# Prevention and improvement of negative operational margin for motor-operated flexible wedge gate valves evaluated via performance prediction in nuclear power plants

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## 1. Introduction

Safety-related Motor-Operated Valves(MOVs) in nuclear power plants in Korea were evaluated to ensure their operability in accordance with Ministry of Science and Technology recommendation in 1997 for the first time, and it is currently executed in accordance with Nuclear Safety Security Commission issue 2016-14. In the evaluation, the performance of MOVs is expressed as operational margin, which is a measure of performance and shall be greater than 0%.

Operational margin is calculated using design values in Design Basis Review(DBR) report. After that, static diagnostic test and dynamic diagnostic test are performed in order at opening and closing stroke, to measure actual values of some parameters for calculating operational margin. Then a report distinct from the DBR report, called final evaluation report, is issued. In the final evaluation report, operational margin is calculated by applying actual values instead of design values. For some MOVs which are not applicable to diagnostic test under dynamic condition, an analytical method called performance prediction is used as an alternative. For performance prediction, a type of analysis program, EPRI MOV Performance Prediction Methodology (EPRI MOV PPM) is used. The operational margin is sometimes verified to be lower than 0% after performance prediction, even though it was over 0% in diagnostic test under static condition. This phenomenon occurs more frequently for flexible wedge gate valves than other types of MOVs.

This study describes a kind of measures for improving or preventing negative operational margin for motor-operated flexible wedge gate valves which performance prediction is applied to.

## 2. Methods and Results

### *2.1 Operational margin calculation*

Safety-related motor-operated flexible wedge gate valves are controlled by limit switch at opening stroke and torque switch at closing stroke. Under this condition, equations for operational margin at opening stroke($M_{open}$) and closing stroke($M_{close}$) are as below.

$$M_{open} = \frac{F_{A,max,open} - |F_{R,open}|}{|F_{R,open}|} \times 100\% \quad (1)$$

$$M_{close} = \frac{F_{trip,close} - |F_{R,close}|}{|F_{R,close}|} \times 100\% \quad (2)$$

where,

$F_{A,max,open}$ : Maximum available thrust at opening stroke (lbf)

$F_{R,open}$ : Required stem thrust at opening stroke (lbf)

$F_{trip,close}$ : Trip thrust at closing stroke in static diagnostic test (lbf)

$F_{R,close}$ : Required stem thrust at closing stroke (lbf)

Required stem thrust at each stroke described in equation (1) and (2) is determined via performance prediction. Performance prediction is the next step of static diagnostic test, and it uses more conservative method than that of static diagnostic test in calculating required stem thrust. This characteristic is noticeable especially in motor-operated flexible wedge gate valves because besides EPRI MOV PPM, there is another method which applies some parameters measured in static diagnostic test to calculation of the required stem thrust at opening stroke. The maximum among the two is applied to the required stem thrust($F_{R,open}$). This is why operational margin at opening stroke becomes more frequently negative after performance prediction.

### *2.2 Performance prediction*

In performance prediction of motor-operated flexible wedge gate valves, the required stem thrust at closing stroke($F_{R,close}$) in equation (2) is determined by use of EPRI MOV PPM. On the other hand, the required stem thrust at opening stroke($F_{R,open}$) in equation (1) is determined by one of the equations below, if the result value from either of the equations is greater than that from EPRI MOV PPM.

$$F_{R1} = F_C \times B + F_p \times (1 - B) + \Delta P \times (A_o \times D - A_s) \quad (3)$$

$$F_{R2} = F_{stat} + \Delta P \times (A_o \times C - A_s) \quad (4)$$

where,

$F_{R1}$ : Predicted unwedging thrust (lbf)

$F_{R2}$ : Predicted unwedging thrust via refined equation (lbf)

$F_C$ : Maximum thrust achieved during static closure stroke (lbf)

$F_p$ : Running load just prior to initial wedging during static closure stroke (lbf)

$\Delta P$ : Design basis differential pressure (psid)

$A_o$ : Mean seating area ($in^2$)

$F_{stat}$ : Measured static unwedging thrust, adjusted for measurement uncertainty (lbf)

$A_s$ : Area of the stem ($in^2$)

B, C, D : Constant based on the wedge half-angle (dimensionless)

If the result values from equation (3) and equation (4) are high, it may cause negative operational margin. The following tables specify information of some valves installed in safety-related service in NPPs and show their evaluation result of operational margin and their parameters for performance prediction according to equation (3) and (4).

Table 1. Valve design information

| Item | Valve A, Valve B, Valve C, Valve D |
|---|---|
| Valve Type | Flexible wedge gate valve |
| Safety direction | Open and close |
| Valve size (in) | 12 |
| Fluid medium | Subcooled water |
| Flow rate (gpm) | 28000 |
| Body material | Stainless steel |
| Disk material | Stainless steel |
| Stem material | Stainless steel |
| Control mode(open) | Limit stopped |
| Control mode(close) | Torque seated |

