The Effect of Stem Lubrication on MOV Thrust Output

Stan Hale
ITI MOVATS Incorporated
200 Chastain Center Blvd.
Suite 250
Kennesaw, GA 30144
(404) 424-6343

INTRODUCTION

Valve stem lubrication changes affect the output thrust of a motor operated valve. While this general statement has been accepted for several years, the degree of degradation between lubrication cycles and the stroke-to-stroke variations that occur with various types of lubricants have not been clearly quantified. This paper discusses several examples of recent testing that help understand these variations and identifies some problem areas that should be avoided.

BACKGROUND

Torque-controlled electric motor-driven actuators are used to position many nuclear power plant valves. The motorized actuator rotates a threaded stem nut causing the threaded valve stem to move, either opening or closing the valve. When resistance to stem movement is encountered, the actuator overcomes the resistance by increasing torque output. A torque limit switch deenergizes the actuator at a pre-set torque output.

Calculations or dynamic tests are used to determine the actuator control switch settings that govern the amount of stem torque available to fully close or open the valve under design basis conditions. These calculations or tests establish the axial stem thrust needed to overcome the sum of valve friction force due to differential pressure across the valve, system rejection force, and stem packing load.

Valve stem geometry and stem and stem nut lubrication determine how efficiently actuator output torque can be converted to axial stem thrust. This torque-to-thrust conversion ratio is typically referred to as stem factor. The required stem thrust is multiplied by stem factor to establish the torque required from the actuator.

The formula used to calculate stem factor requires precise knowledge of stem diameter, thread pitch, pitch radius, pressure angle and friction coefficient. Except for friction coefficient, the variables listed above do not change over time for a given stem. Friction coefficient, however, is a result of the type and distribution of stem lubricant and the physical characteristics of the stem/stem nut contact surfaces.

Each time the valve is actuated, stem lubricant is displaced by the sliding action along the contact surfaces. Some lubricants perform better in this application than others. Some are more fluid and tend to redistribute themselves during and after operation and thus continually relubricate the contact surfaces. Others are drier and tend to be removed by operation and do not effectively relubricate the stem/stem nut contact surfaces. The variation from a well lubricated to a poorly lubricated stem can affect the torque-to-thrust conversion significantly.

Most nuclear plant testing programs attempt to achieve optimum MOV performance before and during testing. Stem lubrication is often applied prior to the test thereby producing a best case stem factor. Since the MOV may be operated for a full fuel cycle or longer period of time before the next lubrication, allowance for stem factor degradation should be factored into torque switch setting acceptance criteria. The amount of expected degradation depends on the type and frequency of use of the stem lubricant. Unfortunately there is limited information available on lubricant performance in this application. Though the EP lubricants and Mobil 28 tend to perform well over short periods of time, how much degradation to expect over an extended period without relubrication is not well understood.

Assumptions are used in the stem factor equation to bound the best and worst case expected friction coefficients. Worst case friction coefficients are typically assumed when calculating the maximum torque output needed from the actuator. Best case stem factors are assumed to calculate proximity to stress limits should the maximum torque occur under good lubrication conditions.

MOV DIAGNOSTICS

Diagnostic equipment is often used to establish the proper MOV torque switch settings. Most diagnostic methods enable the measurement of valve stem thrust. The typical diagnostic test includes the determination of thrust output at torque switch actuation.

Transducers that measure actuator output torque have recently been introduced for use in conjunction with thrust measurement transducers. Simultaneous measurements of thrust and torque enable the direct determination of stem factor. Since the only variable in the stem factor equation that can change for a given stem is the friction coefficient, the changes in friction coefficient due to stem lubrication effects are quantifiable.

RECENT EXPERIENCE

The benefit of good stem lubrication was recognized shortly after thrust measuring test equipment became available for MOVs. Today it is not considered unusual to apply additional lubricant to a valve stem during testing in order to obtain the required output thrust. The significant adverse consequences of bad or degrading stem lubrication have been highlighted by the use of transducers that measure torque and thrust simultaneously. During the industry (NRC, MOV Users Group and Diagnostic Vendors) sponsored validation testing of commercially available stem thrust sensors and during recent in-plant testing, stem lubricant degradation was observed to cause changes in stem factor that are not normally considered in switch setting acceptance criteria.

