Pump ED 101

AC Motor Torque

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As a follow up on my series on AC Motors, I thought it would be a good idea to provide a short overview of work, power and torque as it applies to the AC motor. I will provide you with a reference to a more in depth study at the end of this article.

The AC motor is a machine designed to transform electrical energy into mechanical energy so that work can be performed. Work (w), in a translational (linear) system, is defined as the force (f) applied to some object multiplied by the distance (d) it travels. In the English system force is measured in pounds and distance is measured in feet. The equation for work, $w = fd$, is quite straight forward (no pun intended).

If you were to lift 100 pounds to a height of 10 feet, you would perform 1000 lb-ft of work. You would perform the same amount of work if you lifted a 200 pound object to a height of 5 feet or, for that matter, a 50 pounder to 20 feet.

Work is a somewhat unfortunate term because in order for work to be performed, we must actually move an object in a direction that is opposite of the force acting upon it. For example, if you lift a suitcase off the floor you have performed work because the force you applied overcame the force of gravity that was holding it to the floor. Carrying it across the room, however, is not work for it is not moving in a direction that opposes the force acting upon it. Try telling that to someone with a thirty pound suitcase in each hand. He or she will expend energy but they perform no work.

The equation for work tells us how much work is done but it says nothing about how quickly it gets done. If you carry a 50 pound object up a flight of stairs 10 feet high you will perform 500 lb-ft of work. It makes no difference if you do it in five seconds or five days, the same amount of work is performed. The rate at which work is done is power. Power (p) is equal to work (w) divided by the time (t) it takes to perform it. The equation, $p = w/t$, is also very straight forward.

In the late eighteenth century, James Watt made some major improvements to the steam engine -- improvements that made it a viable alternative to other sources of power. One of the power hungry applications in Scotland at the time was that of pumping water from coal mines. The pumps were powered by horses and Watt needed a way to relate the power of his engine to that of a team of horses. Through experimentation he reportedly determined that the average horse could lift 150 pounds to a height of 220 feet in one minute. The work performed then, is 33000 lb-ft (w = fd). Power or, in this case, horsepower (HP) is 33000 lb-ft/min. This rather cumbersome number is equal to 745.7 joules/sec in the mks system. One joule/sec was called a watt in his honor. Therefore one HP is equal to approximately 746 watts. In the United States we rate a motor's power in horsepower. In most other countries, it is the kilowatt (KW).

Torque is defined as the force that gives rise to rotational motion. It is also the result of rotational motion. Torque (t) is equal to force (f) times the radius (r) through which it acts and the angle (Ø) at which the force is applied. The equation used to calculate torque is t= f (r sin Ø). Torque in a rotational system is analogous to force in a translational system. The straight line distance of the translational system; however, is replaced with an angular quantity.

For any given HP, torque varies inversely with rotational speed. For example a 100 HP motor operating at 3600 RPM produces a torque of approximately 150 lb-ft. At 1800 RPM torque would be about 300 lb-ft and at 1200 RPM about 450 lb-ft. This is exactly what one would expect since HP (power) is the rate at which work is done. If an 1800 RPM motor is to accomplish the same amount of work in the same amount of time as one rotating at 3600 RPM, it must do twice the work per rotation. It is for this reason that the shaft diameter of a 900 RPM motor is larger than that of the 3600 RPM model even though they produce the same horsepower. Lower RPM motors utilize larger diameter shafts to accommodate the higher torque required to do the same amount of work in fewer rotations.

Earlier we defined horsepower as w/t and expressed it in lb-ft or watts. It can also be defined in terms of torque (t) and speed (RPM).

HP = (t x RPM) / 5250

We can also express torque in terms other than force and the radius through which it travels. Rearranging the previous equation we get:

t = (HP x 5250) / RPM

These two equations are probably more useful in daily work than are the previous ones. For a more detailed review of work, torque and power see my October 2007 Pumps & Systems article "Confusing Units of Measure".

Joe Evans is responsible for customer and employee education at PumpTech Inc, a pumps & 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.