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Effect of Wedge Ratios on the Characteristics of Wedge Flowmeter

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1. Introduction

Liquid sodium, which has a higher boiling point than water, is used as a heat transfer fluid in the sodium fast reactor due to its favorable physical, chemical and nuclear properties. The measurement of flow rate in sodium systems presents extraordinary problems due to the severe operating environments commonly related to such system. Two important factors of sodium systems which make the design of flowmeters difficult are the high operating temperatures and the chemical reactivity of sodium. Other design requirements for sodium flowmeters are the ability to withstand corrosion resistance and rapid thermal transients.

The magnet flowmeter has so far been commonly used for flow measurement in most of the sodium systems. This is compared to usual practice in other process systems where differential head type flowmeters utilizing orifice plates, venturi tubes, or flow nozzles are most often used. This difference is due not only to the difficulty of measuring differential heads in a high-temperature sodium system but also to the unique suitability of the magnet flowmeter for use on sodium systems.

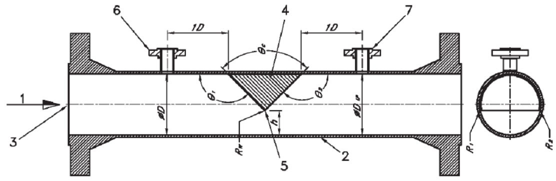
Just as there are advantages inherent to magnetic flowmeters as applied to sodium systems, there are inherent disadvantages. A significant problem area for magnetic flowmeters is the difficulty of calibration. Since the resistivity of the fluid and the pipe wall have a significant effect on the calibration of a magnetic flowmeter, calibration must be done with fluid and pipe wall resistivities closely approaching those to be expected in service. And changes in fluid temperature directly affect the calibration of magnetic flowmeters due to the resultant changes in fluid and pipe-wall resistivity[1].

It was judged that the segmental wedge type restriction device is the most suitable as flowmeter to overcome the disadvantages of magnet flowmeter. Because the differential pressure transducer for segmental wedge flowmeter either can not withstand the high sodium temperature or is appreciably affected by the high temperature, FBG(Fiber Bragg Grating) sensor for the high sodium temperature environment is being developed in KAERI.

The main purpose of this study is to investigate the effect of wedge ratios(Z=h/D) on the characteristics of segmental wedge flowmeter with diaphragm pressure gauge prior to verifying the performance of segmental wedge flowmeter with FBG sensor because the determination of the discharge coefficient is most important for the flow measurement using a restriction device.

2. Description of wedge flowmeter

The wedge flowmeter as shown in Fig. 1 consists of (listed in the direction of flow) an entrance cylinder, an upstream pressure tapping, a pipe section including the wedge element, a downstream pressure tapping, and an exit cylinder. The restriction is characterized by the h/D ration and the wedge angle, where is h is the hight of the restriction and D is the pipe inside diameter. The segmental orifice meter is an special case of a wedge flowmeter with a wedge angle of zero.



1-Flow, 2-Meter body, 3-Meter body centerline, 4-Wedge element, 5-Wedge apex, 6-High pressure tapping, 7-Low pressure tapping

Fig. 1. Geometric profile of wedge flowmeter

The volumetric discharge rate Q for steady, single-phase flow through wedge flowmeters and segmental orifice meter is given by

$$Q = A_0 C_d \left(\frac{2\Delta P}{\rho} \right)^{1/2} \quad (1)$$

where A_0 is the meter open area, ΔP is the pressure difference between upstream and downstream pressure taps, ρ is the fluid density and C_d is the discharge coefficient.

The discharge coefficient C_d is introduced to convert the ideal flowrate into actual flowrate and defined as

$$C_d = \frac{Q_{actual}}{Q_{theoretical}} \quad (2)$$

3. Experimentals

3.1 Design of wedge flowmeter

In this study, the segmental wedges are designed and manufactured for three different wedge ratios(0.3, 0.4, 0.5) and 90° fixed wedge angle as shown in Fig. 3.

The centerline of the tappings is located 1D ± 0.02D from the nearest edge of the wedge element[2].

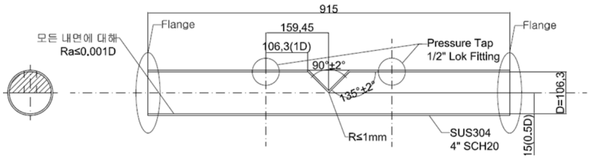
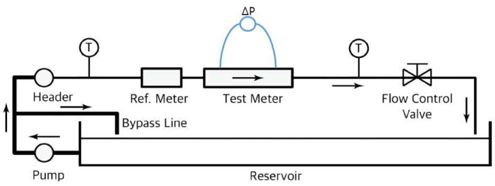


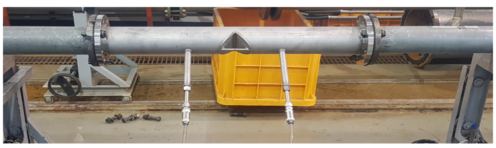
Fig. 2. Schematic diagram of wedge flowmeter

3.2 Experimental methods

The schematic diagram and photograph of experimental set-up are shown in Fig. 3. The wedge flowmeter is installed with a long straight inlet run, with a minimum of 10D of upstream straight length of the same nominal pipe diameter immediately preceding the wedge flowmeter. During the experiment, the temperature is maintained constant at 12.8℃ by temperature controller. The experimental loop consisted of a mass flowmeter (Promass83F1H), differential pressure gauge (Rosemount, 3051CD), and three wedge flowmeters with different h/D ratios. Experiments are performed at Reynolds numbers ranging from 15,000 to 4500,000 capable of measuring differential pressure. And three different-sized segmental wedges with the h/D of 0.3, 0.4, and 0.5 are investigated in various combinations of Reynolds numbers.



