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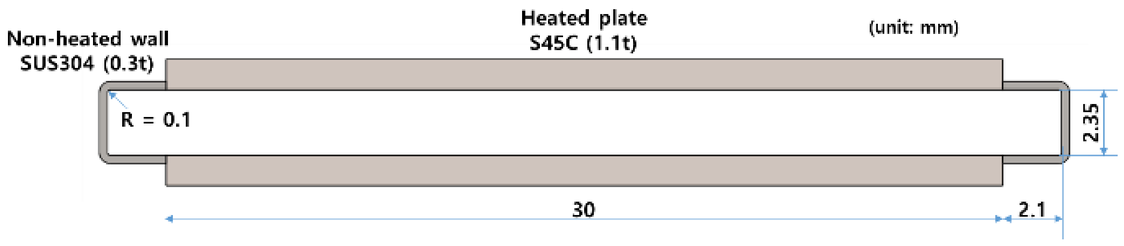
Heating Power Ratio Calculation to Design Test Section Including Non-Heated Side Wall

Kiwon Song[a]*, Hyung Min Son[a], Jonghark Park[a]

aKorea Atomic Energy Research Institute, 989-111 Daedeok Daero, Yuseong Gu, Daejeon, 305-353, Korea
**Corresponding author: k1song@kaeri.re.kr*

Introduction

- KAERI has designed channel for plate-type fuel which includes heated wall and non-heated side wall simulating a frame.
- Since direct heating is applied to the entire channel, non-heated side wall is made of the material with relatively high electrical resistance to reduce heat generation.
- This paper estimates the amount of heat generation at non-heated wall by using CFX code. This study is helpful to design test section including non-heated side wall using direct heating method.



Cross section of KAERI developed test channel

Heating Power Calculation Method

- Since heated plate and non-heated wall has parallel connection to voltage direction, higher resistance yields lower power.

$$P = \frac{V^2}{R}$$

- Material thickness of non-heated wall is designed thinner than heated plate to generate power as low as possible.

Material	Thermal Conductivity	Electrical Resistance	Specific Heat Capacity	Density	Thickness
	W/(m·K)	μΩ·m	J/(kg·K)	kg/m^3	mm
SUS304	16.8	0.72	490	8,000	1.1
S45C	49.8	0.41	486	7,850	0.3

- This calculation doesn't consider heat conduction between two materials assuming that thermal contact resistance is very high.

Heater Plate (S45C)					Non-heated (SUS304)					
Length	Thick-ness	Width	Specific Resist-ance	Resist-ance	Length	Thick-ness	Gap Thick-ness	Width	Specific Resist-ance	Resist-ance
(mm)	(mm)	(mm)	(μΩ·m)	(Ω)	(mm)	(mm)	(mm)	(mm)	(μΩ·m)	(Ω)
600	1.1	30	0.41	0.0075	600	0.3	2.35	4.2	0.72	0.22

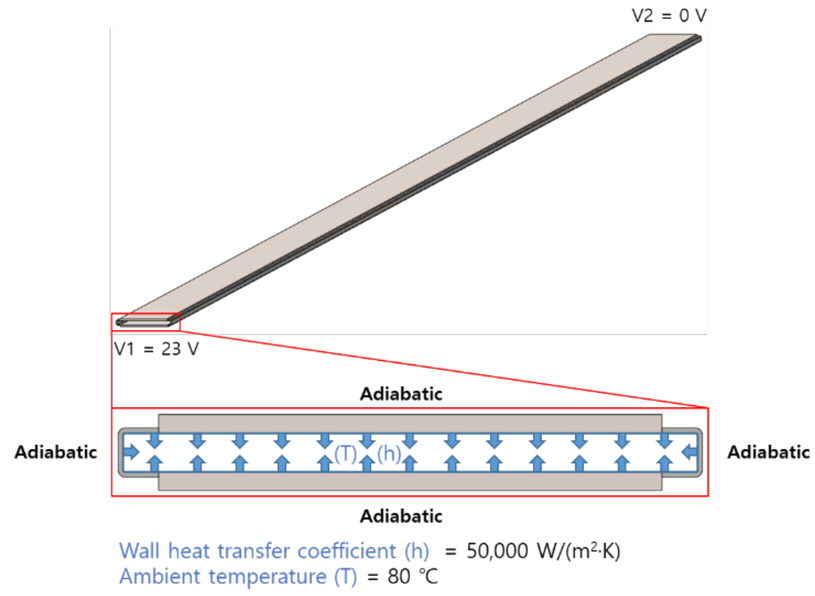
Entire Channel	**Non-heated**	-		
Resistance	**Power Ratio**	Target Heat Flux	Voltage	Current
(Ω)	-	(kW/m2)	(V)	(A)
0.0036	**3.49%**	3,950	23.0	6,386

- In calculation, 3.49 % of total power is generated at non-heated wall.

