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Evaluation of Effective Diaphragm Area for Pneumatic Actuator

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1. Introduction

Nuclear power plant has been installed in various types of pneumatic actuators. For the pneumatic actuator which is driven with air, depending on the type of air pressure acting portion is classified as diaphragm type actuator and cylinder type actuator. In the case of domestic nuclear power plants, about 40% of pneumatic actuators are occupied by the diaphragm actuator.

Currently, the performance assessment for the operability and structural integrity of air operated valves for the domestic nuclear power plant is in progress. One of the important parameters that determine the performance of the air operated valves is the effective diaphragm area of diaphragm type actuator. The effective diaphragm area is the actual area which the air pressure acting on the diaphragm. In general, the effective diaphragm area used for the performance evaluation of pneumatic actuator is provided by the manufacture or the actuator drawing. However, effective diaphragm area appears a difference between the actually measured field test results and provided manufacture's value[1,3].

Therefore, the purpose of this study is to develop a methodology to calculate the exact effective diaphragm area using the results of diagnostic test to be performed in the evaluation of air operated valve performance. By using this developed methodology in pneumatic actuator performance evaluation, it can be reduce the possible errors arising from effective diaphragm area in the evaluation of performance of air operated valves.

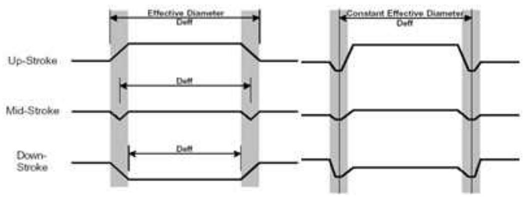
2. Methods and Results

We developed the evaluation methodology for Effective Diaphragm Area (EDA) of pneumatic actuator with diagnostic test results of safety related valve in nuclear power plants. By using this developed methodology, we carried out the assessment for the performance of pneumatic actuator.

2.1 Experimental Method

Diagnostic test results of convoluted type and flat type diaphragm as representative type diaphragm were selected to the analysis.

Fig.1 is a figure that shows the effective diaphragm area (EDA) in accordance with the shape and the position of the diaphragm, and shown that the EDA vary according to the actuator stroke. EDA change according to the actuator stroke is caused by various reasons, in particular geometrical shape change of the diaphragm according to the actuator stem to move influences the changes in EDA.



Flat type Convoluted type

Fig.1. Effective Diaphragm Area(EDA) of diaphragm

Theoretical methodology for calculating the EDA is already known, but the best way to determine the exact EDA is to measure the actual EDA through testing of the actuator. EDA of flat type diaphragm varies depending on location of stroke. In foreign studies on changes in EDA of flat type diaphragm, EDA has been found that there are differences of up to 20 percent[1,2]. On the other hand, the EDA of convoluted type diaphragm appeared to be constant throughout the entire stroke.

Fig.2 is a configuration of diagnostic test system for air operated valve, strain gage was attached on the actuator stem in order to measure the forces acting on the stem, a pressure gauge was installed on the actuator to measure the supply pressure to be injected into the actuator. EDA at fully extended stem position is calculated by measuring the change in force and the air pressure acting on the actuator stem while changing the supply pressure in a state in which the stem is fixed

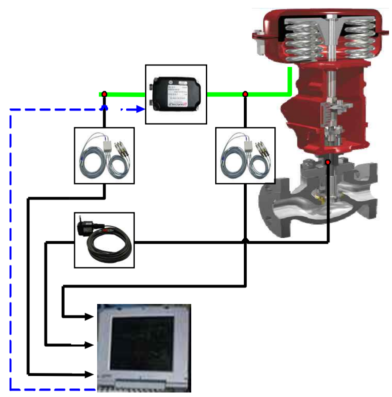


Fig.2. Diagram of diagnostic system

$$EDA = \frac{\Delta F[lbs]}{\Delta P[psi]}[in^2] \tag{1}$$

ΔP : ΔP of diaphragm pressure[psi]

ΔF : ΔF of stem Thrust [lbs]

In the same way, EDA at fully retracted stem position is calculated by using the formula (1) in an actuator stem is fully drawn, and actuator stem is fixed.

2.2 Results

The diagnostic test results of five different sizes flat single diaphragm type actuators and two convoluted diaphragm type actuators were analyzed to EDA analysis.

As shown Table I, the flat type diaphragm shows the difference between the measured average EDA and manufacturer's value of approximately 12%, for a D type it has shown up to a 15% difference. Fig.3 shown that EDA is varying with stroke position, EDA is the maximum when fully retracted, and it can be seen that it has a minimum value at full extended.

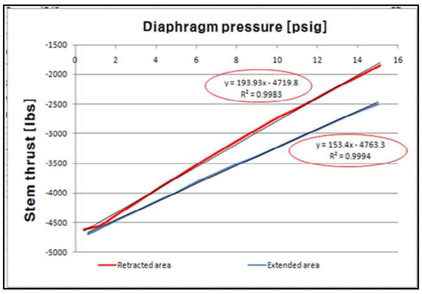


Fig.3. Analysis of flat type EDA (Type C)

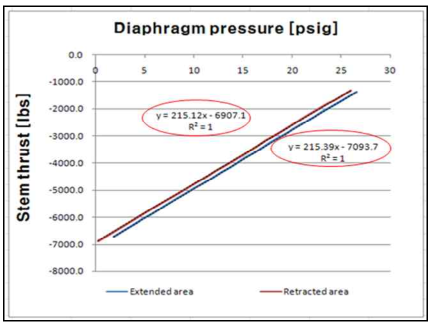


Fig.4. Analysis of convoluted type EDA (Type G)

As shown Table II, the convoluted type diaphragm shows the difference between the measured average EDA and manufacturer's value a relatively small difference of less than 3%. As shown in Fig.4, the EDA showed that almost no change depending on the stroke position.

Table III is the results of comparison with this study and bench mark in order to verify the validity of EDA calculation methodology developed in this study. result to accurately mount the Load cell perform EDA measurement test for the same diaphragm in order to verify the validity of EDA calculation methodology developed in this study and results. The benchmark is the result of precisely measured EDA by mounting load cell for the same diaphragm. Both test results showing a difference with manufacturer's value, but two test results show almost the same results.

Table I: Results of Flat type EDA

Type	EDA [in^2]		EDA Deviation [%]	Manufacture / Measured [%]
	Manufacture	Measured value		
A	22.5	19.9	-11.3	88.7
B	140	125.7	-10.2	89.8
C	200	173.6	-13.2	86.8
D	220	186.8	-15.1	84.9
E	478.6	440.0	-8.1	91.9

Table II: Results of Convoluted type EDA

Type	EDA [in^2]		EDA Deviation [%]	Manufacture / Measured [%]
	Manufacture	Measured value		
F	100	101.2	+1.3	101.3
G	160	167.1	+4.4	104.4

Table III: Comparison with Benchmark results

Type	EDA [in^2]		
	Manufacture	Extended	Retracted
E	478.63	428.6	450.02
Benchmark		429.4	451.17

3. Conclusions

Flat type diaphragm was showed the difference between the measured value of EDA and the manufacture's value, in the case of convoluted type diaphragm has showed that the measured value of EDA and manufacture's value is almost the same. When evaluate a performance of a diaphragm actuator, accurate EDA is to be used because it is an important variable affecting the actuator performance.

Particularly in the case of flat type diaphragm which EDA is changed in accordance with the stroke position, by using the EDA evaluation methodology developed in this study to minimize a possible error due to EDA when evaluating the performance of the air actuator, it will be more reliable for the assessment of pneumatic actuator.

REFERENCES

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