The International Journal of Engineering and Science (IJES)
|| Volume || 12 || Issue || 5|| May || Pages || PP 23-28 || 2023 ||
ISSN (e): 2319-1813 ISSN (p): 20-24-1805

A Comparative Study of Hybrid and Electrical Motors Technologies

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----------ABSTRACT----------
The purpose of this research paper is to review literature on the type of electric motors used for hybrid and electric vehicles and subsequently their efficiencies and other performance indicators. Four major variables are discussed in the paper: efficiency, battery, maintenance and types of motors. Through literature research and the significant difference that exists between the two types of vehicles, results have shown in regard to the four variables; electric vehicles stand as the best due to their efficiency, low maintenance costs, and also its type of motor, which converts much of its energy to the wheels. Therefore, owning an electric vehicle is much more beneficial than owning a hybrid vehicle. In 1960, legislation to produce electric vehicles was passed by the Congress. In 1999, the first mass production of electric vehicles was done and had been growing increasingly leading to the production of another type of motor that do not largely depend on the engine called electric traction motor. Hybrid and electric vehicles utilize a system of batteries and electric motors as part of their energy supply. The type of batteries and electric motors used depend on the energy demand, efficiency, availability of alternative sources of energy. The key significant differences between hybrid and electric vehicles leads to different choices on the type of electric motors. This also leads different choices for batteries and varying efficiencies on the performances of the two vehicles.
(Keywords: Electric Vehicles, hybrid vehicles, electric motors, types of motors)

Date of Submission: 20-05-2023 Date of Acceptance: 03-06-2023

I. Introduction

Electric vehicles and hybrid vehicles use batteries as alternative supply of energy for traction. Electric vehicles depend entirely on batteries for energy supply. Hybrid vehicles have both electric motors and conventional engines for traction. Technological development in automobile industry is due to increased need for environmentally friendly machines and scarcity of nonrenewable sources of energy. In 1960, Congress passed on legislation encouraging the production of electric vehicles. This was an attempt to produce automobiles that would barely use gasoline to produce power but use electricity to produce the forward thrust to drive the vehicles. Although electric vehicles did not hit the market as expected, auto manufacturers have been spending billions of dollars on research. The reproduction of electric vehicles was reborn in 1999 with the first mass production by Honda Insight, beginning the new era of electric vehicles. Hybrid and electric vehicles utilize a system of batteries and electric motors as part of their energy supply. While both types of cars are on our roads and admired by people, there exist great differences and similarities between the two vehicles. When deciding on a specific car, they consider some car motor attributes. Some of these are efficiency which means the energy conversion that enables the car to move, maintenance cost, battery life and the different types of motors used. This paper will compare hybrid and electric vehicles by looking at efficiency, battery, maintenance and the types of motors by conducting research and finally offer a compound analysis of the best type of vehicle to choose from based on the four aspects.

Denton, in his book Hybrid and electric vehicles, argues that, while people view electric vehicles as free from emission, they emit electromagnetic emissions. But compared to the Carbon dioxide produced by hybrid vehicles from gasoline combustion, there is no evidence of the danger of electromagnetic emission to the atmosphere (Denton, 2020). According to him, there are various aspects that one needs to look at before deciding to buy either an electric or a hybrid car. While availability and costs are key considerations when buying a car, Hussain says that what is important to look at are the benefits and the challenges of the two different types of vehicles in the long run. In their article, Weis et al. (2019), air pollution in regard to hybrid vehicles is not a consideration when one is looking at buying a car as the public, in most cases, is not interested in whether their car is generating air pollutants. According to them, the government pushes for electric vehicles as they are much safer when it comes to environmental conservation.

II. Literature Review

Castillo et al. (2020), on the perceptions of the two types of vehicles, claim that three major variables negatively affect the perception of these vehicles. These variables are charging time and limited range. This means that when deciding on the best vehicle to buy between hybrid and electric vehicles, battery life is a major consideration that forms one of the basic differences between them. Calignano et al. (2020), in the assessment of fuel management in hybrid and electric vehicles, say that the car's efficiency is based on the combustion power and the number of costs used to generate the power. As for hybrid cars, energy generation is through gasoline kcombustion and an electric motor that charges the battery, but in electric vehicles, power and energy are from the battery, which releases electric energy to power the motors for the car to move. Tran et al. (2020) argues that while climate change has been one of the driving forces in the invention of electric vehicles, various other aspects, like maintenance of the vehicles, play a part in making the right decision abitur the right vehicle to purchase.

