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Electric Motorcycle Using Hub Motor Technology

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Abstract

Due to the current high demand for clean, efficient transportation systems, designers have looked to the electric motor as a means to end the reign of the internal combustion engine (ICE). This has led to the development of numerous electric vehicles, including motorcycles and scooters, as well as the traditional automobile. The electric drive systems in these vehicles have, for the most part, been retrofitted to mate with existing systems of power transfer commonly found in ICE vehicles. We propose to design a hub motor drive system for motorcycles that eliminates the reuse of these components not necessary in electric motorcycle design. By positioning the motor inside the drive wheel, greater efficiency is achieved, significant parts are eliminated, and space within the frame typically used to house drive components is opened up for battery systems. We plan on utilizing pancake electric motors because of their high torque in narrow configurations. Our motor will be fixed to the swingarm of the bike and will drive an outer housing that will double as the rim of the wheel. We intend to build a functional prototype of the proposed design and fit it to a motorcycle frame for analysis and testing.

Introduction

Project Background

Cultures worldwide have become increasingly reliant on modern transportation systems. The automobile has championed the personal mobility markets in these countries for obvious reasons. However, the vehicles high cost, required maintenance, and most important limited resources for its drive systems fuel have caused innovators to look in other directions to suit transportation needs. The internal combustion engine that supplies drive power to today's transporters has been successfully replaced with the more efficient electric motor. In most cases the performance of these systems has been comparable to that of their gas-guzzling counterpart, the internal combustion engine. Driving range, corporate politics, and more prominently the lack of infrastructure have, for the most part, kept these vehicles out of the mainstream. Some hybrids that utilize both drive systems have been made available, as have other forms of fully electric powered transportation such as bicycles and motorcycles. These production vehicles have been noted for their environmental friendliness, efficiency and low maintenance.

Typically, electric vehicles have been manufactured with a traditional drive system consisting of a belt or chain linked between the motor or transmission and drive wheel. This type of drive system has been implemented with success in several electric motorcycle and scooter designs that are currently available in the market place today. Though these chain and belt driven systems have been redesigned to eliminate reliability issues that plagued them in the past, they are not without faults. With chain type drive systems periodic maintenances are required; lubrication, retensioning, and sprocket replacement due to wear are the most prominent issues. The belt type drive systems have always had slipping and stretching issues, which can best be explained by the fact that the system relies on friction to operate. A few of the electric bicycles and scooters on the market today utilize a relatively new direct-drive system with hardly any moving parts other than the drive wheel. The system is best known as a "hub motor".

A hub motor is an electric motor that when used the shaft of the motor is fixed, and the outer body of the motor rotates when voltage is applied. There have also been designs that utilize a fixed motor that drives a housing around its body. Hub motors have been used on electric forklifts, bicycles, scooters, and some electric prototypes of cars and even buses. Hub motors are on the forefront of electric transportation technology. They save space within the frame of the

Vehicle and utilize space that is not usually taken advantage of. They create more efficient drive systems by eliminating troublesome parts and conserving the energy usually lost through the transmission of power. Also, ease of maintenance is achieved because the entire drive system is located within the wheel, making it very easy to remove for replacement or repair.

Problem Statement

What are the benefits and manufacturing feasibility of an electric motorcycle with a hub motor drive system that has comparable capabilities to a small gas powered motorcycle?

Constraints on the Solution

When considering the design of a hub motor drive system for a motorcycle, several areas of concern are immediately formed. The obvious is power, and whether there will be enough torque using off-the-shelf motor windings. Through comparing rear wheel torque data of production motorcycles and specifications of widely manufactured direct current motors, it has been found that we can achieve comparable performance.

Size is also an area of concern. The completed drive system must fit between the forks of the motorcycle's swingarm. Swingarm widths vary from one bike to the next, but it is a general rule in motorcycle design that the bike must be able to tilt from side to side on the tires in order to steer. A tire of great width would not be able to achieve this unless it was rounded in shape, as nearly all motorcycle tires are. The available width of these types of tires is limited to a maximum of approximately ten inches. This becomes a constraint on our solution, limiting the overall size of the finished hub drive system. This constraint also limits the amount of power that the system can generate, because electric motors become larger as the power requirement increases.

Research into the actual dimensions of an available DC motor that can generate enough torque for our system has revealed that new technology has allowed for small high torque motors to be produced. Our requirements can be met by utilizing an electric motor in the pancake configuration. Pancake motors are defined as having a larger diameter than length. This setup produces high amounts of torque in a very narrow package.

Statement of Work

Our proposed solution along with an alternate solution will be detailed in this section. The feasibility and testing of each solution will be used to help decide on the best solution that fits our requirements.

