Dynamic Testing of Electric Motors for Fault and Noise Analysis

Dynamic testing can now identify such defects as vibration and noise on electric motors before final assembly. An innovative technology can test the complete performance curves of any given motor or application without using external loads and by only using its internal inertia (measured by the system). Usually, only measurements of steady phase characteristics are primarily addressed. However, a new testing method equally supplies additional information on the dynamic phase behavior of an electric motor or an application. The additional information can indicate defects such as vibrations and excessive noise levels, usually not achieved on common production and laboratory quality control means.

The Principle

Newton's 2nd law for rotating devices describes steady and dynamic phases of any given rotating device movement. Each of the phases can be determined for a test measurement:

$$T = T_{load} + J\ dw/dt$$

T (load) represents a motor or application under a conventional dynamometer test on a steady phase (stabilized on a constant-speed, no-acceleration point and subjected to certain load torque value). In order to project the Torque vs. Speed valuable performance curve, dynamometer tests have to be repeated over several times to cool down heated motors to test them again in order to ensure consistent motor performance and accurate results.

$$T = J\ dw/dt$$

J dw/dt represents the motor under the new test on a dynamic phase (during the acceleration duration, where it is not subjected to any external load only using the motor's internal inertia J). The Torque vs. Speed valuable performance curve and other motor curves (amps, volts, pin, pout, efficiency, and power factor, etc.) are accurately projected by the new testers in seconds based on thousands of samples taken on the motor's acceleration process from zero to maximum "no load" speed.

