7.0 PERIODIC DESIGN BASIS VERIFICATION

7.1 Operating Margin

By way of quick review, the operating margin is the difference between the available actuator torque and the required actuator torque. In most motor-operated gate valves, the available actuator torque is determined by the torque switch setting. The setting of the torque switch addresses four concerns:

- The torque switch needs to be set high enough that at design basis loads, the torque switch does not trip before the valve closes (the torque switch setting must be higher than the required actuator torque)
- The torque switch needs to be set low enough (or the actuator motor needs to be powerful enough) that at design basis operating conditions (differential pressure, degraded voltage, elevated temperature, etc.), the motor does not stall before the torque switch trips
- The torque switch needs to be set low enough that the valve and actuator overload limits and the torque spring displacement limits are not exceeded before the torque switch trips
- Calculations using the results of in-plant diagnostic testing need to account for instrument error and for data scatter related to torque switch repeatability.

The first of these concerns, in terms of required actuator torque, was discussed in Section 3.3 and is reviewed here for completeness. This chapter focuses on the second and third concerns. This Section discusses the fourth concern (in-plant diagnostic testing).

Usually, the available torque is determined by the torque switch setting, as discussed in Section 3.1. However, if the torque switch has been bypassed, or if the motor is incapable of providing enough torque to trip the torque switch, it is the peak output of the actuator at or near motor stall, not the torque switch setting, that determines the available actuator torque.

If an actuator equipped with a functional torque switch cannot trip the torque switch, the reason is because the torque switch is set too high relative to the output capability of the actuator. In in-plant applications, the possibility of a motor stalling before the torque switch trips presents serious concerns. If the motor stalls after flow isolation but before torque switch trip, the motor will heat up in its stalled condition until the thermal overload switch trips. This occurrence leaves the valve unavailable for operation until the motor cools off and the thermal switch resets. Such a delay might have serious consequences in an accident scenario where it is necessary to reopen the valve. If the thermal overload switch has been bypassed, or if it fails, the motor will burn out (unless plant operators intervene). If the motor stalls before flow isolation, the additional consequence is that the valve remains partly open, such that the valve fails to achieve its intended safety function.

One of our objectives, then, is to make sure that the actuator will trip the torque switch. The estimate of the required torque is the *lower torque limit* needed to close the valve. Based on this value, a minimum torque switch setting is selected to ensure that the torque switch will not trip before the valve closes.

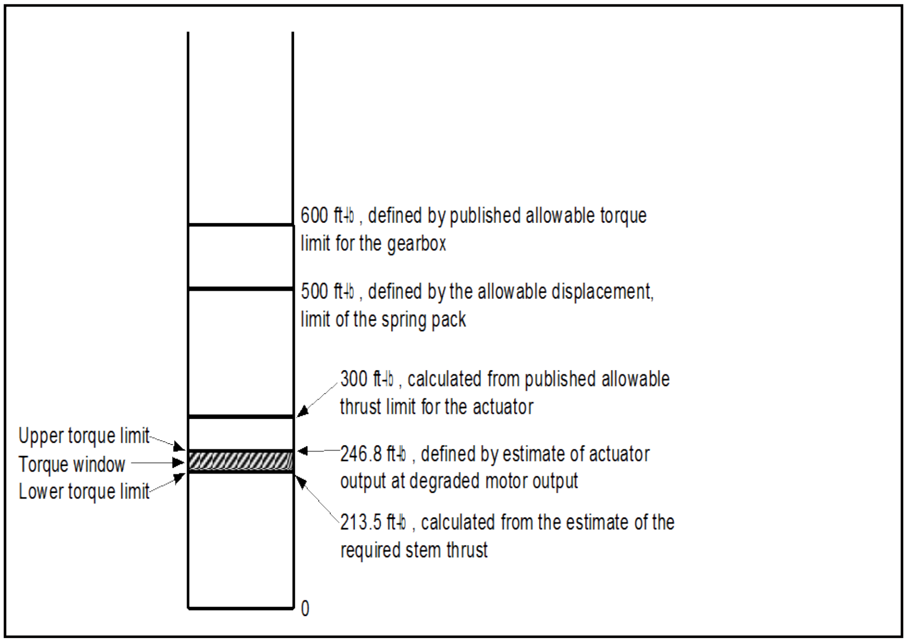
We also need to consider other parameters that might define the *upper torque limit*: the physical displacement limit of the torque spring, the allowable load (torque and thrust) ratings for the valve, the allowable load (torque and thrust) ratings for the gearbox, and the capability of the actuator at degraded motor output. Ideally, the limiter plate on the torque switch prevents torque switch settings higher than those defined by any of these limits. However, for several reasons, including that the limiter plate can be easily removed or modified, the analyst must consider these limits in the analysis anyway, not relying on the limiter plate for assurance. Evaluation of these parameters defines the *upper torque limit* that defines the *maximum torque switch setting*. The Limitorque published literature specifies the maximum torque switch settings for specific spring packs.

