Sensitivity Analysis for DHRS Heat Exchanger Performance Tests of PGSFR

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1. Introduction

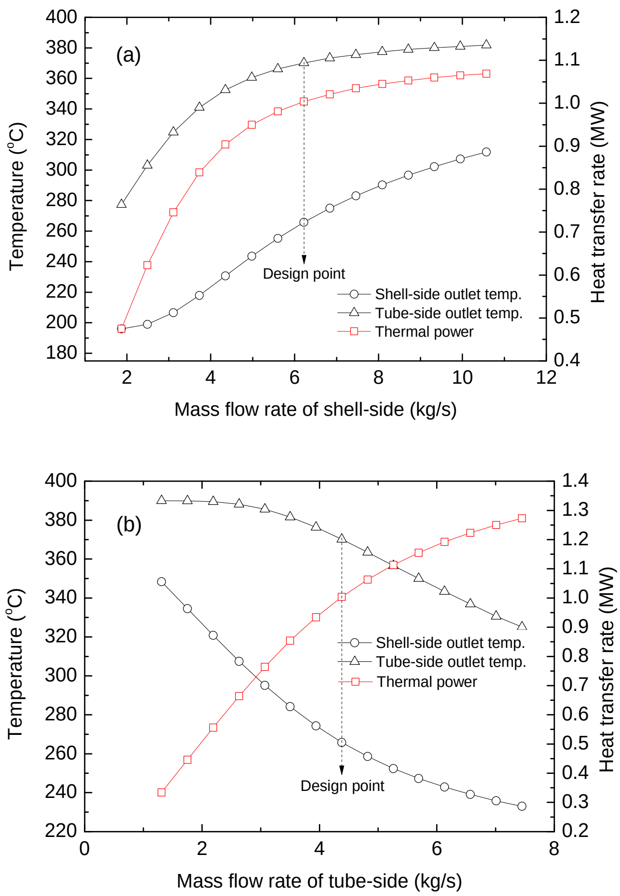
The STELLA program for PGSFR DHR performance demonstration is in progress at KAERI. As the first phase of the program, the STELLA-1 facility has been constructed and separate effect tests of heat exchangers for DHRS are going to be conducted [1-4]. Two kinds of heat exchangers including DHX (shell-and-tube sodium-to-sodium heat exchanger) and AHX (helical-tube sodium-to-air heat exchanger) will be tested for design codes V&V. Main test points are a design point and a plant normal operation point of each heat exchanger. Additionally, some plant transient conditions are taken into account for establishing a test condition set. To choose the plant transient test conditions, a sensitivity analysis has been conducted using the design codes for each heat exchanger.

2. Methods and Results

Two design codes, SHXSA for the DHX and AHXSA for the AHX, were used for the sensitivity analysis. The influence of the change in mass flow rates and inlet temperatures of shell- and tube-sides on the outlet temperatures of shell- and tube-sides and the heat transfer rate (thermal power) was investigated by calculation at the design point and plant normal operation condition.

At the design point of the DHX, the mass flow rates of the shell- and tube-sides and the inlet temperatures of the shell- and tube-sides are 6.22 kg/s, 4.38 kg/s, 390 ℃, and 195.6 ℃, respectively. From the initial point (design point), the gradual change in each parameter caused the change in the outlet temperatures of the shell- and tube-sides and the thermal power. Fig. 1 shows the results of the sensitivity analysis for the design point of the DHX. The effect of the change in inlet temperatures of the shell- and tube-sides on the DHX performance was larger than that in the mass flow rates of the shell- and tube-sides. Table 1 shows the sensitivity of the DHX performance by the relative changes (–20, –10, +10, and +20%) from the values at the design point. The thermal power had the highest sensitivity to the change of the inlet temperature of the shell-side. The outlet temperatures also changed the most as the inlet temperature of the shell-side changed.

In a similar manner, the sensitivity analysis has been carried out at the plant normal operation condition of the DHX and at the design point and plant normal operation condition of the AHX. The DHX heat transfer performance was sensitive to the change in the inlet temperature of the shell-side at the plant normal operation condition. The AHX heat transfer performance was sensitive to the change in the inlet temperature of the tube side at both the design point and plant normal operation condition. Another important concern about the sensitivity of the AHX is how much the intake air temperature of the shell-side affects the AHX performance because it is hard to control the intake air temperature, which depends on the weather. Fig. 2 shows the influence of the intake air temperature on the AHX performance at the design point. Considering hot and cold weather, as the air temperature changed from 40 ℃ to –20 ℃, the outlet air temperature of the shell side decreased by 15.6 ℃ (5.4%), the outlet sodium temperature of the tube side decreased by 28.6 ℃ (14.6%), and the thermal power increased by 90 kW (17%). Therefore, the effect of the change in the intake air temperature by the weather on the AHX performance was not negligible. To achieve the good repeatability for the AHX test, tests need to be conducted under similar air temperature conditions.



