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Validation of the valve factor from performance prediction for flexible wedge gate valves

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1. Introduction

Design basis verification of safety-related Motor-Operated Valves(MOVs) is an essential activity to ensure their operability which can be expressed in a numerical value, called operational margin. Nuclear Safety Security Commission notice 2016-14 requires that licensees verify operational margin of safety-related MOVs and operational margin shall be greater than 0%.

To verify operational margin, MOV design values are used firstly in the margin calculation. After that, static diagnostic test and dynamic diagnostic test are performed in order to measure actual values of some parameters. Valve Factor, one of the parameters, is a principal parameter for calculating operational margin and can be measured in dynamic diagnostic test. On the other hand, valve factor can be assessed by an analytical method which is used as an alternative for dynamic diagnostic test. EPRI MOV Performance Prediction Methodology (EPRI MOV PPM), a type of analysis program, is used as a representative analytical method.

This study describes validation of the valve factor of flexible wedge gate valves assessed by the EPRI MOV PPM, comparing to the valve factor measured in dynamic diagnostic test.

2. Methods and Results

2.1 Valve factor in differential pressure load

For gate valves, the differential pressure load is a friction load. Its magnitude varies with the disk positon and sliding contact surfaces. When the valve is at the fully open positon, the disk is in contact with the guide rails. The fluid load on the disk is small and the differential pressure load is insignificant. As the disk approaches the closed position, the fluid load increases rapidly and the differential pressure load typically becomes the dominant term in the required stem thrust calculation. Figure 1. shows an example of how differential pressure load acts at closing and opening strokes. The equations for the differential pressure load are as below.

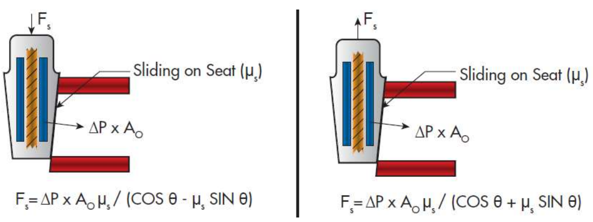

Figure 1. Differential pressure load for a gate valve

$$F_{DP,closing} = \mu_s \times \Delta P \times A_O \times \frac{1}{(\cos\theta \quad _s \sin\theta)} \tag{1}$$

$$F_{DP,opening} = \mu_s \times \Delta P \times A_O \times \frac{1}{(\cos\theta + \quad _s \sin\theta)} \tag{2}$$

where,

μ_s : Coefficient of friction between disk and seat (dimensionless)

ΔP : Differential pressure across the valve (psid)

A_O : Area on which pressure acts (in^2)

θ : Seat angle from stem axis (degree)

A key parameter in the above differential pressure force calculations is the coefficient of friction(μ_s) for the material interfaces. In dynamic diagnostic test, the differential pressure force calculations can be expressed based on valve factor(VF) as below.

$$F_{DP,closing} = \Delta P \times A_O \times VF_{closing} \tag{3}$$

$$F_{DP,opening} = \Delta P \times A_O \times VF_{opening} \tag{4}$$

where,

$$VF_{closing} = \frac{\mu_s}{(\cos\theta - \quad _s \sin\theta)} \qquad \text{(dimensionless)}$$

$$VF_{opening} = \frac{\mu_s}{(\cos\theta + \mu_s \sin\theta)} \qquad \text{(dimensionless)}$$

The equations for valve factor above show that there is a positive correlation between valve factor(VF) and disk-to-seat friction coefficient(μ_s). This means valve factor which can be measured in dynamic diagnostic test is a valid parameter for determining differential pressure load. The differential pressure load is proportional to the valve factor, so high valve factor requires great force to open or close the valve. For this reason, it is critical to measure the valve factor accurately in dynamic diagnostic test. EPRI MOV PPM, an analytical method commonly used, is an alternative for dynamic test, if dynamic diagnostic test is not practical. This program provides valve factor assessment, and it should be conservative assessment to ensure that this analytical method is appropriate as an alternative for dynamic diagnostic test.

2.2 Valve factor comparison of in-situ data and PPM result

In this study, the sample valves are 16, which are flexible wedge gate valves in nuclear power plants. The valve factors of the samples are obtained in dynamic diagnostic test of design basis verification. The sample valves have same design information in common as shown in the table 1, and valve factor the comparison of in-situ data and EPRI MOV PPM results is shown in the figure 2 and the figure 3.

Table I. Valve design information

Valve Type	Flexible wedge gate valve
Safety position	Open and close
Fluid medium	Subcooled water
Body material	Stainless steel
Disk material	Stainless steel
Stem material	Stainless steel
Control mode(open)	Limit stopped
Control mode(close)	Torque seated