The allowable torque and thrust loads for the valve are addressed in the valve manufacturer's weak link analysis. For some valves, the torque and thrust limits are much higher than the limits for the actuator, so we need not consider them here. Other valves might not be as sturdy and the valve's structural limit, rather than the gearbox's, might represent the applicable limit.

The rated torque and thrust limits for the actuator gearbox are specified by the manufacturer [Limitorque selection (SEL) guides] for each of its gearboxes. However, the *published allowable* values are not identical to the torque and thrust ratings specified in the Limitorque selection guides. In general, published allowable values permit 1.2 times the stated torque rating and 1.4 times the stated thrust rating.

An estimate of the torque value that corresponds with the actuator's structural *thrust* limits must consider a conservatively low stem friction, that is, the one expected at seating/wedging in a no-flow, no-pressure closing stroke. This stem friction value can be determined in an instrumented no-load in-plant test. It is more likely, though, that the analyst will simply measure the final thrust in the in-plant no-load test and determine from that measurement that the current torque switch setting does not cause the actuator or the valve to exceed their respective thrust limits. This is the *upper torque limit* defined by the actuator's structural thrust limits.

The estimated output of the actuator at motor stall (theoretically assuming no torque switch) at design basis conditions (including reduced motor output at



1**Figure 7-1 Torque Window Showing Upper and Lower Torque Limits**

degraded voltage, etc.) also represents an upper torque limit. A torque switch setting that produces torque higher than this introduces the possibility that at design basis conditions (differential pressure, degraded motor voltage, elevated motor temperature, etc.), the motor might stall before the torque switch trips. (Because of the conservatisms inherent in the calculations, we cannot say that the motor certainly *will* stall, only that it *might* stall. However, from a plant operations perspective and a regulatory perspective, a torque switch setting higher than the estimated maximum represents a serious problem that must be addressed.) This value is the lowest of the possible upper torque limits we have considered here, so this is the one that defines the *upper torque limit* for the torque window.

Figure 7-1 is a simple sketch that illustrates the *torque window*, as defined by the lower torque limit and the upper torque limit. For this valve and actuator, top of the window is defined by the actuator capability at motor stall, a value of 246.8 ft-lb. The bottom of the window is defined, of course, by the required actuator torque, an estimate of 213.5 ft-lb. The torque switch setting must be such as to produce a torque value (at torque switch trip) somewhere inside the torque window. We need to select a torque switch setting that is high enough to close the valve (at 213.5 ft-lb), yet not so high as to stall the motor (at 246.8 ft-lb). If the upper torque limit were defined by the structural limits of the valve or operator instead of by the capability of the actuator at design basis degraded motor output, then the final torque, not the torque at torque switch trip, would be the relevant torque value.

The manufacturer's chart for this particular torque spring shows that a torque switch setting of 1.5 corresponds with an output torque of 200 ft-lb, while a setting of

1.75 corresponds with an output torque of 250 ft-lb. We would set the torque switch between the two, aiming for an output torque of about 230 ft-lb. (The actual setting of the torque switch at a specific setting is not wonderfully precise; the dial is small, and the scale is not marked in small increments.) This value compares favorably with the actuator capability at motor stall (246.8 ft-lb), because it provides assurance that the torque switch will trip before the motor stalls. It also compares favorably with the required actuator torque of 213.5 ft-lb, providing a *torque margin* of about 15 ft-lb. This margin of 15 ft-lb is smaller than we would like. However, the existence of any margin at all provides assurance that the valve will indeed close when called upon to operate at its design basis loads and operating conditions.