(a)



(b)

Fig. 3. Schematic diagram (a) and photograph(b) of experimental apparatus

3. Results and discussion

Fig. 4 shows the experimental values of differential pressure according to flow rate for wedge flowmeters with different h/D ratio. The experimental results show that three wedge flowmeters with h/D ratios of 0.3, 0.4, and 0.5 give a linear relationship between differential pressure and flow rate, as shown in the figure.

Fig. 5 shows the discharge coefficient data for flow rate of wedge flowmeters with h/D ratios of 0.3, 0.4, and 0.5. As can be seen, the discharge coefficient is almost constant over wide range of Reynolds number. Buhidma[3] reported that the differential pressure produced across the wedge element closely follows the squared relationship of flow(refer to Eq.(1)) even at a low Reynolds number of 500. As shown in Fig. 5, the discharge coefficients of wedge flowmeter increase with a decrease in h/D ratios.

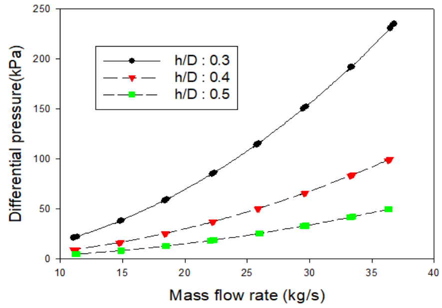
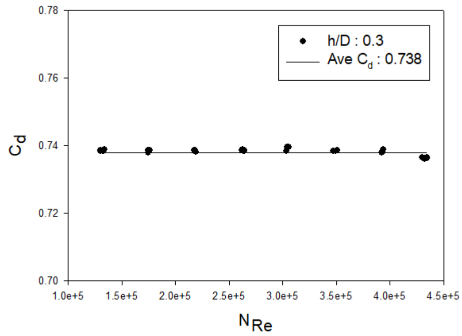
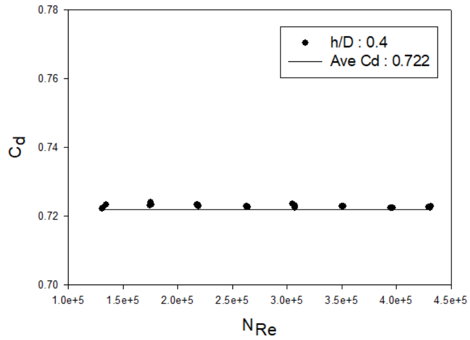


Fig. 4. Differential pressure vs. mass flow rate



(a)



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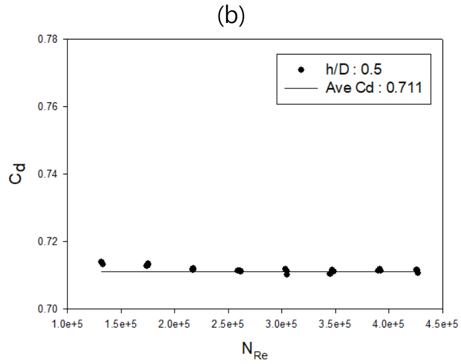

(c)

Fig. 5. Discharge coefficient data for flow rate of wedge flowmeters with h/D ratios of 0.3(a), 0.4(b), and 0.5(c)

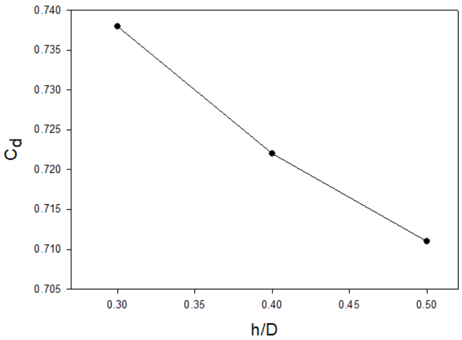

Fig. 6. Discharge coefficient data for wedge flowmeters with different h/D ratios

for the discharge coefficient of a wedge flowmeter was derived from Fig. 6. The resultant correlation equation between discharge coefficient and h/D ratios (Z) is

$$C_d = -0.135Z + 0.778 \quad (3)$$

for $0.3 \leq Z \leq 0.5$

The R-squared for this equation is 98.9%, which seems good.

4. Conclusions

The discharge coefficient was almost constant over wide range of Reynolds number. The discharge coefficients of wedge flowmeter increased with a decrease in h/D ratios. The resultant correlation equation between discharge coefficient and h/D ratios was derived. The present experimental results will be applied to the development of wedge flowmeter for high temperature sodium environment.

ACKNOWLEDGEMENT

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