Characteristic Frequency of the Thermal Fluctuations Induced by a Double Jet

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1. Introduction

Studies of thermal fluctuations are very important in liquid metal reactors where the operation temperature is so high and the temperature difference between the hot region and cold region is large. It is because the temperature difference induces thermal fluctuations that affect the lifetime and stability of the reactor. This phenomenon is called a thermal stripping. In this paper, we focus on the thermal fluctuations at the exit of a fuel assembly where the temperature difference between the hot tubes and cold tubes is large(about 150℃). There are a large amount of experimental studies about thermal stripping [1-5]. But the frequency characteristics of the thermal fluctuations have not been studied much.

In this study, we performed an experiment for the thermal fluctuations at the exit of a fuel assembly, especially for the characteristic frequency. In the experiment, the flow at the exit of the fuel assembly is modeled by a flow induced by a double jet composed of one hot jet and one cold jet.

2. Experiment

The schematic of the experimental facility is shown in Figure 1. The facility consists of a test section and two loops, a cold loop and a hot loop. As the working fluid, we used air instead of sodium because the previous studies[1,4] reported that the thermal mixing phenomena of air and sodium is similar for Re > 2×10^4.

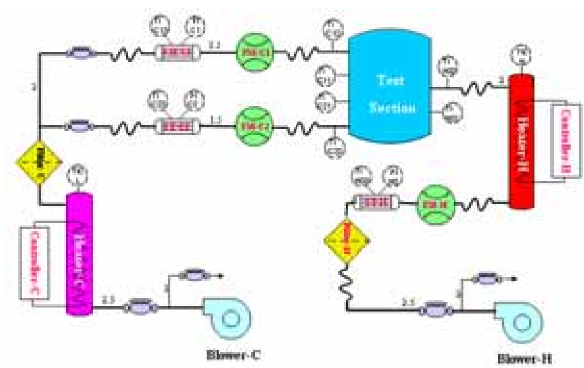

Figure 1. Schematic Diagram of Experimental Setup

The air enters the test section through the nozzles shown in Figure 2. The velocity range is 10~40m/s at the nozzles. The operation temperature is 20~90℃. For the temperature measurement, we used cold wires made by TSI to detect the fast temperature fluctuations. The diameter of the cold wire is 1.27 ㎛ and the time constant is 0.17ms when the velocity is 30m/s. The sampling rate is 4 kHz. We measured the temperatures at 23 different horizontal positions and 12 different vertical positions, a total of 276 positions. The velocity of the hot jet is varied as 10m/s, 20m/s and 30m/s with the velocity of the cold jet being fixed at 10m/s. The temperature of the hot jet is 80℃ and 60℃ and the temperature of the cold jet is 40℃.

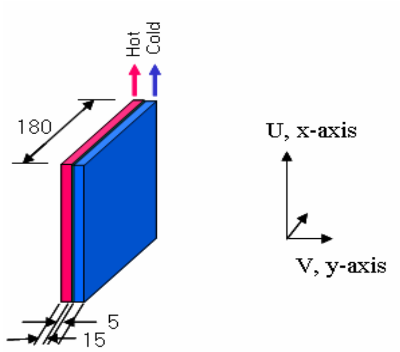

Figure 2. The shape and dimension of the double jet nozzle

3. Analysis

To establish the characteristic frequency, the Fourier transformation was used. The coefficients were obtained by averaging 200 results with the moving window technique. The window size was 1024 samples and the overlap between the windows was 50%. To prevent the aliasing and truncation error, the Hanning window was used. And a 10Hz high pass filter and 2 kHz low pass filter were used to cut off the DC bias and high frequency noise. The characteristic frequencies were calculated by averaging the Fourier coefficients. We introduced a ratio between the temperature signal and background noise. With the maximum ratio, we defined the characteristic frequency of the temperature fluctuations.

4. Results and Discussions

First, we introduce a normalized frequency as follows:

$$f_{nor} = \frac{fd}{U} \quad (1)$$

where, d is the gap between the nozzles and U is the maximum jet velocity.

In Figure 3, we plotted the normalized frequency with respect to the horizontal positions with the vertical positions being fixed. We found that temperature fluctuations with a specific frequency are activated at the center and dampens out as the measuring position moves away from the center. And we also found that the frequency only depends on the velocity profiles and is independent of the temperature distributions. The specific frequencies (From now on, we call it characteristic frequency) and the decreasing patterns, if normalized, are the same, 0.43 except for the case with velocities being 10/10m/s, the symmetric case. For example, the decreasing patterns of the 10/20m/s case and the 10/30m/s case are the same.

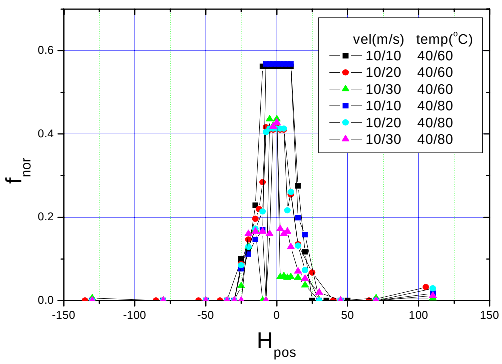

Figure 3. Normalized Characteristic Frequency according to the horizontal positions

Figure 4 shows the characteristic frequencies according to the vertical positions at the center of the horizontal positions. The independency on the temperature distributions also appears as in Figure 3. But the decreasing patterns are different with the different velocity profiles. As the difference between the two jets becomes larger, the fluctuations dampen out faster.

5. Summary and Conclusions

In this paper, we performed experiments to study the characteristics of the thermal fluctuations induced by a double jet. Especially, the characteristic frequencies of the thermal fluctuations are the main issues.

As for the results, we found that the normalized characteristic frequency is only dependent on the velocity profiles not on temperature profiles. Even the decreasing patterns with horizontal positions aren't dependent on the velocity and on the temperature except for the cases with symmetric velocity profiles. But for the vertical positions, when the velocity difference is larger, the fluctuations dampen out faster.

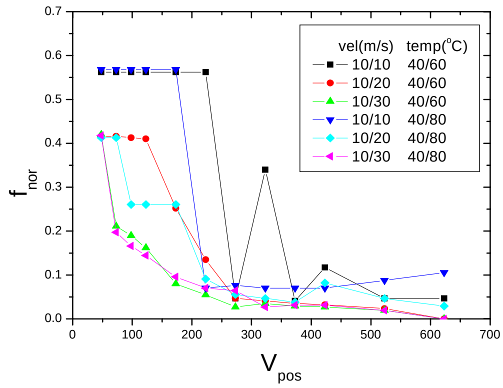

Figure 4. Normalized Characteristic Frequency according to the vertical positions

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