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Fluid Induced Vibration Analysis of a Cooling Water Pipeline for the HANARO CNS

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1. Introduction

CNS is the initial of Cold Neutron Source and the CNS facility system consists of hydrogen, a vacuum, a gas blanketing, a helium refrigeration and a cooling water supply system. Out of these subsystems, the helium refrigeration system has the function of removal of heat from a thermal neutron under reactor operation. Therefore, HRS (helium refrigeration system) must be under normal operation for the production of cold neutron. HRS is mainly made up of a helium compressor and a coldbox. This equipment is in need of cooling water to get rid of heat generation under stable operation and a cooling water system is essential to maintain the normal operation of a helium compressor and a coldbox.

The main problem for the cooling water system is the vibration issue in the middle of operation due to a water flow in a pipeline. In order to suppress the vibration problem for a pipeline, the characteristics of a pipeline and fluid flow must be analyzed in detail. In this paper, fluid induced vibration of a cooling water pipe is analyzed numerically and the stability of the cooling water pipeline is investigated by using pipe dynamic theory.

2. System Analysis

In order to analyze the fluid induced vibration of the cooling water pipeline, detail equations of motion by considering coupled characteristics between pipeline and fluid flow must be derived. These procedures are as follows. First, the infinitesimal element of the pipeline and fluid is taken as the control volume. Secondly, applying Newton's 2nd law to the infinitesimal pipeline element and momentum equations to the fluid control volume, 5 equations of motion can be derived regarding two dimensional systems. Finally, substituting velocity, force and the coefficient of friction to the derived equations and manipulating these equations, the final forms of equations of motion are as follows

$$M_u \ddot{U} + K_u U = F_u \qquad (1)$$

$$M_w \ddot{w} + C_w \dot{w} + K_w w = 0 \qquad (2)$$

$$C_p \dot{P}_d = F_p \qquad (3)$$

$$C_c \dot{C}_d = F_c \qquad (4)$$

Here, equation (1) is the horizontal equation containing 2nd derivative of a horizontal acceleration. M_u, K_u and F_u are the mass, stiffness matrix and force vectors respectively. Equations (2), (3) and (4) are the vertical, pressure and continuity equations. If the fluid velocity and pressure of the pipeline are almost constant, equations (3) and (4) can be eliminated. Generally, a natural frequency of the horizontal motion is greater than that of a vertical motion and the coupled effect between equations (1) and (2) is not serious. Therefore, equation (2) can be solved independently.

Actual system of the cooling water supply system is as shown in Fig. 1.

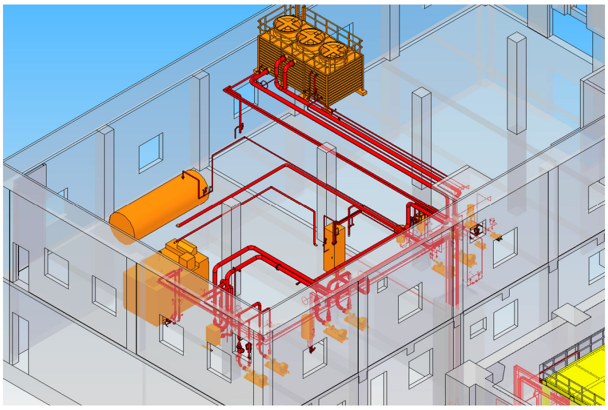

Figure 1. The cooling water supply system

By using the derived equation (2), in the case of choosing a suitable part to express a simple beam system the analysis of a fluid induced vibration for this cooling water system is possible.

3. Test Method and Results

3.1 system characteristics

Chosen pipeline is the portion of connection line between a helium compressor and a heat exchanger. Normally fluid velocity of the pipeline is 1.5~2 m/s. The material of the pipeline is SUS 316 and diameter of 4 inches and the fluid is water at normal temperature and pressure (300K, 1 atm). Fluid induced vibration is simulated regarding a velocity of 1, 2, 5 m/s respectively. For the initial condition, initial displacement in the center of the pipeline is imposed downward (10mm).