Method of Solution

We propose to create an electric drive system for a motorcycle that uses hub motor technology. This drive system will be integrated into the rear wheel of the motorcycle with a battery array and motor controller mounted in the motorcycle frame. The quality of the batteries used will determine the range of the motorcycle. We plan on using sealed lead acid batteries because of their availability, but will compare them with better batteries through calculations to determine how the range will increase with better battery technology.

A pancake electric motor will be mounted in the center of the wheel. Both sides of the motor will be attached to the swing arm to share the weight of the motorcycle. Side A will be fixed to the motorcycle swing arm and side B of the motor will sit in a bearing so it is free to spin, but be mounted to the arm. See Figure-1 in Appendix C. On one side the output shaft will drive a set of planetary gears. The planetary gears will be in an enclosure that is attached to the wheel through a clutch. When the clutch is engaged, the wheel will spin when a voltage is applied to the motor, when the clutch is released, the drive system will be disengaged from the wheel.

The option exists to not use planetary gears and a clutch, but will put a larger strain on the motor, and not allow the system to free wheel. The planetary gear set was chosen for its gear reduction. This gear reduction will require the motor to spin faster to obtain a certain speed, as compared to a 1 to 1 ratio, but will decrease the load on the motor through its acceleration.

Alternative Solution

An alternate solution to integrate electric hub motor technology into the drive system would be to mount several electric motors in a circular array about the center of the wheel. We would use a similar battery array and motor controller as explained in our first solution.

For example, several of the same motors could be mounted on a fixed support that is in the shape of a plus (+). Each arm would have a motor mounted at its end. This fixed support

would mount to the swing arm at the center of the wheel. In the “barrel” of the wheel a large ring gear would be fitted. The outer diameter of the electric motors would have a gear profile that meshes with the ring gear. Each of the motors would spin simultaneously to drive the wheel of the motorcycle (see Figure 1).

Feasibility

The feasibility research for an electric hub motor drive train was evaluated. The capabilities of electric motors were researched to determine if they would function in our proposed application. Our concerns were rpm range, amp draw, efficiency, and torque and horsepower output. It was determined that with a wheel of diameter 22.5” moving at 70 mph required the wheel and hub motor be spinning at 1046 rpm. This number was well below the rpm limit on the considered electric motors. Using a gear reduction, the rpm of the motor increased, but still stayed within its specifications. Operating through an rpm range to acquire a speed of 70 mph, the motors provide reasonable torque and horsepower.

A rear motorcycle wheel needs to be modified, or built from scratch to accommodate the drive system. This wheel must be structurally and dynamically sound, be simple to disassemble when maintenance on the drive system is necessary and be reliable and capable of withstanding its role in the drive system. This includes the support of the weight of the motorcycle and rider and spinning at high rpm’s.

Analysis, Testing & Validation

A database of available motors that could possible suit our needs was first compiled, and then a more in depth look at each of the motor’s specifications was done to determine which motors were candidates for our proposed drive system. Physical size, amp draw, estimated power output, efficiency, voltage and power consumption were all considered.

Initial calculations were made to determine approximately what rpm range we needed for our drive system to be capable of certain speeds. Using the torque and horsepower outputs of gas motors on motorcycles we want our prototype to be comparable to, we came up with approximate torque and horsepower outputs that we desired for our drive system.

With these parameters, we then narrowed down the list of possible motors for the drive system. After a choice is made on the best motor to be used in the drive system tests will be

conducted on the motor and also on a prototype we will build. All calculations will be backed by tests on the actual components involved in the design

Project Management Timeline

A detailed timetable is provided in Appendix A.

Economic Feasibility

Currently the market does not offer an electric motorcycle that provides hub motor technology; therefore it is necessary to devise a comparison with similar technology in order to come up with an estimated cost. A typical motorcycle comparable to our design would range in price from \$4000.00 to \$6000.00. This is a standard range for the more popular brand of motorcycle such as Honda or Yamaha. An electric car ranges in price from \$19,180.00 to \$20,510.00. This is about 37% more than that of a comparable car that runs on gas. With this in mind it is estimated that a electric powered motorcycle would cost somewhere around \$5480.00to \$8220.00

Considering most of the components used in the final product of our electric motorcycle are standard to the motorcycle industry, their cost and means of production have been meticulously worked over for optimization. The only assembly unique in the production of our motorcycle is the hub motor drive system. For this reason, our economic analysis will be limited to its costs. The manufacturing style that we will incorporate is an assembly operation, where the main components will be purchased as complete parts from outside vendors. The pricing is based on small initial quantities of 500-1000 units. Estimations are made from using available data on similar parts. See Table1 in Appendix C.

Societal and Environmental Impact Analysis

In a society where health is the pinnacle concern, antipollution and energy conservation are absolute necessities. In the past two years, states went measures to ban cigarette smoking in public places in efforts to protect the health of the people. We ask then, why do 133 million Americans live in areas that have failed at least one of the National Ambient Air Quality Standards. Americans consume two thirds of the national petroleum supply by means of transportation.

