Technical Brief No. 15

All Technical Briefs are based on past projects at RH Lyon Division

Imbalance
Magnetic circuit
Brushes

Quiet Electric Motors

Sound and Vibration

Design Trends

Small electric motors are a ubiquitous source of noise in daily life. They occur in almost all home appliances and industrial machines. Current trends in product design are increasing the noise that motors make. Greater power densities produce higher levels of excitation. The use of the field (stator) as a structural component reduces the isolation between the motor and supporting structure. The expanding use of lightweight and stiff plastics for appliance structures increases both vibration transmission to noise radiating surfaces and the ability of those surfaces to radiate sound.

The most common motors in use for small and moderate sized appliances are induction motors and universal motors. In both, the primary noise mechanisms are usually imbalance, misalignment, and/or electromagnetic forces. Universal motors also have a contribution from brush/ commutator interaction.

Harmonic Content

The noise from a universal motor is at multiples of rotation speed. These harmonics are "modulated" at twice the line frequency, the frequency of magnetic attraction between the rotor and stator. This modulation also produces sidebands on the motor speed harmonics. These harmonics and their sidebands are strong and highly audible. Although simple imbalance may generate the highest amplitude tone in the noise spectrum, the electromagnetic "runout" is often the largest noise problem.

Induction motor noise also has tonal components at the rotation speed due to imbalance, but its electromagnetic excitation is also strong at a frequency that is the product of the number of rotor conducting bars and the "slip frequency." The slip frequency is the difference between the rate of rotation of the stator's magnetic field and of the rotor. In a small "shaded pole" motor, this electro-magnetic induced frequency can be readily heard.

Higher power densities

Lightweight structures

Higher speeds

Stiff plastics

...more NOISE

Redesign for Noise Reduction

Reducing the noise from these motors can be done at various levels. Magnetic circuit modeling and analysis can reveal the effects of variations in geometry, materials properties, and structural deformation on the magnetic runout. Changes in the design of magnetic materials, geometry, and structural components can then be made to determine the optimal configuration that is achievable at an acceptable cost. Such an exercise can have ancillary benefits apart from noise, such as improved starting torque or smoother operation.

Other Noise Reduction Options

Even if a redesign of the magnetics is not contemplated, modification may still be possible for a quieter design. For example, motors generally do not radiate much sound directly, since they are small and they may be enclosed within the product. But they do excite the outer structure mechanically, and the resulting vibration will radiate sound. Motor vibrations can be determined from their ODS's (operating deflection shapes), which in turn are determined from the forces due to imbalance and electromagnetics and from the vibrational mode shapes of the structure.

Redesigning the structure to minimize vibration transmission may therefore involve a combination of the following: experimental procedures (ODS's), mode shape determination from experiment (modal analysis), and calculation (finite element analysis or FEA), extraction of the forces from ODS and FEA information, and modal modifications to minimize the response of the structure to these forces.

Close Coordination Necessary

A close coordination of experimental procedures and analytical modeling is critical to the success of the above procedures. This combination of methods has application to many devices other than motors, such as gear trains, hydraulic valves and pumps, and actuators.