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Optimizing Speed and Range of an Electric Motorcycle

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ABSTRACT: Transmission system of an electric vehicle is responsible for transmitting power from the motor to the wheel, providing the vehicle a smooth drive on various terrains or on road conditions. This work aims at optimizing the range of an electric vehicle with considering maximum attainable speed. This was achieved by case study of three different cases of attainable speed limited by various factors. The speed was limited by varying the current supplied to the motor and gear ratio of the drive. As main governing factor of range is the current drawn with associated speed, the different cases were analysed. The speed acceleration graphs were plotted for each particular case using MATLAB program and simulation for the verification of the actual speed was achieved. Further associated range was calculated in excel sheet for each case.

KEYWORDS: IC engines, electric vehicles, motorcycles, transmission, KV, $K_m\phi$, Es, Ra.

I. INTRODUCTION

For years IC engines have dominated the automobile industry. The conventional vehicles with IC engines provide a good performance and long operating range. However they have caused and continue to cause serious problems of poor fuel economy, environment pollution and human life. Due to the ever increasing prices of fuel and reducing oil resources at an alarming rate there is need to find an alternate source of powering our vehicles. Electric powered vehicles provide with a better alternative, eliminating the possibilities of polluting the environment. Even though it is a promising alternative it comes with its own difficulties. To manage the maximum attainable speed of vehicle with an appropriate driving range is one of the biggest concerns associated with these vehicles. With an electric two wheeler it is a rather difficult task to get maximum possible range while achieving a considerable speed taking into consideration the limited battery pack. The transmission system plays an important role in providing the vehicle with power so as the speed and acceleration is not affected and making sure that not much power is drawn depleting the battery power with in small distance range. The transmission system consists of an electric motor coupled to a chain and sprocket drive to transmit power to the rear wheel. The main aim of this paper is to analyse a given motorcycle parameters and try to determine the optimum speed and range for the city drive, without affecting the motor power or the battery pack.

II. LITERATURE REVIEW

Ramu Krishnan in 'Permanent Magnet Synchronous and Brushless DC Motor Drives' provides the advantages of a brushless DC motor over brushed DC motors namely, high power to weight ratio, more torque per watt (increased efficiency), increased reliability, reduced noise, longer lifetime and electronic control. Thus a Brushless DC motor supplied by a company Revolt Motors was selected which offers the finest of the above characteristics.

The specifications of the motor are:

- Operation voltage: 24V-96V
- Continuous power/ Peak power: 5KW/ 10KW
- Weight: 4.3Kg

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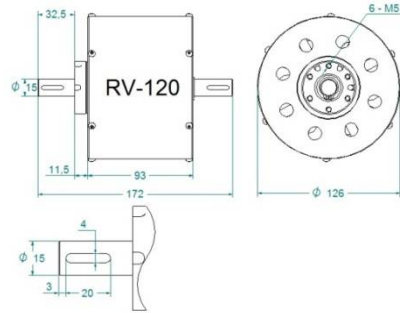


Fig.1: Dimensional Diagram of Motor Used.

In the book, 'Electric Vehicle Technology Explained', James Larminie and John Lowry have explained various concepts of electric transmission systems and parameters used to define the MATLAB program to calculate the acceleration graph of the electric vehicles.

III. OPTIMUM SPEED AND RANGE FOR MOTOR CYCLE USING MATLAB SIMULATION AND RANGE CALCULATIONS

A. Statement of work

The objective of this work is to provide an optimum speed and range for a motor cycle. It is another objective of the work to provide detailed analysis on selection of the speed and range based on three cases of work with the use of speed graphs and range calculations. Furthermore the work will provide a better understanding in maximum attainable driving range and speed through the graphs presented.

B. Field of work

Table 1: Electric Motorcycle Specifications

| | |
|-------------------------|------------------------------|
| Kerb Weight | 120 kg |
| Motor Power | 5kW (continuous) 10kW (peak) |
| Maximum Motor Speed | 3240 rpm |
| Working Current Range | 100-200A |
| Motor Operating Voltage | 72V |
| Battery Capacity | 5.6 kWh |
| Wheel Radius | 0.312m |
| Frontal Area | 1.8 m ² |
| Rolling Co-efficient | 0.007 |

Related terms in calculations:

KV: KV refers to the rpm constant of a motor - it is the number of revolutions per minute that the motor will turn when 1V (one Volt) is applied with no load attached to the motor. The kV directly relates to the torque constant K_t which is expressed as in/oz./amp i.e. torque per amp

$K_m\phi$: This is the quantity governing the torque supplied by the motor and is calculated by: $K_m\phi = 60/2\pi KV$. Further the torque is calculated by-

$$T = K_m\phi E_s / R_a - (K_m\phi)^2 \cdot w / R_a$$

Where,

E_s : voltage supplied in V

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Ra: internal resistance in Ω
w: angular speed of motor in rad/s

IV. RELATED WORK

Using a MATLAB program the speed graph for every particular case can be plotted this giving actual speed attained and acceleration can be calculated.

