Experimental and Analytical Study on the Lift Check Valve

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1. Introduction

In general, the check valve mounted on the flow line is used for the purpose of protecting the pump and the related facility, making the flow path, and maintaining the pressure boundary during the operation mode change in steam power plant and nuclear power plant. Fig. 1 shows the example of check valve in nuclear power plant. Especially, the check valve mounted on safety feed system and nuclear safety system is operated to open state and has a role of acquiring enough fluid such as safety feed and auxiliary feed water in the Design Basis Accident. And the check valve is operated with enough sealing and with protecting steam hammer in normal operational mode [1,2].

For this purpose, the check valve can be open easily and be maintained in the open state in case of small flow velocity. In this research, the experimental and analytical study on the check vale was performed. The flow coefficient and closure time were compared between the experimental and the analytical result by numerical simulation. The validation of the analytical method was performed.

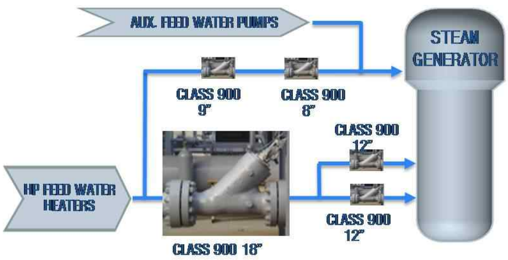

Fig. 1. Check valve mounted on the line in nuclear power plant

2. Methods and Results

In this research, the analysis and the experiment was performed for the lift check valve. And the validation was made with the result of the analysis on the same model in which the experiment was performed.

2.1 Experimental Apparatus and Method

The Fig. 2 shows the experimental apparatus which was made to study the characteristic of the valve.

In the Fig. 2, the apparatus was composed of the serge tank, test check valve, pipe line, pool, rupture disk, various measurement system, personal computer for the data storage of the measured signal, and so on.

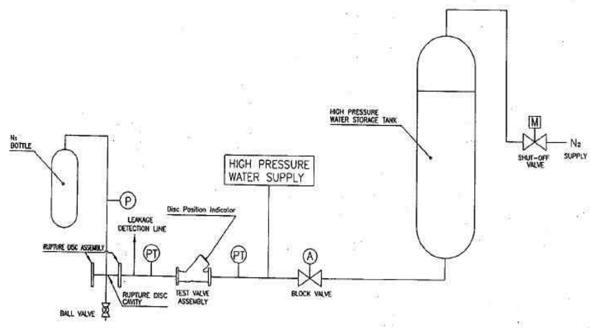

Fig. 2. Schematic of test system at reverse flow

After the test valve was mounted on the pipe line, the air was inserted between two rupture disks with the 70% pressure value to the fracture pressure of rupture disk. And the nitrogen gas was inserted in the water reservoir to make the high pressure with the value 26 kg/m^3. In this situation, the water was full in the pipe line between the water reservoir and the first rupture disk. The pressure at the midpoint of two rupture disks was used to prevent from flowing between the rupture disks and the water reservoir and rupturing of the disks. After the removing of the pressure at the midpoint of two rupture disks, the reverse flow was made in the test valve and the rupture disk was destructed. In this time, the pressure difference and the surge pressure, and the peak pressure were measured at the test valve. And the displacement of the valve disk was measured to know the closure time.

2.2 Numerical Analysis Method

The two dimensional incompressible steady flow analysis with the Raynolds-Averaged Navier-Stokes equation and continuity equation was performed using Fluent 6.0[3]. The turbulent model was k-e model with wall function and the structured grid was used. The Fig. 3 shows the computational range and mesh[4].

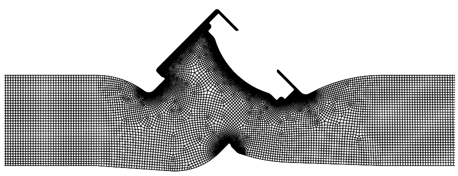

Fig. 3.Computatinal meshes inside valve

The length of pipe line connected to the valve was 10 times to the diameter of valve for the analysis of the fully developed flow pattern. The analysis was performed on six valve disk position with the inlet boundary condition of 10m/sec and the outlet boundary condition of ambient pressure.

2.2.1 flow coefficient

Generally the flow coefficient of the valve, Cv, is used to specify the valve characteristics. The flow coefficient is used to compare flow capacities of valves at different sizes, types and manufacturers. The flow coefficient is in general determined experimentally and express the flow capacity in imperial units - GPM (US gallons per minute) of water with temperature of 60 ^{o}F(16 ^{o}C) that a valve will pass for a pressure drop of 1 lb/in^2 (psi)[5].

$$C_v = Q\sqrt{\frac{\rho}{\Delta P \rho_0}}$$

In this research, the analysis of flow coefficient was performed on the valve whose flow coefficient is 1606 by the experiment. The value of flow coefficient by the analysis was 1569. This analysis was in the error range of 5 %. This result showed that the analysis was good agreement to the experiment.

2.2.2 Closure Time

In the nuclear power plant and steam power plant, the stop of pump makes the fluid around pump flow into the serge tank and the stored fluid in the serge tank flow into the pump in reverse. In this case, the check valve acts a role of protection of the pipe line and the pump. The closure time is the needed time during which the disk position of the check valve is changed from the open state to the close state. The closure time is important parameter which affects the degree of the reverse flow and the surge pressure.

Fig. 4 shows the valve disk position with respect to time when the pressure at the midpoint on two rupture disk was removed and the reverse flow make the valve disk position varied. From the Fig. 4, the closure time was 0.8912 seconds.

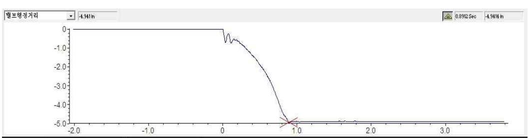

Fig. 4. Valve disk position during the reverse flow

Fig. 5 and Fig. 6 were the velocity profile and streamline from the analysis when the reverse flow was occurred. When the valve disk is closed, the fluid at the outlet flows into the inlet. And the high pressure and the fast fluid flow occurred in the valve. The analytical closure time was 0.9185 seconds using the in-house code and the pressure difference from the flow analysis. The 3% error of close time between the experiment and the analysis is acceptable to the valve designer.

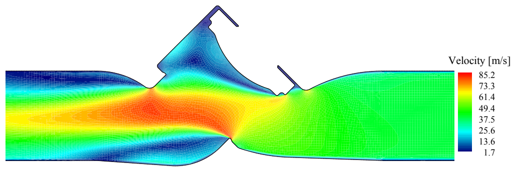

Fig. 5.Velocity contour within the valve operating at supply velocity 10m/sec

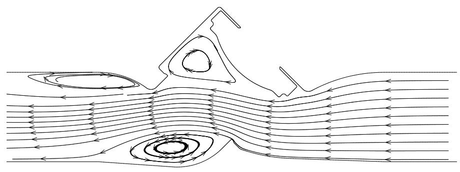

Fig. 6.Streamline inside valve

The comparison between the experiment and the analysis shows that the prediction of the closure time, flow coefficient, and pressure difference by the analysis is proper to the valve design.

3. Conclusions

The experimental study on the closing motion of check valve's disk and the pressure difference in the valve were investigated in this research. The result of experiment was compared to the analytical result by numerical simulation within the error's range of 5%. From the comparison of the analytic result to the experimental result, the analysis by numerical simulation was validated. So this analytical method can be used in the design of the check valve or the similar valve and in the prediction of the related physical value such as pressure and velocity in the valve.

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