Adam (2022), on which is the best car between hybrid and electric, says that range, fuel efficiency and maintenance are some of the elements one must consider. He says that every technological advancement is after how people can save money; thus, the cost of maintaining both types of vehicles is important to consider. These two vehicles use different power systems, with the hybrid having a diesel or petrol engine. In contrast, the electric has a battery for supplying power to the motors. Csere (2021), on the best vehicle to buy between hybrid and electric, says that battery taxonomy is a key factor to consider as it determines the energy produced. Whereas that are greater differences in the types of battery used in the two vehicles, it is important to understand the battery formation and durability in the vehicle. This is because it will determine how long it will last after charging and its life durability.

Type of Motors

The history of electric vehicles started in 1850 with its first boom in 1900 in the U.S.A after development of DC motors. The fuel crisis combined with environmental concerns and global warming in 1973 led to the second boom era (Mohammed, 2020). The second boom was global in nature with companies from Japan, U.S, Germany and China joining the production of electric cars. The historical development of electric vehicles can be seen from the table 1 below.

Table 1: *History of electric vehicles*

Name	Year and country	Type of traction	Notes
Thomas Davenport	1834, USA	DC motor	
Robert Anderson	1832–1839, Scotland	First prototype electric-powered carriage	
Andreas Flocken	1888, Germany	The first four-wheeled electric car	
Pope Manufacturing Co.	1897, USA	The first commercial electric vehicle	
La Jamais Contente	1899, France	The first electric vehicle to travel over 100 km per hour	
	1900, USA	Electricity-powered cars	Capturing 28% of the market
The petrol-powered Ford Model	1908, USA	Electric car Model T	
A Baker Electric	1909, USA	Automobile	
Charles Kettering	1912, USA	The electric starter was invented instead of hand-crank	
Global EV stock	1912, USA		Market, 30,000
Carmaker Tama	1947, Japan	Electric car with a 40 V lead acid battery	
General Motors	1996, USA	EV1 electric car	
Toyota	1997, Japan	The Prius, the world's first commercial hybrid car	
BEV Nissan	2010, Japan	The world's largest electric car sharing service	
Nissan LEAF	2011, Japan	New car models	
PHEV Chevrolet Volt	2012, USA	New car models	

According to Bhatt et al. (2019) the introduction of DC power motors paved way for the development of electric vehicles. Electric vehicles depend on battery system that powers electric motors to produce the required traction. According to Bhatt et al. (2019) found that electric vehicles use various motors depending on manufactures.as show in table 2.

Table 2: *Motors used in electric vehicles*

Company	EV Model	EV Motor
Fiat	Fiat Panda Electra	Series dc motor
Fiat	Fiat Seicento Elettra	Induction motor
Honda	Honda EV Plus	PM BLDC motor
Mazda	Mazda Bongo	Shunt dc motor
Nissan	Nissan Altra	PM BLDC motor
Toyota	Toyota RAV 4	PM BLDC motor
General Motors	GM EVI	Induction motor
Ford	Ford Think City	Induction motor

Chau, K. T., & Li, W. (2014) conducted an overview of electric machines applied in electric and hybrid vehicles. The paper provides a brief introduction and classification of EVs and HEVs and an overview of various machines viable for both vehicles. The paper found that both EVs and HEVs prefer commuter less motors such as induction and permanent magnet synchronous or brushless motors (Mastorakis, 2020). The overview of the type of motors preferred by flagship EVs and HEVs vehicles are shown in table 3 below. Therefore, it is important to understand the criteria for selection of the best motor for a certain electric vehicle. The selection criteria depend on efficiency, power density, reliability and size.