The industry sponsored validation testing was performed at the Idaho National Engineering Laboratory on a MOV load simulator and Copper Never-seize was used for stem/stem nut lubrication. Though the direct stem thrust measurement transducers performed well, significant differences in output thrust were observed over successive test runs at the same torque switch setting. The changes were initially attributed to the rate at which the actuator was loaded (rate-of-loading effect/load sensitive behavior). However, subsequent evaluation of simultaneous torque and thrust data indicates that stem factor changes played a much more significant role.

Failure of a post-maintenance local leak rate test (LLRT) and subsequent MOV diagnostic testing alerted plant engineers to changes in MOV output thrust at the Turkey Point Nuclear Plant. The change in output was detected by, and initially thought to be caused by the testing methodology used. Strain gauges were installed on the valve stem and calibrated using a Torque/Thrust Load Cell as a standard. When the Torque/Thrust Load Cell was removed, the strain gages were used for post-maintenance verification of thrust output.

ITI MOVATS embarked on a significant research and testing program aimed at duplicating and precisely identifying the cause of the observed changes. At least two factors were thought to contribute to the observed changes. The first and most obvious concern was the use of an anti-seize compound as a stem lubricant. The second was the change in stem nut position on the valve stem caused by insertion of the Torque/Thrust Load Cell.

The ITI MOVATS test program utilized both EP-0 and Neolube as a stem lubricant. Neolube is one of the more common anti-seize compounds used as a valve stem lubricant in nuclear power plants. The valve stem was instrumented with strain gages and tests were performed with the Torque/Thrust Cell on and off. Stem engagement was also varied from full engagement to a minimum of one-fifth stem diameter.

EP-0 produced small stem factor changes, including when the Torque/Thrust Cell was installed and then removed. The Neolube test on the other hand, showed changes in output thrust from stroke-to-stroke with no change in configuration. Additional differences were observed with Neolube for configuration changes such as installation and removal of the Torque/Thrust Cell and reduced stem engagement. One plant MOV was also tested as part of the research. The valve stem had been lubricated with Neolube before the original testing began less than two weeks earlier. After a retest, which showed a decrease in thrust output, the valve stem was relubricated with Neolube and tested again. The relubrication returned the output thrust to its original value.

The final conclusion of the ITI MOVATS test program was that the single most significant contributor to the observed changes in stem thrust was stem lubricant. Test results also indicate that stroke-to-stroke variations in thrust at torque switch trip are greater with Neolube than with EP-0. Furthermore, based on the limited testing performed, stem engagements of less than one stem diameter with the Torque/Thrust Cell installed tend to increase the thrust at torque switch trip by improving the stem factor when Neolube is used as a lubricant. The effect is not evident when EP-0 is used.

The Electric Power Research Institute (EPRI) has spent time over the past few years researching valve stem lubricants used in nuclear power plants and several issues have been identified. The report on this initial testing has not been issued, but progress reports have identified problems with anti-seize compounds as a valve stem lubricant.

CONCLUSIONS

Allowances for lubricant degradation should be factored into torque switch setting acceptance criteria regardless of the lubricant or test equipment used. Though EP-0 and Mobil 28 tend to perform well (remain consistent) over short periods of time, some change should be expected between lubrications. Valve stem lubricants should be evaluated based on industry and utility "in-house" experience and allowances made for expected changes over time.

Anti-seize compounds do not produce consistent stem factors from one operation to another during a single test. Examples of variations in stem factor of 10% have been observed during successive operations of typical in-plant tests particularly when the stem was lubricated just prior to the first test. These stroke-to-stroke variations must be included with expected degradation over time when establishing torque switch settings.

If a Torque/Thrust Load Cell is used to determine thrust on MOVs that have Neolube applied as a stem lubricant, changes may occur upon removal if the stem to stem nut engagement is less than one diameter with the TTC installed. Torque/Thrust Load Cell on/off differences are small when EP-0 is used as a stem lubricant.