

Estimation of Recirculation Flow inside Pump for Ship-mounted Molten Salt Reactor

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1. Introduction

MSRs can use a liquid fuel model (fuel dissolved in the salt) or solid fuel rods with salt coolant. They operate at high temperatures without the need for high-pressure vessels, which significantly reduces the risk of explosions.[1] While researched since the 1950s/60s at Oak Ridge National Laboratory[2], current development is seeing a revival due to the need for low-carbon energy. The pump is shown in Fig. 1 and includes a centrifugal impeller and volute with the impeller supported at the lower end of a vertical shaft, gas-lubricated bearings for supporting the shaft, bearing housing, pump tank bowl, and volute support. [3] A molten salt reactor pump volute is characterized by having a structure surrounded by a pump bowl. The pump bowl serves to contain some of the fuel salt sucked from the reactor. The suction section of the MSR pump is located at the top of the reactor and the fuel salt is sucked from the reactor. The inhaled fuel salt passes through the impeller and is discharged into the volute. The volute discharge section is connected to a heat exchanger to generate a steam and is then reintroduced into the lower part of the reactor. Inside the pump bowl, some of the fuel salt that has entered the pump suction section is recirculated into the pump bowl through the bypass passage of the pump discharge section as shown in Fig.2. Inside the pump bowl, the pump drive section is filled with fuel salt, and the upper part of the impeller drive section is filled with gas. Fuel salts is recirculated within the pump bowl contain radioactive gases.

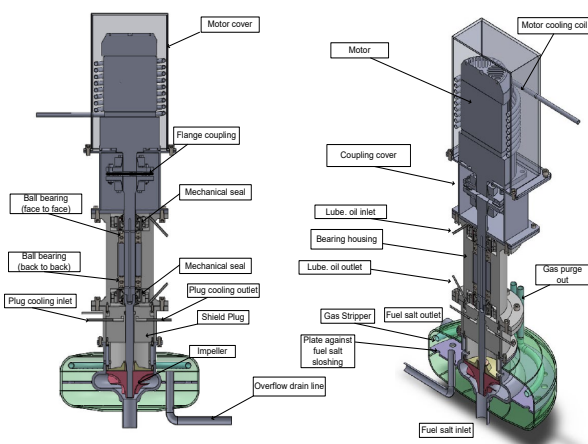


Fig. 1. 3D model of pump for MSR

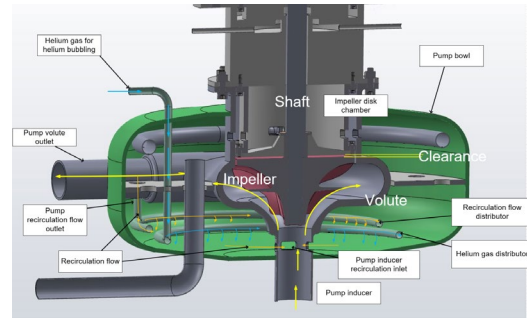


Fig. 2. Recirculation flow inside the pump bowl

To remove these radioactive gases, helium is injected into the liquid portion of the pump bowl. Helium is used to remove gaseous fission products in the molten salt reactor. Helium is an inert gas which doesn't react with the particles or the salt. The radioactive gas particles are adsorbed by helium bubbles, and the gas is then transferred to the upper gas portion. The radioactive gas and helium gas are discharged to the outside through the gas suction line installed in the gas section at the top of the pump bowl.

In this study, CFD analysis was performed to evaluate the recirculating flow occurred in the pump bowl of the circulation pump of a ship-mounted molten salt reactor.

2. Methods and Results

ANSYS CFX was used to analyze the recirculating flow occurring inside the pump bowl. Figure 3 shows the pump performance curve for recirculating flow analysis and pump discharge flow rate cases (500kg/s, 800kg/s, 1085kg/s, 1400kg/s).

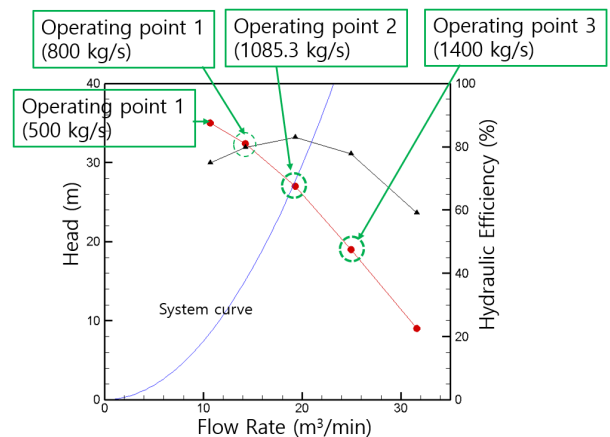


Fig. 3 Pump performance curve

The recirculation flow rate was evaluated as the flow rate discharged from the pump discharge port and re-entered into the window portion installed in the pump induce. Figure 4 shows the analysis results of the recirculation flow rate generated inside the pump bowl when the pump discharge rate is 500 kg/s. The recirculation flow rate re-introduced from the inside of the pump bowl to the pump inlet was calculated to be 51.8 kg/s. Pump discharge flow rate can vary depending on the reactor output, and recirculation amount can vary depending on the operating point of the pump. Figure 5 shows when the pump discharge flow rate is 800 kg/s, and the calculated recirculation flow rate is 44.5 kg/s. Figure 6 shows when the pump discharge flow rate is 1085 kg/s, and the calculated recirculation flow rate is 43.2 kg/s.