Table 2. Evaluation result(low operational margin)

| Item | Valve A | Valve B | Valve C | Valve D |
|---|---|---|---|---|
| $A_o$ (in$^2$) | 83.4 | 83.4 | 83.4 | 83.4 |
| $A_s$ (in$^2$) | 5.63 | 5.63 | 5.63 | 5.63 |
| $\Delta P$ (psid) | 423.7 | 423.7 | 423.7 | 423.7 |
| B | 0.688 | 0.688 | 0.688 | 0.688 |
| C | 0.221 | 0.221 | 0.221 | 0.221 |
| D | 0.178 | 0.178 | 0.178 | 0.178 |
| $F_C$ (lbf) | 52334 | 51238 | 48497 | 58186 |
| $F_p$ (lbf) | 2436 | 1734 | 1773 | 1118 |
| $F_{stat}$ (lbf) | 31682.4 | 40174.4 | 30492.6 | 44471.3 |
| $F_{R1}$ (lbf) | 40710.7 | 39737.5 | 37862.5 | 44329.0 |
| $F_{R2}$ (lbf) | 37118.3 | 45610.3 | 35928.6 | 49907.2 |
| Torque switch set point | 2.1 | 1.8 | 1.8 | 2.7 |
| $M_{open}$ (%) | 0.9 | -6.3 | -0.4 | -5.4 |

To improve operational margins of the valves in table 2, static diagnostic tests for each of the valves were performed again with adjusted torque switch setting. Then, the values of $F_C$ and $F_{stat}$ were measured lower than before because of torque switch setting adjustment. These values have influence on determining $F_{R1}$ and $F_{R2}$. As a result of this change, the operational margins of the valves were improved. The following table shows the information of the valves after operational margin improvement.

Table 3. Evaluation result(improved operational margin)

| Item | Valve A | Valve B | Valve C | Valve D |
|---|---|---|---|---|
| $A_o$ (in$^2$) | 83.4 | 83.4 | 83.4 | 83.4 |
| $A_s$ (in$^2$) | 5.63 | 5.63 | 5.63 | 5.63 |
| $\Delta P$ (psid) | 423.7 | 423.7 | 423.7 | 423.7 |
| B | 0.688 | 0.688 | 0.688 | 0.688 |
| C | 0.221 | 0.221 | 0.221 | 0.221 |
| D | 0.178 | 0.178 | 0.178 | 0.178 |
| $F_C$ (lbf) | 38967.0 | 36832 | 37402 | 37402 |
| $F_p$ (lbf) | 3837 | 2619 | 3022 | 2526 |
| $F_{stat}$ (lbf) | 26192.5 | 29994.6 | 27087.8 | 24838.2 |
| $F_{R1}$ (lbf) | 31944.5 | 30095.1 | 30613.1 | 30458.6 |
| $F_{R2}$ (lbf) | 31628.4 | 35430.6 | 32523.8 | 30274.1 |
| Torque switch set point | 1.3 | 1.3 | 1.4 | 1.2 |
| $M_{open}$ (%) | 10.1 | 3.5 | 3.6 | 5.8 |

It is practical measure for operational margin improvement to lower the values of $F_C$ and $F_{stat}$ by torque switch setting adjustment. Without this measure, valve design change or maintenance is inevitable to improve the operational margin. The distribution tendency of the values of $F_C$ and $F_{stat}$ is shown in figure 1, and it is clearly noticeable that the distribution of values of $F_C$ and $F_{stat}$ is different before and after operational margin improvement.

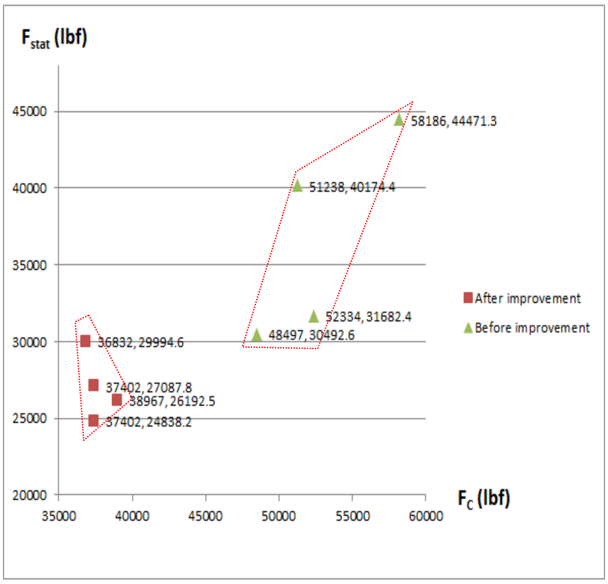


Figure 1. Distribution tendency of $F_C$ and $F_{stat}$

## 3. Conclusions

This study describes the measure for improving operational margin at opening stroke for motor-operated flexible wedge gate valves which performance prediction is applied to. With the review of equation (3) and (4), and comparison of valve evaluation result in table 2 and table 3, it is concluded that maximum thrust achieved during static closure stroke($F_C$) and measured static unwedging thrust($F_{stat}$) are critical parameters determining required stem thrust at opening stroke. To prevent or improve negative operational margins for motor-operated flexible wedge gate valves evaluated via performance prediction, it is recommended in static diagnostic test to adjust the two parameters at low value by torque switch setting within the limits that do not lower operational margin at closing stroke below 0%.

## REFERENCES

[1] EPRI TR-103224, EPRI MOV Performance Prediction Program-Revison2; Performance Prediction Methodology Implementation Guide, August 1998.
[2] EPRI TR-113564, EPRI MOV Performance Prediction Program; Addendum 3 to EPRI TR-103237-R2: An Improved and Validated Gate Valve Unwedging Methodology, December 1999.
[3] EPRI MOV Performance Prediction Program; Performance Prediction Methodology(PPM) Version 3.5 User Manual and Implementation Guide, July 2011.
[4] Nuclear Safety Security Commission issue 2016-14, Regulations for in-service test of safety-related pumps and valves, July 2016.