ELECTRIC MOTORS 101:
Understanding the Basics of Electric Motor Technology

An Overview

Electric motors are all around us, in the toys children play with (remote controlled cars), the planes we fly in and in the appliances (washing machines, blenders, ceiling fans) in the homes we live in. Without electric motors, we would not have many of the common conveniences we enjoy every day.

Electric motors have been used in various automotive applications for nearly 100 years. In fact, GM has been a pioneer in electric motor development since the world's first self-starting engine debuted in 1912, on a Cadillac.

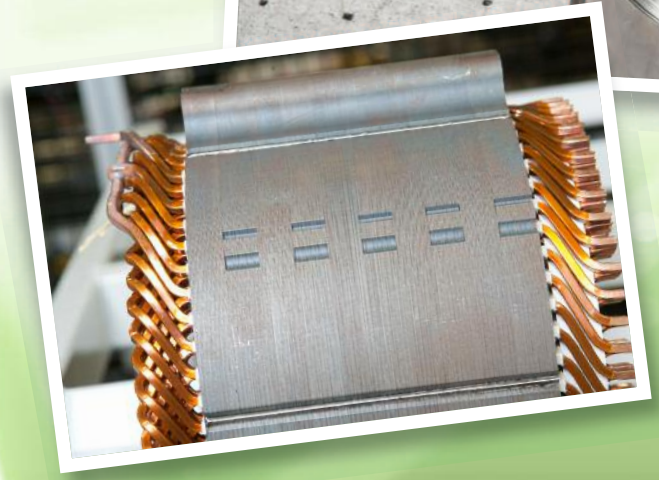
All conventionally-powered cars have several electric motors, such as power windows and seats, windshield wipers, electric power steering, and many small pumps. Some cars can have more than 100 small and medium sized motors.

What are electric motors?

Simply put, electric motors convert electricity into motion when propelling the vehicle and from motion back to electricity when generating power back to the battery. In automotive applications, electric motors are used in hybrid and electric vehicles to move the drive wheels to propel the vehicle down the road, and to capture braking energy which is otherwise lost.

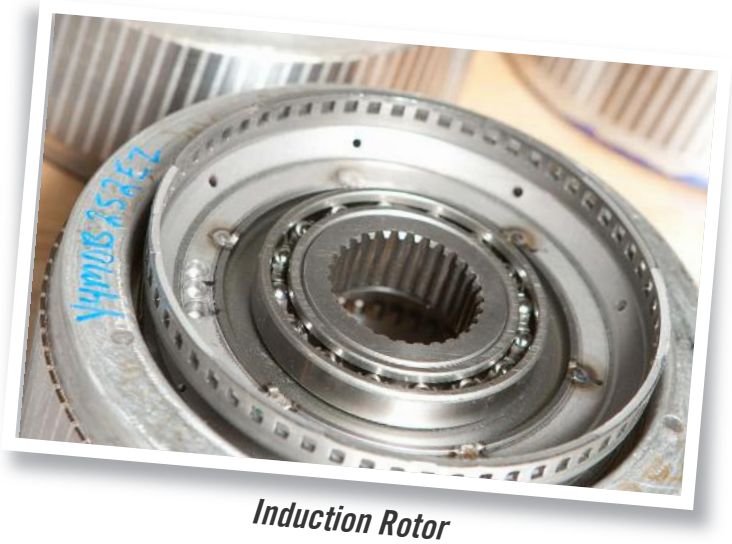
In conventional vehicles, powered by gasoline and internal combustion engines, a transmission transfers the energy generated from the engine to the drive wheels to propel the vehicle. In electric vehicles, electricity is stored in a battery and feeds power to the electric motors to drive the wheels.

Electric motors are the engines of the future for electric and hybrid vehicles. They can be tuned to fit the character of any vehicle, from midsize sedans to high-performance sports cars and full-size SUV's.



Motor Types

There are two basic types of electric motors used in automotive applications: induction and permanent magnet. Induction motors, which don't use magnets, are designed to provide optimum operation at lower power levels and higher speed driving – like some hybrid electric vehicle (HEV) applications. A permanent magnet motor is designed to efficiently handle heavy loads at low and high speeds and operate for long durations. They are perfectly tailored for full battery electric vehicle operation.



