Matching a Motor to an Air-Moving Application

One of the crucial steps when developing an air-moving application such as an air-conditioner fan is matching a motor to the application's load. This is a lengthy process that requires expertise and involves several trial and error cycles. The matching process has to address such issues as ensuring a stable working point, adequate flow, and an acceptable vibrations level; increasing the conflict between time to market; and meeting quality demands.

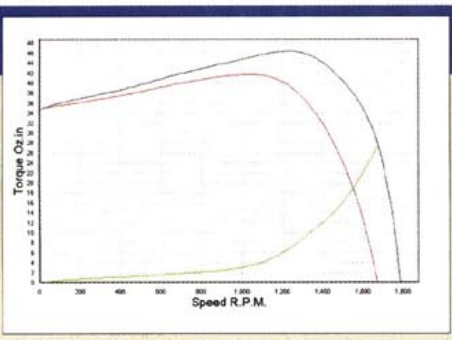

Figure 1. Load Extraction: The load's torque-speed curve (in green) is the difference between the motor's torque-speed curve (in blue) and the motor + load torque speed curve (in red).

The Traditional Process

The process of matching a motor to an air-conditioner's load generally begins when the air-conditioner engineer sends approximated motor specifications together with an air-conditioner prototype to the motor manufacturer. The motor manufacturer proceeds to build a motor that has the required physical dimensions, starting torque, and full load torque. The motor is then sent to the air-conditioner engineer for testing. Following the test results, new requirements are formulated and a second motor prototype is prepared. This process may be repeated several times before the air-conditioner performs adequately. Usually, by the time the motor is complete, the air-conditioner prototype has evolved, and the whole cycle has to be repeated.

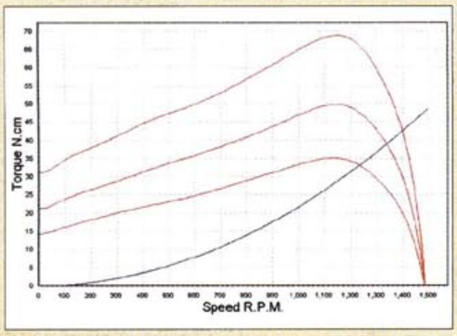

Figure 2. Properly Matched Motor and Load: The three working points—the intersections of the motor curves (in red) and the load curve (in blue) are stable.

Improving the Traditional Process

Obviously, simplifying the process would be most beneficial for both the appliance and motor engineers. The design and test reiteration has to be reduced, and the transfer of hardware across geographic and bureaucratic borders has to be minimized. The optimal motor development cycle should include only one design iteration and minimum hardware component shipments. This could be achieved if a detailed description of motor and load mechanical behavior was available for exchange between the engineers, rather than hardware. Streamlining the motor development phase will obviously have a positive effect on time to market.

A new motor testing system from M.E.A. Testing Systems Ltd. facilitates testing procedures and provides specific motor related design tools, which, in turn, enables the replacement of hardware exchange with data exchange. Using this system, the torque-speed curve of the air conditioner's load can be calculated as the difference between the motor torque-speed curve and the motor + load torque-speed curve. This data, together with the desired working speeds, can be sent to the motor manufacturer instead of to the designer of the air-conditioner prototype.

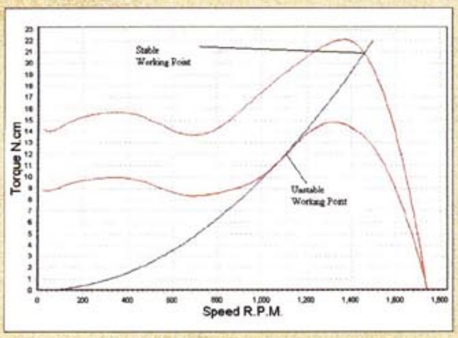

Figure 3. Unstable Working Point: The angle between the low-speed curve and the load curve at the intersection is too small.

The motor can now be developed and tested separately from the air-conditioner for which it is designed. If the air-conditioner is altered, the air-conditioner engineers can email a new torque-speed curve to the motor manufacturer, who in turn, can respond without waiting for the arrival of a physical model. If the torque-speed specifications of the motor and load are correct, the performance of the air-conditioner with the motor installed will match the planned objectives, and the development of an additional motor prototype will not be required. Figure 2 shows an example of a 3-speed motor properly matched to a load.

