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Review TEE

Exploring Electric Skateboards: Comprehensive Insights into Design and Modeling

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Abstract

Environmental protection and energy conservation have become primary concerns in the 21st century, prompting accelerated efforts to plan and develop electric vehicle (EV) technology. EVs offer numerous advantages, including zero emissions, the establishment of a new automobile industry, economic development, and the creation of efficient and smart transportation systems. This project introduces a foot-controlled steering system designed to enhance vehicle control, making it suitable for various road conditions and reducing the rider's effort in driving the skateboard. Presently, permanent magnet brushless direct current (PM BLDC) motors are the preferred choice for automobile industries and researchers due to their high power density, compact size, reliability, noise-free operation, and minimal maintenance requirements. The initial phases of this project involve designing the vehicle using computer-aided design (CAD) and CRE-O, as well as conducting simulation models and equipment and cost analyses. The electrical hub motor drive and skateboard assembly, as well as processor architecture, are all part of the manufacturing procedure. The final stage aims to enhance the e-board's design for offroad conditions and adapt it for use by physically challenged individuals. The project's objectives include improving the skateboard's performance on off-road terrain by incorporating a centralized electric wheel and reducing the effort required to traverse uphill areas. Additionally, the design incorporates foot steering to enhance the skateboard's steering sensitivity. This project aims to reduce dependence on non-renewable resources by leveraging the latest technology. Implementation involves developing an e-board capable of running on battery power as well as manual propulsion.

Keywords: Permanent magnet brushless direct current (PM BLDC) motor, internal combustion (IC) engine, electric vehicle, transmission, direct current (DC) battery

INTRODUCTION

Approximately 93% of vehicles on the road today rely on petroleum-based products, which are projected to be depleted by 2050. To preserve gasoline for the future and enhance vehicle efficiency, the adoption of electric vehicles (EVs) represents a significant breakthrough. EVs are pollution-free and excel in low-speed conditions, particularly in high-traffic areas. However, one drawback is the time-consuming battery charging process. Additionally, EVs may struggle to provide sufficient power during high-speed or uphill conditions. Conversely, gasoline engines are efficient at higher speeds but waste energy in urban settings. Hybrid vehicles offer a solution by combining the advantages of both electric and gasoline systems, utilizing each power source efficiently. The basic design includes a DC battery connected to an inverter, which powers a brushless direct current (BLDC) motor operating on AC. The

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vehicle is propelled at slow speeds by this motor, which is fixed to the front wheel. At higher speeds, an internal combustion (IC) engine connected to the transmission facilitates motion. EVs have many benefits, including lowering pollution levels and supporting sustainable development objectives. They operate most efficiently in conditions where gasoline engines are least effective, such as low speeds and high-traffic areas. Motors consist of coils wrapped skillfully on a stator, a rotating rotor, and magnets to influence rotation electromagnetically. Brushless motors, which have no physical contact within the motor, offer virtually limitless durability. They utilize sophisticated controllers to power individual windings, ensuring continuous movement without stopping. There are two driving systems applied:

1. *Manual driving:* Newton's third law of motion governs manual propulsion, where force applied by pushing off one foot against the ground propels the board forward.
2. *Electrical driving:* This method uses a BLDC motor and controller that are supplied by a 24-V, 15-A batteries to transfer power to the driving wheel. The controller receives feedback from hall sensors inside the hub motor, adjusting power output based on accelerator input. Mechanical brakes are applied to the brake drum by brake shoes, while e-brake is applied to the motor via the Hall sensor, modulating acceleration cable signals. Components of the electrical drive include the hub motor, controller, battery, and throttle sensor.

