Investigation on the Degradation Mechanism of Pressure Reducing Orifice of Nuclear Power Plant

Sun-ki Lee, a Sang-guk Lee, a Sung-gun Park, a

a Korea Electric Power Research Institute (KEPRI),

sunlee@kepri.re.kr

1. Introduction

During the nuclear power plant periodical inspection, crack was detected at the pressure reducing orifice down stream in the Chemical & Volume Control System (CVCS). Damage is serious at the orifice outlet (Fig. 2). This Paper examined the degradation mechanism of reduce pressure orifice of CVCS by the measuring vibration and frequency analysis, internal flow pattern analysis. Results show that the degradation of the pressure reducing orifice was caused cavitation, and suggest design improvement plan for damage prevention.

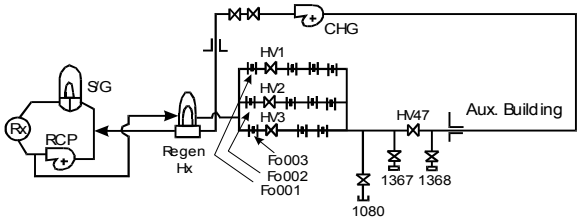

Fig. 1 CVCS letdown system in nuclear power plant

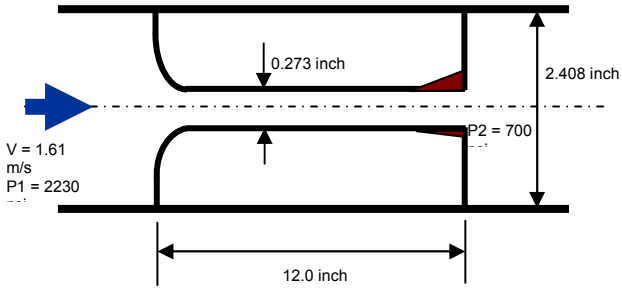

Fig. 2 Degradation outline of orifice

2. Degradation Mechanism

2.1 Vibration Measurement

Vibration measurements were carried out at the CVCS. Results of measurement show table 1 and fig. 3. Vibration was serious in orifice region comparing with heat exchange and main piping region. It means that the vibration source is orifice region. In frequency analysis (Fig. 3), dominate frequency component is not appearing and a lot of peak component are distributed in high frequency area (more than 1000Hz). It means that vibration in CVCS is not caused by resonance of structure but problem of flow itself.

Table 1 Results of vibration measurement

(x, z : vertical y : axis)

Measuring Position	Mode_Fo 003			Mode_ Fo 001 + Fo 002		
	x	y	z	x	y	z
Re Gen Hx	7.0g	10.3g				
Fo 003 Leading Edge	53.7g	46.5g				
Fo 003	33.9g	27.7g		0.72g		
V 1080	37.2g	47.3g			0.21g	0.28g
HV 3 Trailing Edge		50.9g	56.4g			1.01g
Main Piping		5.6g	5.4g			

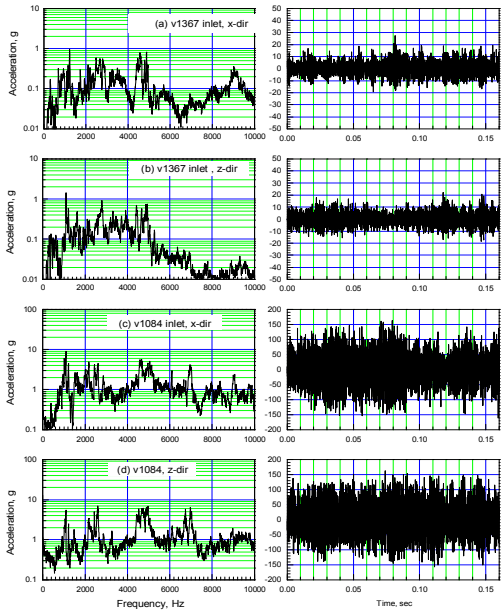

Fig. 3 Results of frequency analysis

2.2 Degradation Mechanism

Degradation mechanisms of pressure reducing orifice are following 3 cases.

(1) Resonance of vortex shedding

Vortex occurred by sudden area extension of orifice outlet and pressure pulsation of fluid by vortex shedding frequency cause resonance. The dominant frequency range of vortex shedding is low frequency area. In this case, is judged that is not thing by vortex shedding because as appear to figure 3, dominant frequency has not been clear and was distributed for more than 1000Hz that peak is high frequency area.

(2) Shock wave problem

Excessive reducing pressure by orifice causes shock wave and damage of structure and vibration. In this case, reducing pressure ratio (P1/P2, inlet pressure / outlet pressure) that shock wave occurs was known as more than about 10. In this case, shock wave does not occur because the reducing pressure ratio is about 3.2 (2230psi/700psi).

(3) Cavitation

In cylindrical type orifice without rounding shape in inlet, separation and cavitation occur at the leading edge. But with rounding shape in inlet, cavitations occur at the trailing edge of orifice and collapses in place that pressure is high. This time, very high pressure wave is occurred. That is, pressure wave by incidence-collapse of cavitation causes damage (erosion) of orifice and vibration of structure and noise. Occurrence-growth-collapse of cavitation is a high speed phenomenon (more than 1000Hz) and peak of frequency does in high frequency range [1].

2.3 Flow analysis

Fig. 4 shows the results of flow analysis using FLUENT code. In Fig. 5(2), orifice inlet region with rounding shape is doing steady state flow condition but orifice outlet region is doing unstable flow condition witch vortex occur and size changes according to time changes. In Fig. 5(3), low pressure region is appeared at orifice outlet and cavitation is occurred.

Fig. 6 shows the stream function distribution in case of with rounding at orifice outlet. Compare with Fig. 5, flow condition at the orifice outlet is stable. It seems that the orifice outlet with rounding shape is valid in design improvement of the cavitation problem.

(1) Modeling

(2) Stream function

(3) Static pressure distribution

Fig. 4 Results of flow analysis

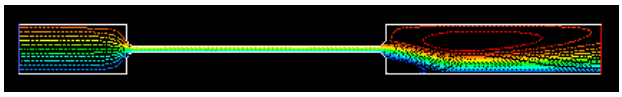

Fig. 5 Stream function (rounding)

3. Conclusion

During the nuclear power plant periodical inspection, crack was detected at the pressure reducing orifice down stream in the CVCS (Chemical & Volume Control System). This Paper examined the degradation mechanism of reduce pressure orifice of CVCS by the measuring vibration and frequency analysis, internal flow pattern analysis.

(1) Pressure wave by occurrence-collapse of cavitation causes damage (erosion) of orifice and vibration of structure and noise

(2) Orifice outlet with rounding shape is valid in design improvement of the cavitation problem

REFERENCES

[1] Kato, 1990, “Cavitaion”.

[2] FLUENT Code, Ver 6.0.12, 1998.