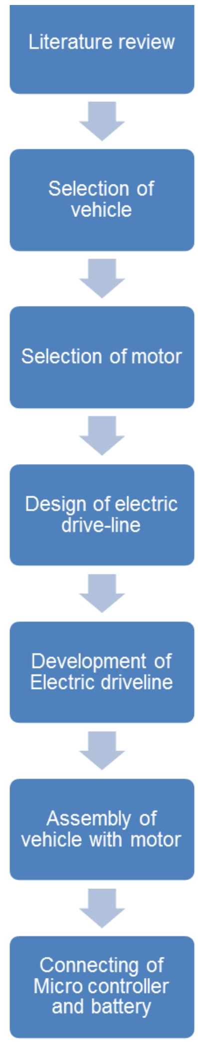

Figure. 1.1 Block Diagram

A. Methodology

The drive-line is designed and the process of conversion is shown in the Figure. 1.1. Literature survey of all the available papers on conversion of gasoline – electric powered vehicles will give us an ideology on the proposed system. Based on that, a feasibility analysis is be made. The vehicle chosen must have the lowest kerb weight and space constraints which will help to improve the overall efficiency of the system. For this a study on the available vehicles is required. For the vehicle chosen and the weight of the components involving gasoline vehicle and not necessary for an electric vehicle contribute to the load of the vehicle, therefore those contributing components must be removed. Required output power from the motor has to be calculated.

II. WORKING

An electric drive-line for an electric car is simple consisting of a battery, a control unit and a motor (Figure. 1.2). The battery used here will be a lithium ion battery or any kind of battery based on the application from where the motor gets the power. Based on the motor specification, the battery is selected mostly a rechargeable battery is used. The controller unit is one from which the speed of the motor and the direction of rotation of the motor is controlled. It may be a simple micro controller unit or a chopper circuit. The motor speed of is regulated by increasing the current through a rheostat set-up and the direction of the motor is controlled by changing the polarity of the supply voltage. The motor is connected to the wheel either directly or through a differential unit or through a gearbox based on what type of electric vehicle it is. For a fully electric vehicle the motor is directly coupled with the wheels or through a gearbox for the step up of torque, for a hybrid electric vehicle it is connected to the wheels with help of differential or through the axles. Regenerative braking is an optional advantage in an electric vehicle, were the braking inertia of the wheel and motor is converted to electricity that is used to charge the battery instantly.

III. CALCULATIONS

A. Selection of the vehicle

Since a vehicle with lowest kerb weight is to be chosen, the vehicle chosen for the conversion of gasoline powered to electric powered vehicle is Maruthi 800.

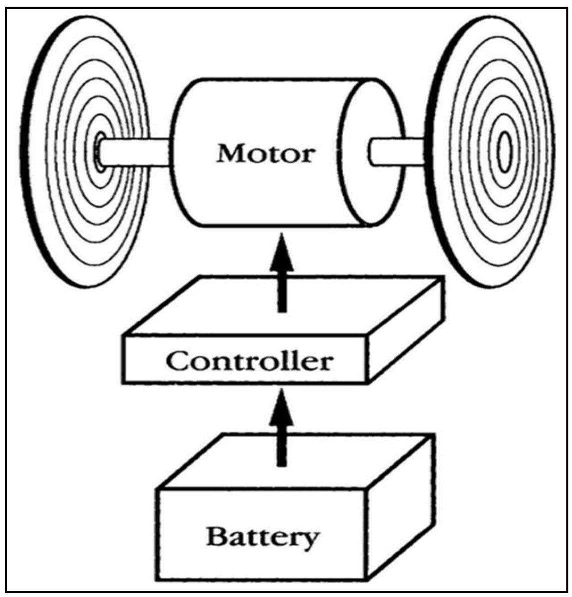

Figure. 1.2 Working of an Electric Motor

Vehicle Specification:

Dimensions

Overall length	333.5 cm
Overall width	144 cm
Overall height	140.5 cm
Wheelbase	217.5 cm
Minimum turning radius	440 cm
Ground clearance	17 cm
Seating capacity	4 persons

Weight

Un-laden Weight	665 kg
Laden Weight	1000 kg
Engine	
Type	4-stroke, water cooled SOHC
Number of Cylinders	3
Piston Displacement	796 cc
Maximum output (Std., AC)	37 bhp at 5000 rpm
Maximum torque (Std., AC)	59 Nm at 2500 rpm

B. Selecting the Motor

DC motor drives are commonly utilized in applications that require variable speed, good speed regulation, and frequent starting, braking, and reversing. Because of their technological development and control simplicity, many DC motor drives have been widely applied to various electric traction applications. Series DC motors are ideal for traction applications with high beginning torque and heavy torque overload. This was true for electric traction prior to the advent of power electronics and microcontrollers. However, there are certain drawbacks to using series DC motors for traction applications such as they are not permitted to run with full supply voltage and without the load torque. Otherwise, their speed will rapidly increase to an extremely high amount.

