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Electrical Car/Vehicle: Future Prospects for Electromobility

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Abstract: Electric cars are automobiles, which are powered by the electric engine and electric energy. The development of the *electric vehicles* is a very perspective and important process. Scientists and engineers managed to create electric engines which are no less effective than the ordinary engines used today. It is obvious that electric cars are more ecologically safe and require less energy for work. In the very close future electric cars will replace ordinary cars, because the natural resources, like oil will be completely exhausted. In numerous cities across the country, the personal automobile is the single greatest polluter, as emissions from millions of vehicles on the road add up. Car pollution is one of the biggest polluters the solution is to have much more efficient vehicles that produce fewer emissions with every mile. So what would be the best thing for cars to run off of in the future? Electric vehicles are the answer to this problem. Electric vehicles or EVs, are vehicles that are powered by an electric motor instead of an internal combustion engine (Frequently). EVs use electricity as the fuel instead of gasoline or some other combustible fuel. The power for the vehicle is stored in many large batteries in the bottom of the car, then from there the power goes to a power regulator where it is changed from DC power to AC power. The engine only has one moving part, which send the power directly to the wheels. Therefore it does all the primary functions of a gas engine with no emissions. (Automobile) With technology like this one might guess who is going to jump on the electric vehicle bandwagon right away.EVs provide fast acceleration by delivering power instantly to the wheels by providing high torque at low speeds, they give a feel of smooth and quick responsiveness (Technology).

Index Terms: Power, Speed, torque, efficiency variation, Electric motor, Battery, Transmission, Engine, Force and electrode.

1. Introduction:

An estimated 600 million more cars will be competing for space on the roads around the world by the year 2020. That is over two times the number of cars already getting jammed up and pushed around now. There are approximately 400 million cars that exist on the roads today. With this increase in vehicle population there will be an ever-increasing demand for fuel or alternative energies to run these vehicles.

With the depleting supply of oil already an issue for the U.S. especially, there is an ever-increasing interest in the possible alternative energies and fuels that could or can be used in the future. Whether there will be a flip from petrol-fueled engines to some other non-petrol power in the near future is very hard to determine, but there are many options that are being experimented with and even beginning to be manufactured. Fuel Cells, Ethanol, electric, electric-hybrid, solar and a few others are some of the top promising possibilities for our future vehicles (Gwynne).

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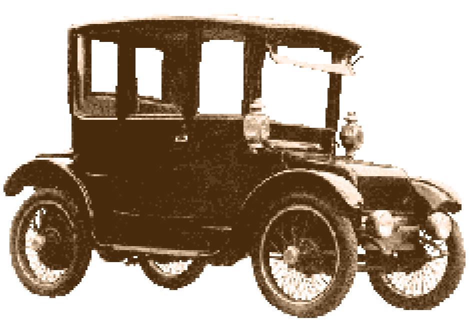
2. History of the Electric Vehicle:

Of these possible new sources of vehicle propulsion, the electric vehicle is becoming ever more popular even though it has been around for years in the past. In fact, it was one of the earliest vehicles made. Sometime between 1832 and 1839 (the exact year is uncertain), Scottish businessman Robert Anderson invented the first crude electric

carriage. In 1865 and then again in 1881 the storage battery technology was greatly improved and in turn enabled the electric vehicles to become a feasible, usable technology. Just before the year 1900, Jamais Contente built his "rocket shaped" vehicle, which broke the 60 mph speed barrier of electric vehicles. His vehicle (pictured to the right) was able to reach a speed of 65.79 mph (Wikipedia).

During the 1900s there were actually more electric cars that gasoline-powered cars. The vehicle pictured at the left is a Rauch and Lang Electric Sedan, built around 1922. At one time there were up to 50,000 Electric Vehicles on the roads and streets of the United States (Consumer).



Some of the first manufacturers of electric vehicles were Oldsmobile and Studebaker. These companies were successful with electric vehicle, but when the gasoline engine market flourished and took over the electric vehicle capabilities, Oldsmobile and Studebaker had to resort to the newer technology to keep up. In 1910, the production lines of vehicles went from complete hand assembly to motorized assembly lines and after this point electric vehicles became virtually non-existent outside of cities. One of the hugely contributing factors to the decline of electric vehicles was the addition of the starter motor on the gasoline engine, which ended the need for the difficult and dangerous crank to start the engine. Here the gasoline cars took over (A Little).

