A Numerical Study on the Validity of Slab Models

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1. Introduction

A slab model has been widely applied in the thermal-hydraulic safety research fields for a simplified test development. However, the similarity in thermal-hydraulic behaviors is strongly dependent on the flow characteristics having a 2-D or 3-D flow field. The slab model is suitable for 2-D flow characteristics. If the slab model is applied in a strong 3-D flow field, the flow distortion grows highly. In this numerical study, the distortion of the flow field is investigated by changing the aspect ratio of the test section.

2. Numerical Model

A simple rectangular parallel shape with a 9-heater array was considered for the slab model validity test. Fig. 1 shows a schematic view of the test section. The height is 60 cm, width is 6 cm, and the depth is 60 cm. The constant N is a switching parameter of the aspect ratio. The aspect ratio (B_R :W_R) ranges from 1/6 to 1/3. The 3x1 heater array is the reference case of the 3x3-heater array. The total volume is not changed with aspect ratio. The diameter of the steel heater is 3 cm, and the length is 8 cm. The surface temperature of the heating element is 99 C as a constant value. The steady-state laminar model was applied. The working fluid is water.

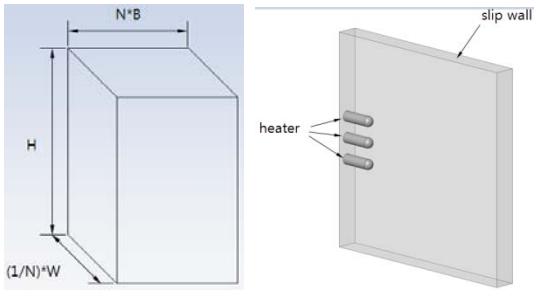


Fig. 1 Geometry of test section

Table 1 Test matrix

Case	B_R :W $_R$ Ratio	W (cm)	B (cm)	Node Million
N01, 1x3 heater	1/3 : 1	60	6	0.62
N02, 1x3 heater	2/3:1/2	30	12	0.78
N03, 1x3 heater	1 :1/3	20	18	0.80
N06, 1x3 heater	2 : 1/6	10	36	0.81
N01x3, 3x3 hts	3 : 1	60	18	1.87

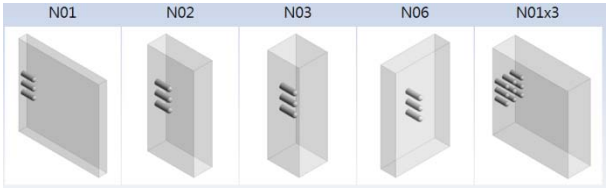
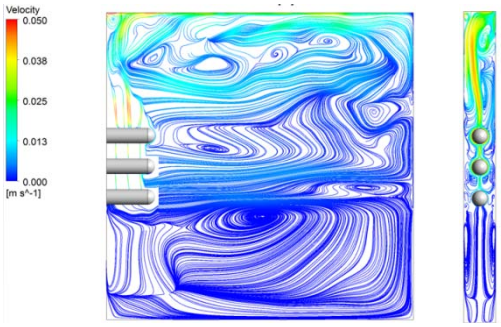


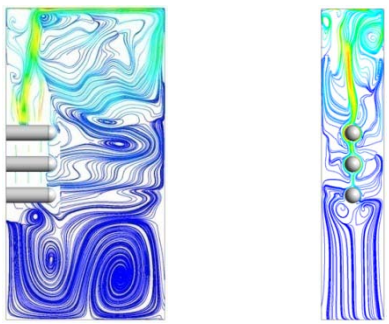
Fig. 2 Aspect ratio(B_R :W_R) ; (N01) 1/3 : 1, (N02) 2/3 : 1/2, (N03) 1 : 1/3, (N06) 2 : 1/6 for 1x3 heater array, and (N01x3) 3x1 for 3x3-heater array as a reference

3. Calculation Results

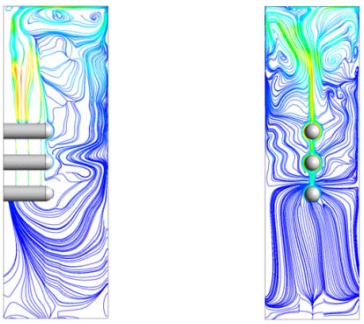
The main objective of this test is to investigate the flow distortion of a slab model when a high aspect ratio is applied for a narrow slab model. The side wall resistance effect is amplified in the high aspect ratio slab model when compared to the flow behaviors having a wide flow geometry model. Thus, the induced flow velocity of a high aspect ratio slab model by a buoyancy driven force is relatively decreased when compared to that of a wide model.



