Transactions of the Korean Nuclear Society Autumn Meeting
Yeosu, Korea, October 25-26, 2018

Required thrust comparison of the performance prediction and the static diagnostic test for air-operated gate valves in nuclear power plants

Bong-Hwan Kim [a*], Ho Soek [a]
[a]*Integrated Safety Assessment Department, KEPCO E&C, 269 Hyeoksin-ro, Gimcheon-si, Gyeongsangbuk-do, 39660*
kbh@kepco-enc.com

1. Introduction

To ensure the design-basis operability of safety-related Air-Operated Valves (AOVs) in Nuclear Power Plants (NPPs) and meet the requirements of In-Service Testing regulation specified in Nuclear Safety Security Commission issue 2016-14, design basis performance evaluation has been performed. Design basis performance evaluation includes the methods of Design Basis Review (DBR), diagnostic test under both static and dynamic conditions, performance prediction and final operability evaluation considering DBR and test results. DBR consists of evaluation process for system design-basis analysis, required thrust/torque analysis, weak link analysis, actuator performance analysis, design basis operational margin analysis and set-point analysis [1].

The safety-related AOVs consist of gate, globe and butterfly valves. Especially, gate valves are used for isolation and initiation of flow. One advantage of the gate valve is that it can accommodate full flow without a restriction in the pipe, resulting in a low piping flow resistance (low pressure drop). Additional advantages of gage valves are that they are small in size compared to a globe valve, useful for applications where the valve is used only to shut off flow, and often cost less. Also, the operating force for a gate valve is usually less than for a globe valve. A disadvantage of gate valve is that it is not as well-suited for throttling service as a globe valve [2]. This study describes the required thrust calculation method and the required thrust comparison of the performance prediction and static diagnostic test results of gate valves.

2. Methods and Results

2.1 Required thrust calculation method

2.1.1. Total required thrust (F_O, F_C)

The total required thrust to open or close the valve disc (F_O, F_C) is the sum of four components (packing force (F_{pack}), piston effect or stem rejection load (F_P), DP thrust (F_{DP}), sealing load (F_{SL}) [3][4].

$$F_O = F_{pack} - F_P + F_{DP} \quad \text{(lbf)} \qquad (1)$$
$$F_C = F_{pack} + F_P + F_{DP} \quad \text{(lbf)} \qquad (2)$$
$$F_{pack} = \pi \times S \times D_S \times L_{pack} \times fY \quad \text{(lbf)} \qquad (3)$$
$$F_P = P_B \times A_S \quad \text{(lbf)} \qquad (4)$$
$$F_{DP} = VF \times \Delta P \times A_0 \quad \text{(lbf)} \qquad (5)$$
$$F_{SL} = (* \ 100 \sim 300) \times \pi \times B_{MS} \quad \text{(lbf)} \qquad (6)$$

* Applied according to fluid difference pressure when sealed

where,
S : diameter direction packing thrust (psi)
D_S : stem dimeter (in)
L_{pack} : packing height (in)
fY : packing friction factor (-)
P_B : bonnet pressure(psig)
A_S : stem sectional area(in^2)
VF : valve factor
ΔP : differential pressure across the valve(psid)
A_O : cross section area for differential pressure(in^2)
B_{MS} : average contact diameter of up and down seat(in^2)

2.1.2. Total static thrust(F_S)

The total static thrust required to operate the valve consists of three components (running thrust (F_{run}), piston effect thrust ($F_{P,DB}$), differential pressure thrust ($F_{DP,DB}$)) [5].

$$Opening\ static\ thrust,\ F_{SO} = F_{run} - F_{P,DB} + F_{DP,DB} \qquad (6)$$
$$Closing\ static\ thrust,\ F_{SC} = F_{run} + F_{P,DB} + F_{DP,DB} \qquad (7)$$

where,
F_{run} : running thrust (lbf)
$F_{P,DB}$: piston effect thrust (lbf)
$F_{DP,DB}$: differential pressure thrust (lbf)

2.2 Performance prediction

As part of the EPRI Air-Operated Valve (AOV) Performance Prediction Program (PPP), state-of-the-art engineering methodologies (Performance Prediction Methodology, PPM) were developed to predict the thrust or torque required to operate gate, globe and butterfly valves installed in safety-related service in NPPs [6]. To run a thrust prediction, the information is needed in basic categories. The used information is specified below.