Figure 1.3 depicts the speed–torque characteristic of a series DC motor. In the case of a DC series motor, any increase in torque is accompanied by an increase in armature current and, hence, magnetic flux increases. Because flux increases with torque, the speed decreases to maintain a balance between the induced and supply voltages. As a result, the characteristic displays a severe decline. At the rated torque, a standard-design motor operates at the knee point of the magnetization curve. The magnetic circuit saturates at high torque (high current) overload, and the speed–torque curve approaches a straight line.

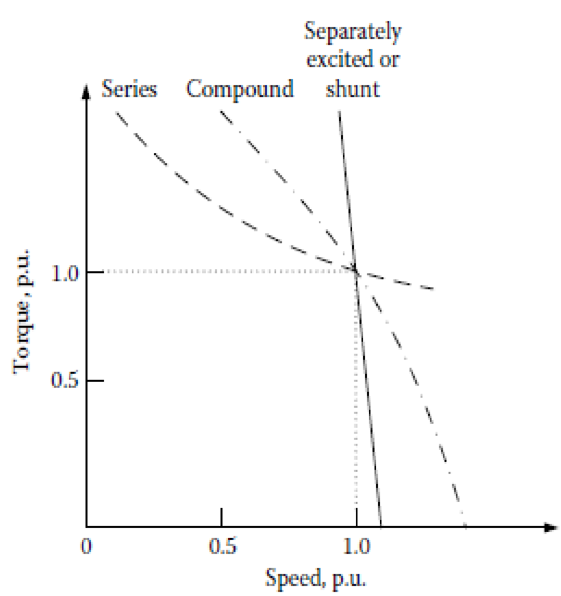

Figure 1.3 Speed characteristics of DC motors.

The application of the vehicle is in such a way that the speed of the vehicle must be less than 20 km/h. Therefore it is enough that the selected motor has enough power that matches the mentioned application. Considering the weight of the vehicle as 500 kg and the speed as 20 kmph the power is calculated.

POWER = $\frac{Rt\, V}{3600\, \eta}$ (1)

R_t = **R_{roll} +R grad +R air** (2)

R_{roll} = **10 kg for 1 ton**

For 500 kg(R_{roll}) = 50 N (3)

R_{grad} = **m * g * sine (θ)**

= 500 * 9.81* sine (2)

= 171.182 N (4)

R_{air} = $\frac{1}{2}\rho AV^2$

= $0.5*1.226*1.6*5.55^2*0.35$

= 10.57 N (5)

Adding equations (3), (4) and (5),

R_t = 231.742 N (6)

Substituting equation (6) in (1),

Power = 1.36 kW

1kW = 1.341 HP

Power = 1.825 HP (7)

Where,

R_t - Total Resistance

V - Vehicle Speed

η - Efficiency of the motor (95%)

R_{roll}` - rolling resistance encountered.

R_{grad} - gradient resistance
R_{air} - air resistance
M - Mass of the vehicle
g - Acceleration due to gravity
θ - Angle of gradient
ρ - Co-efficient of air (1.226)
A - Frontal area of the vehicle ($1.6m^2$)
V - Speed of the vehicle (m/s)

Since the power required by a motor for a vehicle of 500kg is low to 1.825 HP and considering for a little higher weight of the vehicle a standard 5HP, 1500rpm DC motor is selected for this application.

C. Designing of the Driveline

The torque of the motor is first calculated and compared with the maximum torque of the selected vehicle, here Maruthi 800.

Torque T $= \frac{3.7*1000*60}{2*\pi*1500}$

= 23.55 N-m

But the engines torque is much higher than that of the motor, so set up of torque is required. First gear ratio of the vehicle is always higher, therefore multiplying the motor torque with the first lets calculate the tractive force developed. Considering the weight of the vehicle is 500 kg.

