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Flow Distribution in theCurved Narrow Channels of a Tubular Fuel

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1. Introduction

A tubular type fuel has been developed as one of the candidates for the Advanced HANARO Reactor(AHR), because the tubular type fuel has a few strengths in its thermal-hydraulic and structural safety. Larger ratio of the surface area to the volume than the rod type fuel makes the fuel surface temperature lower. Bended plate is strong against a bending and a vibration.

But some problems in the thermal-hydraulics may happen when there is a severely uneven flow distribution in each flow channel of a tubular fuel. So, from the viewpoint of the thermal-hydraulics, it is necessary to find out the flow characteristics such as the flow distribution in each flow channel as well as the pressure drop of the tubular type, which are basic requirements for a thermal-hydraulic design and analysis.

According to the experimental results, the maximum unbalance of the flow distribution in the tubular fuel is about 28% when compared with the average velocity. The maximum velocity is located on the inner first channel as expected to be the minimum velocity. The change of the flow rate(or velocity) did not affect the flow distribution. Pressure drop of the tubular fuel is less about 30% of that of the rod type fuel of HANARO.

2. Experimental Apparatus and Procedures

2.1 Test Facility and Test Section

A hydraulic test loop to examine the flow distribution and the pressure drop in the tubular fuel was constructed. Figure 1 shows the schematic of the test loop. It consists of a magnetic type volume flow-meter, a reciprocal type pump, a test-section and a data acquisition system. De-mineralized water is used in the test loop and the flow rate depends on the revolution of the pump driven by a inverter type motor. The test-section is made of transparent acryl pipe. A flow straightener made of small caliber tubes to make the flow straight is installed at the bottom of the test-section. Static pressure taps are installed to measure the pressure drop in the tubular fuel at both ends of the test section.

A piezometer ring was employed to reduce the error caused by a pressure fluctuation. The piezometer ring can give us an average of the measured pressure values coming from several pressure taps located circumferentially[1].

2.2 Measurement of Flow Velocity

The pitot-tube employed in this experiment is a simple and very useful probe to measure the flow velocity. If we can obtain the dynamic pressure, the velocity can be calculated.

The pitot-tube was especially manufactured to be a 2.3mm body diameter which has two 0.2mm diameter static pressure holes at an interval of 180 degree to be free from the wall effect. Because the pitot-tube can be moved axially as well as radially, only one pitot-tube for each 1/3 section is needed to measure the velocity at all the channels. The influence of a blockage by pitot-tube is ignored.

3. Results and Discussions

Dimensionless relative velocity can be obtained from dividing the local velocity by the average velocity and its distribution is plotted as shown in Fig. 2. The relative velocity gives us a more distinct flow distribution. Another important thing in this figure is that all the graphs for the four cases congregate into one graph which means that the flow distribution in the tubular fuel is independent of the flow rate change. In this figure it can be seen that the maximum velocity is located on the innermost channel and the minimum velocity located on the outermost channel for all the 1/3 sections. The maximum doesn’t exceed 15% of the average velocity. At one outermost channel there is too much of a difference at about 28% to that of the average velocity which leads to some hydraulic problems.

Although there is some difference among three 1/3 sections, the three velocities for the same channels in each 1/3 section are averaged to establish general flow distribution in the tubular fuel as shown in Fig. 3. According to this figure, the flow in the tubular fuel would be a maximum at channel 1. Velocity becomes less and less at channels 2 and 3. After that the velocity is somewhat recovered at channels 4, 5. The decrease of the velocity at channel 6 may be caused by the wall effect.

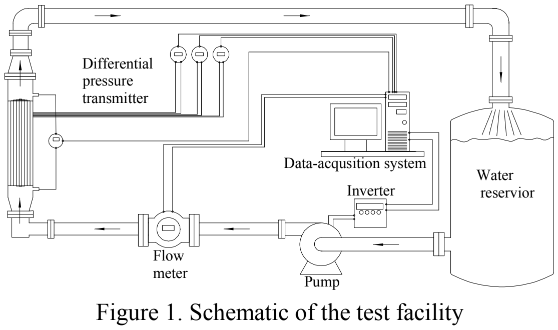
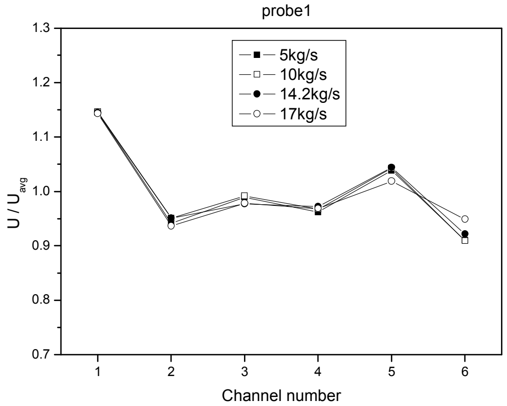


