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Effect of the Reynolds Number on the Friction Loss Coefficient in a Micro Gap

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1. Introduction

As one way to improve the reliability of a steam generator for a sodium-cooled fast reactor, a double-wall tube steam generator (DWTSG) is being developed. The current focuses on the DWTSG development 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 [1].

In the conventional pre-stressed double wall tubes (DWT), the inner tube and the outer tube are made of the same material. When the temperature difference between the inner tube and the outer tube increases, the heat efficiency decreases. To improve the heat transfer capability of a double wall tube, the inner tube is used with a material having a thermal expansion coefficient about 10 to 15% greater than that of the outer tube as shown in Fig. 1 [2]. For on-line and real-time detection of whether the heat transfer tube is damaged or not, a detection method was developed by comprising the heat transfer tube gaps and the detection holes meeting with a one-to-one correspondence in the lower tubesheet.

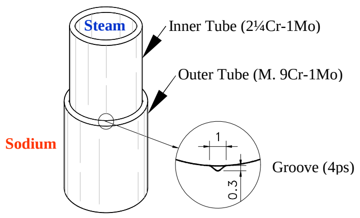

Fig. 1 Double wall tube with the different materials

In the pre-stressed DWT, 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 narrow space is ejected into the sodium (0.1Mpa), and if the inner wall is broken, the superheated gas (16.5Mpa) is ejected into the space filled with helium gas. If four grooves with 0.2-04mm depth are dug in the inner surface of the outer wall to flow the helium gas easily, we can detect the leakage by checking a change in gas volume in the groove on-line.

2. Experiment

A basic experimental study has been performed to evaluate the validity of this technology and to predict the delay time necessary for detecting a fracture. An experimental apparatus has been set up to measure the amount of leakage through the gap by using the initial pressure simulating the drawing pressure, the contact pressure simulating the residual stress, and the surface roughness as experimental parameters. The surface roughness of the double wall tube is 0.2-0.8 ㎛ and the residual stress in the gap is 10-20Mpa. The presented preliminary experiment was performed with a different specimen type [3].

The difficulty of a DWT fabrication with several gap conditions, forced the use of the specimen forming with two contacted plates instead of a DWT as shown in Fig. 2. The experiments have been performed to measure the amount of leakage of helium gas between two surfaces by pressing the specimen with a hydraulic press simulating the drawing pressure and the residual stress. The experimental apparatus consists of a helium gas supplying system, a press system, and measuring systems for flow rate and pressure drop.

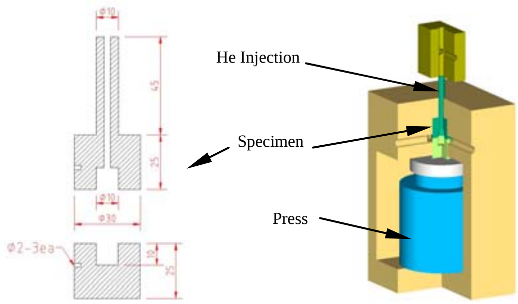

Fig. 2 Test specimen

The range of the experimental parameters for a surface roughness is 0.99-1.284 micrometer. The initial pressure was varied for seven cases in the range 253-606MPa, and the contact pressure were varied for six cases in the range 1.25-24MPa. The material of the specimen was Modified 9Cr-1Mo steel.

3. Result and Discussion

In this paper, only the effect of Reynolds number, which is an important parameter in a friction factor, was described. The leakage in the gap was measured five times by controlling the pressure of helium gas. A friction coefficient (*f*) in the pressure loss by flowing fluid generally can be expressed in terms of the Reynolds number (*Re*) as the following formula;

$$f = \frac{B}{\mathrm{Re}^{C}} \quad (1)$$

where, *B* and *C* are positive constants when the other parameters are fixed. In the analysis of the experimental data, *B* was strongly dependent on the surface roughness, the initial pressure, and the contact pressure. But *C* was nearly independent on those parameters.

Figure 3 shows the leakage characteristics in terms of the Reynolds number of the helium gas when the initial pressure was 404MPa in two cases of the surface roughness (Ra). The results of the experiment show that the friction coefficient in the gap is inversely proportional to the Reynolds number of the helium gas in the log-log plot. Therefore, Eq. (1) appears also as a suitable formula for calculation of the friction factor in a macro gap. In the analysis, the gap size was assumed to be three times that of the surface roughness (ε) in meter units, but ε was micrometer units in the Y-axis of the figure.

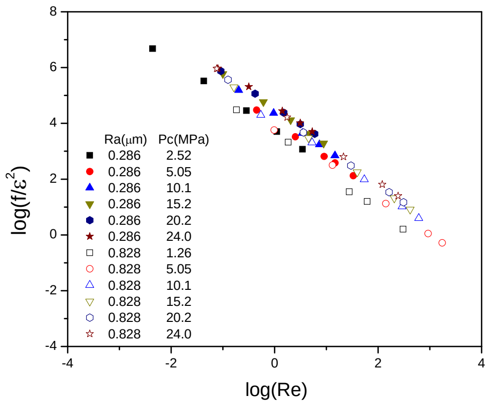

Fig. 3 Effect of Reynolds number on the friction coefficient

Figure 4 shows the value *C* in terms of the contact pressure and the surface roughness of the specimen. All of the initial pressure conditions were accounted in the analysis. In the fig. 4, when the initial pressure and the surface roughness are fixed, the variation of the data is caused by the effect of the initial pressure. The range of the C is 1.2-1.4, and the average value is about 1.3.

The constant *B* can be described in terms of the initial pressure, the contact pressure, and the surface roughness. The correct trends of the constant will be quantified through future analysis.

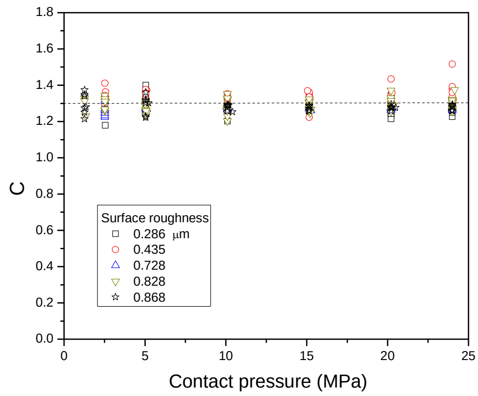

Fig. 4 *C* value according to surface roughness

4. Conclusion

An experiment has been carried out to evaluate the validity of an on-line leak detection method for a double wall tube and to predict the delay time necessary for fracture detection. The friction coefficient in a micro gap can be expressed in the form of B/Re^{C} and the constant *C* is about 1.3. According to the analysis of the experimental data, the detection of the leakage can be made possible by measuring the pressure changes in a gap of the double wall tube.

Acknowledgement

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