Tractive effort T $= \frac{gr*t*df}{r}$

Where,
gr is the gear ratio of the first gear
t is the motor torque Nm
df is the differential ratio
r is the radius of the wheel in m

T $= \frac{3.58*23.55*3.5}{0.304}$

T = 970.66 N

Now, the tractive force at first gear considering the engines torque of maruthi 800 with its laden weight 1000kg is calculated.

Tractive effort (T) $= \frac{gr*t*df}{r}$

T $= \frac{3.58*44.25*3.5}{0.304}$

T = 1823 N

Since we have already considered the vehicle weight to minimum of 500kg for the conversion of the gasoline vehicle to electric vehicle, T/2 will be the tractive force needed for a 500 kg vehicle.

T/2 = 911.5 N

T of motor (500 Kg) = 970.66 N

Therefore the motor is connected to the first gear of the vehicle with some suitable drive system.

IV. BATTERY and CONTROLLER UNIT

A. *Controller Unit*

Choppers are used to drive DC motors for a variety of reasons, including high efficiency, control flexibility, light weight, small size, fast response, and regeneration down to very low speeds. The controller unit comprises of a chopper control circuit that is responsible for both the speed and direction of the motor. The chopper circuit is shown in Figure. 1.4, which regulates the motor in all four quadrants of the V-I plane by controlling the output voltage and current.

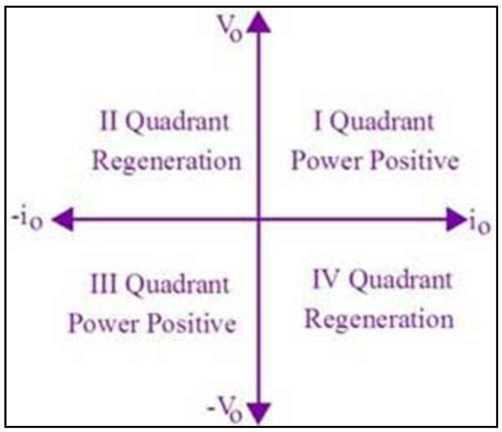

Figure. 1.4 Chopper circuit Four Quadrants

Power goes from the source to the load in the first quadrant and is presumed to be positive. The voltage remains same and the current change its direction in the second quadrant so the power becomes negative. In this instance, the load to the source power flow occurs at inductive load. The voltage and current are both negative in the third quadrant, yet the power is positive. Voltage is negative in the fourth quadrant, but current is positive. As a result, the power is negative.

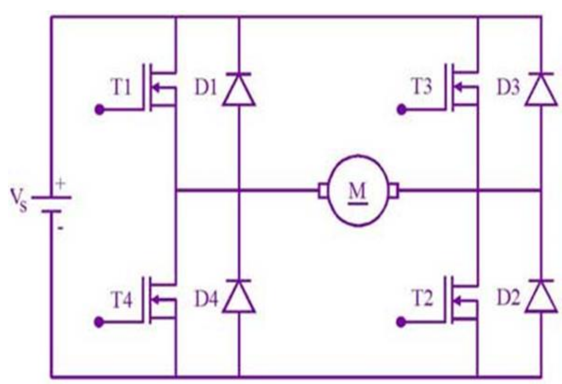

Figure. 1.5 Chopper Circuit Diagram

The four quadrant operational circuit of chopper with bipolar voltage switching is shown in Figure. 1.5. The first quadrant initiates with a positive voltage and current condition, resulting in positive power supplied to the motor. Here, T1 operated and T2 switched ON.

II quadrant initiates with voltage positive and current negative, resulting in a negative power. Because of the presence of the inductive load, power flow in the opposite direction, from load to source, in this circumstance. Both T1 are T3 are turned off, T4 is ON and T2 is operated continually.

III quadrant starts with both voltage and current negative, although the input power supplied is positive. As a result, the power is transferred from input to load. T3 is operational in this quadrant. T4 is operational, while T1 and T2 are inactive.

In IV quadrant, the current is negative, and the power is negative. T2 is turned on here, and T4 is turned on overall time. Because the inductor doesnot allow for abrupt changes in the current, T4 and D2 will conduct freewheeling current during OFF condition of T2. Thus the choppers activity in the first and third quadrants corresponds to the power flow from the input source to the load, and is referred to as forward power flow. Reverse power flow is represented by the operations in the fourth and second quadrants.

