Operational margin improvement of motor operated gate valves using Thrust Uncertainty Method in nuclear power plants

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1. Introduction

The EPRI Motor Operated Valve (MOV) Performance Prediction Methodology (PPM) is a validated method for determining the required thrust or torque to stroke gate, globe and butterfly valves under design basis conditions. For gate valves, the PPM includes a friction algorithm which determines the coefficient of the friction for the various bearing surfaces in the valve as a function of material, temperature, fluid medium, contact stress and contact configuration. The actual seat coefficient of friction for a specific valve can only be determined by performing a dynamic test, the difference between the required thrust predicted by the PPM and the actual required thrust is an uncertainty. The EPRI has developed and validated a method, deemed the “Thrust Uncertainty Method” (TUM), for calculating this uncertainty and incorporating it into a statistical evaluation of the required setup parameters for torque switch controlled strokes. This study describes the EPRI TUM and the operational margin improvement when compared to use of the PPM without TUM.

2. Methods and Results

2.1 Description of methods

The EPRI Thrust Uncertainty Method (TUM) is applicable to torque switch controlled closing strokes of solid and flexible wedge gate valves at cold water temperature condition. Table 1 lists the applicability requirements for use of the TUM is as bellow.

Table 1. TUM Applicability

Category	Applicability
General	The PPM prediction must use default friction coefficients.
Valve type	- Solid and flexible wedge gate valves, excluding Borg-Warner gate valves - Anchor/Darling double disk gate valves (flow isolation only)
Stroke direction/control method	Torque switch controlled closing strokes
Fluid medium and temperature	Water at up to 150°F
Flow rate	Up to 50 ft/sec
Nominal seat contract stress	No greater than 15,000 psi

If the valve stroke meets the requirements in Table 1, implements the EPRI MOV PPM for the stroke to determine the required thrust to reach initial wedging (for gate valves). The nominal required stem thrust (F_{NOM}) is calculated by the following equation.

$$F_{NOM} = (F_R \times APR) + (1 - APR)(F_{pack} + F_P) \qquad (1)$$

where,
F_R : PPM Required stem thrust at closing stroke (lbf)
APR : Average Prediction Ratio(dimensionless), APR = 0.74
F_{pack} : Packing thrust at closing stroke in PPM (lbf)
F_P : Piston effect force of design basis of review (lbf)

The thrust prediction uncertainty (U_{TPU}) related to the nominal required thrust is calculated by the following equation.

$$U_{TPU} = \frac{1.014 \times F_R}{F_{NOM}} - 1 \qquad (2)$$

Then, the Adjustment Factor (AF_{min}) to account for uncertainties is calculated based on the characteristic of uncertainties described as bellow. The equation (3) is determined by the use of the PPM without TUM and the equation (4) is determined by the use of the TUM.

$$AF_{min} = B_{ROL} + SPR + SLD + \sqrt{{U_{RD}}^2 + TSR^2 + {U_{ROL}}^2} + \frac{U_{FS}}{F_R} \qquad (3)$$

$$AF_{min} = B_{ROL} + SPR + SLD + \sqrt{{U_{RD}}^2 + TSR^2 + {U_{ROL}}^2 + {U_{TPU}}^2} + \frac{U_{FS}}{F_{NOM}} \qquad (4)$$

where,
B_{ROL} : Bias due to Rate Of Loading(dimensionless)
SPR : Spring Pack Relaxation(dimensionless)
SLD : Stem Lubrication Degradation(dimensionless)
U_{RD} : Reading Uncertainty of Total Torque Measurement(dimensionless)
TSR : Torque Switch Repeatability(dimensionless)
U_{ROL} : Uncertainty due to rate of loading (dimensionless)
U_{TPU} : Uncertainty due to thrust prediction (dimensionless)
U_{FS} : Full Scale Uncertainty of Total Torque Measurement(lbf)

Then, the minimum required stem thrust ($F_{R,min}$) at closing stroke is calculated considering the adjustment factors as follows. The equation (5) is determined by the use of the PPM without TUM and the equation (6) is determined by the use of the TUM.