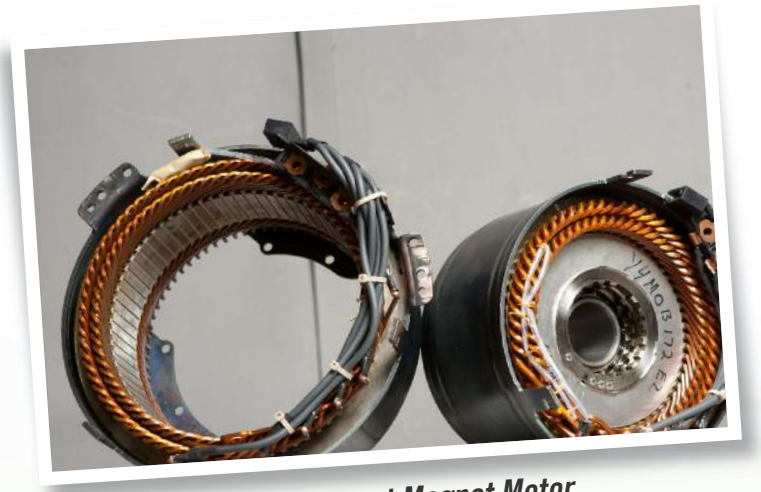
Induction Rotor

Electric Motor Components

There are essentially two parts to an electric motor: a rotor and a stator.

Rotor

The rotor is the part of the motor that rotates to transmit torque through a gear set to the drive wheels. Rotors move using magnets in permanent magnet motors and aluminum bars in induction motors. The torque is created by the magnetic forces that pull or push the outside of the rotor at varying speeds.



Permanent Magnet Motor

Induction Motor

Permanent Magnet Motor

Stator

The stator is the still part of the motor that contains the conductor constructed from copper wires. The conductor can be arranged in either stranded wire or bar wound configurations.

Stranded wire, used in some of GM's induction motors, is composed of a bundle of round wires to make a large conductor. Stranded wire is more flexible than solid wire, making it more pliable and easy to work with.

Bar wound wire, used in GM's permanent magnet motors, is a solid piece of wire bent into a defined shape. The bar wound configuration places these wires in a uniform arrangement, aligned side-by-side separated by insulation. Bar wound wires help motors to handle higher energy loads for longer periods of time. The square wire designs used by GM are more efficient and stay cooler during heavy operation. Improved conductivity means a vehicle can go further on a single battery charge.

Stator

Motor Comparison

	PERMANENT MAGNET	INDUCTION
Optimal Speed	Low and high speeds	High speeds
Optimal Loads	Heavy loads	Low loads
Vehicle Power Source	Primary	Secondary
Applications	Voltec, EV, full hybrids	eAssist

2012 Chevrolet Volt

Chevrolet Spark EV

Electric Motors Operation

Opposites attract. Electric motors operate on magnetic forces. Even though the stator is still, a controlled electric current is injected into the copper bar windings in the stator, creating a moving electromagnetic field. This pulls on an opposing magnetic field in the rotor, which creates a twisting force, or torque.

In a permanent magnet motor configuration, a magnetic field is created by an array of magnets embedded in the steel of the rotor. In an induction motor configuration, the controlled electric current is still injected into the copper windings in the stator, but the aluminum bars in the rotor naturally create a magnetic field, which is opposite the magnetic field in the stator, which creates a twisting force, or torque.

The turning motion of the rotors provides the power to move the car down the road. The animation below provides a detailed visual as to how these motors work.

Safety

Electric motors are very safe and reliable and have to pass strict performance guidelines, just like conventional technology, before they are used in any vehicle application.

Durability

Given the extreme conditions that vehicles must operate in every day, guaranteeing the integrity of the electric motor is critical.

GM motors undergo the following tests to ensure durability and reliability:

- Under-voltage operation
- Over-voltage operation
- All-weather testing
- All-terrain testing

GM motors are designed and built to withstand a long lifetime of rigorous use. All motors undergo testing to demonstrate "three lifetimes" of usage before wearing out. A lifetime is defined as 200,000 miles of use by the most demanding drivers.

Recyclability

The materials used in the manufacturing of electric motors—copper and steel—can be easily recycled. Approximately 1.5 kg/3.3 lb. of copper can be recovered from e-Assist motors and 14 kg/30.8 lb. can be recovered from motors used in the Chevrolet Volt, for example.

Also, the materials also used to make the magnets used in permanent magnet motors—neodymium and dysprosium—are 95% recoverable

Fast Facts

- Amount of copper used in each motor depends on motor size, but various from 1.5 to about 9 kg (3.3 to 19.8 lbs.).
- The number of magnets in a permanent magnet motor depends on the size of the motor and particular design. There can be more than 100 magnets, the size of a matchbook.
- GM is developing motors in-house, with most of its engineering in its Pontiac facility, and a prototype facility in Wixom.
- Beginning in 2013, GM will be the first major automaker to own and operate its own motors facility in the U.S., in White Marsh, MD.

ELECTRIC MOTORS 101

CLICK ON PLAY BUTTON ABOVE TO VIEW ELECTRIC MOTORS ANIMATION.