The load on the motor is only its own momentum of inertia. From the

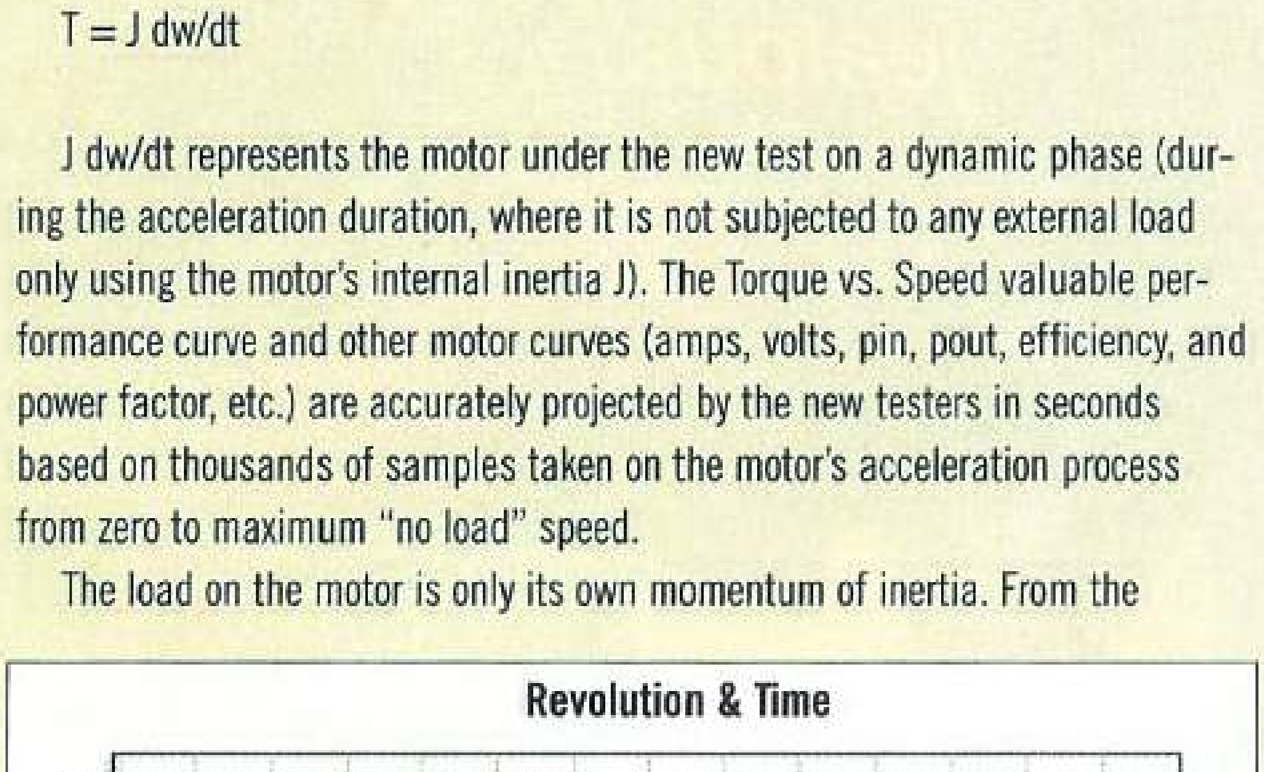

Figure 1. The Speed vs. Time test shows different acceleration process of each of the three motors from the same production batch as tested on the new tester. Motor 1 is a good motor with smooth acceleration; Motor 2 was designated as just tolerable and Motor 3 shows alternating acceleration-deceleration during run-up. Contrary to Motor 1, Motor 3 is subjectively perceived as noisy.

