Overview

While there are diverse ranges of electric vehicles designed for specific functions, the underlying components that make up an electric vehicle do not vary much from vehicle to vehicle. Electric vehicles typically have a motor, a power source, a motor controller, and a control receiver.

Motor Controller – Distributes power to the motor from the batteries. Must generate a signal to properly drive the type of motor being used. First line of defense towards detecting internal issues and preventing the accidental overloading the motor.

Motor – Receives power from the motor controller and converts electrical energy into mechanical motion. The type and design of a motor decide the output performance and limitation of a motor.

Battery – Source of electrical power in the system. Must safely output enough power to run the system under any load condition or extreme scenario. A safety system must be in place to watch the charging and discharging of batteries to prevent battery venting or fires.

Controller and Receiver – Some way for a pilot or driver to interact with the system. The specific method of delivering control information can vary widely from a steering wheel and pedal in a car to the small handheld remote used for electric skateboards.

Power and Torque

The design of an electric vehicle requires the consideration of three key attributes of the system. The first attribute that must be taken into account is the power requirement for the system. The batteries must be able to supply enough power to run the system. The electrical power supplied by the batteries must be enough to get the desired output performance.

\[ P = F \cdot v = \tau \cdot \omega = V \cdot I \]

Take note that power can be expressed as torque multiplied by the rotational velocity as well as a voltage multiplied by current. The equation above can be used to calculate the power at different points along the system. While power is very important, torque must also be taken into consideration. Since torque is needed to overcome wind resistance and climb hills, the amount of torque produced at specific speeds will become very important to the engineer designing the system.

Motor

Most electric skateboards are powered by Brushless DC Outrunner motors. Along with having a high torque to weight ratio, Outrunner motors operate at lower rpm so there is no need for excessive gearing mechanism in order to meet the output requirements of the system.

As with most electric motors, the Brushless DC out-runner motor operates by energizing electromagnets as specific intervals to drive a rotor consisting of permanent magnets. Coiled wire around the stator stacks of the motor become energized as current is fed through the wire. The direction of current defines the polarity of the electro magnet, and by turning the internal stators on and off at precise times the stator stack electromagnets can attract the permanent magnets fixed to the rotor and spin the motor in the desired direction.

The rotor (on the right) is the moving part of the motor that is connected to the drive shaft.

The internal coils (on the left) are fixed in place and unmoving. The coils are energized to create electromagnets that drive the motion of the outside rotor.

Physics of Motion

Newton’s First law of Motion states that objects at rest stay at rest unless operated upon by an external force, therefore the force that drives the motion of an electric skateboard must come from an external force. For a driven wheel, the power from the motor is transferred to the wheel and attempts to rotate the wheel about its axis. Friction between the wheel and the road opposes the rotation of the wheel trying to prevent it from slipping and exerts an opposite force back onto the wheel.

The force exerted from the friction between the wheel and the ground must go to push the board forwards in order to get linear motion. Therefore the force cannot go towards spinning the wheel about its axis. By engaging the motor and preventing the wheel from rotating in response to the force exerted due to friction, the force applied to the system can go towards accelerating the system forwards.

Dynamometer Data

A Dynamometer measures the power output of a motor at different speeds. Using the power equation from before this dyno data can be used to calculate output torque at specific speeds.

Notice the linear behavior of the graph until 14 mph. Torque is relatively constant up until 14 mph at which point torque output begins to drop off at higher speeds.

Acknowledgments

Special thanks to StephanieDicenzo and Jeff Steele for their help and patience. Also, a big thanks to all the people at the Pikes Peak Makerspace for their advise and help.