3. What the Electric Vehicle Has to Offer:

Although the electric vehicle (EV) has been left set for some time now as the technology to catch up with the gasoline vehicles has been slow and sometimes non-existent, there is still a great chance that the EV will make a comeback. Interest and technology are now being put back into the electric vehicles because of how much more efficient they are to run. These new electric vehicles have definite green advantages. These EVs do not emit any pollutants and have great energy efficiencies (Gwynne).

One of the biggest benefits of the EV is the fact that it reduces our dependence on oil and the fluctuation markets that go along with it. To go along with conserving resources the electric vehicle gives off a negligent amount of heat comparatively speaking to the gasoline and diesel vehicles on the market now, which contribute to the world issue of global warming (Wikipedia).

Looking at what is being driven on the roads now and comparing to the EVs, there is a large reduction in noise from the engines although the road noise from the tires and drivetrain is still very apparent. Another advantage about the propulsion method used in EVs is that there are many less moving parts than in a normal gasoline-powered car, which in turn makes for less breakdowns and need for service and parts. Electric vehicles are one of the cleanest and most environmentally friendly cars available at this point in time. These vehicles reduce pollutants by more than 90% when they are compared with the most efficient gasoline powered vehicles on the market. This statistic includes the emissions from the power plants that generate the power to charge the EV's batteries (Electric).

A special benefit of the EV comes when it is time for everyone else to go to the station to fill up with petrol. In this case the EV owners will not be making those trips to the station to fill up anymore. The fill-up can happen at home overnight or at work during the day. The car is simply plugged in while it is stationary for a given time period. Another way the car is charged is while it is being driven. When the car is coming to a stop and the brakes are applied, the kinetic energy of the car is converted back into chemical energy in the battery. This is a double-profiting operation where the car is being slowed down as well as being recharged simultaneously (Wikipedia).

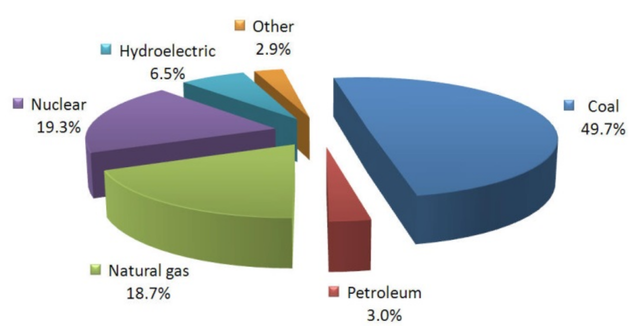
4. Comparing the EVs to the Gasoline Cars:

A normal gasoline powered vehicle ranges in miles per gallon (mpg) from 16 to 30. If an EV has a mpg value given to it, it would be around the 200-mile range, which in turn costs approximately three cents a mile. The cost to own the EVs has a large dependency to do with the type and capacity of the batteries used. The batteries are the most expensive portion of the car. The technology in batteries has been increasing greatly in the past 20 years. The need for better batteries has been increasing with the use of laptop computers, cell phones, and other electronic devices. Because of these battery advances, the electric vehicle industry has reaped the benefits by acquiring some of the technology for its own larger batteries (Wikipedia).

Probably the largest disadvantage in comparison to the conventional vehicles is the driving range for EVs. Currently the average range for an EV is anywhere from 50 to 130 miles per charge. The fluctuation in range can be cause in part by the vehicle's weight, engineering, design, type of battery, weather extremes, and the use of heating and air conditioning. The batteries are the part of the car that makes all the difference. Just like the engines are chosen in cars today for their power and quality, so the batteries are chosen for strength and endurance (Consumer).

One thing that many first-time drivers are expecting from an EV is slow acceleration and sluggish driving abilities. To their pleasant surprise, the EVs have a modest acceleration, while depending on the size of the motors and batteries the acceleration can vary greatly. When AC motors are used and approximately 50 batteries like in the yellow Tzero EV on the right, the acceleration is no different if not better. Here the Tzero has taken a Dodge Viper off the line in a drag test. Electric motors tend to have a very constant torque even at low speeds, which plays a part in having an efficient acceleration. Some of the models of EVs have an electric motor for each wheel. Having these four motors not only allows for better propulsion, but also for the use of braking and changing the kinetic energy back into chemical energy in the batteries. The traction that the car gets is also increased with each wheel driving. In some of the EV models the electric motors can be mounted directly inside the mounting for the wheel, which enables a loss of all the moving parts between the motor and the wheel. When there is no axle, differential, or transmission, the EVs have less drivetrain rotational inertia, which just takes more power to overcome

Looking at energy efficiency more closely can show how much more efficient EVs are. A typical EV uses .17 to .37 kilowatt-hours of energy per mile. Most of this energy consumption has to do with the inefficiencies of charging the batteries. The average gasoline powered vehicle gets about 23 miles per gallon, which is equivalent to 1.58 kWh per mile. This comparison is from the approximation that there are 36.4 kWh per US gallon of gasoline.