CFX Calculation for Heating Power Ratio for Test Channel

Boundary condition

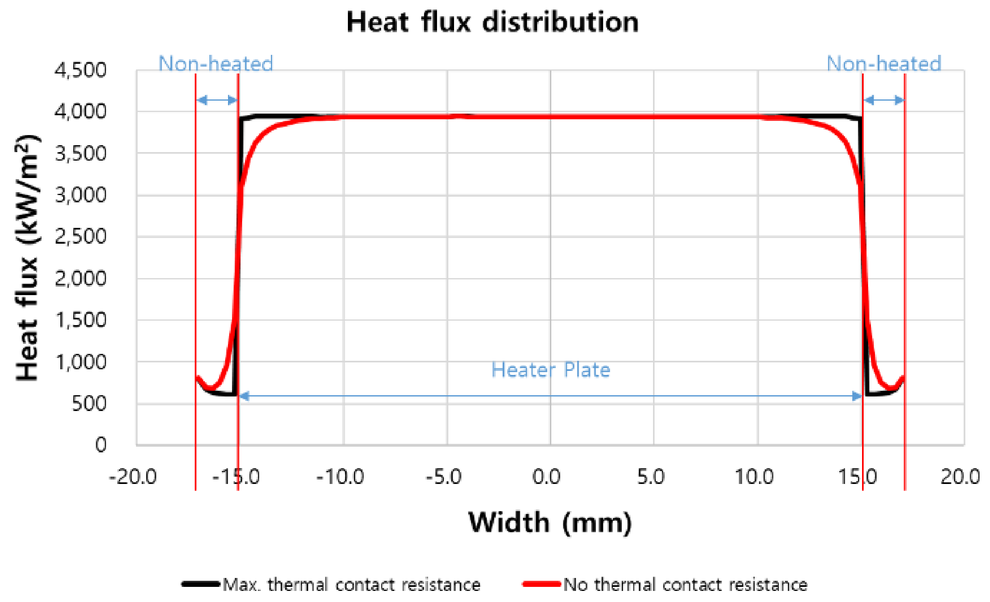
- Since the value of the heat flux does not affect its distribution, target heat flux is assumed 3,950 kW/m^2. Required electrical potential was estimated 23 V to generate target heat flux.
- Inside of the channel is cooled with 50,000 W/(m^2·K), while outside of the channel is adiabatic. Since the value of heat transfer coefficient has effect on the absolute value of the wall temperature, but has no effect on temperature distribution, heat transfer coefficient was arbitrarily decided. For a similar reason, 80 ℃ ambient temperature was chosen.
- In this study, two cases of calculation was carried out: maximum thermal contact resistance, and zero thermal contact resistance.



Cross section of KAERI developed test channel

Calculation Result

- High and uniform heat flux is applied from the center of the heater plate to near non-heated wall.
- In maximum thermal contact resistance case, heat flux falls steeply at contact surface, while heat flux falls slowly in zero thermal contact resistance case.



Surface heat flux distribution along the channel width

- Since heater plate material S45C has the higher thermal conductivity, heat flux at heater plate can easily be uniform distribution. On the other hand, less heat is transferred to non-heated wall due to the low thermal conductivity of SUS304, which is fit for purpose of the test section design.

	Total power (kW)	Heat generation @ heater plate (kW)	Heat generation @ non-heated wall (kW)	Heat generation ratio @ non-heated wall
Hand Calculation	142.2	137.2	5.0	**3.49 %**
CFX No thermal resistance	146.1	139.4	6.8	**4.63 %**
CFX No thermal conduction	146.1	141.1	5.1	**3.46 %**

- Without considering of conduction heat transfer at contact surface, heat generation (power) ratio at non-heated wall to total is estimated 3.49 % and 3.46 % at hand calculation and CFX calculation respectively.
- In no thermal contact resistance case, 4.63 % of the total heat is generated at non-heated wall, which is 1.17% higher than maximum thermal contact resistance case. This 1.17% heat can be considered as the amount of conduction heat transfer through contact surface.

Summary

- Regardless of conduction heat transfer at contact surface, hand calculation has very similar result with CFX code calculation.
- This study can conclude that minimum 3.46 % to maximum 4.63 % of heat can be generated at non-heated side wall in 30 mm heater plate test section.