§18. Heat Transfer of Pebble Bed Considering Strong Volumetric Heat Generation inside Pebbles

Yokomine, T. (Kyushu Univ.),
Seo, K., Sagara, A.

In present ceramic breeder blankets, both the neutron multiplier and the breeder materials are used in the form of pebbles. An experimental study to measure the effective thermal conductivity in a pebble bed has been conducted usually without consideration of heat generated inside each pebbles. Actually, when the volumetric heating has occurred in the each pebble, the difference of amount of volumetric heating between contacting pebbles should make the inhomogeneous temperature profile near the contact interface. The effect of the temperature gradient occurred in the discrete pebbles independently on the heat flow near the contact interface cannot be taken into consideration by conventional experiments. In the present study, focusing attention on two contacting rods with cylindrical contact surfaces to simulate contacting pebbles, the effect of the amount of heat flow through the interface and the each temperature gradient near the interface on the thermal conductance is investigated.

Figure 1 shows the schematic view of experimental apparatus. Two test specimens are contacted vertically. Each test specimen is copper block (W30mm×H100mm×D 85mm) and the boundary of contact area has 15mm of curvature radius. Plate heater is mounted on the upper test specimen. Two cartridge heaters (ϕ6×100mm) are inserted into each test specimen: each location is 15mm apart from the contacting interface. A cooling block cooled by flowing water thorough a channel in it is mounted under the lower test specimen. The temperature is measured by inserted thermocouple into specimen: ϕ0.25mm thermocouple is located at 3mm, 6mm and 9mm away from the contact interface and ϕ1.0mm thermocouple is used at distance of 55mm, 65mm and 75mm from the contact interface.

Figure 2 shows the dependence of inhomogeneity of volumetric heating on the temperature difference and heat flux through the contact interface. The inhomogeneity of volumetric heating is reproduced by difference of input power between heaters 2 and 3. From both figures, though the level of temperature is decreased with increase in contact pressure, the temperature difference at the contact interface is not changed distinctly. On the other hand, the passed heat flux is decreased about 10% with increase in the input power ratio. It is suggested that the heat generation of lower temperature side pebble curbs the heat flow through the contact interface.

Figure 3 shows the dependence of the input power ratio of heater #1 and #2 (Q_2/Q_1) on the heat flow ratio of overall heat flow ($Q_{1\to 2}$) and heat flow through the contact interface (Q_{2S}) and contact thermal conductance h. The heat flow through the contact interface is at the most 10% of the overall heat flow. When the Q_2/Q_1 is constant, heat flow ratio and contact thermal conductance are both increased 20 to 30% with increasing the input power of heater 3. The heat flow near the contact surface inside the contacting bodies is disturbed due to the non-uniformity of microscopic contact condition. According to the above result, it is considered that the heat flow is contracted and the disturbance of heat flow inside specimen is suppressed near the interface by the existence of heat generation in the lower specimen side. That is, it should be considered for the design of solid blanket that the inhomogeniety of volumetric heating between the contacting pebbles.

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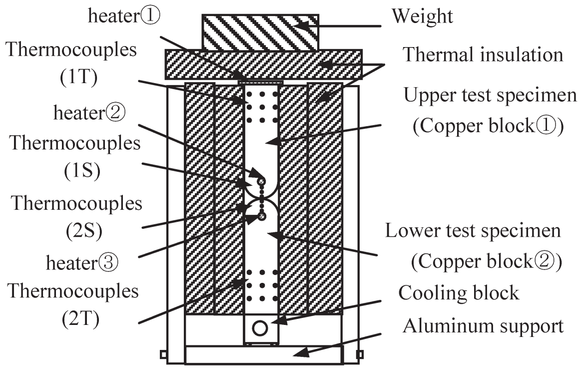

Fig. 1. Schematic view of experimental apparatus

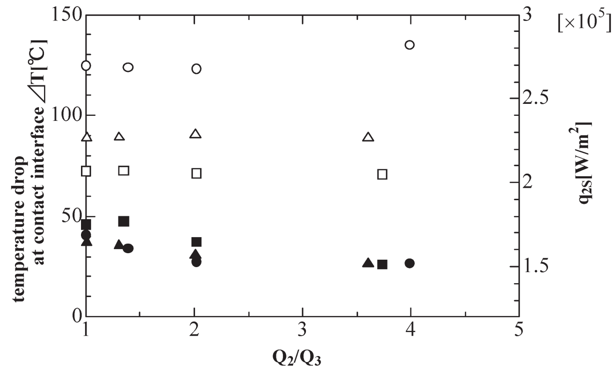

Fig.2 The dependence of inhomogeniety of volumetric heating on the temperature difference and heat flux through the contact interface: ○; P=1.2MPa, △; P=1.9MPa, □; P=2.0MPa for temperature difference, ●; P=1.2MPa, ▲; P=1.9MPa, ■ P=2.0MPa for heat flux

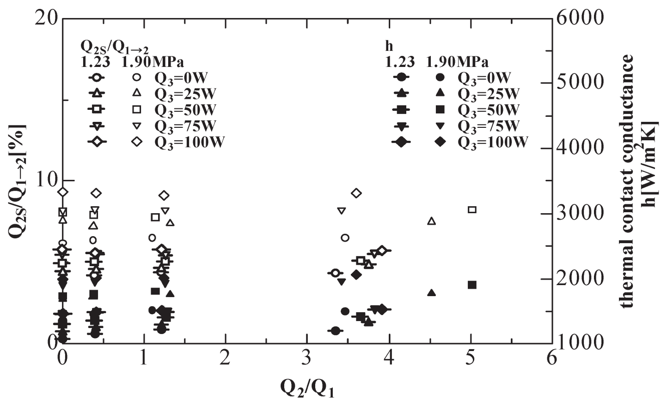

Fig. 3 Heat flow rate and thermal contact conductance