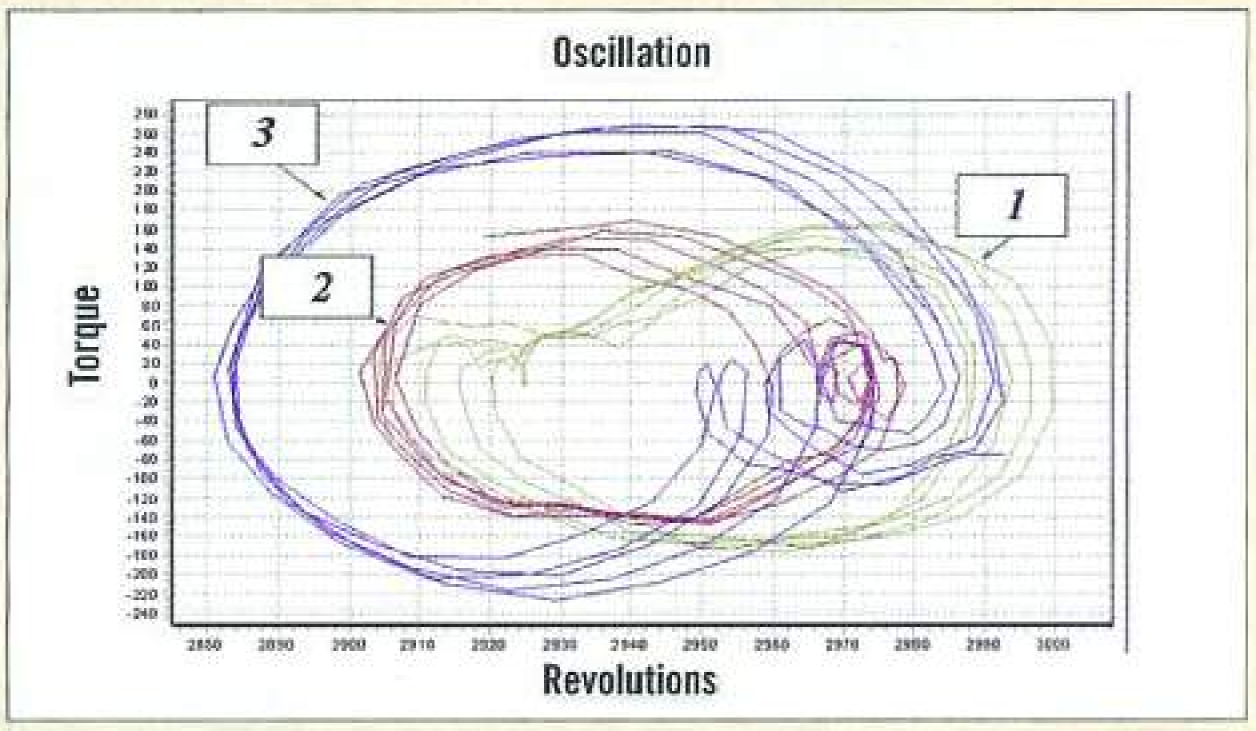

Figure 2. The Torque vs. Speed Oscillations test reveals five times larger amplitudes of the oscillations of Motor 3 when compared to Motor 1 during acceleration.

recorded values, software calculates the complete speed range, including power input, power output, efficiency, and direction of rotation.

Additional unique tests to reveal noise, vibrations, assembly misalignment, and bad bearings due to electrical and mechanical sources, include Torque and Speed Spectrum, Torque Speed Oscillations, and Friction Torque. The method is highly valuable for production verifying quality control of the motor's complete parameters. It is also valuable for R&D and quality laboratory applications, easily testing dozens of motors per day by a single operator, detecting defects on early stages, and projecting various built-in reports.

The determination of the complete characteristics of an electric motor over the whole speed range offers advantages. Checking motors only at the maximum "no load" speed satisfies most motor manufacturers' present requirements. However, this has only minimal value. It shows only that the motor is capable of rotating. In most cases, faults do not evidence at maximum no-load speed, but in the lower speed range. The new testing system conducts measurements on complete motor's performance curves, record data, and displays information within seconds.

In addition, the high resolution of the test results allows simultaneous viewing and analysis of the motor or applications dynamic processes. Very often, no irregularities are recognizable in the "steady" characteristics of a motor, while they become visible by measuring transient behavior. An example from real life illustrates this.

Detecting Defects in a Production Batch of Three Motors

A leading European manufacturer of household appliances intended to deliver a new appliance model to the market. The prototype tested to specification with its drive installed fully satisfied. The manufacturer was ready for mass production. Production began, and the motors bought from an outsourced supplier were installed.

Unexpectedly, some motors were not as quiet as the prototype tested. A check in the acoustic laboratory revealed differences. The appliance producer then tested the three motors using the new testing method. The motors included a good motor (1), a tolerable motor (2), and a bad motor (3), originally from the same production batch.

The test recorded voltage, auxiliary voltage, capacitor voltage, main current, auxiliary current, speed, torque, power input, power output, efficiency, friction torque, torque speed oscillations, and torque and speed spectrum analysis.

The resulting power output, torque, and efficiency of the three motors differed only slightly. The peak values for output and torque of the bad motor