LITERATURE SURVEY

The primary concerns of the 21st century are energy conservation and environmental preservation, which has sped up the planning and development of EV technology. EVs provide zero emissions, the creation of a new automobile sector, economic growth, and an effective and intelligent transportation system. Viswabharathy et al.'s [1] foot-operated steering technology makes controlling the car simple. It is made to fit any kind of road and lessen the rider's effort when riding a skateboard. The automotive industry and researchers currently favour permanent magnet brushless direct current motors due to their high power density, small size, dependability, noiselessness, and low maintenance needs [1]. A record of past events that offers important insight into the real invention and borrowing processes connected to skateboard evolution improves the research of Prentiss et al. [2]. Winter Fox [3] has created and tested a new design for skateboard trucks in an attempt to lessen the unpleasant vibration that comes with skating. Along with integrating with the current hardware, the new design has a split axle shape that permits independent wheel movement for the left and right. A thorough analysis of the skateboard electric vehicle chassis was presented by Shashank et al. [4]. It went over the important design factors for the skateboard EV chassis, like structural integrity and weight distribution [4]. All of the powertrain parts, batteries, power electronics, motors, and suspension and braking systems were incorporated in the Pinheiro et al. [5] skate-chassis. The research on the process of developing and refining the EV powertrain, including general EV arrangement, electric motor design, gearbox design, battery design, and layout design selection, was presented by Pham et al. [6]. It has been shown that side impacts into stationary obstacles, like poles, are the most critical. Belingardi and Scattina [7] offered a few concerns pertaining to the impact protection of the battery pack.

Designing a skateboard chassis for the Tata Ace that is lighter than the current Tata Ace engine chassis was the primary goal of Chandra et al.'s [8] study. Sujitha et al. [9] suggested using computer-aided design (CAD) tools to conceptualize and construct the electric skateboard. Then, they suggested developing simulation models to verify the device's functionality in a range of road conditions [9]. Subramani et al.'s [10] geared motor powers an electrically powered skateboard with two foot pedals for acceleration and braking. A potentiometer, which is regulated by the pedal and motor speed controller, supplies the motor with the power that is extracted from it. A cam-operated steering device is used to steer the skateboard. The base plate, which is fastened to the skateboard directly, is where the cam is fixed. Additionally, the cam is housed inside the hanger, which has a carved cam following profile. The skateboard can be maneuvered by adjusting the relative motion between the cam and the hanger's profile [10].

To start, one simply rotates the rotary knob (pot) mounted on the handle, initiating slow movement. The speed can be adjusted by further rotation, and to stop, the knob is returned to its initial position. The project utilizes a chain drive sprocket mechanism, consisting of wheels with teeth and chains fitted onto them, comprising both driver and driven sprockets. The system was selected because to its capacity to manage weights as high as 45 kg [11]. In conclusion, this project has yielded a complete and refined product, meeting the intended objectives [3].

SKATEBOARD AND E-BOARD

Skateboard

To guarantee the best possible ride for the rider, every detail has to be considered during the design process. The e-skateboard is capable of functioning in various weather conditions, and its rechargeable battery pack comes with a 29-V charger, an essential part is the battery management system (BMS), which keeps an eye out for over discharge, overcharge, and temperature fluctuations in cells to guarantee the safety of the batteries. In crowded environments, a separate horn mounted on the handle provides additional safety. Operating the e-skateboard is straightforward, suitable for individuals of all age groups. Skateboarding is a versatile activity encompassing riding and executing tricks with a skateboard. It can be enjoyed recreationally, as an art form, a profession, or a means of transportation. Many skateboarders have molded and inspired the sport over decades [4]. A 2024 report estimated the skateboarding market to generate around $3.22 billion in annual revenue, with approximately 11.08 million active skateboarders worldwide. Modern skateboard decks vary in size, typically ranging from 7 to 10.5 inches (18–27 cm) in width, with wider decks providing enhanced stability for transition or ramp skating. Standard decks might have manufacturer impressions, blank surfaces, or custom designs. They are usually 28 to 33 inches (71–84 cm) long [5]. Two metal trucks, typically composed of aluminum alloy, are fastened to the deck to link the wheels and bearings. The trucks are made up of an axle-running hanger and a base plate that is fastened onto the deck. Bushings offer turning cushioning and are situated between the base plate and hanger. Adjusting the kingpin nut tightens or loosens the trucks, affecting turning responsiveness and stability. Skateboard wheels are typically made of polyurethane and come in various sizes and shapes to suit different skating styles.

