DESIGN OF TRANSMISSION SYSTEM FOR A HYBRID VEHICLE

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ABSTRACT

Conventional vehicles use gasoline or diesel to power an internal combustion engine which produces harmful gases into the environment. The best way to overcome this problem is by using a hybrid vehicle. The goal of a hybrid vehicle which is a rear wheel drive powered by both electric motor and IC engines to maximize the performance of the vehicle in supplying maximum power to the wheels independently from both electric motor and IC engine, which is the parallel type of transmission. To provide the proper transmission system in the hybrid vehicle it is capable of effectively transfer motion from the engine to the wheels and also acts as Eco-friendly. Efficient by maximizing performance output with minimal power losses. Compared with the battery electric vehicle, the available conventional internal combustion engine generates the power, together with the battery, the motor-driven hybrid electric vehicle, after filling the oil and the electricity, can travel about 500~1000 kilometers. When the hybrid electric vehicle decelerates and brakes, the drive motor transforms into the generator, it will change the braking energy into the electrical energy, feeding back to the power battery, causing the deceleration and the braking energy recycled. The present work includes analysis, of resistance parameters, acceleration, and gradability.

KEYWORDS: *Engine Layout, Gearbox, Electric Motor, Rolling Resistance, Aerodynamic Resistance & Gradability*

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1. INTRODUCTION

The drivetrain of hybrid vehicle transmits power to the driving wheels of the vehicle. A hybrid vehicle has various forms of motive power the Powertrain includes all the components used to transform stored potential energy power sources for the hybrid vehicle may either use coal, compressed natural gas, gasoline, diesel, flywheel, hydrogen, solar, wind, electric batteries, hydraulic accumulator etc.^[1] Transmission is one of the most important and vital systems in one of the automobile. It is a combination of different components which varies from one automobile to another automobile according to needs and requirements of a particular usage^[2]. They are many components involved in it. Some important components are engine, gearbox, clutch etc. There are different types of hybrid which are being used in our daily life. Based on the design there are i) parallel hybrid have both IC engine and an electric motor that can both individually run the car or being coupled. ii) Series hybrid is an extended range electric vehicle. iii) power split hybrid is the parallel hybrids that incorporate power split devices^[3]. Based on hybridization there are micro-hybrids, mild hybrids, full hybrids, and plug-in hybrids.

2. ENGINE LAYOUT

The type of transmission design which is suitable for the car is the parallel drive. The engine system design is given in figure1:

Figure 1: Layout of Engine Design

In this, both IC engine and electric motor work constantly to get more power.

3. WORKING PRINCIPLE

The engine supplies energy to the gearbox input shaft through a chain drive. Similarly the DC motor draws power from the battery connected to it and supplies it to the shaft through another chain drive, where both of the motor and IC engine are connected to gearbox input shaft through sprockets provided with single direction lock which adds an advantage of using both the IC engine and electric motor in powering the vehicle independently along with power multiplication of both IC engine and electric motor that is being transmitted to the wheels. Then the power is transmitted through differential to the wheels [4-5].

4. ENGINE

The major component of the entire transmission system and the heart of the vehicle is an engine which acts as an input to the entire system of the transmission [6]. It is also called as a driven component. According to the current analysis, Briggs and Stratton 1450XR Engine is used.

The specification of the engine is mentioned below

Table 1: Specifications of the Engine

Model Number	19N1
Engine Displacement(cc)	306cc
Power	10HP@3600RPM
Torque	19.5Nm@2800RPM
Number of cylinders	1
Fuel Type	Gasoline
Engine oil grade	5W-30

Figure 2: Power vs RPM Graph

4.1. Engine Power

Engine power which is also termed as horsepower is the maximum power of an engine output. Expressed in the form of kilowatts or horsepower [7]. The output power depends upon the size and design of the engine. It is also based on the speed and the applied load and torque.

$$\text{Engine Power} = \frac{(\text{Engine Rpm} \times \text{Torque(ft-lbs)})}{5252} = 10\text{HP}$$

The power output of the engine is 10HP@_3600 RPM.

5. ELECTRIC MOTOR

As it is a hybrid model of the vehicle, the electric motor has been used. The electrical motor used is a BLDC motor 2KW. The specification of a motor is given below

Table 2: Specifications of the Motor

Model number	BLDC125/5D
Power	2KW
Continuous Torque	8Nm
Peak Torque	24Nm
DC Voltage	48V
Rated Current	35Amp
Peak Current	80Amp

6. GEARBOX

The gearbox is the one of the foremost components in deciding the performance of the vehicle. The main function of the gearbox is to vary the torque and power from one gear to another gear [8]. By this phenomenon, it will give the flexibility to drive the vehicle and make the vehicle ready for all the conditions. The gearbox used is a customize gear box and the gear ratios are derived from the calculation by considering all the factors that are restricting the motion of the vehicle. The major advantage of this type of gearbox is that it is designed and manufactured according to the need and requirement. This gives the complete control over the vehicle and drives according to our need [9]. The required calculation of the gear ratios is mentioned below

- First gear ratio: - 4.66
- Second gear ratio: - 3.117
- Third gear ratio: - 2.136
- Fourth gear ratio: - 1.41

Figure 3: Manufacturing of Gearbox

Figure 4: Final Output of a Gearbox

6.1. Required Torque on Wheels

To get the required torque to move the car the following calculations are required to perform. The following steps will give the torque at each drive wheel. So, the required steps are:

- Rolling Resistance (RR)
- Grade Resistance (GR)
- Aerodynamic Resistance (AR)

We assume that

The mass of the vehicle = 275Kg

Driver weight = 75Kg

Gross weight of the vehicle = 350Kg (3432.32N)

6.1.1. Rolling Resistance (RR)

The force which required to overcome the rolling friction of a wheel is called as rolling resistance.