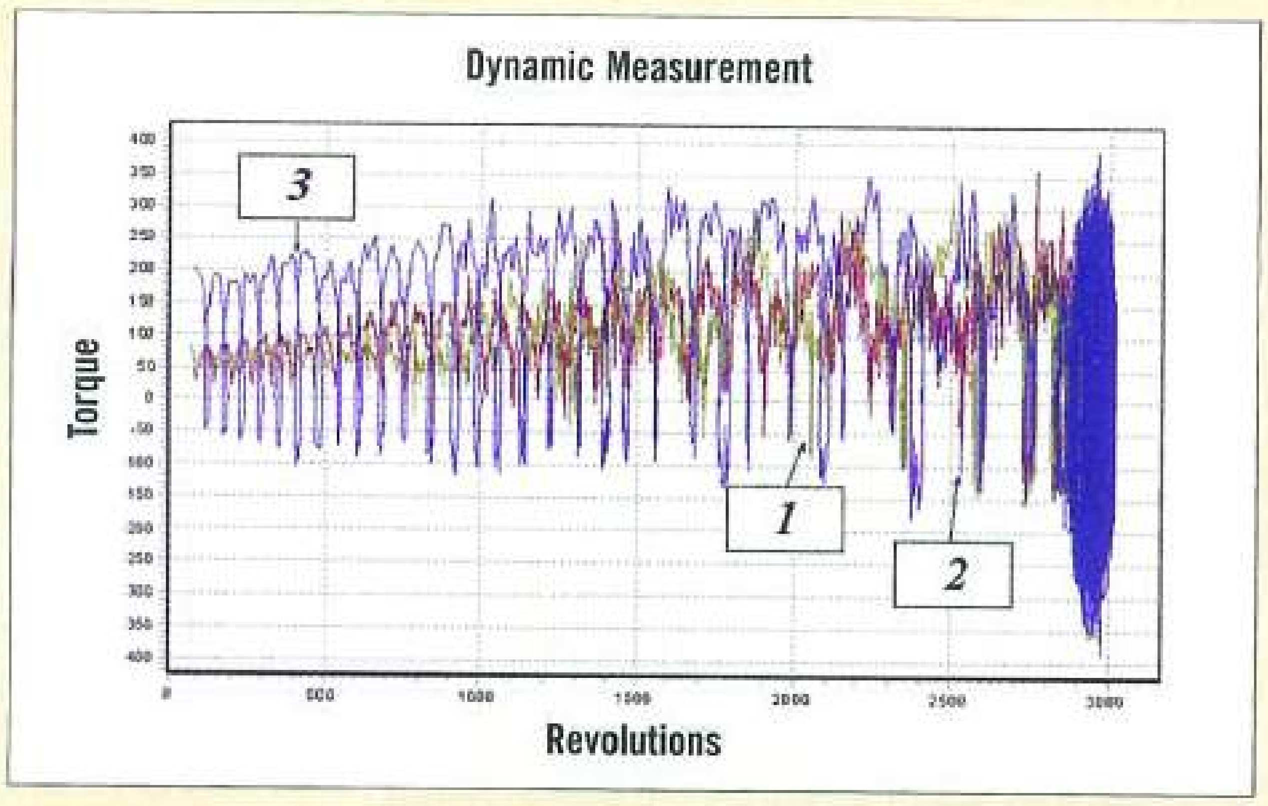

Figure 3. The Dynamic Torque vs. Speed test shows oscillations during acceleration and at the steady speed. Motor 3 is still the most unsteady.

were approximately 7 percent below those of the good motor. Since the current input had changed and, therefore, also dropped the power input, the measurement of the steady motor characteristics showed no significant differences, explaining the reasons for the different acoustic behavior of the motors.

When the recorded data was evaluated in a different way, more useful information was gathered. Figure 1 shows the increase in speed of the three motors over time during acceleration. It is clearly visible that the good motor runs up steadily to its maximum speed, while the bad motor periodically decelerates during acceleration. The tolerable motor shows similar behavior to the bad motor, although less pronounced.

This instability also resulted in torque oscillations during acceleration, as shown in Figure 2. Even the smoothly running, "good" motor executes oscillations around the mean value, yet the oscillation amplitudes of the unsteadily running bad motor are approximately five times as large. Figure 3 shows that a similar picture was obtained at the point of maximum speed. Oscillations around the mean value of the point of maximum speed increase from the good motor to the tolerable motor, and again to the bad motor, although the amplitudes are not as serious as in the acceleration phase. A frequency analysis (Figure 4) shows the frequencies having the largest torque amplitudes. The disturbance has electromagnetic reasons with double line frequency of 100 Hz, as can be seen in Figure 4. If the motors with excessive torque spectrum were to be used inside the appliance application, it would result in an unpleasant audible effect.