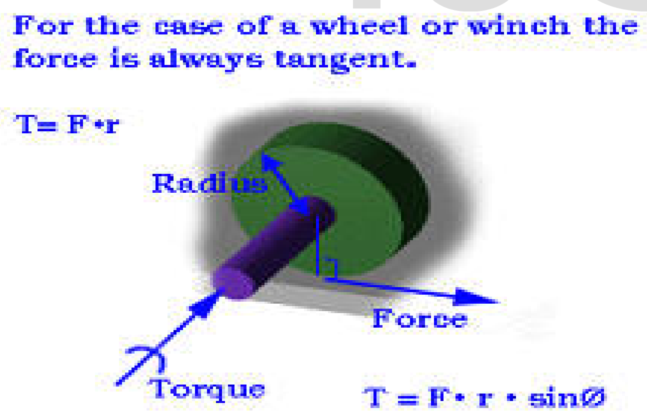


To charge these EVs the electricity needs to be generated from somewhere and from some resource. Depending on how the electricity is generated determines on how much of an improvement is made in terms of CO_2 emission. The improvement in emissions can range from 55% to 99% better depending on the way the electricity is generated. To the right is a diagram of where the United States gets its electricity from as of 2005. Most of these methods releases CO_2 gas, but in different amounts. The US national average of 1.28 lbs. CO_2/kWh for electricity generation gives the EVs a range of .2 to .5 lbs CO_2/mi, which is not much compared to the .83 lbs /mi for the average US vehicle.

5. How the Electric Vehicles Operate:

The way the EVs are made has a wide range of designs when looking at the different manufacturers. Some of the models are more similar to the make of a gasoline-powered vehicle and some are completely different such as the models with the electric motors placed in the wheel housing. Although there are many different models and makes, there are three main components that are put into the EV: the batteries, the electric motor controller, and the electric motor(s). In short, the electric motor controller takes the power from the batteries and delivers it to the motor(s). Another component of the EV is the battery charger, which is chosen depending on the type and number of batteries (Consumer).

6. Power from the Electric Motor:



To know how the electric cars work the basic principles of an electric motor need to be known. An electric motor has power and in turn puts out a force that is measured in torque. Torque is the rotational measurement of force. To the right is a diagram showing the basic equation of torque. The units of torque are Nm (Newton's time's meters) or ft-lbs (foot pounds). When looking at the physics behind an electric motor we need to remember what power is. The basic equation for power is:

$$P = Tw \qquad (1)$$

This is when the T is torque and the w is the rotational velocity. For a basic motor there are two parameters that can help show how the motor works. The first parameter is the Stall Torque (T_s), which is the minimum torque needed to stop the motor shaft from turning. The second parameter is the No Load Speed (W_n), which is the rotational speed of the motor when there is no torque being applied to it. The equations for these parameters follow respectively:

$$T = T_s - (T_s / w_n)\, w \qquad (2)$$

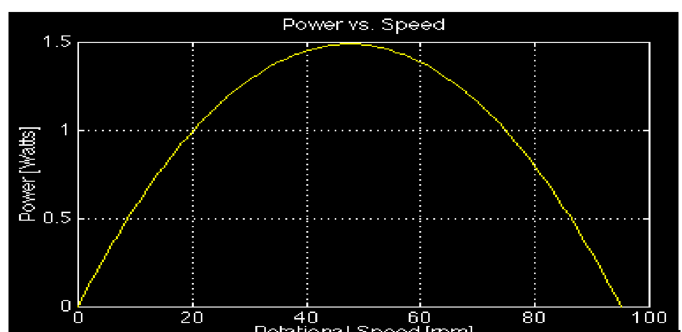
$$w = (T_s - T)\,(w_n / T_s) \qquad (3)$$