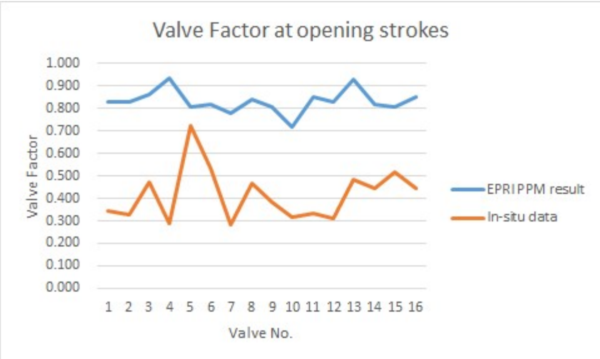

Figure 2. Valve factor at opening strokes

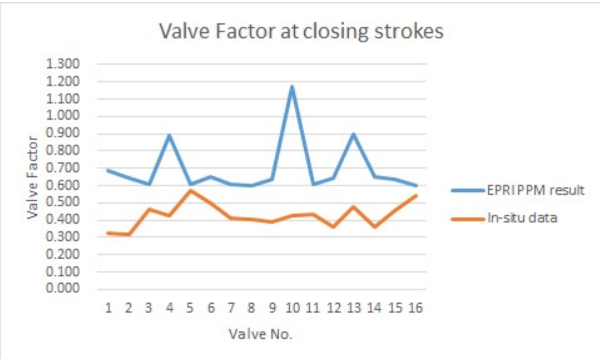

Figure 3. Valve factor at closing strokes

The figure 2 and the figure 3 show that use of EPRI MOV PPM provides bounding valve factor which covers in-situ data from dynamic diagnostic test at design basis verification for flexible wedge gate valves. The material of the sample valves is stainless steel and the fluid medium is subcooled water. Overall, the valve factor assessment by EPRI MOV PPM is quite conservative, and the degree of conservatism can be expressed by use of 'prediction ratio' which is the ratio of the in-situ data to the EPRI MOV PPM result. The average prediction ratio of sample valves is 0.50 and 0.64 at opening and closing strokes respectively. In addition, the maximum prediction ratio is 0.89 and 0.95 at opening and closing strokes respectively. The prediction ratio of every sample valve is shown in the figure 4 and the figure 5. The table 2 shows the raw data of the valve factors from the EPRI MOV PPM result and dynamic diagnostic test of the sample valves.

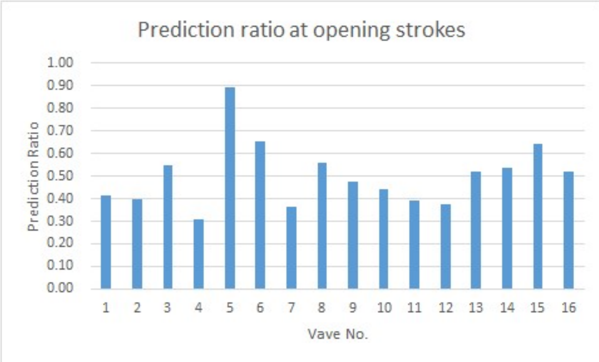

Figure 4. Prediction ratio at opening strokes

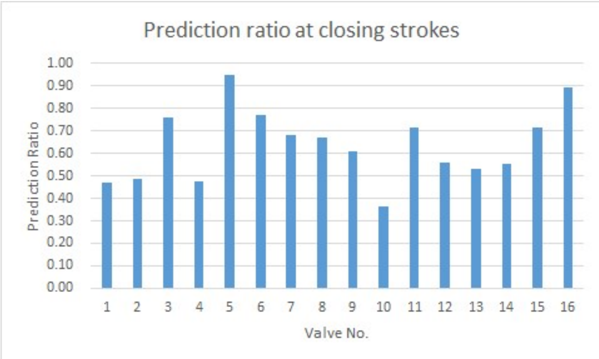

Figure 5. Prediction ratio at closing strokes

Table II. Valve factor from EPRI PPM and in-situ data

Valve No.	EPRI PPM result		In-situ data	
	VF_{open}	VF_{close}	VF_{open}	VF_{close}
Valve 1	0.828	0.684	0.3434	0.3234
Valve 2	0.828	0.646	0.3276	0.3139
Valve 3	0.861	0.609	0.4724	0.4634
Valve 4	0.935	0.892	0.2870	0.4264
Valve 5	0.809	0.604	0.7231	0.5747
Valve 6	0.820	0.651	0.5352	0.5005
Valve 7	0.782	0.608	0.2845	0.4150
Valve 8	0.840	0.603	0.4680	0.4056
Valve 9	0.805	0.639	0.3815	0.3888
Valve 10	0.718	1.176	0.3187	0.4262
Valve 11	0.854	0.604	0.3332	0.4332
Valve 12	0.828	0.646	0.3084	0.3612
Valve 13	0.932	0.894	0.4836	0.4750
Valve 14	0.820	0.651	0.4424	0.3608
Valve 15	0.805	0.639	0.5154	0.4578
Valve 16	0.854	0.603	0.4425	0.5393

3. Conclusions

This study describes the validation of the valve factor of flexible wedge gate valves assessed by the EPRI MOV PPM, comparing to the valve factor measured in dynamic diagnostic test, and it is concluded that the use of EPRI MOV PPM is appropriate to assess valve factor with enough conservatism. The degree of conservatism can be shown by prediction ratio which is the ratio of the in-situ data to the EPRI MOV PPM result. All of the sample valves have prediction ratio below 1.0, which means validation of valve factor from EPRI MOV PPM.

REFERENCES

[1] EPRI 3002008055, Evaluation guide for valve thrust and torque requirements, August 2016.
[2] EPRI TR-103224, EPRI MOV Performance Prediction Program-Revison2; Performance Prediction Methodology Implementation Guide, August 1998.
[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 notice 2016-14, Regulations for in-service test of safety-related pumps and valves, July 2016.