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Modeling, Simulation and Analysis of Electric Vehicle Driven by axial flux Motor and Cobalt Batteries

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Abstract: In today's world, transportation is vital. The conventional cars are substituted by electric vehicles because of their potential to reduce air pollution, lessen the effects of greenhouse gas emissions, and avoid the depletion of fossil fuel supply has already made them attractive substitutes for conventional cars. This is because electric vehicles are produced centrally.
Electrical energy is utilized to power electric cars. The emissions from energy produced from centralized sources can be regulated and are more efficient than those from internal combustion engines. Additionally, electric vehicles store and transform their kinetic energy into electrical energy 4 while braking and casting. The primary part of an electric vehicle (EV), which replaces internal combustion engines, is an electric motor. Here we have modeled an electric car model powered by cobalt batteries and an axial flux motor. The simulation experiments show that the axial flux motor has a high degree of stability when driving the EV in various motion modes.
Keywords: Electric vehicle, Axial flux motor, Cobalt batteries, internal combustion engine.

INTRODUCTION

The use of electric engines in place of internal combustion engines in automobiles is one of the latest trends in the automotive industry, as air pollution has a negative impact on the environment. In addition electric vehicles have shown an improvement in characteristics like speed, eco-friendliness, user-friendliness, innovation in vehicle electronics, recyclability, and resource management. In spite of other methods to electric vehicle technology, motor management and battery management are the two primary pillars that are still challenging to improve upon in terms of efficacy and results. The operation of the axial flux motor, including its speed, efficiency, motor life, power/weight ratios, motion, torque, and friction, is the focus of this study.

Comparative studies of batteries indicate that because of their excellent energy efficiency and rapid charging times, lithium-ion batteries are found in most electric cars. But using these batteries in electric cars has a number of serious problems, including thermal runaway and thermal instability. As a result, it puts individuals in grave danger because there is a higher chance of catching fire (as shown in fig 1). It is suggested that lithium cobalt batteries be used in the design of the electric vehicle to get around these battery-related limitations because of their high thermal stability, quick charging speed, light weight, efficient recyclability, low self-discharge rate, high energy density and high power rate. It has not only concentrated on battery replacement but also on the power and specs of the motor. There are certain drawbacks including high cost associated with using magnets, issues with high-speed performance, a small constant power range, vibrations and rather complex wiring. Over 17 million electric vehicles were sold globally between 2012 and 2021 (that includes all-electric vehicles and plug-in hybrid vehicles combined). By 2030, 145 million electric vehicles are anticipated to be on the road (including electric cars, buses, vans, and heavy trucks). The plug-in passenger car sales increased to 9% globally in 2021 when compared to 2.5% in 2019 and 4.6%in 2020.

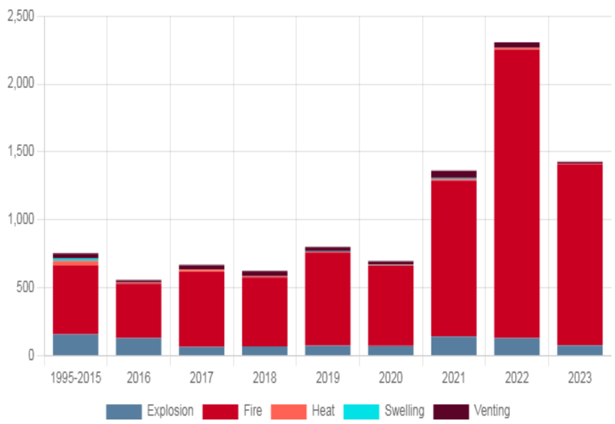

Figure 1: Survey of accidents held using Lithium-ion batteries

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Performance Analysis of BLDC Motor in Electric Vehicles with Lithium Ion Batteries (Existing System)

High torque, great efficiency, low noise, simple speed control, and a longer lifespan are all characteristics of brushless DC motors. They do not have brushes, thus they are commuted electrically.