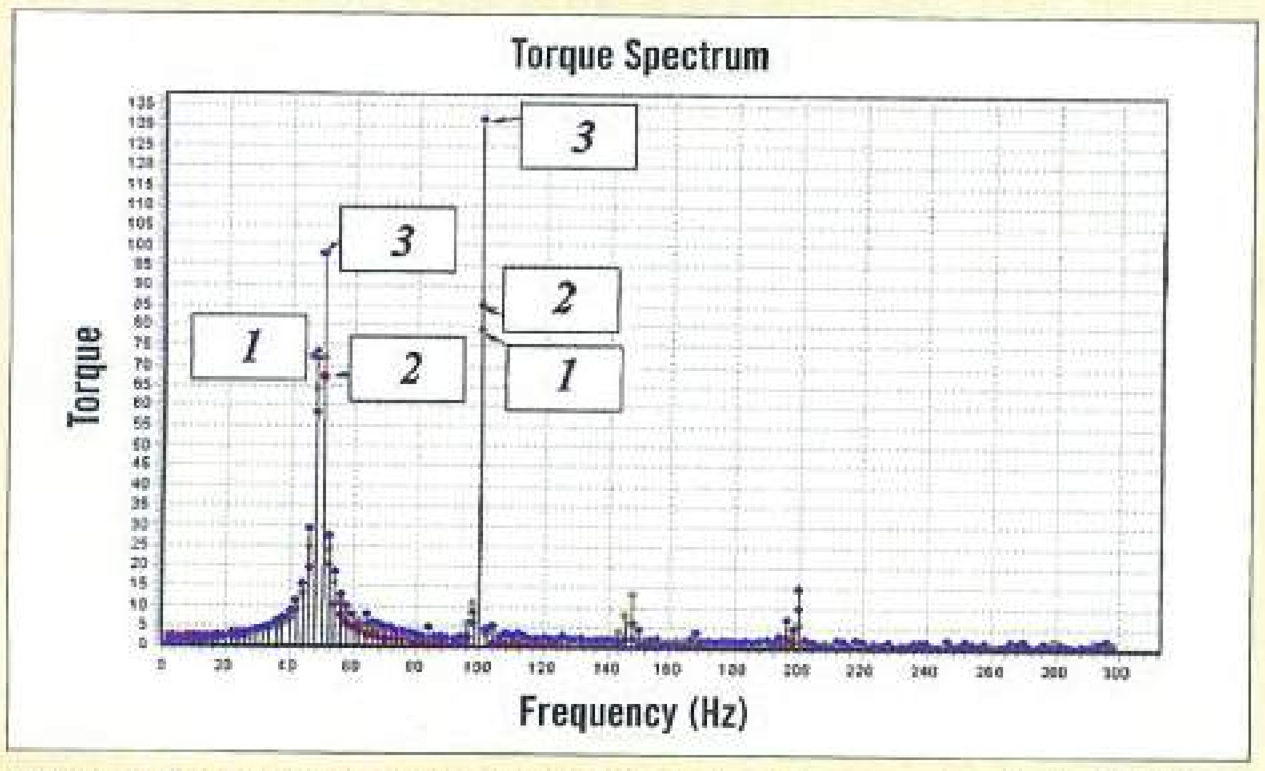

Figure 4. The Torque vs. Frequency test indicates the reason for the instabilities. In this case, excessive torque ripples are due to non-even air gaps between the rotor and stator, which causes a humming noise, as seen on the double line frequency of 50 Hz and its harmonics.

Conclusions

It is concluded that the new testing technology easily identifies outstanding motors with excessive performances and indicates the reasons for the noise development. Similar investigations conducted on gear motors or complete drives with various components check stability in transient and steady state operation. Gear defects and bearings and brush problems can also be recognized immediately.

Delivering motors of unsatisfactory quality as described above incurs considerable cost for the appliance producers as well as for their electric motor supplier (this includes returns of appliance products, disassembling products, tests on appliance laboratory plants, returns of motors to their manufacturers, tests on motor manufacturer plants, and delays in delivery and production).

Implementations of the new test capabilities on appliance and electric motor plants, quality assurance entrance control, and R&D and assembly lines, can avoid significant costs.

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