# Effects of Channel Size on Thermal Sizing of Printed Circuit Steam Generators with Micro Straight Semicircular Channels Connected by Cross Bridges

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## 1. Introduction

Korea Atomic Energy Research Institute (KAERI) has been developing a Printed Circuit Steam Generator (PCSG) to substitute a conventional shell-and-tube type steam generator in a small modular reactor [1-6]. The previous study [6] showed dependency of the size of the PCSG with micro straight semicircular channels connected by cross bridges on its length. In this study, the effects of the channel size on thermal sizing of the PCSG are investigated.

## 2. Calculation Method

The channel arrangement tested in this study is shown in Fig. 1. The channels of primary and secondary sides are straight and have a semicircular cross section whose diameter is *D*. A gap between the primary and the secondary sides is $\delta$. The channels on the one side are connected by cross bridges, whose cross section is equivalent to that of the main channels, with an interval of 5*D*. The diameter and the gap of the reference case are 3 mm and 1 mm, respectively.

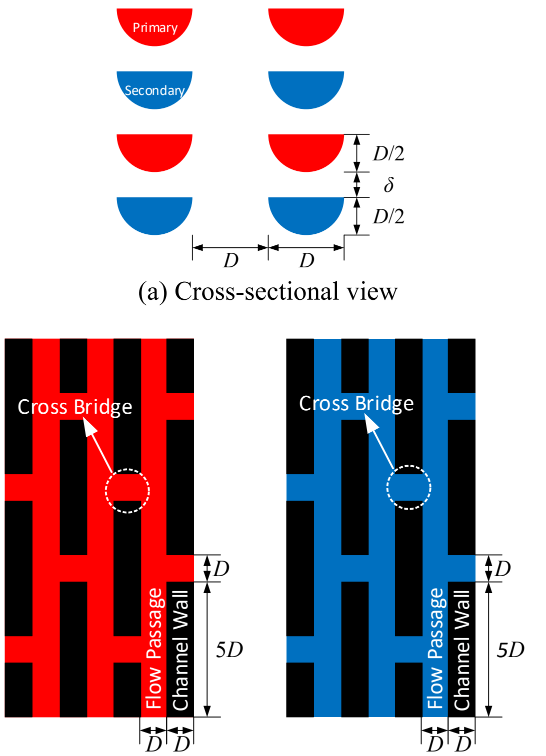
The calculation methodology for evaluating the thermal power of the PCSG was proposed by Kim et al. [1], and followed the analysis method of the existing performance analysis code for once-through steam generators, which was validated experimentally. In this study, their methodology was adopted, but, because the channel geometries were revised, the Nusselt number for calculating the heat transfer coefficient and the friction factor for predicting the pressure drop in the channels were used as follows [7]:

$$\mathrm{Nu} = 0.024\,\mathrm{Re}^{0.794}\,\mathrm{Pr}^{0.555} + 0.198 \quad (1)$$

$$f = 0.493\,\mathrm{Re}^{-0.447} + 0.0046 \quad (2)$$

where Re and Pr are the Reynolds number and the Prandtl number in the flow channel, respectively. It is expected that the calculation methodology and the new correlations give a reasonable tendency of thermal sizing, and additional experiments are planned to evaluate their quantitative validity.

Values of the flow rate, inlet temperature, inlet pressure in the primary channel and the flow rate, inlet temperature, outlet pressure in the secondary channel were given to be same to those of the SMART reactor [8], however, the thermal power was obtained from the calculation. The calculations were conducted for the various channel diameter from 1.2 to 4.5 mm, and there are two cases for a channel diameter; the gap between the primary and the secondary sides is fixed to be 1 mm, and adjusted to be proportional to the reference case (*D* = 3 mm), as shown in Table 1. For all the cases, the length of the PCSG was set to be 1 m.