The Table 2.1 specifies the performance index of the BLDC motor and Table 2.2 gives the Specification of BLDC motor [1]

Table 2.1: Performance Index of BLDC Motor

Parameter	Value
Rated voltage	154V
Rated power	10 Kw
Rated speed	3000rpm
Rated torque	32Nm

Table 2.2: Specification of BLDC Motor

Specification	Value
Rated voltage	24V
Rated torque	0.2Nm
Rated power	82W
Rated speed	3950 rpm
Rated current	5A
Rated power	82 W
Torque coefficient	0.0475Nm/A
Resistance of phase	0.49 ohm
Inductance of phase	0.16 mH
Number of pole pairs	2

In the modern automotive business, battery-powered electric vehicles are becoming increasingly significant.Electric vehicles are powered by a variety of batteries. The table 2.3 provides a basic comparison [2]:

Table 2.3: Comparison Between Different Batteries

Sl .no	Types of batteries	Mass energy density	Volume energy density	Power density	Charging/ discharging efficiency
1	Lead acid battery	30-40 Wh/Kg	60-75 Wh/L	180 W/Kg	70-92%
2	Nickel-Metal battery	40-120 Wh/Kg	140-400 Wh/L	220 W/Kg	65-80%
3	Solid state battery	100 Wh/Kg	75-120 Wh/L	150 W/Kg	75-85%
4	Ultra-capacitor battery	120 Wh/Kg	100-140 Wh/L	200-275 W/Kg	60-70%
5	Lithium-ion battery	100-180 Wh/Kg	200-300 Wh/L	250-340 W/Kg	95-99%

Here we can see that the best level of efficiency is provided by lithium ion batteries. Lithium ion batteries have high electric charge capacity. The relative high power-to-weight ratio, specific energy, and energy density of electric vehicles define them. The bulk of today's batteries have a lower specific energy than liquid fuels, which commonly reduces a vehicle's potential all-electric range. Instead of using lithium metal,lithium-ion batteries operate on lithium ions.

The most common battery types in contemporary electric vehicles are lithium-particle and lithium polymer batteries because of their high energy density relative to their weight.

Amongst the different battery-powered types used in electric cars, zinc-air and sodium nickel chloride batteries are less frequently employed than lead-corrosive, nickel-cadmium, and nickel-metal hydride batteries.

Performance Analysis of Axial Flux Motor in Electric Vehicles with Lithium Cobalt Batteries (Proposed System)

Due to the axial flux motor's normal efficiency of 96% is achieved in electric vehicles as per the specifications mentioned in the Table 2.4, we have analyzed the same in our horology

Table 2.4: Performance Analysis of Axial Flux Motor

Parameter	Value
Rated voltage	280V
Rated power	60kw
Rated speed	4800 rpm
Rated torque	34Nm
Number of slots	12
Number of poles	10
Number of turns ofwinding	14
Length of air gap	0.8mm
Polar arc coefficient	0.8
Arc radius of permanent magnet	19
Permanent magnetthickness	3.4

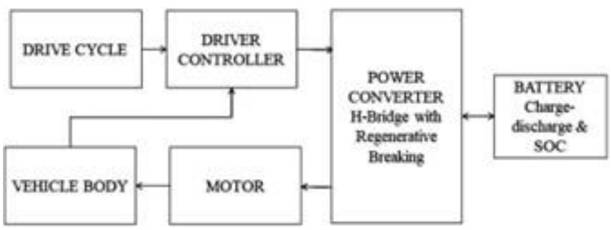

Figure 2: Vehicle body - Block diagram

Figure 2 shows the basic block diagram of the vehicle model [3]. The major blocks include:

1. **Vehicle Body**-This block gives the representation of the body of a vehicle with wheels which is connected to the motor through a transmission system.
2. **Motor and Controller**- The Motor and controller are instrumental in ensuring the smooth operation of the vehicle. According to the requirements of the motor, the controller gives feedback signals for efficient operation.
3. **Battery Pack and Power Converter**- Battery pack

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is the most essential block of the EV model. It provides power to every block of the EV model. The Power converter transforms energy from battery to an optimum level as required by the motor, and additionally provides regenerative energy to the battery there by charging the vehicle during deceleration.

4. **Drive Cycle Source**-It is a series of data points representing the speed of a vehicle versus time.

