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Natural Convection Heat Transfer Experiments of Horizontal Plates with Fin Arrays

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1. Introduction

Core melt in a severe accident condition, forms a molten pool in the reactor vessel lower head. The molten pool is divided by a metallic pool (top) and an oxide pool (bottom) by the density difference [1]. The crust between the metallic layer and the oxide pool may be formed by solidification of the molten metallic materials. So the surface of the crust is formed irregularly [2].

Experiments were performed to investigate the irregular crust as a preparatory study before an in-depth severe accident study. The natural convection heat transfer were investigated experimentally varying the height and spacing of fins, top plate of different kinds and the plate separation distance with/without the side walls. In order to simulate irregular crust surface condition, the finned plates was used. Using the analogy concept, heat transfer experiments were replaced by mass transfer experiments. A cupric acid–copper sulfate (H_2SO_4-$CuSO_4$) electroplating system was adopted as the mass transfer system and the electric currents were measured rather than the heat transfer rates.

2. Previous studies

The natural convection heat transfer of the horizontal plate-fin is influenced by the height, length, thickness, and spacing of the fins on the base plate [3].

Eric Arquis and Mohamed Rady [4] studied the natural convection from a horizontal fluid layer with finned bottom surface experimentally and numerically. The *Ra* ranged from 2×10^3 to 3×10^4. They focused on the influence of the height and spacing of the fins. Fig. 1 shows flow patterns with/without fins. The natural convection heat transfer for a finned plate is larger than that for a bare plate as the fins increase the heat transfer area and the Benard cell. The heat transfer area increases with the increase of the Benard cell.

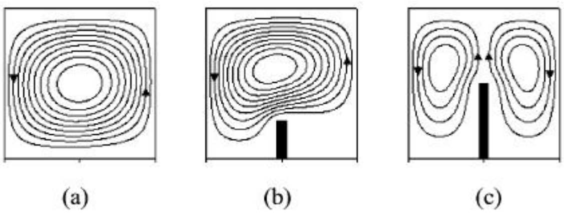


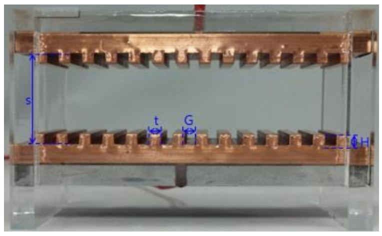
Fig. 1 Flow patterns : (a) Without fin, (b) low fin, (c) high fin

Senol Baskaya et al. [5] studied the natural convection heat transfer from rectangular fins numerically. The *Ra* ranged from 2.1×10^2 to 1.8×10^5. They focused on the influence of the height and length of the fins. They reported that the heat transfer coefficient reduces with fin length. This is due to variations in the flow patterns. They concluded that the overall heat transfer is enhanced with increase in fin height and fin length

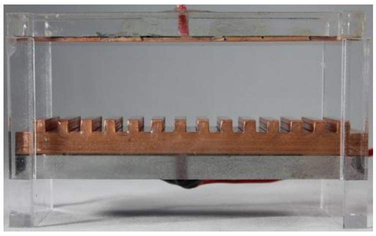
3. Experiments

3.1 Apparatus and Test Matrix

Fig. 2 shows test apparatus. The apparatus consisted of a downward-facing rectangular copper anode plate, an upward-facing copper cathode plate and acrylic supports of either open or closed sides, which is immersed in a solution tank of enough volume.



(a) Finned plate at the top



(b) Flat plate at the top

Fig. 2 The experimental apparatus.

Table 1: Test matrix.

Fin spacing (m)	Fin height (m)	Separation distance (m)	Side wall	Top plate
0.0025, 0.005, 0.01	0.0025, 0.005	0.0015 0.002 0.003 0.005 0.007	Open, Closed	Flat, Finned

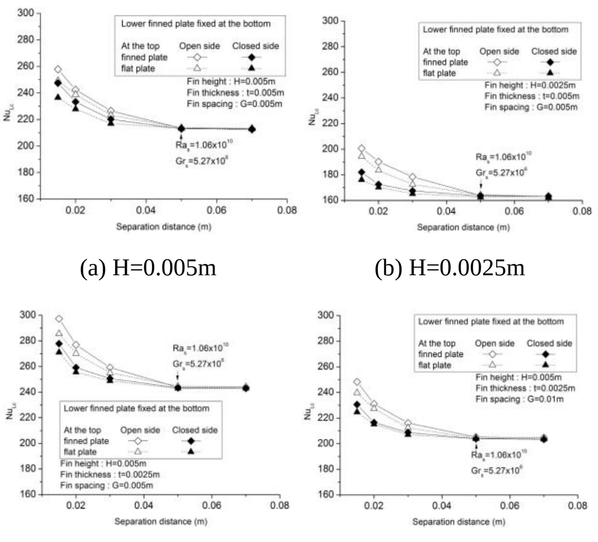
Table 1 is the test matrix. Spacing of fins, height of fins, plate separation distances, presence of side wall, and top plate of different kinds were varied accordingly. The Ra_s depending on the separation distance ranged from 2.87×10^8 to 2.91×10^{10} and *Pr* was 2,014.

3.2 Experimental Methodology

Heat and mass transfer processes have analogy characteristic as the governing equations and parameters are of the same type [6]. Therefore, heat transfer problem can be solved by mass transfer experiment, or vice versa. In this study, the measurements of mass transfer rates using limiting current technique were performed. A more detailed explanation of the methodology can be found in Chung et al. [7-8].

4. Results and discussion

Fig. 3 shows the measured Nu_{Lc} varying the separation distances with/without the side walls for top plate of different kinds. The measured Nu_{Lc}'s show similar trends and they decrease with the plate separation distances. At about 5cm of the separation distances between the lower and the upper plates, the influence of the upper plate disappear. As the area of plate increases, the measured absolute value of the Nu_{Lc}, increases.



(a) H=0.005m (b) H=0.0025m

(c) G=0.01m (d) G=0.005m

Fig. 3 The effect of fin height (H) and fin spacing (G) depending on Separation distance.

The Nu_{Lc}'s measured for closed side walls are less than those for open side walls. It can be explained by the circulating flow which causes the inflow of the cold fluid at side while the hot plume was rising [9].

The Nu_{Lc}'s measured for flat plate at the top are less than those for open side walls. And the Nu_{Lc}'s measured for (b) and (d) less than those (a) and (c) . The Nu_{Lc}'s measured for (d) less than those (c) respectively. It can be clarified by the heat transfer areas of plates increases.

The differences of the Nu_{Lc}'s between the open and the closed side walls, the flat and the finned top plates become clear when the plate separation distances reduce.

5. Conclusions

The natural convection heat transfer were investigated experimentally varying the height and spacing of fins, top plate of different kinds and the plate separation distance with/without the side walls. It is confirmed that the increase of the fin height and the decrease of fin spacing and the decrease of the plate separation distance enhanced the natural convection heat transfer.

The heat transfer rates for open side wall cases were larger than ones for closed side wall cases. And the heat transfer rates for finned plates at the top were larger than ones for flat plates at the top.

In order to simulate the crust between the metallic layer and the oxide pool occurs in molten pool in the severe accident conditions, further works are undertaken such as material property investigation, scaling analysis, etc.

6. Further Studies

Further studies are investigated material property, such as the metallic layer, the oxide pool, and the crust in the Severe accident. So, the experimental study of natural convection heat transfer of the irregular crust will be studied concretely.

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