(a) Cross-sectional view

(b) Primary-side floor (c) Secondary-side floor

Fig. 1 Channel arrangement

Table 1 Test matrix (reference case: *D* = 3 mm)

| Diameter, *D* (mm) | Gap, $\delta$ (mm) | |
|---|---|---|
| | Fixed | Adjusted |
| 1.20 | 1.00 | 0.40 |
| 1.50 | 1.00 | 0.50 |
| 1.80 | 1.00 | 0.60 |
| 2.25 | 1.00 | 0.75 |
| 3.00 | 1.00 | |
| 3.75 | 1.00 | 1.25 |
| 4.50 | 1.00 | 1.50 |

### 3. Calculation Results

Figure 2 shows the variation of the thermal power of PCSGs with various channel diameters. As the channel diameter decreases from 4.5 mm, the thermal power increases. This is because the effect of increased heat transfer coefficient is greater than that of reduced heat transfer area, resulting in decreased convective thermal resistance.

Also, as the channel diameter becomes smaller than 2.0 mm, the thermal power for the adjusted gap increases monotonically, but that for the fixed gap decreases. For the adjusted gap, the conductive thermal resistance is maintained regardless of the channel diameter, however, for the fixed gap, the resistance increases along with the channel diameter. Thus, in the region where the channel diameter is smaller than 2.0 mm, it is meant that the conductive thermal resistance is dominant than convective thermal resistances.

Figure 3 shows that the PCSG volume is approximately proportional to the channel diameter. When the channel diameter is smaller than that of the reference case, the PCSG for the fixed gap is bigger than that for the adjusted gap. On the contrary, in the range of the channel diameter larger than that of the reference case, the PCSG volume for the fixed gap is less than that for the adjusted gap.

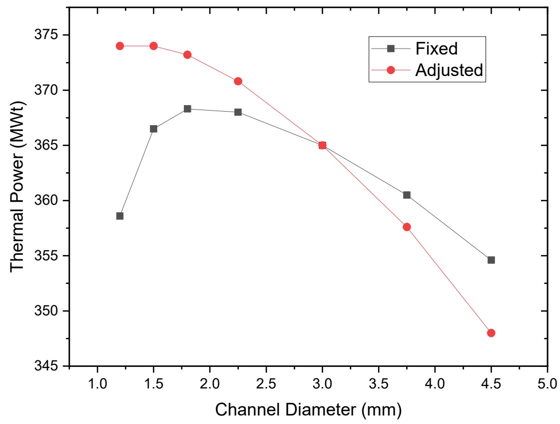



Fig. 2 Thermal power versus channel diameter

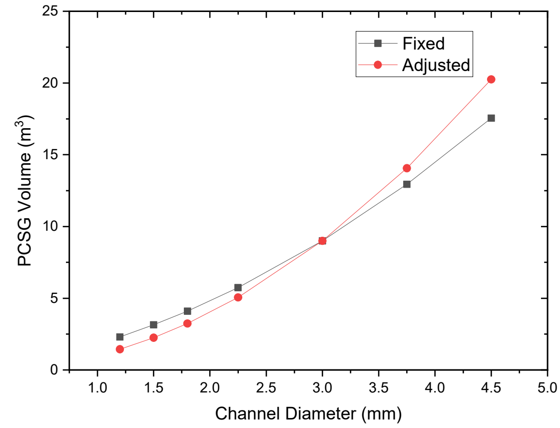



Fig. 3 PCSG volume versus channel diameter

### 4. Conclusions

In this study, the effects of the channel size on thermal sizing of a PCSG with straight semicircular micro channels connected by cross bridges were investigated. Decreasing the channel size gives reduced convective thermal resistance, resulting in increased thermal power. However, for the fixed gap between the primary and secondary sides, a decrease in the channel size occurs an increase in conductive thermal resistance. Hence, the thermal power for the fixed gap has the maximum at a specific channel diameter, but the thermal power for the adjusted gap increases monotonically for decreasing the channel diameter.

### Acknowledgement

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