Carbon monoxide, nitrogen dioxide, sulphur dioxide, benzene and formaldehyde are major contaminants in car exhaust. Benzene, the same chemical in cigarettes, has been related in the cause of leukemia and lymphoma. As learned in thermodynamic analysis, carbon monoxide is produced from incomplete carbon-containing reactants in combustion. CO can be deadly if exposed for profound amounts of time, but more commonly, it binds to hemoglobin and prevents oxygen to surrounding cells. This can lead to cardiovascular disease. Other contaminants cause hypertension and ischemic heart disease. The only way to protect human life from car exhaust is to eliminate the use of polluting vehicles.

Electric vehicles average to be 75% efficient compared to the internal combustion engines at 32%. This means that 68% of petroleum products are wasted in vehicles. Considering that we spend \$1.59 a gallon, and get approximately 17 miles to the gallon. We drive about 12,000 miles a year. This works out to be \$1,347 per vehicle per year on average. At 68%, each person loses \$970 each year. This money should and will be saved with implementation of the new and efficient electric vehicle technology. Imagine how the economy would flourish if everyone in the world had \$970 to spend.

Another problem that we face is overpopulation. Large numbers of people means large numbers of vehicles and smaller amounts of space to drive and park. Motorcycles prove an alternate solution for this problem. With a smaller and more environmentally friendly vehicle, parking and traveling becomes hassle free. The electric motorcycle with hub motor technology proves to be a healthier, environmentally friendly solution for transportation.

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Appendix A- Gantt chart

Appendix B-Figures

Figure 1: Exploded Proposed Hub Motor Design

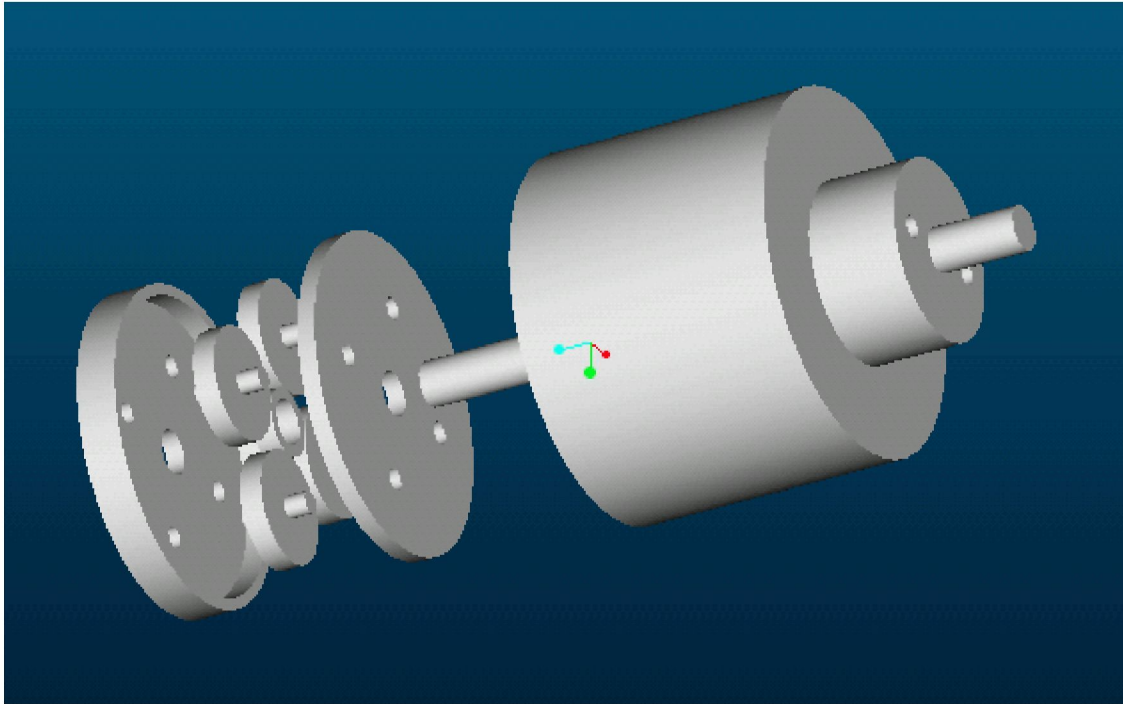


Table 1: Cost Analysis

Part	Cost
Brushless DC Motor	300.00
Planetary Gear Set	35.00
Clutch Assembly	40.00
Aluminum Housing Assembly (Including press-fit Barings)	325.00
Sealed Lead Acid Battery Pack	200.00
Controller	300.00
Labor for Assembly and Installation (3hr)	36.00
<i>TOTAL</i>	<i>1336.00</i>

Appendix C-Resumes



To protect personal information, resumes and/or curricula vitae have been removed from this document.

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