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# Analyses of Turbulence Induced Vibration on Trim Shape of Control Valve with High Pressure Drop

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## 1. Introduction

Control valves play a critical role in the regulation of fluid flow and pressure management within nuclear power plant systems, where significant temperature and pressure gradients are present. These valves ensure the stable and efficient operation of the plant by maintaining optimal pressure conditions, mitigating potential risks associated with excessive temperature and pressure fluctuations. Abrupt pressure fluctuations can induce phase transitions, which consequently result in cavitation, flashing, elevated vibration, and noise generation. These phenomena have the potential to compromise the overall safety and structural integrity of the power plant, necessitating careful monitoring and control mechanisms to mitigate risks. In order to progressively attenuate the internal flow energy within a valve system, a trim is employed as a vital component that facilitates the necessary pressure regulation and energy dissipation. In the contest of the domestic industry, there exists a monopolistic provision of this technology by international manufacturers, there is a need for technological self-reliance in the field of control valves. In this study, to simulate high-pressure fluid flow using CFD(Computational Fluid Dynamics) and quantitatively assess vibrations occurring within the trim by employing the FFT(Fast Fourier Transform) method. Additionally, the study conducted a comparative analysis of the performance between existing foreign products and a trim under development using PSD(Power Spectrum Density).

## 2. Analyses models and methods

### *2.1 Analyses models*

The analyses have been carried out fluid dynamic and performance analysis on two types of trims: a newly developed one and an existing one, as shown in Fig 1. The existing trim is a labyrinth type horizontal flow design and undergoes a sequential depressurization as the fluid direction changes and the flow area expands. The newly developed model has been designed to achieve comparable or superior performance to the existing model by adding a 3D flow path and an inlet resistance, in addition to the existing model's features. To investigate the flow characteristics of the internal trim of a control valve, an analysis model was developed at a fully open position with 100% opening. To ensure the development of the flow in the inlet and outlet areas of the control valve, the models were created with a pipe length of 10 times the diameter of the pipe from analysis target flange.

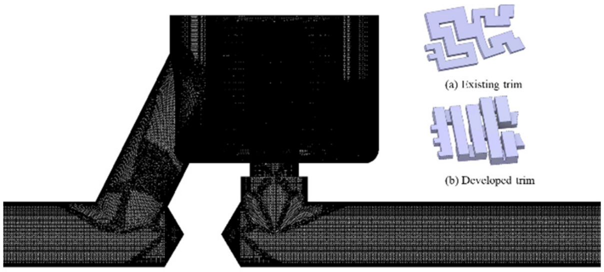


Fig. 1. Analyses models

### *2.2 Analyses methods*

In order to validate the accuracy of the analysis methodology, performance test was carried out according to the guidelines and conditions of ISA 75.02[1] as Fig 2. The experimental and analytical flow coefficient were compared using equation (1) from ISA 75.01[2].

$$C = \frac{Q}{N}\sqrt{\frac{\rho_1/\rho_2}{\Delta P}} \quad (1)$$

where $C$ is flow coefficient. $N$ and $Q$ are numerical constants and volumetric flow rate. $\rho_1/\rho_2$ and $\Delta P$ are relative density and differential pressure between upstream and downstream pressure.