Larger diameter wheels (55–85 mm) roll faster and handle pavement cracks better, ideal for transition skating. Smaller diameter wheels (48–54 mm) provide quicker acceleration and lower center of gravity, suitable for street skating.

This e-skateboard is specifically crafted for short commutes within college campuses, cities, and both large- and small-scale industrial areas. Its compact design enhances its portability and usability, boasting excellent build quality. Additional features include wheel grip liners for enhanced traction on roads, rubber pads for increased height and ground clearance, and a grip tape made of adhesive sandpaper material placed on the board's surface. It has both head and taillights for safety when travelling at night. The components of the mechanical skateboard are presented in Figure 1. Wheel hardness, measured on the Shore durometer "A" scale, ranges from very soft to very hard, affecting speed and grip. Different types of skateboards include the following:

Longboard: Typically longer and wider than standard skateboards, favored for cruising, downhill riding, and transportation.

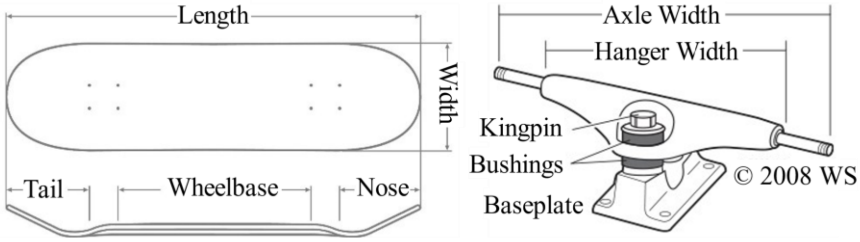

Figure 1. Mechanical skateboard structure.

Cruiser: Compact and versatile, suitable for commuting and cruising in urban environments.

Penny Board: Small and lightweight, characterized by a plastic deck, ideal for short commutes and maneuverability in tight spaces. In addition, specialized wheels are used for specific skating disciplines such as vert skating, slalom skating, longboarding, and downhill skateboarding, with variations in size and hardness tailored to each style's requirements [6]. These wheels often feature hard plastic cores for reduced weight and enhanced durability.

Electric Skateboard

An electric skateboard is essentially a modified skateboard powered by an electric motor, typically controlled using a radio-frequency (RF) remote. Just as on a regular skateboard, the rider adjusts the direction by adjusting their weight. Initially conceived for local transportation, electric skateboards now include "off road" models that cater to thrill-seekers. These off-road boards are capable of navigating various terrains such as grass, gravel, dirt, and hard sand with ease. They are often spotted on beaches during low tide, offering riders a new and exhilarating sport experience.

A basic representation of the designed electric skateboard is shown in Figure 2.

Hub Motor

Types of DC Motor: Brushed hub motors, brushless hub motors. A comparison of the different DC motors is presented in Table 1.

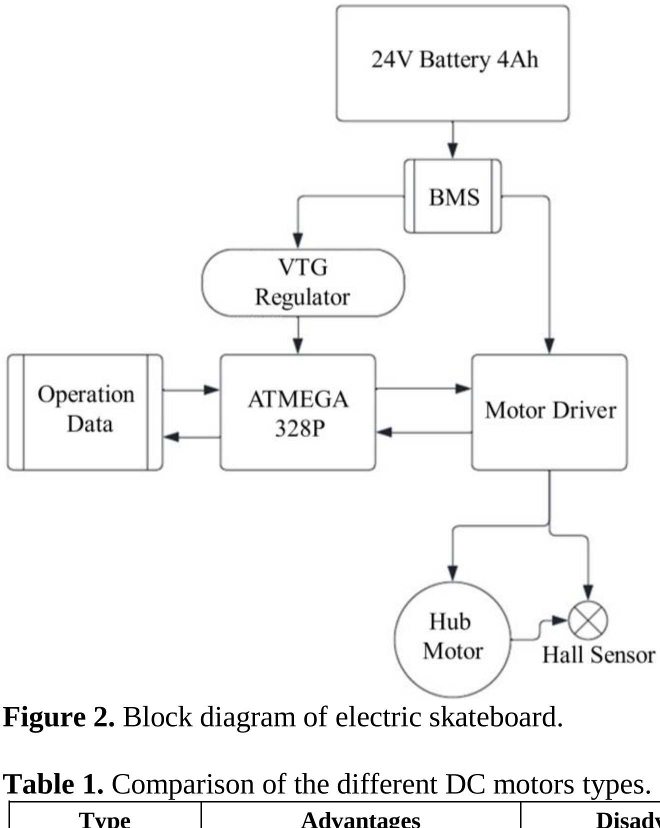

Figure 2. Block diagram of electric skateboard.

