§9. Heat Transfer Between Pebbles Considering Large Temperature Gradient Inside Pebble

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Conventional experimental study for heat transfer in a pebble bed has been conducted by means of oven-type experimental apparatus, that is, all pebbles is equally heated by external heaters. After all, it is found that the effective heat conductivity of bed is affected by the external load. That means the heat transfer between pebbles near their contact region is dominated for the effective heat conductivity. When the volumetric heating is occurred in the each pebble, the large temperature gradient will be generated and/or inhomogeneous temperature profile will be occurred near the interface. The effects of above phenomena cannot be taken into consideration by oven-type experiment. In present study, focusing attention on two contacting pebbles, the effect of the amount of heat flow through the interface and the each temperature gradients near the interface on the thermal conductance is investigated and estimated quantitatively by using two contacting rods in which heaters is amounted to simulate the volumetric heating.

Fig.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.

Fig.2 show 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_{2S}) and heat flow through the contact interface ($Q_{1\to 2}$) and thermal contact 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. It is considered that the heat flow is contracted and the turbulence is suppressed near the interface by the existence of heat generation in the low temperature side of test specimen. That is, it should be considered for the design of solid blanket that the inhomogeneity of volumetric heating between the contacting pebbles.

The dependence of theoretical contact pressure on the heat flow rate is showed in Fig.3. The theoretical value of contact pressure is derived from Hertz's contact theory by using measured contact area. From the measured contact area, the corresponding theoretical pressure becomes 3GPa on the assumption that the contact body is complete circle. Using the value of 10MPa as a maximum pressure referred to the conventional solid blanket design, the heat flow rate is only 2% regardless of presence of volumetric heating at a low temperature side. Therefore, it should be emphasized that the effective introduction of convective heat transfer with fluid is dispensable for actual design of a solid blanket.

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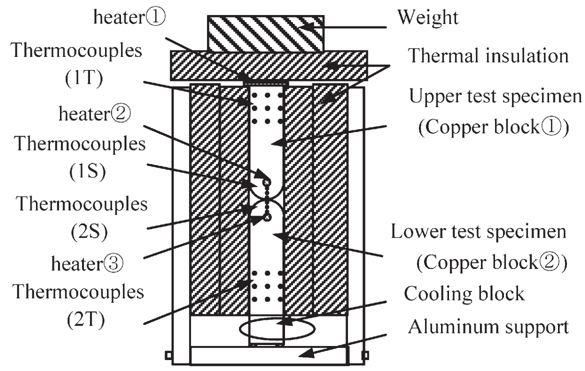

Fig. 1. Schematic view of experimental apparatus

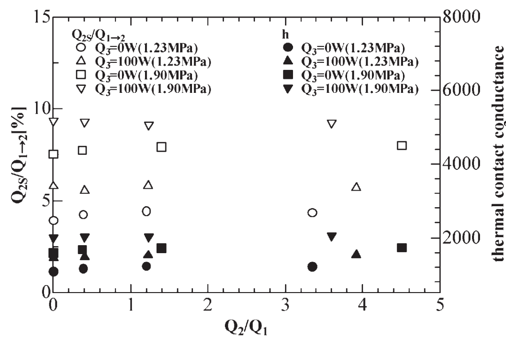

Fig. 2. Heat flow rate and thermal contact conductance

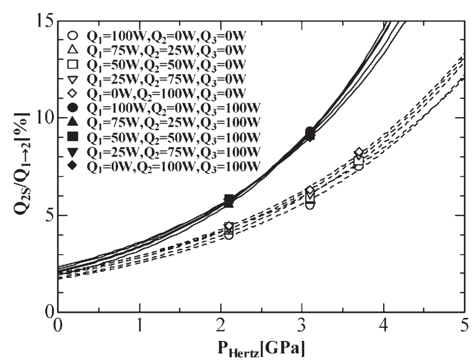

Fig. 3. Heat flow rate vs. load pressure