Mat lab program used:

```
t=linspace(0,50,501);
vel=zeros(1,501);
d=zeros(1,501);
dT=0.1;
for n=1:500
    if vel(n)<10.8
        vel(n+1)=vel(n) + dT*(1.57 - (0.00145*(vel(n)^2)));
    elseif vel(n)>=10.8
        vel(n+1)=vel(n)+dT*(7.30-(0.53*vel(n))-(0.00145*(vel(n)^2)));
    end;
    d(n+1)=d(n) + 0.1*vel(n);
end;
vel=vel.*3.6;
plot(t,vel); axis([0 30 0 50]);
xlabel('Time/seconds');
ylabel('Velocity/kmph');
title('Full power (WOT)acceleration of electric scooter');
```

The MATLAB program plots the graph considering the differential equation of speed given by-
 $(G/r)*T = \mu_r * M * g + 0.625 * C_d * A * V^2 + (M + I * (G/r)^2) dv/dt$

Where,

- M: mass of the vehicle
- μ_r : rolling friction co-efficient
- Cd: co-efficient of air drag
- A: frontal area
- G: gear ratio of chain drive
- r: radius of wheel in meters
- $(M + I * (G/r)^2)$: It accounts for the 5% increase on inertia of the vehicle

Thus dv/dt is calculated in terms of V^2 and V and the equation is substituted in the mat lab program obtaining the graph. Changing the gear ratio G and limiting the maximum current drawn, affecting the torque supplied by the motor, different cases are obtained.

Case I

Table 2: Specifications of Case I

| | Mass | Wheel Radius | Req. Torque | Motor Voltage | No Load Speed | Current | Km(/) | Motor Torque | Gear Ratio | Torque on Wheels |
|--------|------|--------------|-------------|---------------|---------------|---------|-------|--------------|------------|------------------|
| Case I | 210 | 0.312 | 192.82536 | 72 | 3240 | 100 | 0.212 | 21.2 | 3.5 | 74.2 |

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Here current supplied is 100 amperes and the gear ratio is 3.5. Thus the graph obtained using mat lab is:

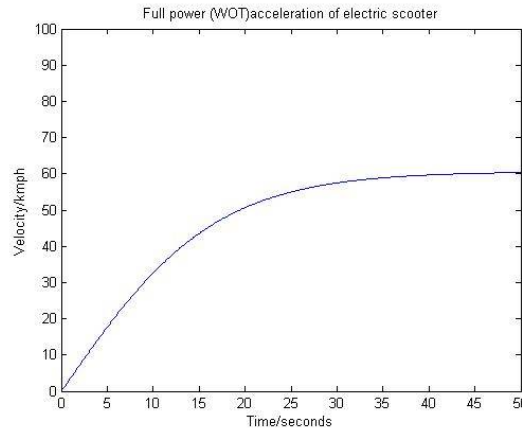


Fig.2: Graph for Case I

Thus the actual speed obtained is 61 kmph with acceleration of 0.823 m/s^2 .

Case II

Table 3: Specifications of Case II

| | Mass | Wheel Radius | Req. Torque | Motor Voltage | No Load Speed | Current | Km(/) | Motor Torque | Gear Ratio | Torque on Wheels |
|---------|------|--------------|-------------|---------------|---------------|---------|-------|--------------|------------|------------------|
| Case II | 210 | 0.312 | 192.82536 | 72 | 3240 | 180 | 0.212 | 38.16 | 3.75 | 143.1 |

Here current supplied is 180 amperes and the gear ratio is 3.75. Thus the graph obtained using mat lab is:

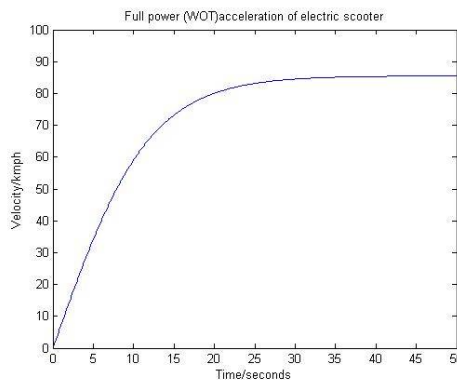


Fig.3: Graph for Case II

Thus the actual speed obtained is 85 kmph with acceleration of 1.85 m/s^2 .