Clearly, sending documents describing torque-speed curves is much more efficient than sending hardware. This practice however, is not widely spread, since torque measurements are not easy to perform and load torque-speed curves are not easily calculated. This situation highlights the need for a testing system, which integrates motor testing with computer-aided engineering tools such as load curve and working point calculations.

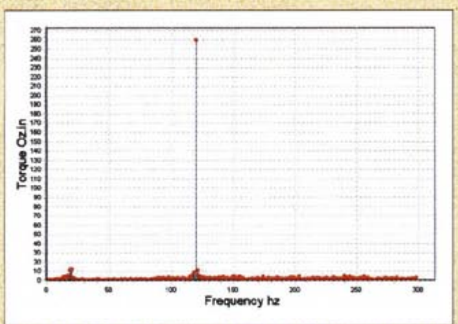

Figure 4. Torque Spectrum: The spectrum shows the hum noise at 120 Hz and the mechanical spectral component at 20 Hz.

Unsuccessful Matching

If the motor is not properly matched to its load, one problem that may occur is unstable operation at low speed. Consider for instance the graph in Figure 3, in which the low speed working point—the intersection of the motor low speed (lower red curve) and the load (blue curve)—is not well defined. Small variations in motor performance, due to either voltage change or friction increase, will dramatically change the speed of this motor + load couple. The same effect can also be created by changes in the air filter resistance.

Vibration and Magnetic Hum

This system also helps in measuring motor hum-noise (also known as magnetic hum), the alternating torque created by every a.c. motor at twice the line frequency. These torque variations are converted to acoustic noise by the application structure. It is especially desirable to use motors with low hum-noise in instruments designed for operating quietly. In addition to creating irritation, hum-noise may shorten some mechanical parts' lifetime. Therefore, it is recommended that appliance producers specify a hum-noise limit as part of the motor requirements.

Hum-noise specifications can be given in terms of torque variation amplitude at a certain working point. The amplitude can be measured by a spectral analysis of the varying torque. For this purpose, a device capable of producing a time-series of the torque variations sampled at adequate resolution is required. Consider, for instance, Figure 4, which shows a torque spectrum obtained by M.E.A.'s MotorLab.

As shown in Figure 4, the spectrum was calculated from a torque recording of an asynchronous motor operating at a 60-Hz line frequency. It clearly shows the hum-noise at a prominent peak at 120 Hz. The spectrum provides a quantitative measurement of hum-associated torque variations.

The spectrum also shows a smaller peak at around 20 Hz, which corresponds to vibrations at the motor rotation frequency. This diagnostic instrument can also detect other phenomena such as torque variations at the slip frequency (the difference between the magnetic field rotation frequency and the mechanical rotation frequency), which appears when the rotor is asymmetrical, and high frequency torque variations known as whistling.

Another method for assessing how smoothly the motor runs is by plotting its steady-state behavior on the torque-speed plane. If the motor is running very smoothly, a single point on the torque-speed plane will represent its steady state. If a path is displayed instead of a point, the motor is experiencing oscillations in speed and torque while running, and the so-called steady state speed is actually an average value. Again, for disclosing rapid oscillations, fast data sampling is required. Figure 5 shows plots of two motors, differing in smoothness of operation.

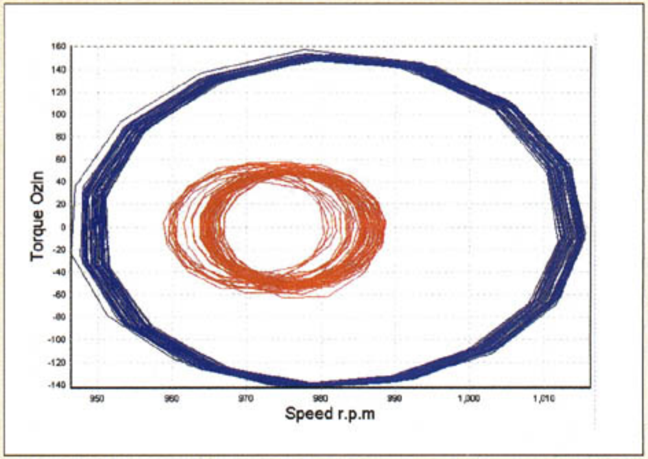

Figure 5. Torque-Speed Oscillations: Plots of two motors steady state run on the torque-speed plane. The smaller curve (in red) represents the smoother running motor.

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