Pump ED 101

AC Motor Efficiency

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AC Motor Efficiency and How It is Achieved

In 2011 I did a five part series on AC motors and briefly discussed motor efficiency. This article will go into more detail.

Efficiency defines how well a motor converts electrical energy into mechanical energy. If a motor was 100% efficient, it would take only 746 watts to produce 1 horsepower. If its efficiency was reduced to 50% it would take 1492 watts to produce that same output. Unfortunately physics does not allow any machine to be 100% efficient but larger motors can hit 96%. Even 1 horsepower motors can exceed 80%.

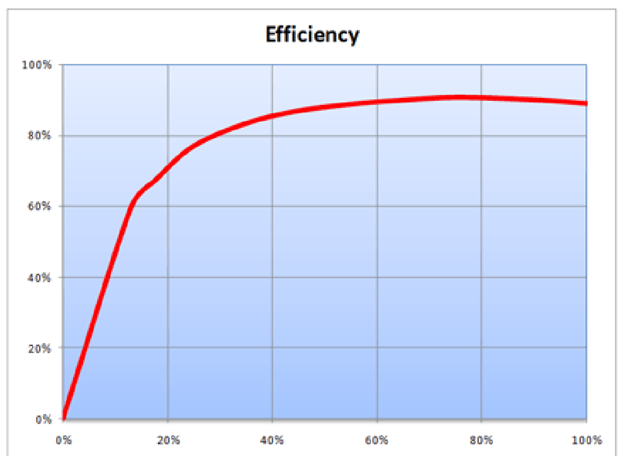
So, where do those excess watts go? The largest single loss (30%) is the stator resistance loss (Stator I^2R). If the stator wire size for a given motor horsepower is increased, resistance losses are reduced. The second largest loss (20%) is rotor resistance loss (Rotor I^2R). Larger rotor bars will lower resistance and thus reduce these losses. One of the reasons that premium efficient motors are more expensive than lower efficiency models is the increase in copper in the stator and new rotor designs that allow larger rotor bars. The third largest (19%) are core losses. Core losses are composed of hysteresis and eddy currents and these are a result of the continuously changing magnetic field in the steel laminations of the stator and rotor. Hysteresis losses can be reduced by using higher quality steel while eddy current losses are lowered by using thinner and better insulated laminations. Lengthening the lamination stack will also reduce core losses by reducing the flux density within the stack. These improvements also add to the cost of premium efficiency motors. The fourth largest (18%) is called stray load losses and they are dependent upon motor loading. These losses usually increase with the motor load and can be reduced through proper motor design. Coming in last (13%) are friction and windage losses. Friction is due to friction in the ball or roller bearings and there is very little that can be done to increase bearing efficiency. Windage is a combination of the drag produced by the spinning rotor and the internal or external cooling fan. Fans are sized to meet a motor's cooling requirements at the lowest possible energy requirement.

Nameplate versus Actual Efficiency

A motor's full load efficiency can be higher or lower than its nameplate efficiency. The efficiency shown on the nameplate is the "nominal" efficiency. Nominal efficiency is defined as the average efficiency of a large population of motors of the same design. So the nameplate on a 50 horsepower, 1800 rpm motor will show the average efficiency for some number of motors that were tested. Any single motor may have an actual efficiency that is higher or lower than the one shown on its nameplate. There is, however, a minimum efficiency that must be met by any motor in the group. The nameplate for a 50 horsepower, 1800 rpm motor will show a nominal efficiency of 94.5%. It could be higher but its guaranteed minimum efficiency is 93.6%. Sometimes this can be an issue if the engineering specifications require that a motor be tested at the factory and it comes in under its nameplate rating.

Full Load versus Partial Load Efficiency

Many think that a motor will reach its maximum efficiency when running at full load. Actually, almost all NEMA motors will reach their maximum efficiency between 65% and 80% of full load. This maximum efficiency is often a full percentage point greater than full load efficiency. Sizing a motor to run at about 80% of full load will decrease operating temperature and increase insulation life without decreasing efficiency. It also will allow for higher than normal ambient temperatures, voltage drops and a small percentage of phase unbalance.



The Effect of EPACT and EISA

The Energy Policy Act (EPACT) that came out in 1992 set a minimum efficiency (EPACT Efficiency) for T-frame motors from 1 to 200 horsepower operating at 1200 rpm to 3600 rpm. These efficiencies were detailed in NEMA MG1, Table 12-11. This law did not apply to lower speed motors, those above 250 horsepower and several "General Purpose" designs. Also the mandate was not enforceable until October of 1997. Premium (higher) efficiency motors were also available from some manufacturers but they were not required.

In 2010 EPAC was replaced by the Energy Independence and Security Act (EISA). This law stated that all T-Frame motors from 1 to 200 horsepower operating from 1200 rpm to 3600 rpm must meet the premium efficiencies detailed in NEMA MG1, Table 12-12. General Purpose motors up to 500 horsepower and 900 rpm motors that were exempted from EPACT are now required to meet the EPACT efficiencies outlined in NEMA MG1, Table 12-11. Many T-Frame motors 200 horsepower and larger, already meet the efficiencies shown in Table 12-12. Prior to EPACT the typical efficiency of a 10 horsepower, 1200 rpm motor was about 87.5%. EPACT raised it to 90.2% and EISA increased it to 91.7%.

Higher motor efficiency is a good thing because the cost of electricity will continue to increase. However, higher efficiency motors have very little impact when we use them to operate pumps at off BEP flows. Don't forget that the total efficiency of a pump and motor is the product of their individual efficiencies. Always run that centrifugal pump as close to BEP as possible.

Higher Efficiency versus Motor Speed

They synchronous speed of a four pole motor is 1800 rpm. This the speed at which the magnetic field rotates about the stator. The actual rotational speed of the rotor (slip speed) will always be somewhat less. The actual slip speed will depend upon the design. Due to the design characteristics of premium efficiency motors, their slip speed will be higher than most motors produced prior to EISA. Usually, this is not a problem but there can be applications where it should be considered. For example if a pump is tested in the factory at 1725 rpm and it runs at 1760 rpm the speed increase is just 2%. But, since HP varies as the cube of a change in speed it could increase by 6%. Slip speed is also sensitive to the terminal voltage. It increases with an increase in voltage and decreases with a drop in voltage.

As a final note, three phase voltage unbalance offers a double whammy. It reduces both insulation life and motor efficiency. An unbalance of just 2% can reduce useful life by 50% and efficiency by 2%. It is important to test for voltage unbalance, find the cause and fix it. If not, you probably will not be able to benefit from that improved, nameplate efficiency.

Joe Evans is responsible for customer and employee education at PumpTech Inc, a pump & packaged systems manufacturer & distributor with branches throughout the Pacific Northwest. He can be reached via his website www.PumpEd101.com. If there are topics that you would like to see discussed in future columns, drop him an email.