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Construction of Gas Entrainment Test Facility for IHX Inlet Windows in SFR

Yong-Seok Choi*[,1], Woo-Shik Kim[1], Dong-Jin Euh[1], Ji-Woong Han[2], Minsuk Kong[1]
[1]*Thermal Hydraulics and Severe Accident Research Division, Korea Atomic Energy Research Institute, Daejeon, Korea*
[2]*SFR Reactor Design Division, Korea Atomic Energy Research Institute, Daejeon, Korea*

Corresponding author: cys@kaeri.re.kr

1. Introduction

The Sodium-cooled Fast Reactor (SFR) receives much attention as a next generation nuclear power plant. The SFR uses a kind of liquid metal, sodium, as a primary coolant and by adopting high-energy thermal neutron for nuclear fission, it has a superior operability and high efficiency even with good inherent safety characteristics. The SFR has a pool type reactor vessel having a reactor core, upper internal structures (UIS), primary pumps, and intermediate heat exchangers (IHX) as a reactor coolant system (RCS) and a primary heat transport system (PHTS).

Above the reactor hot pool, cover gas is charged over the sodium to reduce pressure transients and to prevent the sodium leakage along the reactor head. Therefore, if the cover gas is entrained from the sodium free surface, it can generate a gas pocket which degrades the reactor safety as follows: (1) damage of primary circulating pump, (2) reactivity insertion to the core, (3) rapid change of the local heat transfer coefficient in the core, and (4) thermal stress to the internal structure due to the large difference in the thermal conductivity between the cover gas and the sodium.

In this paper, a series of basic design of test facility for characterizing the gas entrainment on the IHX inlet windows are presented. The experimental requirements, basic design for the test section and test loop, and experimental methods are briefly introduced.

The basic design of current study would be a base of the design validation tests, and the experimental database generated in the study will contribute to the quantification of safety and operational margin. Furthermore, experimental database will be used to develop a multidimensional estimating model of two phase flow by evaluating the effect of variables on the gas entrainment phenomena.

2. Design Requirements

2.1 Similitude analysis

The most important parameters for the gas entrainment from the free surface are Froude number (*Fr*), Reynolds number (*Re*) and Weber number (*We*). However, it is impossible to simultaneously satisfy all the non-dimensional parameters since the water is used as a working fluid in this experiments. In a number of previous studies, *Fr* number is evaluated as the most important parameter when the flow is fully developed turbulent, the surface velocity is slow, and the surface curvature can be neglected. Therefore the test facility is designed to conserve the *Fr* number as follow:

$$\left(\frac{V}{\sqrt{gL}}\right)_P = \left(\frac{V}{\sqrt{gL}}\right)_m \tag{1}$$

Here, L is the characteristic length, the length from the free surface to the IHX entrance. V is the entrance velocity into the IHX. The subscript p and m represent prototype and model, respectively.

2.2 Working fluid

As the major dimensionless numbers related to the gas entrainment are *Fr*, *We*, and *Re*, the main properties to be considered are the density, the viscosity, and the surface tension. Although the density of the test fluid, water at 25℃, is similar to that of the sodium at 545℃, the surface tension of the water is about half of that of sodium. It is known that the gas entrainment occurs well in the water than in the sodium because the critical *Fr* decreases as the surface tension decreases. Therefore it is conservative to use the water as a working fluid. However, since the *We* number is distorted by using the small scale test facility and the water, the effect of *We* should be checked by modifying the surface tension by adding surfactants.

2.3 Test Facility

The test facility consists of centrifugal pumps, a storage tank to control the level of the free surface, a damper to remove pump pulses, a bubble trap to collect entrained gas, and a test section. The test section is designed based on the quarter of hot pool in the SFR through 1/5 linear length scale law and Froude number similarity. To visualize the gas entrainment and the flows, the test section is constructed using a transparent acrylic.

The measurement variables are as following:

- Flow distributions and velocities according to the elevation
- Water temperature to account for the property changes
- Surface tension to evaluate the effect of We number
- Flow rate to the test section

- Wave amplitude of the free surface
- Recording of gas entrainment initiation.

2.4 Test matrix

Test matrix was determined by conserving Froude number. In addition, a wide range of fluid velocity, water level, and surface tension were selected to evaluate the effects of major parameters on the onset of gas entrainment. The test matrix is shown in Table 1.