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Case III

Table 4: Specifications of Case III

| | Mass | Wheel Radius | Req. Torque | Motor Voltage | No Load Speed | Current | Km(/) | Motor Torque | Gear Ratio | Torque on Wheels |
|----------|------|--------------|-------------|---------------|---------------|---------|-------|--------------|------------|------------------|
| Case III | 210 | 0.312 | 192.82536 | 72 | 3240 | 150 | 0.212 | 31.8 | 3.75 | 119.25 |

Here current supplied is 150 amperes and the gear ratio is 3.75. Thus the graph obtained using mat lab is:

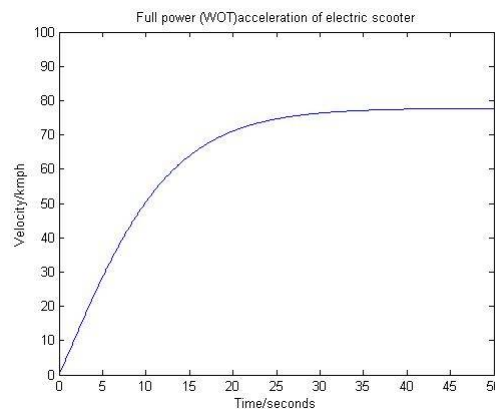


Fig.4: Graph for Case III

Thus the actual speed obtained is 77.5 kmph with acceleration of 1.48 m/s².

Obtaining the three different cases of speed we can subsequently calculate the range in kilometres as the current and maximum speed in each case varies. Thus analysing each case we can obtain the optimized speed and range case.

V. RANGE CALCULATIONS

The range for each case presented was performed on excel sheet considering the battery power to be 5.6 KWh, 72 V and 78 Ah. As the current considered in each case changes the consequent range also changes. The term KWh/Km is used. This gives the consumption of any vehicle depending on weight, drag co-efficient, frontal area, discharge rate and speed of the vehicle. As the only changing parameters are the discharge rate and speed of the vehicle range varies with the changing values.

Case I

In this case the current was 100 amp and the speed attained by the vehicle is 61 kmph. The range as calculated for this case is:

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| Velocity | | Range in km |
|----------|-------|-------------|
| km/h | m/s | |
| 20 | 5.56 | 261.5 |
| 25 | 6.94 | 229.8 |
| 30 | 8.33 | 194.9 |
| 35 | 9.72 | 163.5 |
| 40 | 11.11 | 137.4 |
| 45 | 12.50 | 116.2 |
| 50 | 13.89 | 99.1 |
| 55 | 15.28 | 85.4 |
| 60 | 16.67 | 74.2 |
| 65 | 18.06 | ## |

Fig.5: Range in Km for Case I

Thus this case gives us with a range of 74 kms if driven at a constant speed of 60 kmph.

Case II

In this case the current was 180 amp and the speed attained by the vehicle is 85 kmph. The range as calculated for this case is:

| | | Range in km |
|------|-------|-------------|
| km/h | m/s | |
| 20 | 5.56 | 245.2 |
| 25 | 6.94 | 215.4 |
| 30 | 8.33 | 182.7 |
| 35 | 9.72 | 153.3 |
| 40 | 11.11 | 128.8 |
| 45 | 12.50 | 108.9 |
| 50 | 13.89 | 92.9 |
| 55 | 15.28 | 80.0 |
| 60 | 16.67 | 69.6 |
| 65 | 18.06 | 61.0 |
| 70 | 19.44 | 53.3 |
| 75 | 20.83 | 47.0 |
| 80 | 22.22 | 41.6 |
| 85 | 23.61 | 37.1 |

Fig.6: Range in Km for Case II

This shows that driving in the higher speed range with higher current limits the range to 37 km at constant 85 kmph speed and also drops the average range obtained.

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Case III

In this case the current was 150 amp and the speed attained by the vehicle is 77.5 kmph. The range as calculated for this case is:

| | | Range in km |
|------|-------|-------------|
| km/h | m/s | |
| 20 | 5.56 | 254.5 |
| 25 | 6.94 | 223.6 |
| 30 | 8.33 | 189.7 |
| 35 | 9.72 | 159.2 |
| 40 | 11.11 | 133.7 |
| 45 | 12.50 | 113.1 |
| 50 | 13.89 | 96.5 |
| 55 | 15.28 | 83.1 |
| 60 | 16.67 | 72.2 |
| 65 | 18.06 | 63.4 |
| 70 | 19.44 | 55.4 |
| 75 | 20.83 | 48.7 |
| 80 | 22.22 | 43.2 |

Fig.7: Range in Km for Case III

In this case range is between 43 km to 48 km at the constant speed of 77.5 kmph and this also indicated a rise in overall average range.

VI. RESULTS AND CONCLUSIONS

Analysing all the three cases the speed and range case optimum case is of Case III, though the case II provides a better range but it lacks in attaining a suitable maximum speed for a city drive, driving on an empty road with the limited speed of 60 kmph creates a bitter drive experience. Also as seen in Case III though a speed of 85 kmph is achieved the range collapses subsequently.

Considering a speed of 77.5 kmph and the consequent range values it can be said that this provides a better drive for the vehicle in terms of speed achieved as compared to case I and an better range as compared to case III.

A. Future Scope

1. This study does not consider drive cycles of various city or road conditions while calculating the range on the three different cases.
2. The study also does not consider power transmitting components used in the system and their effect on the power delivery and efficiency, thus affecting the maximum speed and the range of the vehicle.

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