Experimental Study on the Friction Loss Coefficient in a Micro Gap

Ho-Yun Nam, Byoung-Hae Choi, Jong-Man Kim, and Byung-Ho Kim

Korea Atomic Energy Research Institute
E-mail: hynam@kaeri.re.kr

1. Introduction

A fast reactor, which uses sodium as a coolant, has a lot of merits as a next generation nuclear reactor. However, the possibility of a sodium-water reaction occurrence hinders the commercialization of this reactor. As one way to improve the reliability of a steam generator, a double-wall tube steam generator is being developed in GEN-4 program.

The current focuses of this research are an improvement of the heat transfer capability for a double-wall tube and the development of a proper leak detection method for the failure of a double-wall tube during a reactor operation. The ideal goal is an on-line leak detection of a double wall tube to prevent the sodium-water reaction. However, such a method is not developed yet. An alternative method is being used to improve the reliability of a steam generator by performing a non-destructive test of a double wall tube during the refueling period of a reactor. In this method a straight double wall tube is employed to perform this test easily, but has a difficulty regarding the absorption of a thermal expansion of the used materials. If an on-line leak detection method is developed, the demerits of a straight double-wall tube are avoided by using a helical type double-wall tube, and the probability of a sodium-water reaction can be reduced to a level less than the design-based accident [1].

A basic experimental study has been performed to study the possibility of a leak detection method by measuring the pressure in the gap between the inner tube and outer tube of a double wall tube. In the double wall tube there exists a very small space due to the surface roughness of the inner wall and outer wall. Thus, if the outer wall is broken, the Helium gas (2Mpa) in the very small space is ejected to the sodium (0.1Mpa), and if the inner wall is broken, the superheated gas (16.5Mpa) is ejected to the very small space filled with Helium. If four grooves with 0.2-04mm depth are dug in the inner surface of the outer wall so that the Helium can flow easily, we can detect the leakage by online checking the change of volume of gas in the groove.

2. Experiment

In order to evaluate the validity of this technology and to predict the delay time necessary for detecting a fracture, an experiment at room temperature has been conducted to mimic the gap between the outer and inner wall in the double wall tube. An experimental apparatus has been set up to measure the amount of leakage through the gap by using the drawing pressure, the residual stress in the gap and the surface roughness as experimental parameters. In the designing the double wall tube, the surface roughness is 1 μm and the residual stress in the gap is 10-20Mpa.

The experiments have been done to measure the amount of leakage of Helium gas by pressing the test section by the hydraulic press so that the pressure was the same amount as the residual stress. The experimental apparatus consists of the Helium gas supplying system, the press system for the specimen and the measuring systems for flow rate and pressure. Both sides of the specimen were filled up with the packing and the gas plenum sealed with o-ring was installed above them. Then, the flow rate of the Helium gas into the plenum and the pressure of the plenum were measured.

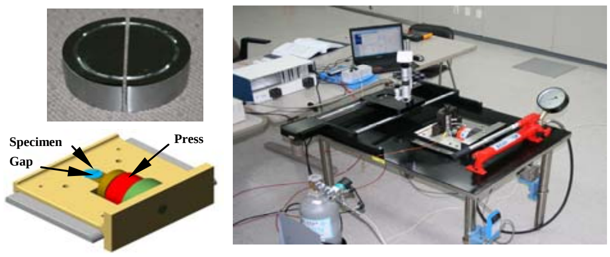

Fig. 1 Experimental apparatus

3. Result and Discussion

The initial pressure that mimics the drawing pressure at the time of a manufacturing and the contact pressure that mimics the residual stress in the gap was established. And the leakage in the gap was measured by controlling the pressure of Helium gas. The experiment for the effect of a surface roughness is under way.