Table 3: *Application of Existing Machines to EV and HEV*

Machine types	Car models
DC	Fiat Panda Elettra, Citroën Berlingo Electrique, Reva G-Wiz DC
SR	Chloride Lucas; Holden ECOmmodore
Induction	GM EV1, BMW Mini E, Tesla Roadster, Reva G-Wiz i; GM Chevy Volt, Imperia GP
PM Syn	Nissan Leaf, Mitsubishi i-MiEV, Citroën C-Zero, Peugeot iOn, BYD e6; Toyota Prius, Ford Fusion Hybrid
PM BLDC	Smart Fortwo ED; Honda Civic Hybrid

For the electric vehicle, it uses an electric traction motor. This motor uses power from the battery pack and converts it to a driving force that makes the wheels of the car move. This traction motor directs 70 % of the power to the wheels; thus, no regenerative power is used from this type of motor.

On the other hand, the hybrid vehicle uses an AC-powered motor (Cao et al., 2021). Like the electric vehicle, this motor is powered by the battery charge to create an electromagnetic field interacting with another magnet to produce the motion. Therefore, in electric vehicles, the driving power is produced by the traction motor using the power from the battery, while in hybrid cars, the driving force is from the combustion engine, which develops the driving motion assisted by the AC motors.

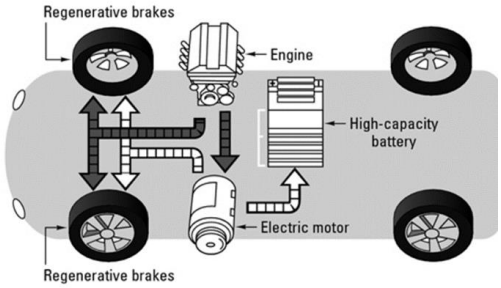

Figure 1:Electric traction motor in electric vehicle

The AC motor used in hybrid vehicles uses a backup to provide extra rapid vehicle acceleration. Therefore, it conserves fuel, especially when the car is idling gar moving at low speeds (All-Electric Vehicles, 2017). This means that with the hybrid vehicle, the motor makes it more efficient in fuel usage. But the motor is generally used in electric vehicles to provide the full driving force. There is no backup and either slow driving; the battery provides the power, and thus, in electric vehicles, the batteries drain much faster because there is no self-charging, and the battery solely provides the power and energy required to drive the vehicle.

III. Comparison and Data Analysis

Similarities

Both EVs and HEVs utilize different types of electric motors according to manufacturers specification. The most preferred for both vehicles are induction motors, PM BLDC and PM Syn. Induction motors and permanent magnet synchronous motors have provided high power and therefore suitable for four-wheel vehicles. Although induction motors do not have high starting torque like DC motors, the use of control techniques allows maximum speed to be achieved at the start. Various control techniques may be used to control flux density B. Induction motors have the advantage of ability to control flux compared to permanent magnet motors. The graph below shows operation area for the induction motor and how various variables can be used to control torque and speed. Permanent magnet BLDC have high torque characteristics when compared to induction or PM synchronous motors at any given point. PM BLDC have highest efficiency followed by PMS and then induction motors as shown in table 4.

