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Comparative Study of using Different Electric Motors for EV

Ansh Thattil[1], Sumit Vachhani[2], Darshan Raval[3], Piyush Patel[4], Priyanka Sharma[5]

[1,2,3,4]U.G. Students, Automobile Engineering
[5]Associate Professor, Automobile Engineering Department, Indus University, Ahmedabad.

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Abstract - *The future of the automotive sector is going to be Electric Vehicles. Higher efficiency, low maintenance and emitting almost zero amount of pollution, makes electric vehicles more preferable to IC powered vehicle. Rapid advancement in technology is helping vehicle manufacturers to overcome the drawbacks of IC powered vehicles. The main source of power in an EV is from its electric motor. There are various suitable motors available today for vehicular application. These motors, with the help of graphs and tables, are compared to identify the ideal motor.*

Keywords: Electric vehicle, DC brushed motor, BLDC motor, Induction motor, Synchronous motor, Switched reluctance motor.

1. Introduction

The electric vehicle consists of three core components which are batteries, electric motor and motor controller. The electric motor is the primary source of energy for the propulsion of an electric vehicle. The electric energy from the battery is converted into mechanical energy through the electric motor. This mechanical energy is transferred to the appropriate transmission system which drives the wheels and in turn moving the vehicle in the given direction. Electric vehicles use different types of electric motors depending upon the use of the vehicle. Selection of a particular motor for an electric vehicle must be done judiciously as motor characteristics affect the overall performance of a vehicle [1].

2. Comparative Study

The various types of electric motor all demonstrate different characteristics. Therefore, it is necessary to conduct a thorough analysis of which motor to be used in a particular vehicle. Simple design, high specific power, low maintenance cost and good control, are the different attributes that the electric motor should have for use in electric vehicles. Motors that are widely used by electric vehicle manufacturers are DC brushed motors, DC brushless motors, AC Induction motor, Switched Reluctance motor.

2.1 DC Brushed motor

In a brushed DC motor, the brushes and the commutators help to transfer the electric energy from the armature of the motor to the external supply circuit. Brushes can be made up of carbon, copper, carbon graphite, metal graphite and are mostly rectangular in shape [2]. DC brushed motors have the ability to achieve high torque at low speeds, which makes them suitable for traction system [3]. The continuous cutting with brushes causes the commutators to wear out faster over time. Also another drawback of this motor is that the friction between the brushes and the commutators limit the maximum motor speed. DC brushed motors are preferred for use in vehicles with low power. As shown in Figure 1, DC series wound motor has high starting torque. Also, speed decreases with increase in torque.

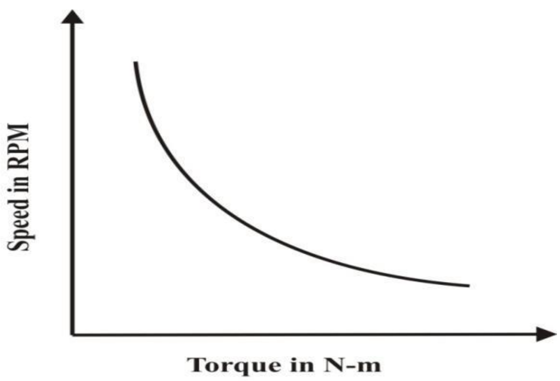


Figure -1: Torque versus speed characteristics of DC Series Wound Motor

2.2 DC Brushless motor

DC Brushless motor or commonly known as BLDC motor have electronic commutation as compared to the mechanical commutation in a DC brushed motor [4]. BLDC motors have higher efficiency and lower maintenance when compared to a brushed DC motor. BLDC motor is defined as rotating self-synchronous machine with a permanent magnet rotor and known rotor shaft positions for electronic commutation [5]. The advantage of this motor as compared to the other motors is that this motor provides higher torque at the peak values of current and voltage. These motors are generally used in compressors, pumps and ventilation systems. DC shunt motors have medium staring torque, but speed decreases slightly with increase in torque as shown in Figure 2. Therefore, DC shunt wound motors are used in constant speed application.

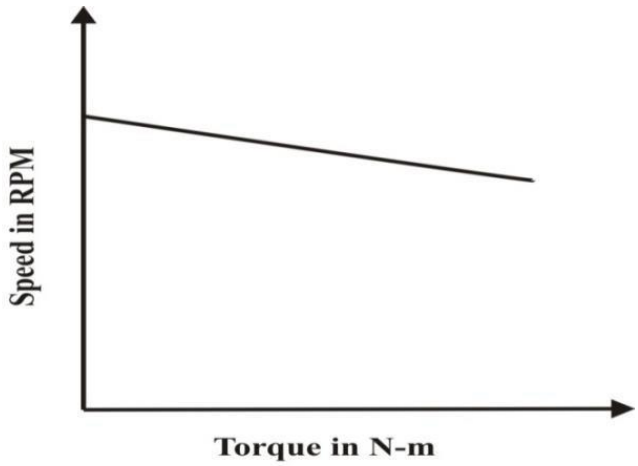
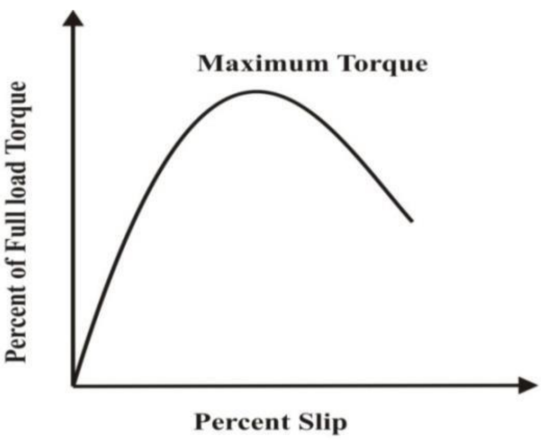