Figure 2 shows the leakage characteristics in terms of the Reynolds number of the Helium gas. The results of the preliminary experiment show that the friction coefficient in the gap is inversely proportional to the Reynolds number (*Re*) of the Helium gas in the log-log plot. Thus, the frictional coefficient (*f*) in the gap can be expressed in terms of the Reynolds number as A/Re^B. Here, A and B are the positive constants and *d* is the unit parameter for the surface roughness.

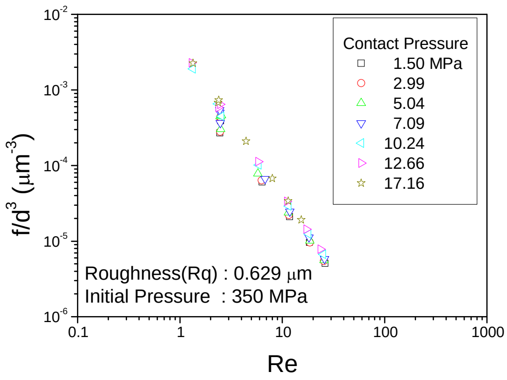

Fig. 2 Effect of Reynolds number on the friction coefficient

Figure 3 shows the leakage characteristics in terms of the contact pressure. The friction factor increases with the increase of the contact pressure. For the limit of the preliminary experiment, the friction factor is approximately proportional to the 1/4 power of the contact pressure.

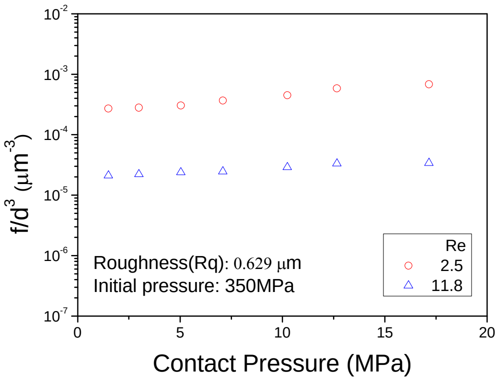

Fig. 3 Effect of the contact pressure on the friction coefficient

Figure 4 shows the leakage characteristics in terms of the initial pressure. When the initial pressure is lower than the yield stress (398~413 MPa) of the specimen, which is made of the Mod. 9Cr-1Mo, the flow friction factor is low, while when the initial pressure is larger than the yield stress, the friction coefficient becomes higher. However, even if the initial pressure is much higher than the yield stress, the change of the friction factor is small. Thus, it is expected that the constants A and B can be described in terms of the initial pressure, contact pressure and surface roughness. The correct trends of the constants will be analyzed and quantified through future experiments.

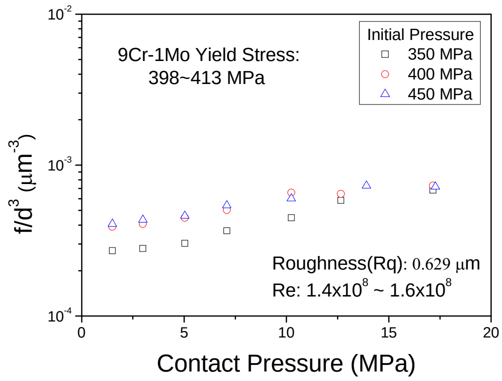

Fig. 4 Effect of the initial pressure on the friction coefficient

4. Conclusion

According to the preliminary experiment, the friction coefficient in a gap in terms of the Reynolds number of the Helium gas can be expressed in the form of A/Re^B and the constant *B* is larger than 1. And it is approximately proportional to the 1/4 power of the contact pressure**.** In the future, for the manufacturing condition of a double wall tube, it is anticipated that the detection of the leakage can be possible by measuring the pressure changes in a gap.

Acknowledgement

This study has been supported by the Nuclear Research and Development Program of the Ministry of Education, Science and Technology of Korea.

REFERENCE

[1] Ho-Yun Nam, Byoung-Hae Choi, Jong-Man Kim, and Byung-Ho Kim, "Current Status on the Development of a Double Wall Tube Steam Generator," KAERI/AR-788/2007, 2007.