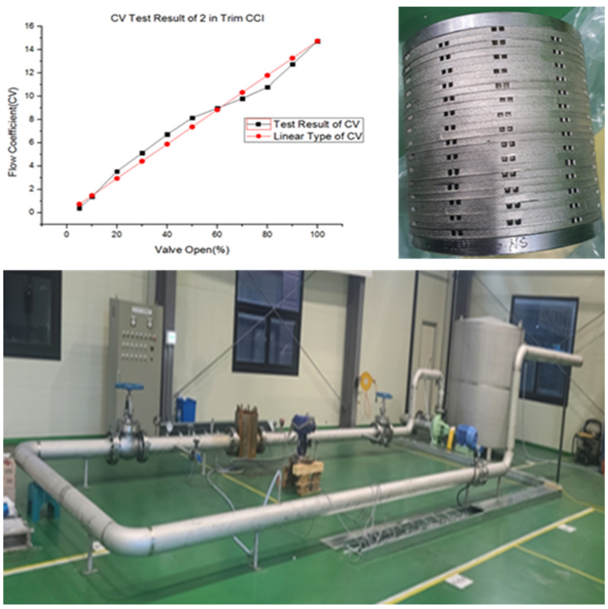


Fig. 2. Flow coefficient test and result

To compare the performance of the models under high-pressure drop conditions, boundary conditions were applied 72.4 bar at the inlet and 14.4 bar at the outlet. The wall grid was developed with five layers hexahedral cells to achieve an average y+ value of 30-50. To generate vibration data in the frequency domain according to the internal flow, the study was calculated the PSD through FFT. In order to perform FFT analysis, pressure fluctuations were obtained using time history analysis. Detached eddy simulation model was employed as the turbulence model, and initial conditions were derived from steady-state results. The time step was set at 0.01 seconds, considering future eigenfrequency analysis outcomes.

## 3. Analyses results

*3.1 CFD analysis results*

Fig 3 presents the outcomes derived from a CFD analysis. The graphical representation effectively illustrates the pressure reduction performance in correlation to the fluid travel distance. Notably, an initial pressure of approximately 72 bar is observed at the trim inlet; this value progressively diminishes owing to the fluid resistance encountered. In contrast to the conventional trim, which reduces pressure to 21 bar, the newly developed trim demonstrates a superior pressure reduction capacity, decreasing pressure to a mere 15 bar.

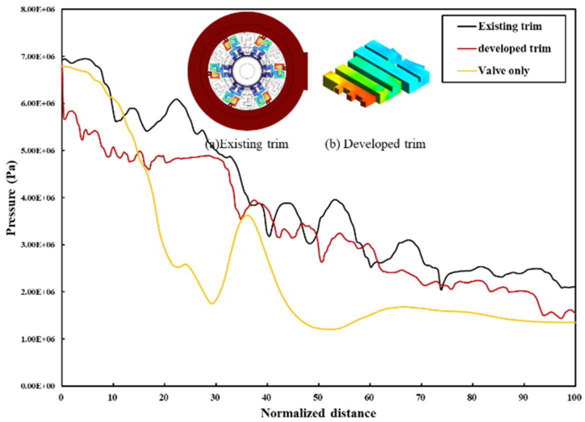


Fig. 3. CFD analysis results

*3.2 FFT analysis results*

Fig 4 portrays the transformation of fluid velocity into the frequency domain, contingent upon the time history. Within the low frequency spectrum, analogous vibration characteristics are discernible.

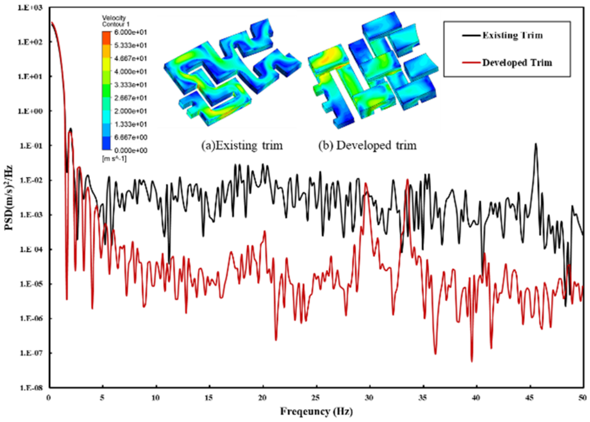


Fig. 4. FFT analysis results

However, in frequency ranges exceeding 10 Hz, a noteworthy observation emerges: the newly developed trim exhibits diminished vibration values when compared to its conventional counterpart. Previously, vibrations were assessed according to the energy level in relation to the trim exit velocity, but no internal trim vibration criteria were established. A comparison and analysis of energy fluctuations and analytical data is panned.

## 4. Conclusions

Through a comprehensive flow coefficient analysis, the performance of the innovative trim design was meticulously evaluated. In an effort to examine and compare the internal vibration phenomena within the trim, PSD values were utilized as a crucial comparative matric. The assessment results indicate that the developed trim exhibits a performance and structural integrity either equivalent to or surpassing that of the conventional trim designs.

## REFERENCES

[1] ANSI/ISA, Flow Equation Capacity Test Procedure, ISA 75-02, 1996.
[2] ANSI/ISA, Flow Equation for Sizing Control Valves, ISA 75-01, 2007.