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Influence on Accuracy of Flow Rate under Position of Orifice Flowmeter using Numerical Analysis

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1. Introduction

The calculation of fluid flow rate by measuring the pressure difference across a pipe restriction is perhaps the most commonly used flow measurement technique in industrial application including the nuclear field. Because of the availability for all pipe sizes and the cost effectiveness for measuring flow rate in larger pipes (over 6” diameter), the orifice flowmeter is widely used in the nuclear power plant. These kinds of orifice flowmeter shall be installed in the pipeline at a position such that the flow conditions immediately upstream sufficiently approach those of a fully developed profile and are free from swirl.

The industrial code such as ASME PTC 19.5 ([1],[2]) gives guidelines for installation requirements of these kinds of flowmeter. However, compared with the 1972 edition of ASME PTC 19.5, the 2004 edition is more strict in the standards for recommended straight lengths of orifice flowmeter. For example, in the 1972 edition, 16D (16 times the diameter of the pipe) is needed to make a fully developed upstream flow for the case of two or more bends in the same plane, but 36D is suggested in the 2004 edition. However, it’s not always easy to conclude which of edition is correct and is suitable for applied system.

In the present study, the flow characteristics of the orifice in the auxiliary feedwater system (AFWS) were investigated by changing the upstream and downstream length of the orifice, and each edition of ASME PTC 19.5 was compared.

2. Methods and Results

2.1 Orifice in Auxiliary Feedwater System

AFWS in the nuclear power plant is a safety related system that maintains an inventory in the secondary side of the steam generators to ensure a heat sink for the removal of reactor decay heat. Thus, the proper operation of AFWS is critical for the prevention of core melt in the pressurized water reactors, and maintaining the performance of auxiliary feedwater pumps is important. [3] For this reason, there is a recirculation line in AFWS for testing and verifying a performance of the auxiliary feedwater pumps, and measuring a flow rate by using the orifice flowmeter. The simple geometry for the recirculation line and orifice flowmeter in AFWS is illustrated in Fig. 1.

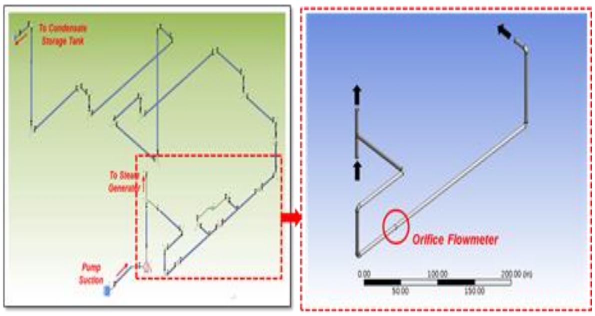

Fig. 1 Isometric view of a recirculation line in AFWS (left) and installed position of orifice flowmeter

2.2 Selection of Turbulence Model and Near Wall Treatment

Fluent v6.2, one of commercial CFD code, was used to analyze flow characteristics of the orifice and to verify whether the velocity profiles at orifice inlet was fully developed or not. Realizable k-e model and enhanced wall treatment were selected for accurate simulation considered to wall boundary effect. [4] Fig. 1 shows the computational domain and definition for upstream and downstream length.

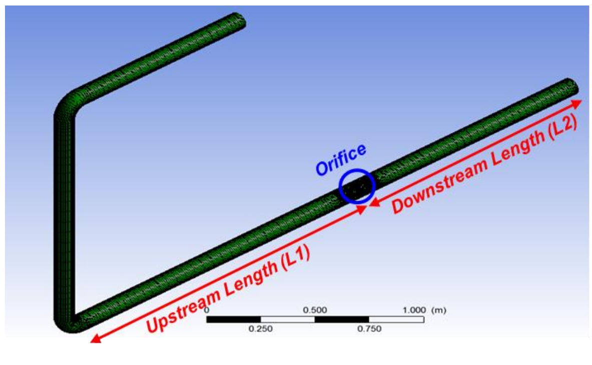

Fig. 2 Computational domain

2.3 Evaluate Fluid Characteristics of Current Position

The fluid flow characteristics of the orifice in the current installed position, about 18D, were evaluated. The streamline distribution is represented in Fig. 3. It is shown that recirculation zones in the downstream region of the orifice plate are asymmetrical and it means the inlet flow conditions are not sufficiently fully developed. It is more clearly to see the velocity profiles at orifice inlet, as illustrated in Fig. 4. The difference between the solid and dotted line is that the velocity distribution in upper and lower region of pipe cross section are unmatched.

