Technical Brief No. 12

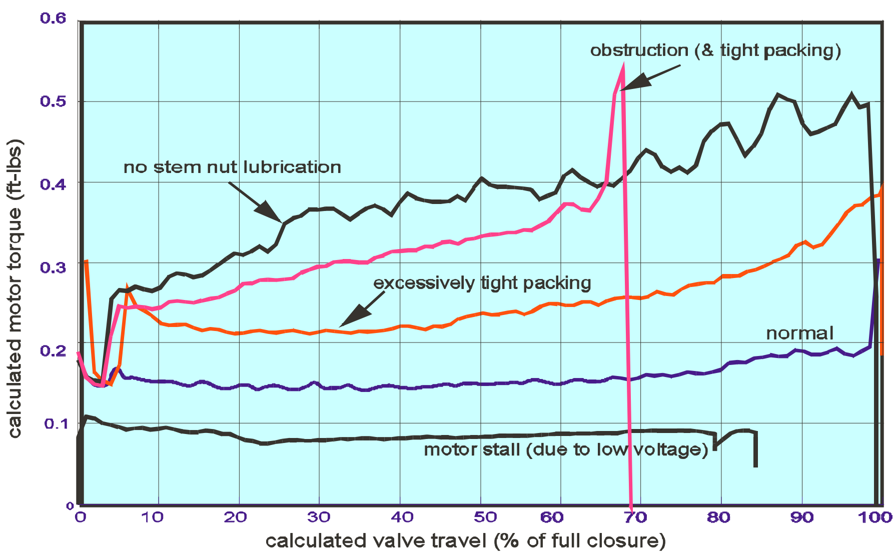
All Technical Briefs are based on past projects at RH Lyon Division

Motors
Valves
Torque

Motor-Operated Valves: Estimating Torque and Motion

Non-invasive methods for determining average and dynamic torque of 3-phase induction motors using line voltages and currents, and the rotation of gears in motion control systems using housing vibrations, can be used to diagnose the condition of such systems while they are in service. These methods, initially developed at M.I.T., have been further developed at RH Lyon for application to the motor-operated valves (MOV's) that are widely used in power plants, water treatment facilities, the chemical process industry, and on ships.

This Brief describes two different, but complementary, non-intrusive methods for determining forces and motions in motors and gearing systems. One method is the determination of torque generated in 3-phase induction motors using line voltages and currents. The second is determination of gear rotations by analyzing the vibrations they produce. These two methods, used in combination, form the basis of a portable PC-based MOV diagnostic system developed at RH Lyon.



Torque vs. travel signatures for different faults

The conceptual basis for using line voltages and currents to determine torque is as follows: In a balanced 3-phase motor, torque is the product of flux linkage and stator winding current. Since the flux linkages can be determined from a modified time integration of the line voltages, and the currents are known, the instantaneous motor torque can then be calculated. The gear rotation procedure uses housing vibrations that are induced by the motor pinion gear mesh forces. This gear meshing frequency is determined by a combination of spectral modeling and analyses of the measured vibration to determine the instantaneous (actually, averaged over a short interval) mesh frequency. The pinion mesh is tracked, rather than the more direct worm gear mesh, since its higher frequency generally makes it less susceptible to contamination by flow-induced vibration, and it can be tracked with greater precision than the lower frequency worm mesh. With knowledge of the gear ratios, these frequency estimates can then be integrated over time to obtain gear rotation, and therefore, the motion of attached mechanisms. In a MOV, the motion of interest is valve travel. A useful type of MOV "diagnostic signature" can be formed by displaying motor torque as a function of valve position.

The figure here shows comparisons, obtained on an MOV flow loop with flow present, of calculated motor torque and valve travel for a normal valve closure compared to a variety of abnormal valve closures. The torque curves show an initial surge as the motor starts, the engagement of the drive system soon after starting, and the torque rise at the very end when the valve seats. The "hash" on the torque signal (visible in a plot of torque vs. time) is not noise, but is gear tooth engagement between a worm and worm gear in the MOV transmission. As can be seen, the calculated torque vs. travel signatures can be used to distinguish between various faults that were introduced in these tests.

Future developments of this technology include applications to single phase motors for production quality assurance and in-service testing.