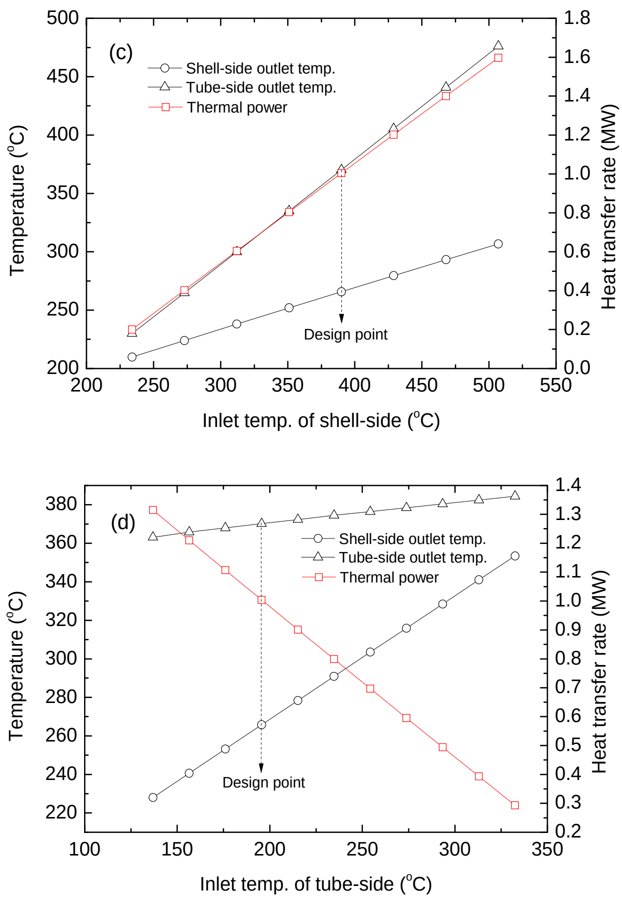


Fig. 1 Results of the sensitivity analysis at the design point of the DHX. Each figure shows the influence of the change in (a) the mass flow rate of the shell-side, (b) the mass flow rate of the tube-side, (c) the inlet temperature of the shell-side, and (d) the inlet temperature of the tube-side.

Table 1. The sensitivity of the design parameters at the design point of the DHX.

Change in parameters		$T_{out,s}$ (℃)	$T_{out,t}$ (℃)	Q (kW)
$\dot{m}_s$	–20%	–22.2	–9.6	–54
	–10%	–10.5	–4	–23
	+10%	+9.2	+3.1	+17
	+20%	+17.3	+5.4	+31
$\dot{m}_t$	–20%	+18.4	+11.4	–150
	–10%	+8.5	+6.1	–70
	+10%	–7.2	–6.7	+59
	+20%	–13.4	–13.6	+109
$T_{in,s}$	–20%	**–27.7**	**–70.3**	**–400**
	–10%	**–13.8**	**–35.2**	**–200**
	+10%	**+13.7**	**35.2**	**+198**
	+20%	**+27.4**	**70.6**	**+396**
$T_{in,t}$	–20%	–25.2	–4.4	+206
	–10%	–12.6	–2.2	+103
	+10%	+12.6	+2.1	–103
	+20%	+25.1	+4.3	–205

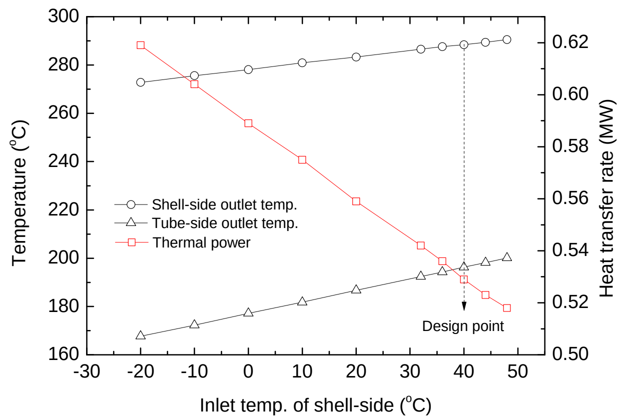


Fig. 2 The influence of the change in the inlet air temperature of the shell-side on the AHX performance at the design point.

3. Conclusions

The sensitivity of the PGSFR DHRS heat exchanger tests (the DHX and AHX in the STELLA-1 facility) has been analyzed through a parametric study using the design codes SHXSA and AHXSA at the design point and the plant normal operation point. The DHX heat transfer performance was sensitive to the change in the inlet temperature of the shell-side and the AHX heat transfer performance was sensitive to the change in the inlet temperature of the tube side. The results of this work will contribute to an improvement of the test matrix for the separate effect test of each heat exchanger.

ACKNOWLEDGMENTS

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