Table 1. Test matrix

Item	Range
Pressure	0.1~0.2 Mpa
Temperature	60℃
Flow velocity	0.45 V_p ~1.0V_p (V_p: Velocity of prototype)
Surface tension	0.5σ_m ~1.0σ_m (σ_m: surface tension of model)
Level of test fluid	0.6H_m ~ 1.2H_m (H_m: distance of IHX entrance to free surface)

3. Construction of test facility

3.1 Test loop

Fig. 1 shows the schematic diagram of the test loop. In order to decide the pump capacity and the sensor ranges, the test flow rate and pressure drop across the test loop are evaluated. This loop has two pumps to control the level of free surface in the test section easily by matching the supplying and draining flow rate to be the same. Considering the required flow rate and the corresponding pressure drop, the pumps have 25 kg/s capacity at the 20 m water of total dynamic head.

Isometric drawing of the test section is also drawn in the Fig. 1. Main components in the test section are Redan, UIS, Shroud, and IHX. The working fluid is supplied from the core outlet section at the bottom and then passes the UIS and Shround. The water is then entrained into the IHX window and finally drained through the lower part of the IHX at the bottom. To visualize the gas entrainment phenomena, the upper part of the Redan is fabricated by transparent acrylic. The lower parts are mainly made of stainless steel and there are four acrylic windows to visualize the flow from the bottom side.

3.2 Data acquisition system

For the gas entrainment experiment, the static pressures, flow rates, temperatures, differential pressure for the leveling of the test section, and wave amplitude of the free surface by adopting ultra-sound sensors are measured. The data acquisition system consists of multi-channel analog inputs, analog output, digital inputs, digital outputs, RTD analog inputs. Fig. 2. shows the HMI display of this data acquisition system.

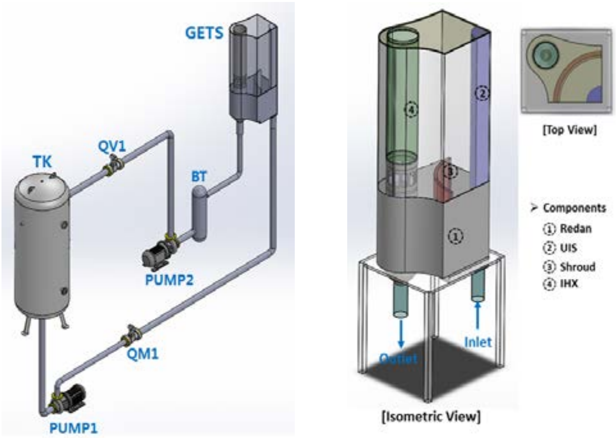

Fig. 1. Schematic diagram of the test loop and test section of the IHX entrance gas entrainment test facility

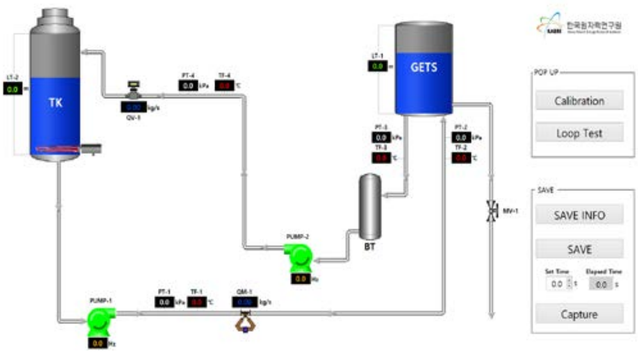

Fig. 2. Schematic diagram of the HMI display

4. Conclusion

Test facility for characterizing the gas entrainment on the IHX inlet windows is constructed. The experimental requirements, basic design for the test section and test loop, and experimental methods are briefly described. The experimental database will be generated in this study to contribute to the quantification of safety and operational margin. Furthermore, experimental database will be used to develop a multidimensional estimating model of two phase flow by evaluating the effect of variables on the gas entrainment phenomena.

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REFERENCES

[1] M. Kong, et al., Basic Design Report of Test Facility for Gas Entrainment to IHX Inlet Windows in SFR, KAERI/TR-6951/2017, KAERI, 2017.