$$F_{R,min} = F_R \times (1 + AF_{min}) \quad (5)$$

$$F_{R,min} = F_{NOM} \times (1 + AF_{min}) \quad (6)$$

Safety-related motor-operated solid and flexible wedge gate valves are controlled by torque switch at closing stroke. Under this condition, the equation for operational margin at closing stroke (M_{close}) is as below.

$$M_{close} = \frac{F_{trip,static} - |F_{R,min}|}{|F_{R,min}|} \times 100\% \quad (7)$$

where,
$F_{R,min}$: Minimum required stem thrust at closing stroke (lbf)
$F_{trip,static}$: Trip thrust at closing stroke in static diagnostic test (lbf)

2.2 Operational margin calculation

Table 2 shows the result of operational margin at closing stroke for motor operated solid and flexible wedge gate valve using the EPRI PPM without TUM. The values of uncertainty (B_{ROL}, SPR, SLD, U_{RD}, TSR, U_{ROL}, U_{FS}) for the calculation of the Adjustment Factor (AF_{min}) at closing stroke is determined from static diagnostic test. The adjustment factor and the minimum required thrust are calculated by the equation (3) and (5), respectively.

Table 2. Evaluation result (using PPM without TUM)

Item	Valve A	Valve B	Valve C	Valve D
F_R(lbf)	12791	59446	13127	4043
B_{ROL}	0.1	0.1	0.1	0.1
SPR	0.05	0.05	0.05	0.05
SLD	0.1	0.1	0.1	0.1
U_{RD}	0.083	0.075	0.075	0.83
TSR	0.05	0.05	0.05	0.05
U_{ROL}	0	0	0	0
U_{FS}	38.2	205.9	38.2	3.97
AF_{min}	0.350	0.344	0.343	0.348
$F_{R,min}$(lbf)	17266.4	79871.8	17630.2	5449.5
$F_{trip,static}$(lbf)	18284	80588.5	18206.5	5698
M_{close} (%)	5.9	0.9	3.3	4.6

Table 3 shows the result of operational margin at closing stroke for motor operated solid and flexible wedge gate valve using the EPRI PPM with TUM. The nominal required stem thrust (F_{NOM}) and the thrust prediction uncertainty (U_{TPU}) are calculated by equation (1) and (2), respectively.

Table 3. Evaluation result (using PPM with TUM)

Item	Valve A	Valve B	Valve C	Valve D
F_R(lbf)	12791	59446	13127	4043
APR	0.74	0.74	0.74	0.74
F_{pack}(lbf)	748	3216	815	966
F_P(lbf)	1841.3	2351.5	1841.3	608.4
F_{NOM}(lbf)	10138.6	45437.6	10404.6	3401.2
U_{TPU}	0.279	0.327	0.279	0.205
B_{ROL}	0.1	0.1	0.1	0.1
SPR	0.05	0.05	0.05	0.05
SLD	0.1	0.1	0.1	0.1
U_{RD}	0.083	0.075	0.075	0.083
TSR	0.05	0.05	0.05	0.05
U_{ROL}	0	0	0	0
U_{FS}	38.2	205.9	38.2	3.97
AF_{min}	0.549	0.593	0.547	0.478
$F_{R,min}$(lbf)	15708.5	72398.3	16097.7	5027.7
$F_{trip,static}$(lbf)	18284	80588.5	18206.5	5698
M_{close} (%)	16.4	11.3	13.1	13.3

Table 2 and Table 3 show that the minimum required stem thrust calculated by the use of the TUM is less than the PPM without TUM. And the TUM represents about 10% increase for operational margin at closing stroke when compared to use of PPM without TUM. It means that the PPM thrust prediction for gate valves is conservative. The TUM quantifies the conservatism in the PPM thrust prediction and treats it as an uncertainty.

3. Conclusions

This study describe the EPRI Thrust Uncertainty Method (TUM) and the operation margin improvement at closing stroke for motor operated solid and flexible wedge gate valve using the TUM. Overall, based on the table 2 and 3, it can be concluded that the use of TUM can result in significant reduction in the minimum required thrust when compared to the PPM thrust prediction (without TUM). Thereby, the TUM can be used to increase operational margin. If the desired operational margin is not achieved based on the result of the PPM prediction, the TUM can improve operational margin at closing stroke.

REFERENCES

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