2.4 Evaluation of Orifice Position as Changing Upstream and Downstream Length of Pipe

As aforementioned, a recommended upstream length of the orifice was different in the 1972 and 2004 edition of ASME PTC 19.5. For evaluating each standard, the flow characteristics through the orifice were investigated as changing upstream and downstream length of the pipe. The range of upstream length was from 10D (10 times the diameter of the pipe) to 40D. The calculated pressure drop and discharge coefficient of the orifice is represented in Fig. 5 and 6, respectively. The x-axis indicates upstream length of the orifice expressed as multiples of the pipe diameter, D. The y-axis indicates a normalized pressure drop through the orifice for Fig. 5 and a discharge coefficient for Fig. 6.

It is shown that the pressure drop and the discharge coefficient are conversed within 0.5% as the upstream length is longer than 30D. The pressure drop at the current position, 18D, is 2.3% higher than the conversed value and it can produce a measurement error when converting from pressure to flow rate. In the 1972 edition of ASME PTC 19.5, the recommended upstream length for this kind of two or more bends in the same plane is about 16D and it is insufficient to make a fully developed profile at the orifice inlet. On the other hand, in the 2004 edition, the required upstream is suggested as 36D and it is somewhat but not too strictly restricted.

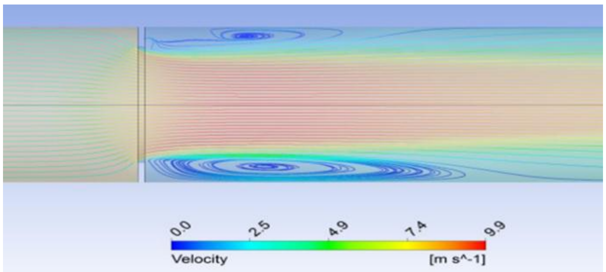

Fig. 3 Streamline distribution through the orifice at the current installed position

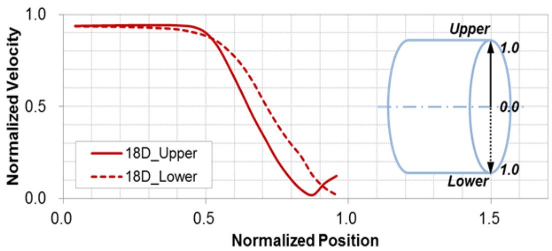

Fig. 4 Velocity profile at upper and lower region of pipe cross section

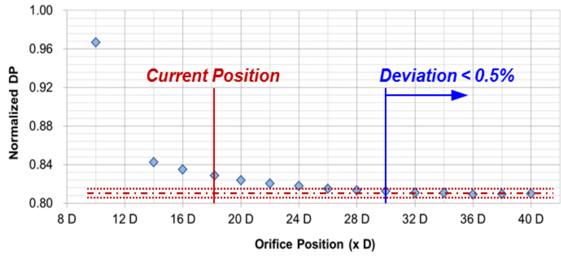

Fig. 5 Calculated pressure drop through the orifice

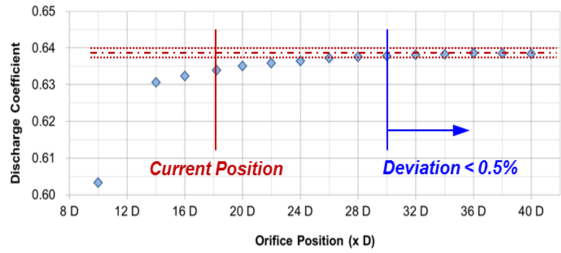

Fig. 6 Calculated discharge coefficient of the orifice

3. Conclusions

The present study shows that the current installation of the orifice in AFWS needs a more straight upstream pipeline, which is more than 30D, to avoid the flow disturbance which can cause the distortion in the velocity profile and to measure accurate flow rates. And it is also concluded that the 2004 edition of ASME PTC 19.5 gives reasonable but somewhat strict guideline for flowmeter installation.

REFERENCES

[1] General Requirements for Fluid Metering: Installation, ASME PTC 19.5-72, pp. 179-181, 1972.
[2] Flow Conditioning and Meter Installation Requirements, ASME PTC 19.5-2004, pp. 64-66, 2004.
[3] Combustion Engineering Technology Cross Training Course Manual. USNRC
[4] N.S. Kim, S.K. Lee, B.S. Shin, O.H. Keum, Investigation on Fluid Flow Characteristics of the Orifice in Nuclear Power Plant, Proceedings of International Conference on Nuclear Thermal Hydraulics and Safety (ICNTHS-2011), Apr.27-29, 2011, Venice, Italy.