Table 1. Comparison of the different DC motors types.

Type	Advantages	Disadvantages	Typical Application
Stepper DC	Precision positioning stepper DC high holding torque	Slow speed, requires a controller	Positioning in printers and floppy drives
Brushless DC electric motor	Long lifespan, low maintenance, high efficiency	High initial cost, requires a controller	Hard drives CD/DVD players, electric vehicles
Brushed DC electric motor	Low initial cost, simple speed control	High maintenance (brushed), limited lifespan	Treadmill exercisers (automotive)

Brushless Direct Current Motor

In a handled DC motor, brushes and a mechanical commutator are usually used to provide information. However, in a BLDC motor, feedback is achieved using multiple sensors [7]. Hall detectors and optical encoding devices are the two most widely utilized types of sensors. These sensors play a crucial role in providing feedback about the motor's position and speed, enabling precise control and efficient operation [12]. Compared to brushed DC motors, BLDC motors have a number of advantages. First of all, because brushed motors do not have the electrical and friction losses that they do, they have a longer service life. Additionally, BLDC motors require minimal maintenance due to the elimination of brushes and mechanical commutators, components prone to wear and tear. Moreover, BLDC motors produce reduced electromagnetic interference (EMI) and noise, as they lack the ionizing spikes generated by brushes. This feature makes them particularly suitable for environments with dirt, oil, grease, and other contaminants, as BLDC motors can be fully sealed. Finally, BLDC motors utilize Hall sensor commutation, enabling precise control and efficient operation [8].

Motor Controller

The controller, sometimes referred to as an electronic speedometer or ESC, is a circuit made of electronics that controls the direction and speed of an electric motor as well as having the ability to function as a dynamic brake. ESCs generate a low-voltage, three-phase electric power source to drive the motor. In brushless ESC systems, this involves producing a tri-phase AC power output from a DC power input onboard, allowing brushless motors to operate. The circuitry of the ESC rotates a very low impedance by producing a series of AC signals. This procedure guarantees effective performance and allows for exact control over the motor's functioning as shown in Table 2 and Figure 3 [9].

Battery

Through electrochemical discharge reactions, batteries transform chemical energy into electrical energy. Typically, a battery is made up of one or more cells, each of which has an electrolyte, separator, positive electrode, and negative electrode. Primary and secondary cells are the two main classifications for these cells. Once the reactants in primary cells run out, they cannot be recharged and need to be replaced. Examples include lithium-sulfur dioxide, lithium-manganese dioxide, and lithium thionyl chloride, as well as carbon-zinc (Leclanché or dry cell), alkaline manganese, mercury-zinc, and silver-zinc. A comparison is presented in Table 3. However, secondary cells can be recharged and need a DC charging source in order to restock their reactants and reach a fully charged state. Lead-lead dioxide (lead acid), nickel-cadmium, nickel-iron, nickel-hydrogen, nickel-metal hydride, silver zinc, silver-cadmium, and lithium-ion batteries are a few examples of secondary cells. Rechargeable batteries are widely employed in many different applications, such as electric vehicles and handheld electronics, because they provide the benefit of repeated cycles of use.

Table 2. Specifications for a brushless direct current (BLDC) motor.