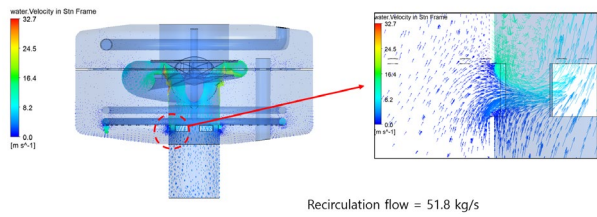


Fig. 4. Recirculation flow calculation
 (pump discharge flow rate: 500kg/s)

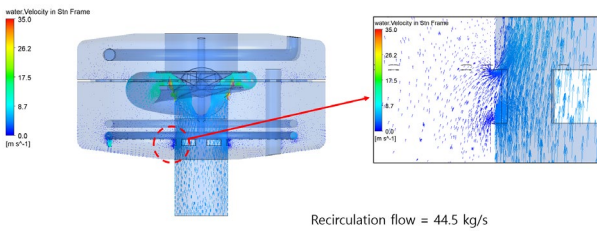


Fig. 5. Recirculation flow calculation
 (pump discharge flow rate: 800kg/s)

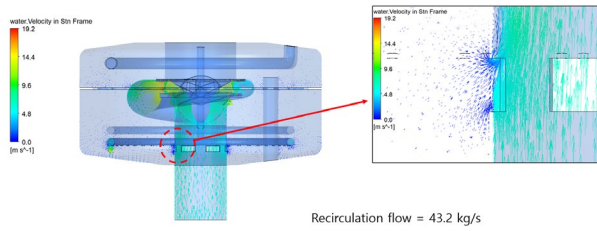


Fig. 6. Recirculation flow calculation
 (pump discharge flow rate: 1085kg/s)

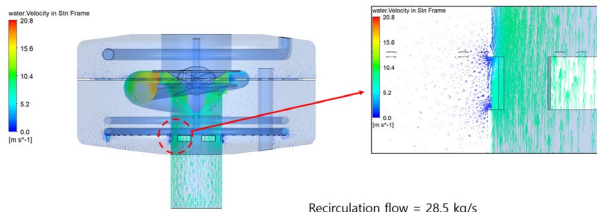


Fig. 7. Recirculation flow calculation
 (pump discharge flow rate: 1400kg/s)

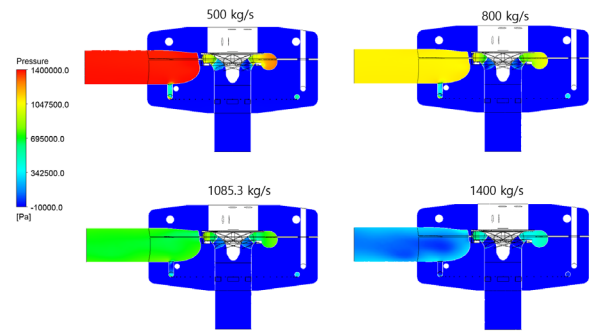


Fig. 8. Pressure contours at each flow rate

Figure 7 shows when the pump discharge flow rate is 1400 kg/s, and the calculated recirculation flow rate is 28.5 kg/s. The pressure distribution according to the flow rate shows in the Fig. 8, and it was confirmed that the recirculation flow rate decreases as the pressure difference between the pump discharge and inlet, which generate the recirculation flow rate. It decreases as the pump discharge flow rate increases.

3. Conclusions

In this study, the recirculation flow generated inside the fuel salt circulation pump bowl used in a ship-mounted MSR was analyzed through CFD. Ship-mounted pumps have a structure in which a pump bowl, designed to remove radioactive gases generated inside the reactor, surrounds the pump. In this study, the amount of recirculation occurring inside the pump bowl was calculated according to the flow point of the pump. As a result, when the pump discharge rates were 500 kg/s, 800 kg/s, 1085 kg/s, and 1400 kg/s, the recirculation amounts were calculated as 51.8 kg/s, 44.5 kg/s, 43.2 kg/s, and 28.5 kg/s, respectively. This result evaluates the effect of changes in the pump's flow rate on the recirculation flow rate, assuming there is no pressure change in the gaseous part above the pump bowl.

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