3.2 Calculation Results

Fig. 2 is the graph of the position, velocity and acceleration for the fluid velocity of 2 m/s. the results for velocity of 1, 5m/s are similar to that of Fig. 2. As shown in Fig. 2, the amplitude of the vibration trend is constant due to the constant fluid velocity and material characteristics

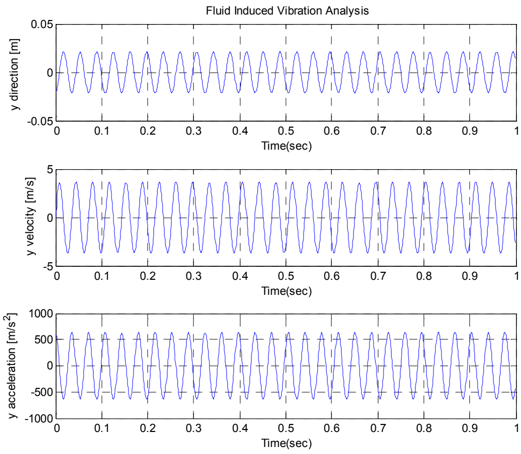

Figure 2. Fluid induced vibration graph of the pipeline

Here, the most significant point is to analyze the divergence and flutter. This phenomenon occurs in the case when the system frequency and fluid velocity are equal. This value can be solved by equation (5).

$$C_{1,2} = \sqrt{\frac{1}{m_w} EI_p \left(\frac{n\pi}{2}\right)^2} \qquad n=1,2 \qquad (5)$$

Here, m_w is the mass per unit length for the water and EI_p is the flexible rigidity of the pipeline. $C_{1,2}$ is the divergence and flutter velocity of the fluid. Through by using this equation, the calculated values of the divergence and flutter velocity are 193.84, 387.68m/s respectively

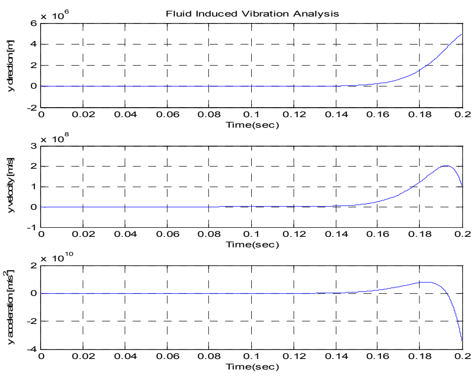

Figure 3. Divergence graph of the pipeline (193.84m/s)

Fig.3 shows the fluid induced vibration graph in the case when the fluid velocity is 193.84 m/s. As shown in Fig.3, the displacement increases as time passes. Finally, the fracture of the pipeline can occur but this value is beyond the operating region speed of the fluid. Therefore, it is confirmed that a divergence and flutter doesn't occur.

4. Conclusions

In this paper, a fluid induced vibration for the cooling water supply system in the HANARO CNS is analyzed by using pipe dynamics theory. The modified equations are derived by considering an infinitesimal element and control volume and applying a suitable mode functions. As a result, in the case when the velocity is constant under operation of the cooling system vibration trend remains constant regarding time. The results for the different fluid velocities (1, 2,5m/s) are similar. Finally, the velocities of the divergence and flutter are greater than the normal operating values of the fluid velocity. Therefore, these influences don't occur in this system.

Acknowledgements

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REFERENCES

[1] Lee, U. S., Kim, J. H., 1995, "Internal Flow-Induced Vibration of a Series Pipeline," Journal of Mechanical Engineering Science" Vol. 19, No 12, pp. 3230~3240.
[2] B. S. Kim, et al. Fundamental Design of Systems and Facilities for Cold Neutron Source in the HANARO, KAERI/TR-3126/2006 pp.15-17, 2006.
[3] Park, C.H., Lee, U. S., Hong, S. C., Kim, T. R., 1991, "Stability Analysis of Piping System Conveying Unsteady Flow," Journal of Mechanical Engineering Science" Vol. 15, No 5, pp. 1512~1521.
[4] Daniel J. Inman, 1996, "Engineering Vibration," Prentice Hall, pp. 304~336.
[5] J.N. Reddy, 1993, "Finite Element Method", McGraw-Hill, pp. 18~58.
[6] Kim, H. R, Basic Design of the Cold Neutron Research Facility in HANARO, KAERI/TR-3051/2005, pp87-118, 2005.
[7] Ashley, H. and Haviland, G., 1950, "Bending Vibrations of a Pipeline Containing Flowing Fluid," Journal of Applied Mechanics, Vol. 72, pp.229~232.