Table 1. Design basis information

Item	WI-V012	WI-V013
Safety direction	Close	Close
Valve type	Gate	Gate
Valve size (in)	12	12
System method	ERM	ERM
DP (psid)	78.3	78.3

Fluid medium	Water	Water
Flow rate (gpm)	2474	2474
Valve function	PCW Return VV	PCW Supply VV

*ERM : Equivalent resistance method

Table 2. Internal design information

Item	WI-V012	WI-V013
Disk overall	Flexible wedge	
Disk seat edge type	Chamfer w/o broken edge	
Disk guide surface material	Carbon steel	
Disk guide BT edge type	Corner w/o broken edge	
Body guide configuration	Integral rail	
Body guide surface material	Carbon steel	
Body guide end	End exists	
Friction conditions	Steel-on-steel	

2.3 Required thrust comparison of the static diagnostic test results and the performance prediction results

2.3.1. Static diagnostic test results (Min. Margin)

Static diagnostic tests of the air-operated gate valves were performed in NPPs. Using the result of static diagnostic test, performance prediction was implemented. Among that results, Table 3 shows the static diagnostic test results. The piston effect thrust and differential pressure thrust were measured the same value respectively. On the other hand, the running thrust (packing thrust), each number differently was measured and affected the static diagnostic test margins. As a result, the static diagnostic test margins secured sufficiently positive margins.

Table 3. Evaluation result (using Static Diagnostic Test)

Item	WI-V012	WI-V013
F_{run}	488.1	669.7
$F_{P,DB}$	191.0	191.0
$F_{DP,DB}$	2554.1	2554.1
$F_{R,O}$	2851.2	3032.8
$F_{R,C}$	3233.2	3414.8
Min. M_S(%)	20.7%	15.0%

2.3.2. Performance prediction results (Min. Margin)

Performance prediction of the gate air-operated valves also was performed. Performance prediction was carried out as an alternative to the dynamic diagnostic test. Because it is often impossible to form flow and differential pressure (dynamic diagnostic test condition) at the site. Performance prediction methodologies can eliminate unnecessary valve modification and provide an alternative to expensive dynamic diagnostic test as a means of demonstrating air-operated valves operability (Min. Margin). The results show that margin of performance prediction was bigger than static diagnostic test margin. It means that design basis performance prediction evaluation of the air-operated gate valve is assessed conservatively.

Table 4. Evaluation result (using PPM)

Item	WI-V012	WI-V013
F_{pack}	488.1	669.7
F_P	190.7	190.7
F_{DP}	1845.2	1845.2
F_C	2524.0	2705.6
Min. M_P	54.2%	44.8%

3. Conclusions

This study describes the comparison with performance prediction results and static diagnostic test results of the air-operated gate valves. The results of performance prediction methodology have been compared with static diagnostic test results for air-operated gate valves in NPPs. With the review of static diagnostic test data and performance prediction methodology results, it is concluded that the performance prediction methodology is conservative to predict a required thrust of the air-operated gate valves.
Performance prediction methodology is a sufficiently conservative and safe method, since performance prediction was evaluated in previous studies in a more conservative method than dynamic diagnostic test result and this time more conservative than static diagnostic test results.

REFERENCES

[1] Byoung Eui Lee, Sun Dong Shin, Woo Bang Lee, Performance Evaluation Technology for Air Operated Valves in NPPs, Korean Nuclear Society Spring Meeting, May 10~11, 2007.
[2] EPRI 1022646, Nuclear Maintenance Applications Center ; Air-Operated Valve Evaluation Guide – Revision 1, August 2011.
[3] Air-Operated Valve Design Basis Performance Evaluation Guideline (Standard Guideline-9043-26), AOV Thrust and/or Torque Analysis, KHNP.
[4] Air-Operated Valve Design Basis Performance Evaluation Guideline (Standard Guideline-9043-33), AOV Performance Prediction (PPM), KHNP.
[5] Air-Operated Valve Design Basis Performance Evaluation Guideline (Standard Guideline-9043-34), AOV Static Diagnostic Test, KHNP.
[6] KVAP User's Manual ; Document No. 2099C - Revision 4, October 2005, Kalsi Engineering Inc.
[7] EPRI MOV Performance Prediction Program ; Addendum 2 to EPRI TR-103237-R2 : Thrust Uncertainty Method, Revision 1, November 2002.
[8] EPRI MOV Performance Prediction Program ; Performance Prediction Methodology(PPM) Version 3.5 User Manual and Implementation Guide, July 2011.