Rolling Resistance(RR) = Gross weight(GVW) $\times$ Surface Friction(Fr)

RR= GVW $\times$ Fr

RR= 3432.32 $\times$ 0.022 = 1716.16N

6.1.2. Grade Resistance (GR)

The force required to climb an inclination on the road is called as Grade resistance.

Grade Resistance(GR) = Gross weight(GVW) $\times$ Sin α

GR = 3432.32 $\times$ Sin (2.3)

GR = 137.79N

6.1.3. Aerodynamic Resistance (AR)

It is also called as drag force that acts parallel and opposite to the direction of flow exerted by the air on an object.

$$\text{Aerodynamic Resistance}(AR) = \left(\frac{1}{2}\right) \rho v^2 A C_d$$

$$AR = \left(\frac{1}{2}\right) 1.125 * 1.3889^2 * 0.8 * 0.57$$

$$AR = 0.49N$$

$$\text{Total Road Load} = RR + AR + GR$$

$$= 1716.16 + 137.79 + 0.49$$

$$= 1855.032N$$

$$\text{Tractive Effort} = 3432.32 * \cos(0) * 0.4 = 1372.928N$$

Maximum tractive effort is taken by considering all the friction losses

Therefore, Maximum Tractive effort

$$= \text{Tractive effort} * 1.15$$

$$= 1372.928 * 1.15$$

$$= 1578.8672N$$

$$\text{Torque Required at Wheel (Tw)} = \text{Total Road Load} * \text{Dynamic Rolling Radius}$$

$$Tw = 214.972 * 0.2413 = 51.87N\cdot m$$

6.2. Acceleration

Acceleration is the rate of change of velocity of an object with respect to time.

$$\text{Acceleration} = \text{Tractive effort} / \text{Gross weight}$$

$$= \frac{1444.032}{320}$$

$$= 4.512m/s^2$$

6.3. Maximum Speed

$$V_{\max} = \frac{(RPM * \pi * \text{DIA}(ft))}{(\text{DIFF RATIO} * \text{FINAL GEAR RATIO} * 88)}$$

$$= \frac{3600 * 3.14 * 1.583}{2.136 * 2.667 * 88}$$

$$= 54.101MPH$$

$$= 87.067KMPH$$

6.4. Gradability

Gradability is defined as the highest grade a vehicle can ascend maintaining at a particular speed.

It is measured in multiple ways, mainly:

- At an angle of inclination to the horizontal (20°, 30°, 45°, etc.).
- As a percentage of rising overrun.
- As a ratio of one part run to some number of parts

$$P = \left[\frac{F_z}{9.81G_z} - F_R \right]$$

$$= \left[\frac{1444.032}{9.81 \times 320} - 0.02 \right] = 43.2\%$$

Figure 5: Installation of Power Train

7. RESULTS AND DISCUSSIONS

Based on the experimental and theoretical calculation, the design of the gearbox and installation of all the components had been done. As per the design the first gear ratio is 4.66 which gives the speed of 26.41kmph from Engine and 20.11kmph from motor, second gear 3.117 which gives the speed of 39.41kmph from the engine and 31.33 from motor, the third gear ratio is 2.136 which gives the speed of 57.63kmph from engine and 45.7kmph from the motor and the final gear ratio is 1.41 which gives the speed of 87.3kmph from engine and 67.12kmph from motor [10-11]. Finally, it is observed that by varying the gear ratio speed of the vehicle is also varied, but the friction comes out to be 1902.95 N.

Table 3: Speed at Different Gears: (Engine)

Gear	Gear Ratio	Speed(KMPH)
1 st	4.66	26.41
2 nd	3.117	39.49
3 rd	2.136	57.63
4 th	1.41	87.30

Table 4: Torque and Rpm: (Engine)

Gear	RPM at Wheels	Torque(Nm)
1 st	290.42	243.69
2 nd	434.193	162.98
3 rd	633.604	111.69
4 th	959.843	73.72

Table 5: Speed at Different Gears: (Motor)

Gear	Gear Ratio	Speed(KMPH)
1 st	4.66	20.11
2 nd	3.117	31.33
3 rd	2.136	45.7
4 th	1.41	67.12

8. CONCLUSIONS

A Hybrid Powertrain had been powered parallelly by the engine and the motor. As it is designed as per the proved results the maximum speed and maximum fuel economy has been attained. When there is need of maximum torque and for eco-friendly, the gearbox uses the source of motor, whereas for getting maximum speed engine is used. It is capable of effectively transfer motion from the engine to the wheels and Efficient by maximizing performance output with minimal power losses.

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