B. Battery

Battery is an electro chemical pressure maker which converts electrical energy into chemical energy during charging and during discharging process converts the chemical energy into electrical energy and there by supply to the electrical load.

Figure. 1.6 Traction Battery

A standard battery has an operating voltage of 12V whereas traction batteries have an operating voltage of 24V, 48V or 80V. The battery consists of number of cells which are linked in series. The nominal cell has a rated voltage of two volts and therefore, a traction battery with 48V operating voltage consists of 24 battery cells connected in series as shown in the Figure 1.6.

V. DESIGNING OF DRIVELINE OF THE MOTOR

Since the dimensional length of the motor is larger than the space available by the absence of the engine, another way to connect the gearbox shaft and motor shaft is to be thought off. Direct coupling of the two shafts are not possible because of the length restrictions. Therefore the motor shaft should be offset above the gearbox shaft. The most conventional method to transmit the power will be a chain drive system. C-section members are to be used to form an L structure and fitted to the chassis, as to form a bed like support for the motor to be fixed (Figure. 1.7).

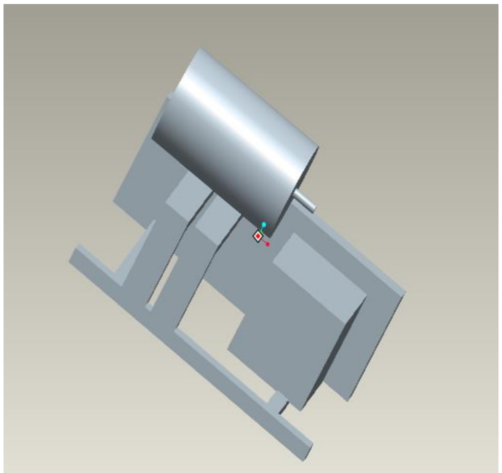

Figure. 1.7 Pro E Design of the Driveline of the Motor

Chain drive system is best suitable and conventional method for this application to transmit the power from the motor to the gearbox for torque multiplication. (Figure. 1.8and 1.9) shows the chain and sprocket fitted to the motor shaft and gearbox shaft respectively.

Figure. 1.8 Sprocket of Motor Shaft with Chain

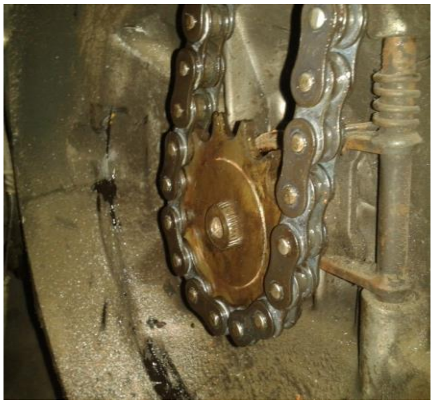

Figure. 1.9 Sprocket of gearbox shaft with chain

VI. CONCLUSION

Thus an electric driveline was proposed and designed for a vehicle with lowest kerb weight. (Figure. 2.0) shows the converted electric powered vehicle from a gasoline powered vehicle. The electric vehicle now can be used for the specific application with a less effect on the environment.

Figure. 2.0 Converted Electric Vehicles (Maruthi 800)

REFERENCES

1. Shaik Amjad, S.Neelakrishnan, R.Rudramoorthy, "Review of design considerations and technological challenges for successful development and deployment of plug-in hybrid electric vehicles", *IEEE* 2009.
2. Juan W. Dixon & Micah E. Ortlizar Catholic University of Chile "Ultracapacitors + DC-DC Converters in Regenerative Braking System", *IEEE* 2002.
3. Jeongwoo Lee and Douglas J. Nelson –"Rotating Inertia Impact on Propulsion and Regenerative Braking for Electric Motor DrivenVehicles," *IEEE* 2005.
4. Taizo Sakamoto Kuniaki Hirukawa Tsutomu Ohmae, "Cooperative Control of Full Electric Braking System With Independently Driven Four Wheels", *IEEE* 2006.
5. PENG Dong, ZHANG Jianwu, YIN Chengliang, "Regenerative braking control system improvement for parallel hybrid electric vehicle", *IEEE* 2007.