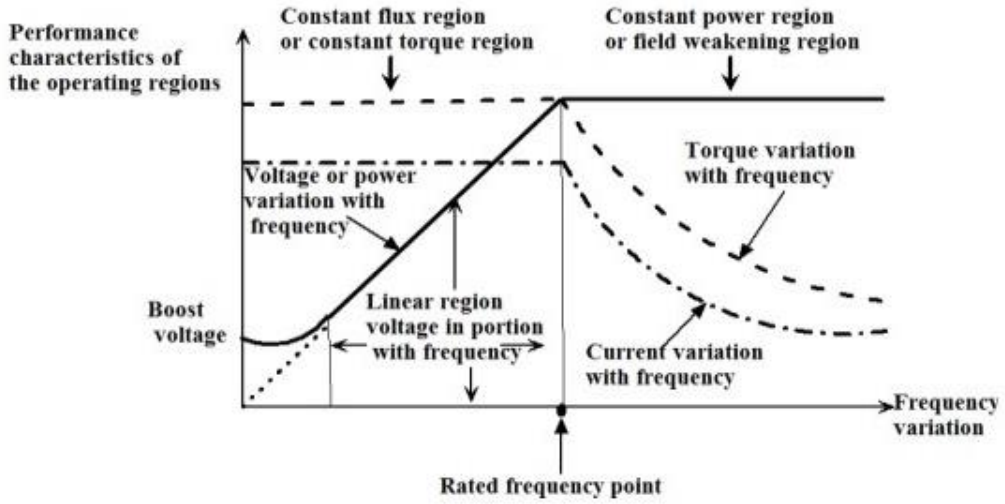

Figure 2: Performance characteristics of the operating regions

Table 4: Performance Evaluation of Existing Machines

	DC	Induction	SR	PM Syn	PM BLDC
Power density	2	3	3.5	4.5	5
Efficiency	2	3	3.5	4.5	5
Controllability	5	4	3	4	4
Reliability	3	5	5	4	4
Maturity	5	5	4	5	4
Cost level	4	5	4	3	3
Noise level	3	5	2	5	5
Maintenance	1	5	5	5	5
Total	25	35	30	35	35

Both vehicles use electric motors to supply power for the locomotion. While the hybrid car uses gasoline combustion for power production and the electric car uses battery power, both vehicles require electric motors to boost the conventional energy produced after gasoline combustion for the hybrid car and boost the battery voltage to produce more energy for the vehicle to move.

Another similarity between the two types of vehicles is both are fitted with batteries. The function of the battery is to store power and release it small by small to the requirement of the vehicle as it moves. These batteries are rechargeable for both vehicles and can be charged outside the car and then fitted back into the vehicle.

Both vehicles require maintenance. Automobiles usually have wear and tear, and when used for some time, it requires some internal check to ensure that it is roadworthy and safe for the passengers. Therefore, maintenance is an activity for hybrid and electric cars as they do the same work but have different ways of doing it (transport). Therefore, whether one owns a hybrid or an electric car, one must incur maintenance costs when servicing the vehicle.

Differences

Battery: Hybrid vehicles have a relatively small battery that is self-charged. When the engine, which can be either diesel or petrol, is running, and the gasoline is being combusted, the energy produced is used to move the vehicle while some I use to charge the battery. This is opposite to the electric car, which has a larger battery than the hybrid car. While the hybrid car uses energy combustion to drive, the electric car largely depends on the power supplied by the battery and thus requires a lot larger battery that can store more energy (Xing et al., 2011). Another difference is that the battery in hybrid vehicles is charged through regenerative braking and the internal combustion engine. This means that the battery in the hybrid cars is self-charging and does not need outside charging ports. This is the opposite of electric vehicles, which do not have internal combustion engines, and therefore, their battery is charged from an external site, normally charging stations. When the power in the battery drains, it must be recharged. Also, to note is that hybrid car batteries provide a longer driving range for vehicles than electric vehicles. This is because the electric vehicle's battery capacity is somewhat limited and is not self-recharged; thus, once it diminishes the power, it has to be charged, which is not the case for hybrid vehicles that charge their own batteries.

Maintenance:

Most of the maintenance required in a vehicle is from the engine. This is because the engine keeps running as much as the vehicle is moving, so there are more chances of wear and tear in the engine. This, therefore, means that for the hybrid vehicle, the maintenance costs are a bit higher than the electric car. An electric car has fewer components, and thus, they only need small checkups and maintenance. The spare parts of the combustion engine are more expensive; thus, when hybrid cars are being serviced, the maintenance costs are high. For electric vehicles, there are not many components that require change, and thus, it requires fewer spare parts. The only component that requires change is the battery, which is common in hybrid vehicles. In an electric vehicle, there are not many moving parts as there is no engine, there is no transmission, and even spark plugs; thus, only a few parts require maintenance as compared to a hybrid, and thus, in the long run, the maintenance cost for hybrid cars is much higher.