Using Simulink the analytical model was established as shown in Figure 3.

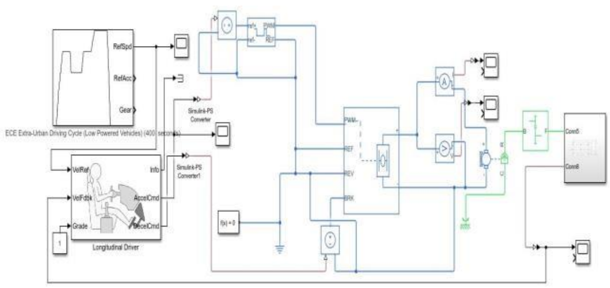

Figure 3: Vehicle body - Simulink Circuit diagram

To confirm the accuracy of the model and design, the air-gap flux density, back electromotive force (EMF), and torque under no-load and load circumstances were calculated and examined. The effects of the permanent magnet thickness, pole arc coefficient, and permanent magnet radius on cogging torque were then examined using a parameter scanning optimization method. The AF motor with unequal-thickness arc permanent magnets had its characteristics adjusted. The outcomes demonstrate an improvement in the air- gap magnetic field's sinusoidal degree and a decrease in the maximum torque ripple of the AF motor to 2.92%.When selecting a battery to power electric vehicles, lithium cobalt batteries are unsurpassed. Cobalt has a high energy density, therefore using it in batteries can make them lighter and more energy-dense. Furthermore, cobalt has the immediate ability to tolerate extreme temperatures, making them very dependable and secure. Lithium-cobalt batteries are unrivaled for powering EVs. The following characteristics of cobalt set them apart from the others:

- High energy density
- Thermal stability
- High specific power
- Low self-discharge rate
- Low weight
- Recyclability
- Lithium-cobalt batteries enhance safety and sustainability while also extending the range of EV.

RESULTS AND DISCUSSION

The delay between each spike in the figure 4 demonstrates MATLAB's processing power and capability—is only 0.001 seconds or 1 millisecond. A current vs. time graph for a period of 120 seconds is displayed in figure 5. It demonstrates how, when a vehicle is driving at a steady speed, the value of the current graduallydiminishes.

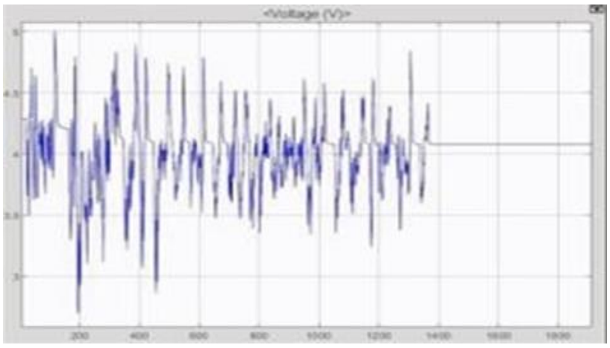

Figure 4: Voltage excitation

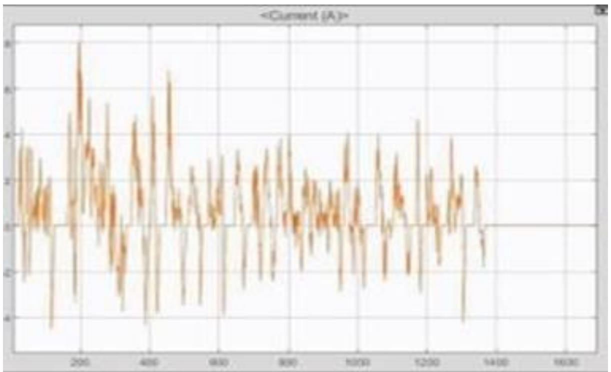

Figure 5: Current increases as the motor starts

The speed (m/s) from the drive cycle and speed feedback from the vehicle body is plotted in order to understand the response of the model according to the drive cycle data as shown in Figure 6.