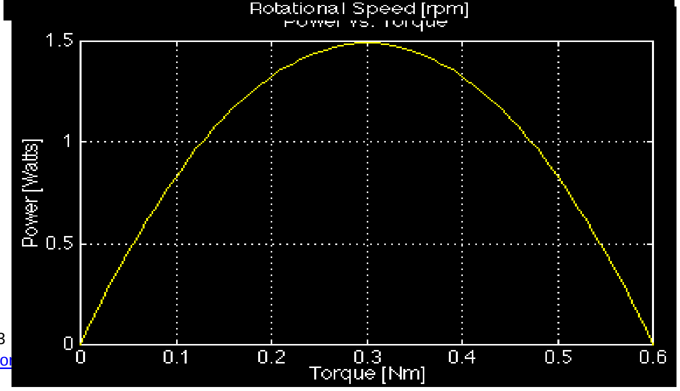
The power can then be determined in terms of either torque or velocity with these equations by multiplying the first one by w and the second by t. The new equations are then functions of either torque or velocity and are as follows:

Velocity function: $P\ (w) = -\ (T_s\ /\ w_n)\ w^2 + T_s w$ (4)

Torque function: $P\ (w) = -\ (w_n\ /\ T_s)\ T^2 + w_n T$ (5)

Directly below is the torque function and the graph on the right is the velocity function.

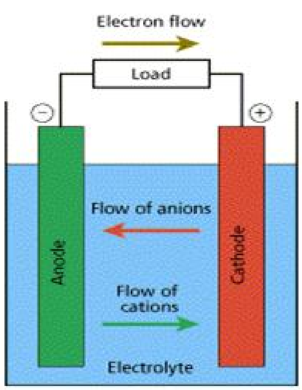




By looking at the two graphs we can see that there is a maximum power for a certain range of speed and torque. The motor will be performing at its maximum power if it is running at the specific speed and torque. For each motor the optimum speed and torque that create the most power are going to be different. In order to make an EV have the correct power and acceleration capabilities, the electric motor has to have the correct torque and speed to match the power needed to accelerate the vehicle up hills, against wind, and in many other varying conditions. These requirements are used to help determine the size and power of the electric motors for the EVs, which can also be different depending on how many motors are used for the electric car. If each wheel has a motor driving it, the power and size of the motors needed will be less, but when there are only one or two motors, the power needed will be much more (Design).

7. Batteries for the EV:

To power the electric motors the energy can be stored in various kinds and numbers of batteries. These batteries play a huge role in how the vehicle operates and how far it can travel before it is in need of recharging. Some batteries are made for a higher output while others are made for duration and longevity.

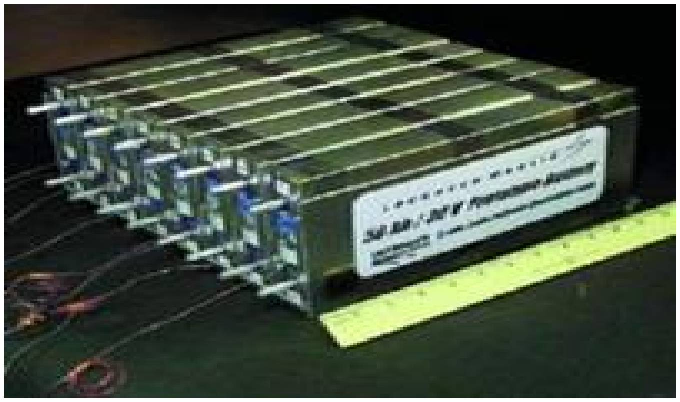


The basic concept of a battery is fairly simple. A battery is just an electric cell that undergoes a chemical reaction thus causing electrons to flow, which in turn can power some sort of electrical device. This electric cell consists of a negative electrode; an electrolyte, which conducts the ions; a separator, also an ion conductor; and a positive electrode. When the negative electrode is connected to the positive electrode the flow of electrons begins with the negative electrode supplying the positive electrode with electrons. To gain power from this flow of electrons the device being powered is connected in between the positive and negative electrodes and in this way the electrons must flow through the device. The batteries that are used for electric cars are rechargeable, which means that the flow of electrons can be reversed to flow back the way they came from to essentially "reload" the negative electrode so that the process can be repeated again (Dawson)

There are numerous kinds of batteries that can be used for the electric vehicles, which include; Nickel-Cadmium, Nickel Metal Hydride, and Lithium batteries as well as others.

The Nickel-Cadmium battery uses nickel oxide in its positive electrode (cathode), a cadmium compound in its negative electrode (anode), and potassium hydroxide solution as its electrolyte. Nickel-Cadmium is one of the older forms of rechargeable batteries; it is also one of the cheapest and most unreliable. This is not the best battery for an EV because of its unreliability. These batteries will lose charge capacity quickly if they are not maintained and charged often. This loss in capacity will also be greatly increased if the battery is not completely discharged first before recharging. The proper charger for these batteries has the capability of discharging the battery completely and then turning around and recharging it (Lithium).

