Understanding Electric Motor Efficiency Losses

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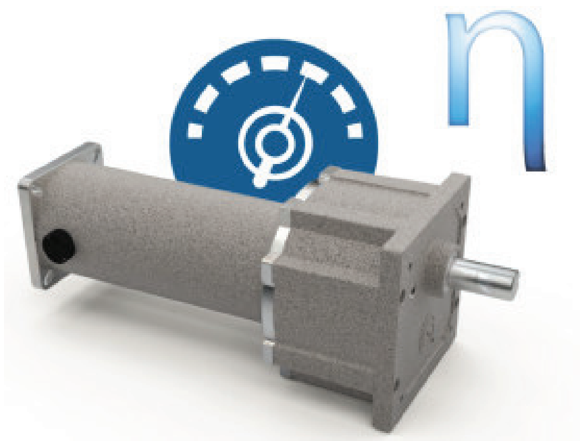
Advertised efficiency of motors is a big deal in the market. Motor efficiency is a ratio of how well the motor converts electrical energy into mechanical energy and is calculated by dividing the power into the motor by the power out of the motor. Understanding motor efficiency losses matters because less efficient units leads to higher operating costs over the life of the motor.



So what happens to the energy that is not converted to mechanical energy? The Law of Conservation of Energy says that energy can neither be created nor destroyed, but can change form. The difference of the input power to the output power, often referred to as watt loss, is actually converted to heat. Several conclusions can be made from this. A more efficient motor will cost less to operate. It could run cooler or could convert more power per volume than a similar sized motor.

WHAT ARE COMMON SOURCES OF ELECTRIC MOTOR EFFICIENCY LOSSES?

FRICTION LOSSES

These losses are attributed to the force it takes to overcome the drag associated with rotating the motor's rotor or armature. Examples of friction losses are friction of bearings, bushings or brushes in a universal or brushed type DC motor. In general, the frictional losses are proportional to the rotor speed.

WINDAGE LOSSES

In an air cooled motor, these losses are caused by turbulence in the air acting against the rotation of the rotor. Examples of these are armature slots or geometries that are not cylindrical or fans. Windage losses are estimated as being proportional to the cube of the rotor speed.

IRON LOSSES

Also called core losses, these are associated losses in the magnetic paths of the motor. They are usually characterized as watt loss per mass. Different steels have different characteristics that impact these losses. In order to understand iron losses better, we can further divide them into hysteresis losses and eddy current losses.

- **Hysteresis losses** are due to the changing polarity of the flux in the steel core. Hysteresis losses are effected by both the ability of the material to change polarity easily and by the total flux density in the steel.

- **Eddy current losses** are circulating currents induced in the steel core by the changing polarity of the flux. Eddy current losses are effected by the total flux density, the frequency at which the polarity of the flux changes and area available for eddy currents to flow. Motor designs use laminated cores of steel to reduce the area available for the eddy currents to flow because the electrons are unable to jump from lamination to lamination.

OHMIC LOSSES

Ohmic losses or I^2R losses are due to current flowing through the conductors of the motor. These losses are equal to the square of the current multiplied by the resistance of the path through which the current flows.

STRAY LOSSES

Stray losses are generally categorized as losses that don't correlate to the losses explained above. This is sometimes used as a safety factor in design calculations.

Regardless of motor type, the described losses cannot be completely designed out. The design engineer needs to look at several possible designs in order to optimize the motor for the most efficient operation. Trade-offs like minimizing ohmic losses could cause increased iron losses. Increased efficiency usually comes at a cost, whether it be from more expensive materials or difficult manufacturing processes. It is not important for all engineers, who specify motors, to understand the math behind the losses, but it is good to know that they exist.

View part one of our Energy Efficient Motors blog for more about energy-saving capabilities.