Figure 1. Schematic of the test facility

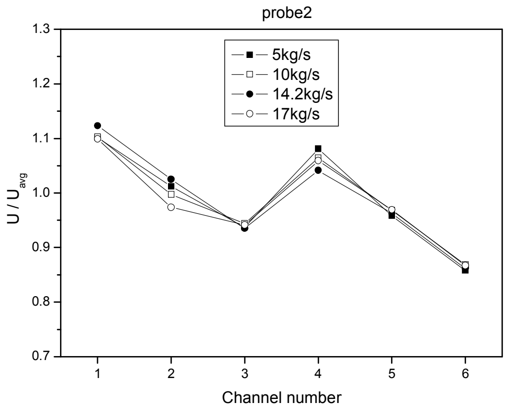
Figure 4 shows the correlation between the pressure drop and the mass flow rate. Flow rate is changed in the range of 2kg/s to 23kg/s. At the design flow rate 21kg/s, the tubular fuel a causes pressure drop of about 165kPa. With fitting the data linearly, a correlation can be obtained as the following,

$$\Delta P = 736.2\dot{m}^{1.777} \tag{1}$$

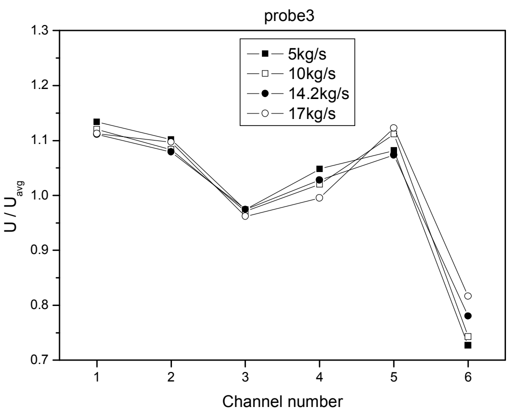
Pressure drop of the 36 fuel rods assembly in HANARO is about 209kPa at 19.6kg/s. At the same flow rate the pressure drop of the tubular fuel is 145.7kPa which is 70% that of the HANARO fuel.



(a) probe 1



(b) probe 2



(c) probe 3

Fig. 2 Relative velocity distribution in each channel of tubular fuel

4. Conclusion

An experiment was conducted to investigate the flow distribution and the pressure drop in a tubular fuel. From the results the following are summarized.

The flow distribution in the tubular fuel is not affected by the flow rate. The maximum velocity is located on the innermost channel which was expected to be the minimum velocity channel. The outermost channel has a minimum velocity due to the wall friction effect. The maximum velocity does not exceed 15% of that of the average velocity, but the minimum is too small a velocity reaching about 28% that of the the average.

The pressure in the tubular fuel is about 165kPa at a design flow rate. Compared with the HANARO rod type fuel, the tubular fuel has much lesser pressure drop of about 70% that of HANARO fuel at a regular flow rate.

REFERENCES

[1] Benedict R. P, 1968, Fundamentals of Temperature, Pressure and Flow Measurements, 3rd Ed. John Wiley & Sons.

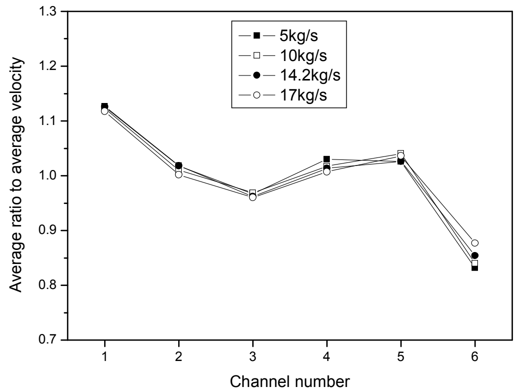


Figure 3. Averaged velocity distribution in each channel of tubular fuel

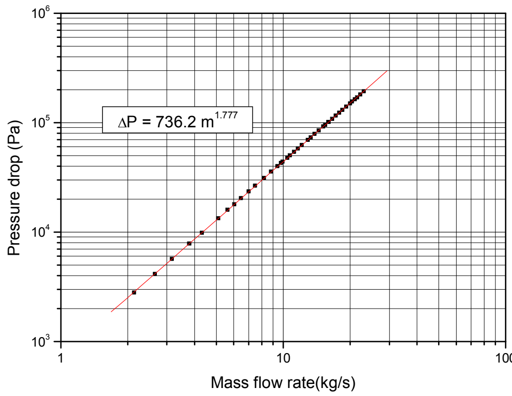


Figure 4. Pressure drop with changing of mass flow rate