Nickel Metal Hydride batteries are the "new and improved" Nickel-Cadmium rechargeable battery. They are partly becoming more popular because of the health and environmental concerns with the production of Nickel-Cadmium. There is still much research going into the Nickel Metal Hydride batteries. Most of the focus is on improving the hydride anode. The desired anode would have the following characteristics: a long life cycle, high capacity, high rate of charge and discharge at a constant voltage, and retention capacity. Right now the Nickel Metal Hydride (NiMH) batteries have been the most economical and promising for the future of electric cars although they could be improved. These batteries are cost efficient, are available, and are long-lived. The batteries on the market right now have proven to last the life of and EV or at least ten years and 100,000 vehicle miles. Many are saying that the batteries can probably last closer to 200,000 miles than 100,000 (NiMH). When charging these batteries it is important to prevent them from being overcharged. Overcharging the batteries will decrease life and strength. A Constant trickle charge is desired, but not continuous. It is better to go in cycles so that the batteries are charging for a period of time and then left set for some time before the charging continues. The chargers for these batteries often have this capability as well as being able to stop the charging process when it is fully charged to prevent the overcharging (Wikipedia).



The Lithium Ion battery design is one of the newer battery technologies on the market. This is not to be confused with the light, single-use, straight Lithium battery. These Lithium batteries are mainly used for portable devices that are aimed at a lighter duty. The Lithium Ion batteries have a high density, which essentially means that for the same weight and size as other batteries it can store more energy. This new technology is great for the EV because the EV utilizes the energy quickly and the more energy available the longer the range on a charge. Charging Lithium Ions are different than most batteries because it is better to keep them topped off with a charge rather than completely discharging them and recharging them. This is the biggest drawback for the EV and why it is not very common for the EV because they get completely drained during transit (Lithium). The picture to the left is a prototype of a 75 watt-hour/kilogram lithium ion polymer battery. Newer Li-ion cells can provide up to 130 Wh/kg and last through thousands of charging cycles (Wikipedia).

8. The EV of Today:

The electric cars today are just beginning to come back onto the market after many believe they were pushed off to make way for gasoline cars and the profits available from petroleum. Many say that the oil companies made the EV disappear back when the oil was plentiful and not considered a scarce resource and now that the supply of oil is more of an issue, the electric vehicle is finding its way back into the economy.

Today there is much controversy in what GM is doing or not doing in terms of battery technology and use. They bought the rights to the NiMH batteries for the EVs, but they have showed no signs of an attempt to improve them. Even more recently the rights were sold to Texaco, which was then absorbed into Chevron making it even more difficult to get the technology for the batteries. To the left is the GM EV1 that has been using the NiMH in recent years. In 1997 GM was using bad battery technology from Delco and better Panasonic lead-acid batteries weighing around 1300 pounds and only giving the EV1 a range of 110 miles per charge. GM then used the NiMH batteries in the 1999 EV1 to give it a range of up to 160 miles and weighing only 700 pounds. The technology here in batteries is a huge benefit and with possible increase in technology the EV1 could be a huge success (Economist).

Toyota also has a very promising EV for the market called the RAV4-EV. The average EV goes about 3 to 6 miles per kWh of stored energy. This average comes from the everyday driving of the EV1, NiMH Honda EV-plus, Ford Ranger-EV, and the Toyota RAV4-EV. To the right is a picture of the RAV4-EV. For being an SUV type vehicle it does fairly well with power and battery endurance. This EV can hold at most 28 kWh and can go approximately 80 miles at 80 mph, 100 miles at 65mph, 120 miles at 55 mph, and up to 150 miles at 35 mph. Comparing this to the EV1, which is much more aerodynamic, the EV1 gets approximately 4 to 6 miles per kWh (Electric).

9. Conclusion:

With the number of expected vehicles doubling on the roads in the near future the need for this alternative energy is very evident and has promising returns. With just the batteries, electric motor, and the modulator as the three significant parts of the car there are many benefits of these vehicles in comparison to the gasoline-powered cars. The lack of repair and maintenance of these vehicles will most likely soon be a huge seller for the EV. Some of these vehicles are on the road already, but not in an available form for the common driver. The hope for these vehicles is that they will be able to soon replace the gasoline vehicles with nearly the same range of travel as them. In doing this it will reduce the use of the ever decreasing supply of petroleum. The EV is not a new idea, but the technology to improve the old concepts of the EV is still being worked on to make it more promising for today's fast-paced world.

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