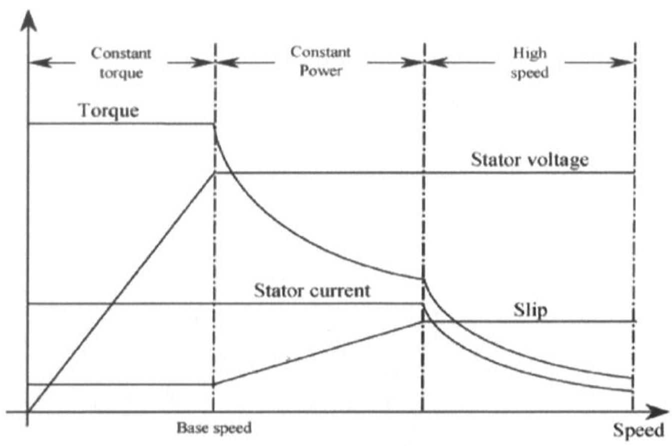
Figure -2: Torque versus speed characteristics of DC Shunt Wound Motor

2.3 AC Induction motor

Three phase AC induction motors are widely used in electric vehicles because of high efficiency, good speed regulation and absence of commutators. New technology like regenerative braking systems require motors like AC induction motors which help to recover the energy lost during braking. Three phase AC supply is connected to stator winding, due to which revolving magnetic field is established. This revolving magnetic field interacts with stationary rotor conductors, and induced current flows through rotor conductors. Induced current establishes its own magnetic field. Interaction between revolving magnetic field and field due to induced currents gives rise to unidirectional torque [3]. Torque-speed characteristic for medium value of rotor resistance is as shown in Figure 3 (a).



(a)



(b)

Figure -3: (a) Torque slip characteristics of three phase Induction Motor (b) Different characteristics of induction motor

2.4 Switched Reluctance motor

Switched reluctance motor produces torque by variable reluctance method. When stator coils are energized, variable reluctance is set up in the air gap between the stator and the rotor. Rotor tends to move to a position of least reluctance thus causing torque [6]. The advantages of these motors is that they have simple and rigid construction, high fault tolerance and excellent torque-speed characteristics. It can operate under a wide constant power region. This type of motor is not seen commonly in electric vehicles as they have high noise, high torque ripple need special convertor topology and have an electromagnetic interference. Torque-speed characteristic of Switched Reluctance Motor is as shown in Figure 4.

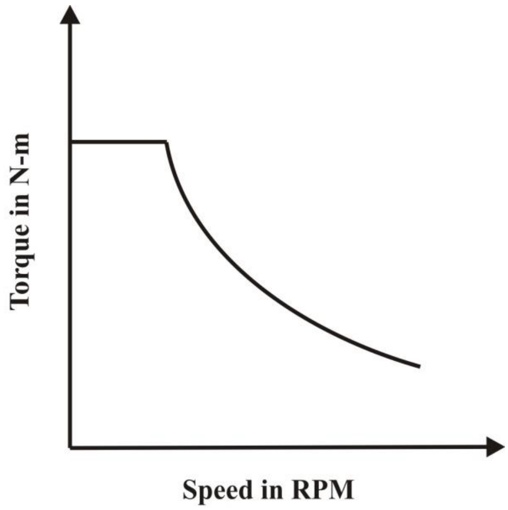


Figure-4: Torque versus speed characteristics of Switched Reluctance Motor

3. Comparison of The Efficiency Of Motors

Electrical efficiency of an electric motor gives us relation between electrical input and useful mechanical output of motor and is generally given by ratio of shaft power output and motor input power [7]. All electric motors are designed to operate at maximum efficiency at rated output of a motor. When an electric motor is used in electric vehicle, motor will be operated at different loads. Therefore, peak efficiency and efficiency at different loads of a motor must be considered before choosing it for an electric vehicle application. Efficiencies of different electric motors at peak load and at 10% load are tabulated below [8].

Table-1: Efficiency Comparison of Different Electric Motors

Motor Type	Peak Efficiency (Percent)	Efficiency at 10% load (Percent)
DC Brushed Motor	85-90	80-85
DC Brushless Motor	>95	70-80
AC Induction Motor	>90	>90
Switched Reluctance Motor	<95	>90

The traction systems commonly used in EVs are evaluated based on six factors. As shown in Table 2, a score out of 5 is given for each point to each motor.

Table -2: Evaluation of different traction systems for EV

	DC	IM	SRM	BLDC
Power Density	2.5	3.5	5	3.5
Efficiency	2.5	3.5	5	3.5
Controllability	5	5	4	3
Reliability	3	5	4	5
Technological Maturity	5	5	4	4
Cost	4	5	3	4
Total	22	27	25	23

IV. Conclusion

The induction motors have been known as the best candidate for the EV applications because they are robust, less costly, mature in technology and need less maintenance. In this paper, it is demonstrated that in terms of pollution and fuel consumption, the brushless DC motors have more priorities such as less pollution, less fuel consumption and more power to volume ratio which makes them attractive in the EV applications.

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