This estimate of the margin assumes that the estimated required torque, the estimated available torque (determined by the torque switch setting), and the upper torque limit (a parameter that contributes to the selection of the torque switch setting) are conservative estimates. Thus, it represents the *minimum estimated* margin. If the evaluation shows that the margin is small or nonexistent, the analyst might simply set the torque switch higher, provided that the higher torque switch setting won't cause the motor to stall or otherwise exceed the upper torque limit. If the needed higher torque switch setting would exceed the upper torque limit, the analyst must consider replacing the motor or the motor/gearbox with a more powerful unit, or changing the hardware configuration for a more favorable overall gear ratio or stem factor (different pitch and lead).

The evaluation described here assumes the absence of in-plant testing of the valve. This kind of evaluation is highly theoretical, and somewhat impractical, because of the imprecision of the torque switch setting. In practice, the utility usually does not rely on this kind of theoretical evaluation, but instead performs in-plant testing to set the torque switch, with measurement of torque, thrust, or (preferably) both. The tests are usually conducted at no-load conditions, with margins built in to the evaluation to account for load-sensitive behavior and other concerns. The evaluation that uses in-plant testing to set the torque switch is similar in concept, but different in details, compared to the evaluation described in this chapter. The evaluation that uses in-plant testing is described in the next chapter.

If it is possible to perform instrumented tests in the plant at design basis flow and pressure loads, the *required* stem thrust and *required* actuator torque can be measured, in which case the measured values can be used instead of estimates. In such cases, it is still necessary to calculate an estimate the actuator output at the motor's design basis reduced output (degraded voltage, elevated temperature) to help define the upper torque limit, as explained in the previous paragraphs. (In-plant testing does not routinely attempt to duplicate design basis degraded voltage and elevated temperature conditions for the motor.) For all applicable measurements, the analyst must account for instrument error and torque switch repeatability, as explained in the next chapter.

In some instances, the evaluation might show that the estimated margin is small or nonexistent, when in fact plenty of margin exists. This situation might be caused by the accumulation of conservatisms in the calculations that contributed to the estimates. In the absence of data from instrumented tests, conservative assumptions must be used. If the analyst suspects that the assumptions are excessively conservative, and that this excessive conservatism has produced the illusion of a small or nonexistent margin, the analyst might identify the excesses, revise the inputs, and recalculate. This approach is acceptable, provided that there is good justification for the revisions, so that there is assurance that the estimate remains conservative.

As an alternative, the analyst might perform instrumented tests to produce data that are more accurate than the conservative estimates that contributed to the calculation. Of course, the analyst would need to provide justification for the use of these alternative values, providing assurance that the results of the calculation are still conservative.

Further, if an instrumented test with a pump flow load produces a sufficient differential pressure to demonstrate a stable stem friction value of 0.12 at flow isolation (see "Threshold Method," Section 3.3.1), then this lower stem friction value can replace the default value (0.15) used in our original calculation.

Where in-plant testing at full design basis loads is impractical, instrumented testing at lower loads can provide useful data. As another example, a test conducted at 80% of design basis differential pressure provides useful data for extrapolation purposes. Experience has shown that extrapolating the results of an 80% test to estimate the response at 100% of design basis conditions is reliable and conservative.

Figure 7-2 (the same as Figure 3-2, shown again here for convenience) is a flow chart illustrating, in simplified terms, the process for estimating the torque margin for rising-stem valves (gate and globe valves) and for quarter-turn valves (butterfly, ball, and plug valves). An informal procedure describing this process is provided in NUREG/CR-6100, *Gate Valve and Motor-Operator Research Findings*.

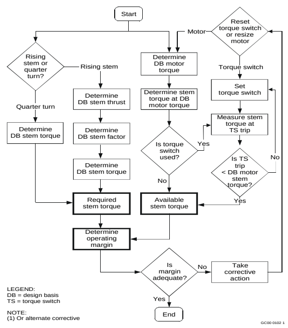


Figure 7.2 Flow Chart for Estimating Torque Margin