S.N.	Particulars	Specifications
1	Rated capacity	0.35 kW
2	Input voltage	12–24 V DC
3	Rated current	15 A
4	Starting current	Not exceeding 2 times of nominal current
5	Overcurrent limit	20% of nominal
6	Speed range	300 RPM (±10)
7	Overvoltage limit	10% of nominal voltage
8	Motor feedback	Hall effect sensors
9	Commutation	Trapezoidal
10	Mode of operation	Velocity mode (closed loop control)
11	Input signals	Run/stop emergency stop
12	Operating temp/humidity	00–55°C/95(±3%)
13	Size	165 × 70 (diameter × width) in mm

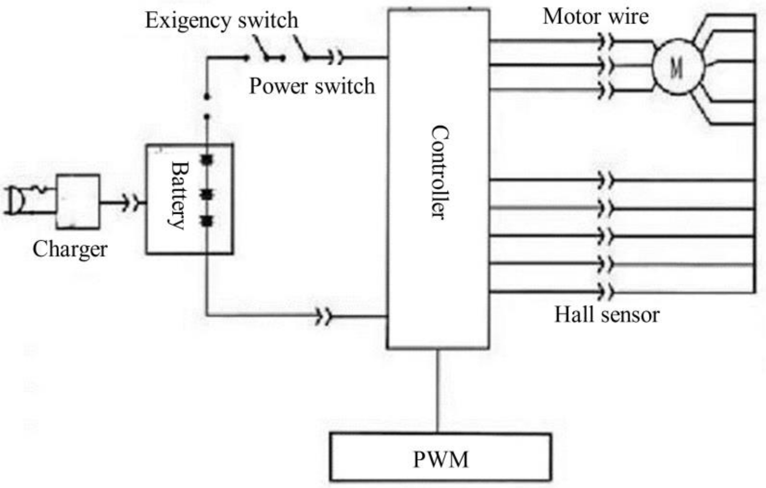

Figure 3. The function of microcontroller in e-skateboard.

Table 3. Specifications for brushless direct current (BLDC) motor.

Electrochemistry Cell	Voltage
Lead-acid	2.0
Nickel-cadmium	1.2
Nickel-metal hybrid	1.2
Lithium-ion	3.4
Lithium-polymer	3.0
Zinc-air	1.2

The 18650-battery pack that we have constructed comprises two cells linked in series (2S) and two cells joined in parallel. Each cell holds a nominal voltage of 3.7 V. When connected in series, the overall voltage of the battery pack elevates to 7.4 V (3.7 V × 2). Furthermore, each cell possesses a capacity of 2000 mAh. When coupled in parallel, the cumulative capacity of the battery pack remains at 2000 mAh. Hence, the specifications of my 18650-battery pack are outlined as follows: Configuration: 2S2P (2 cells in series, 2 cells in parallel). Nominal voltage: 7.4 V, total capacity: 4000 mAh (2000 mAh × 2). This battery pack configuration enables enhanced voltage output while preserving the same capacity as a single cell. Consequently, it facilitates heightened power delivery and prolonged operational durations in devices powered by the battery pack.

The battery management system (BMS) we have integrated is designed for a 7S configuration, meaning it is compatible with a battery pack consisting of seven cells connected in series. Additionally, the BMS is rated for a maximum continuous discharge current of 40 A, ensuring efficient and safe operation within specified parameters. In summary, the specifications of the BMS are as follows:

Configuration: 7S (for a battery pack with seven cells in series); maximum continuous discharge current: 40A. This BMS plays a crucial role in safeguarding the battery pack by monitoring individual cell voltages, balancing cell charging, and providing protection against overcharging, over-discharging, and overcurrent conditions. It enhances the overall performance, longevity, and safety of the battery system.

CONCLUSION

EVs utilize both manual and battery power sources. Manual drive is employed for low-power applications, while electric power is utilized for high-power applications where significant power is required. Electric drive systems demonstrate optimal efficiency at high speeds, ensuring that EVs operate efficiently in both modes. This dual-mode operation makes EVs particularly efficient in urban environments, especially in high-traffic areas where electric skateboards offer enhanced efficiency. This paper presents a review of techniques utilized for modeling board designs and implementing a centered wheel system on skateboards. The vehicle discussed serves as a light electric vehicle solution for single riders, offering improved fuel utilization. It finds suitability for various applications, including industrial supervision and transportation. The integration of lithium batteries enhances charging behavior, facilitating high-speed charging processes.

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