Efficiency:

Electric motors are considered to be more efficient in many aspects as compared that in hybrid vehicles. One point of efficiency is its motor efficiency. An electric vehicle converts all the electricity stored in the battery into movement. Electric vehicles convert 77% of the electrical energy to the wheels. Still, for hybrid vehicles using gasoline, the energy generated from internal combustion is not used on the wheels, and only 12-30 of the energy generated is geared to the wheels (Bejgam et al., 2021). This means that in terms of power consumption and usage, electric vehicles are more efficient.

In environmental conservation, electric vehicles are more efficient than hybrid ones. This is because electric vehicles do not have any combustion engines; thus, they only emit electromagnetic emissions that are not harmful to the environment. Unlike electric vehicles, hybrid vehicles have internal combustion engines, either petrol or diesel, which release carbon dioxide into the environment. This makes it less efficient in environmental conservation because they contribute to climate change, thus leading to the global challenge of global warming.
The hybrid vehicles are, however, time efficient. This is because hybrid vehicles spend the minimum amount of time in gas stations; thus, they are used most of the time in moving. But for electric vehicles, they are less time efficient, more so in charging stations. This is because a full recharge at the charge stations can take 3-12 hours.

Analysis

From the data obtained from the discussion and the insights from the literature review, it is fair to say that despite the two types of vehicles, hybrid and electric, offering transport services, there exist great differences in their motors that may change the perception about the type of vehicle to have. As has been indicated, critical factors need greater consideration when deciding on the best car type. From the four factors discussed, namely efficiency, battery, maintenance and the type of motors, one can clearly deduce which of the two vehicles is better. On the battery and battery life, hybrid vehicles have the best battery despite being relatively small, and they stay

longer before they drain their power compared to that of electric vehicle. This is because the battery in hybrid vehicles self-charges when the engine is running, but electric vehicles have to be charged from a charging point which takes a relatively long time of 3 hours to 12 hours.

Electric motors are less costly for maintenance as they have relatively fewer moving components, and thus their maintenance is less. This is opposite to the hybrid vehicles, which have many active parts like the engine, the transmission system, lubrication and cooling. Therefore, it requires more maintenance practices and is thus costly to maintain. Electric vehicle data has also indicated that it is more efficient in many aspects than the hybrid. One is that they are efficient in environmental conservation because, unlike hybrid vehicles, it does not emit air pollutants gas. They only emit electromagnetic emissions that are not harmful to the environment, as opposed to a hybrid that releases carbon dioxide gas, which threatens climate change. Electric vehicles are also efficient in power usage in that all the power produced from the battery, 70% of it is directed to the wheels for moving, which is not the case for the hybrid, which only uses 12-30% of the power produced for the wheels.

Finally, on the type of motors used in the two types of vehicles, electric vehicles use electric traction motors that are powered by the battery to produce the driving force for the wheels as opposed to the hybrid that uses AC motors, which are used as back up to the engine for providing power for the wheels. Therefore, hybrid cars are better than electric vehicles because they can use AC motors to provide energy when idling and driving slowly. Still, for electric vehicles, there is no backup energy, and thus, there is no energy efficiency because it uses its battery charge in every activity. The results show that as far as the four factors are concerned, it is worth having an electric car over a hybrid car as it has more positives compared to the hybrid in the four areas, namely efficiency, battery life, maintenance and the types of motors. Despite hybrid cars being better in the types of motors and the battery life, electric cars are much better than hybrid cars.

IV. Conclusion

Technology in automotive engineering is growing daily, and the emergence of electric vehicles has attracted many people to switch away from hybrid vehicles. While it is still important to note the benefits of hybrid vehicles over electric vehicles, this paper has shown that, in many aspects, electric vehicles are so much better than hybrid vehicles. Thus, it is economical to own an electric vehicle instead of a hybrid one. One of the most important things when owning a vehicle is to be able to maintain it in good condition. Suppose the maintenance of the vehicle is high. In that case, it becomes a burden to the car owner. Therefore, people are opting to have an electric car as it has fewer maintenance costs than a hybrid which requires deep maintenance regularly because of the many moving parts that may lead to wear and tear. Electric vehicles are also efficient in energy and the environment, making them safer and aligned with the climate change goal in developed countries. Therefore, this means that it is safer and cheaper to own an electric vehicle than a hybrid one.

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