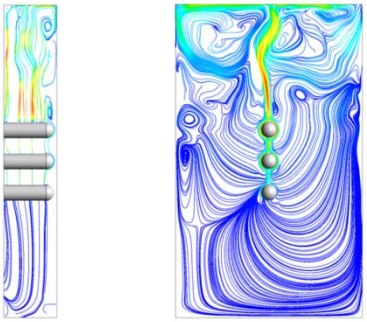
(a) N01, 1x3 heater : 1/3 : 1 slab model



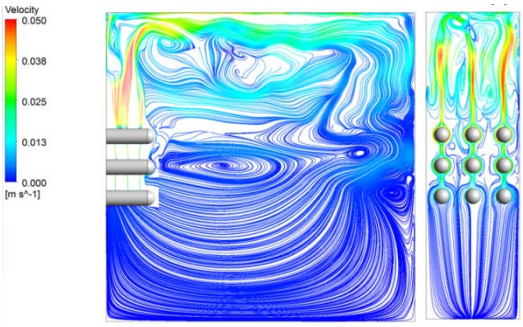
(b) N02, 1x3 heater : 2/3:1/2 slab model



(c) N03, 1x3 heater : 1 :1/3 slab model



(d) N06, 1x3 heater : 2 : 1/6 slab model

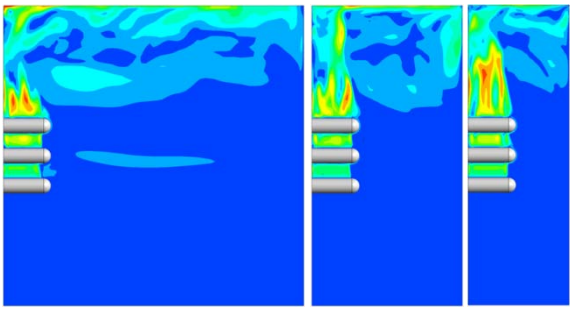


(e) N01x3, 3x3 heaters: 3 : 1 Reference model

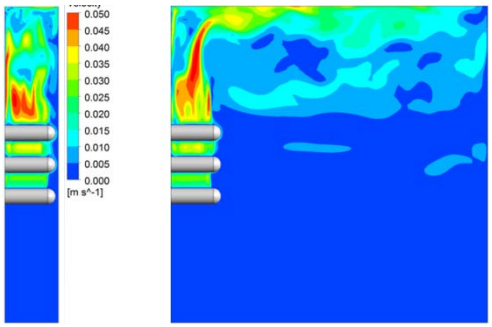
Fig. 3 Stream lines with aspect ratio

Fig. 3 shows the stream lines with their aspect ratio. Fig. 3 (a) is a high slab model. The side wall effects of the one-array (N01) slab model on the buoyancy driven velocity around the heaters are the highest among the presented models. Figs. 3(a) and 3(e) show the 1/3 slab model and reference base case results, respectively. The height and the depth ratios are 1/1, although the width is reduced to 1/3 from the reference case of (e). The stream lines at the lower part are also distorted from the shape of the reference case.

Fig. 4 shows the velocity contour lines with the aspect ratio. Fig. 4 (a) and 4(e) show the difference in the buoyancy driven velocity around the heaters for a 1/3 slab model and the reference base case, respectively. As described above, the rising velocity around the heaters is decreased due to the relatively increased wall resistance when compared to the reference case. As a result, the buoyancy driven velocity is distorted for the slab model having a high aspect ratio.



(a) N01: slab model (b) N02 (c) N03



(d) N06: slab model (e) N01 x 3 array

Fig. 4 Velocity contour lines with aspect ratio.

4. Conclusions

A numerical calculation was performed with various aspect ratios to evaluate the applicability and validity of slab models. From the present results, it can be concluded that the slab model should be well considered to conserve the flow pattern. A 2D flow pattern can be distorted due to an increased wall resistance when a high aspect ratio model is adapted.

Acknowledgement

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