Investigation of Heat Dissipation by Natural Convection from Flat Heated Plate Using Thermal Imaging

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ABSTRACT

The cooling of heated surfaces is a challenge encountered in several engineering applications. For example, heat sinks frequently used to cool electronic devices are more likely subject to surface temperature rise, increasing the risk of failure for these devices. Other examples of common heated surfaces include roof windows, glass walls, and windows that allow daylight energy transfer to buildings' infrastructures, impacting significantly heating performances in these infrastructures. This project aims to theoretically and experimentally investigate the energy dissipation on a 20cm x 30cm heated flat rectangular plate cooled by natural convection using thermal imaging techniques. It is hypothesized an increased cooling rate of the bottom surface of the heated plate compared to the top region by natural convection due to the air density changes in the vicinity of the plate's surface. An iterative method with Microsoft Excel was used to create a theoretical simulation of different heat fluxes. Results indicate a logarithmic growth of the plate's surface temperature from the bottom along with the height of the plate, which corresponds to a similar decrease in the heat transfer coefficient. Primary results of the plate's surface temperature captured using a FLIR E4 Infrared Camera with an 80x60 I R resolution confirmed the theoretical temperature profile observed. Further experimental data will be collected using thermal imaging techniques in future investigations to understand better the heat dissipated from flat vertical surfaces used in several engineering applications.

INTRODUCTION

Cooling of heated surface is a challenge in engineering applications. Various cooling methods including forced convection, natural convection and advanced cooling method have been investigated for effective cooling. Natural Convection is a mechanism in which fluid motion is generated by density differences due to temperature gradient. It can only take place in gravitational fields. It occurs by natural means such as buoyancy forces.

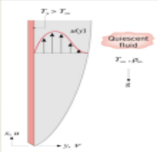


Figure 2: Natural Convection Natural[2]

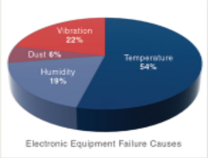


Figure 1: Electronic Failures Causes[1]

OBJECTIVE

The experiment was conducted to investigate the heat dissipation by natural convection from a flat heated vertical plate using thermal imaging.

Theoretical and experimental investigations of surface temperature distribution over the heated plate were conducted.

HYPOTHESIS

The surface temperature profile increases along the height of the plate.

There is an increased cooling rate from the bottom surface of the heated plate compared to the top region by natural convection as a result of the air density changes in the vicinity of the plate's surface.

METHOD AND EXPERIMENTAL

The theoretical method consisted of an iterative process where the surface temperature Ts was obtained using Microsoft Excel. The surface temperature and heat Transfer coefficient were generated for three constant heat flux q" of 150 W/m2 , 140 W/m2, 120 W/m2 . Ts was computed along the height of the plate with increments of 0.001 m, 0.002 m, and 0.005 m. The governing equations were:

- Laminar flow, uniform surface heat flux equation

$$T_s(x) - T_\infty = \left[\frac{4 + 9Pr^{1/2} + 10Pr}{Pr^2}\left(\frac{v^2}{\beta g}\right)\left(\frac{q_s''}{k}\right)^4 x\right]^{1/5}$$

- Newton's Law of cooling equation

$$q = hA(T_s - T_\infty)$$

The experimental method consisted of collecting thermal images of the heated plate will be collected for different heat fluxes.

RESULTS

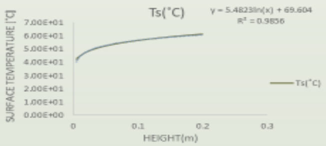


Figure 3: Variation of surface temperature with height of the plate

Heat Flux q" = 150 W/m^2

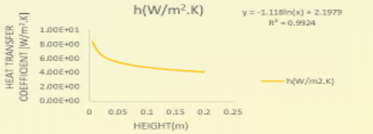


Figure 4: Variation of heat transfer coefficient with height of the plate

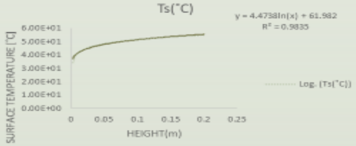


Figure 5: Variation of surface temperature with height of the plate

Heat Flux q" = 120 W/m^2

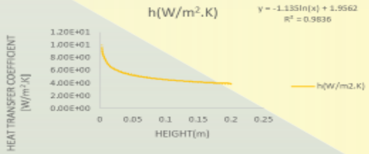
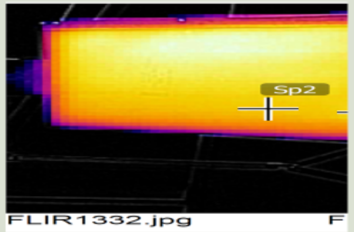
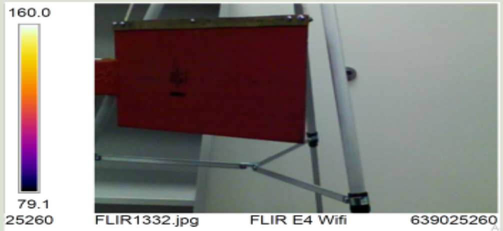


Figure 6: Variation of heat transfer coefficient with height of the plate

EXPERIMENTAL RESULTS





CONCLUSIONS

- Heat transfer coefficient is within the [5, 30] W/m2.K
- Surface temperature graph has a logarithmic growth.
- Heat transfer coefficient decreases along the height.
- Heat removal decreases with increasing height, cooling is effective at the bottom of the plate

FUTURE ENDEAVORS

- Thermal images of the heated plate will be collected for different heat fluxes.
- The experimental results will be compared to the theoretical results.
- A Computational analysis will be carried using Ansys

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