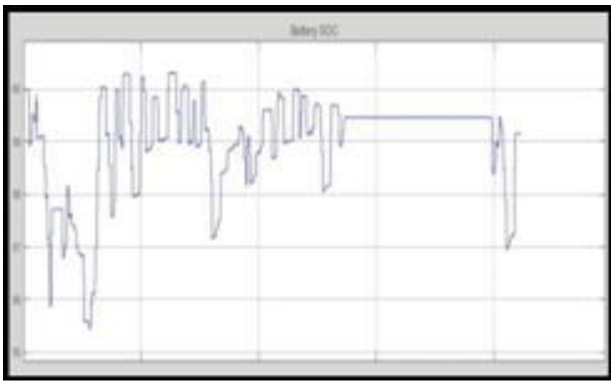

Figure 6: Speed comparison curve

Figure 7 and Figure 8 shows the velocity and current plots respectively. The (blue curve) of the vehicle almost follows the Reference curve (yellow curve) throughout the simulation. During peak decelerations, difference in velocity which is encountered due to inertial effects of the vehicle and instantaneous velocity drops in the reference curve. The motor speed and engine speed, in addition, as shown in figure 9 demonstrate the vehicle's distortion-free

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operation. The simulation's progression was seen, and a number of variables play a role in the modeling of an electric vehicle.

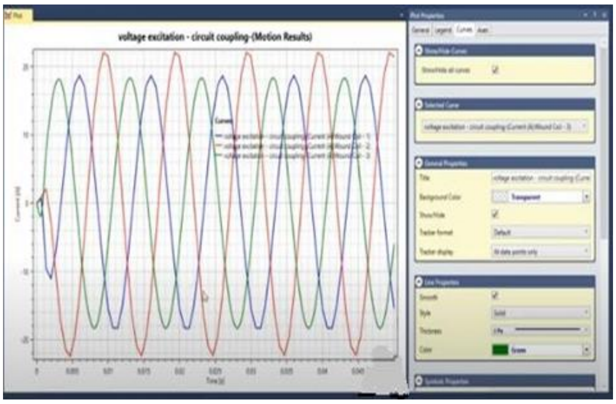

Figure 7: Voltage excitation plot

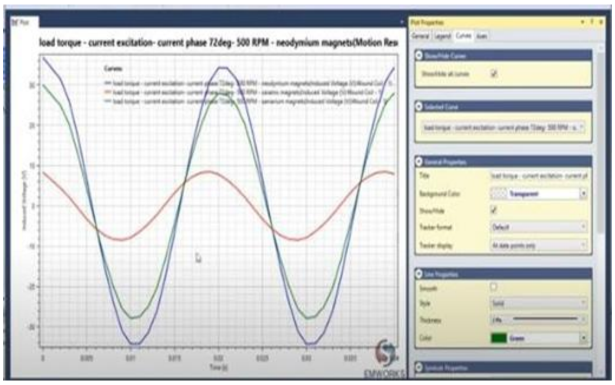

Figure 8: Current excitation plot

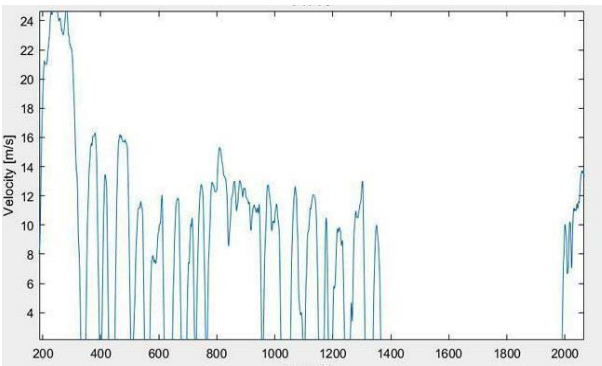

Figure 9: Engine Speed/ Motor Speed Plot

CONCLUSION

The modeling, simulation, and analysis methods used in the research of electric cars driven by cobaltbatteries and axial flux motors are finally covered in detail in this review paper. We have conducted a comparison of the performance of various batteries, as well as that of BLDC and axial flux motors, by looking through the body of available literature. Additional simulations were run, and the axial flux motor- driven electric vehicle's performance was monitored. This paper provides insightful data for academics, engineers, to promote the growth and integration of electric vehicles into mainstream transportation systems.

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