Relationship between Natural Convection Cooling Performance and Tilt Angle of Thin Enclosure

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This paper describes cooling performance of natural convection in thin enclosures such as LCD Monitor. Natural convection cooling is widely used in electronic equipment which cannot use fans in order to decrease power consumption and to avoid a generation of noise. However, sometimes a tilt angle of an enclosure of thin type electronic equipment are changed according to the operating environment by a user. Natural convection is generated by the relationship between the gravity and the generation of the buoyancy force by generation of the distribution of air density by temperature rise. Therefore by changing the tilt angle, the natural convection cooling performance is changed and an accurate thermal design may not be achieved. Therefore, an additional database about natural convection cooling performance in the tilted enclosure should be prepared.

From these backgrounds, in this research, the cooling performance of natural convection of heat transfer enhancement device for electrical chips mounted in thin enclosure were investigated while changing the tilt angle of the enclosure. The investigations were performed by the 3D-CFD analysis with Boussinesq assumption. The reliability of the analysis was evaluated by the comparison with the experiment. Through the research, we clarified the relationship between the cooling performance, the design parameters of the enclosure and the tilt angle.

Key words: Tilt angle, Thin Enclosure

I. INTRODUCTION

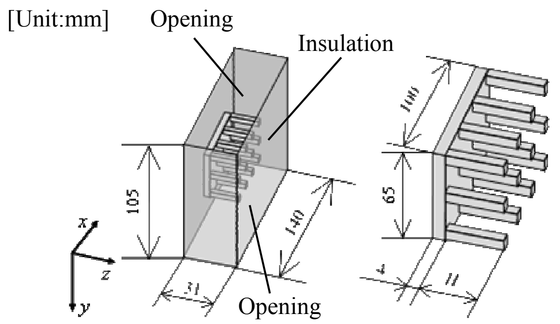
There are a certain number of electronic devices that attempt to dissipate heat by natural convection without using a fan for the purpose of securing quietness and cost reduction. For example, a thin type electronic device such as a liquid crystal television or a display which dislikes fan noise to acquire sound quality is a typical example.

On the other hand, the heat transfer coefficient obtained by natural convection is generally small and the power is also due to the buoyancy due to the density change of the air, so the influence of the flow from the surrounding is large.

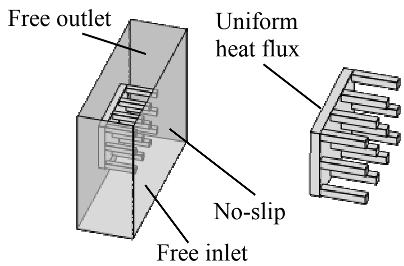
This is one of the difficult cases of thermal design. In recent years, the ability to freely select the posture of use, such as the inclination and orientation of these electronic devices, has led to the attractiveness of the product, requiring a thermal design that can keep operation guarantee temperature independent of posture

For example, Kitamura et al. [1] discusses the change in heat transfer due to the inclination of a thin enclosure, and Hayamatsu et al. [2] reports on the inclination of the fin heat sink. On the other hand, considering the recent thinning of the enclosure, restrictions on the flow inside the cabinet also become large, and construction of a more detailed database is required for advanced thermal design.

Therefore, in this research, we aimed to construct a database for advanced thermal design of thin electronic equipment that performs natural convection cooling. In particular, in this paper, the influence of the inclination of the enclosure to the heat transfer performance on the heat sink installed for promoting heat transfer inside the thin enclosure was verified by numerical analysis while changing the number of fins, the fin height and so on. I will report on its contents.



(b) Dimensions of analytical model.



(a) Dimensions of analytical model.

Fig.1 Analytical model of heat sink in thin enclosure.

Table 1 Analysis conditions.

Ambient temperature T_{air} [K]	293.15
Tilt angle θ [deg.]	0 ~ 90
Fins height H [mm]	1 ~ 27
Number of fins N_x [-]	6 ~ 21
Number of fins N_y [-]	10 ~ 22
Clearance W [mm]	4~12
Fins base$_x$ B_x [mm]	50,150
Fins base$_y$ B_y [mm]	50,150

II. ANALYTICAL MODEL

The analysis model studied in this paper is shown in Fig. 1 (a). heat sink (material: aluminum, width 100 mm, height 45 mm) is installed in a thin enclosure (width 140 mm, depth 31 mm, height 105 mm) assuming display. Gravity is the y positive direction in Fig.1 (a). From the backside of the heat sink base we gave a uniform heat flux of 5 W modeling the computing element.

As shown in Table 1, in this paper, we examined the relationship between the number of heat sinks with the parameters to be verified in the width direction, the number of the height direction, the fin height and the tilt angle θ when the casing was tilted. Thereafter, as shown in Fig. 1, in a state in which the fin is parallel to the y axis (a state where the casing stands vertically) is θ = 0 deg., The fin is tilted until it is parallel to the z axis Horizontal state) is defined as θ = 90 deg. Also, the distance from the tip of the fin to the casing wall is referred to as clearance [mm].

III. ANALYTICAL METHOD AND CONDITIONS

ANSYS icepak 16.2 was used for analysis code. The working fluid was air, steady state analysis of conjugate heat transfer was carried out using Boussinesq approximation assuming laminar flow.

As the boundary condition of the flow field, the upper and lower faces of the cabinet were allowed to flow in and out, and the other faces were made as a non-slip boundary. In addition, as a boundary condition of the temperature field, uniform heat flux condition was set for the heat sink base, and the other surface was made the adiabatic condition.

IV. RESULT AND DISCUSSION

The thermal resistance is defined as the difference between the ambient air temperature and the heat sink average temperature divided by the input heat quantity.

Fig. 3 shows the results when the fin height and the tilt angle were changed for the thermal resistance. The larger the fin height, the higher the cooling capacity but it saturates at H = 19 mm. On the other hand, when the tilt angle is increased (the heat sink faces downward) the flow of the inside air is restricted, so the cooling capacity is reduced.

Fig. 4 shows the result of changing the number of fins and the tilt angle in the y direction with the number of fins in the x direction fixed at 15. Increase the number of fins in the y direction increases surface area in the air flow direction, the cooling capacity increases.

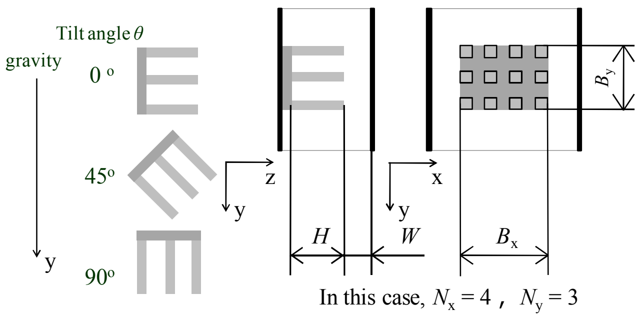


Fig.2 Definition of parameter in this model.

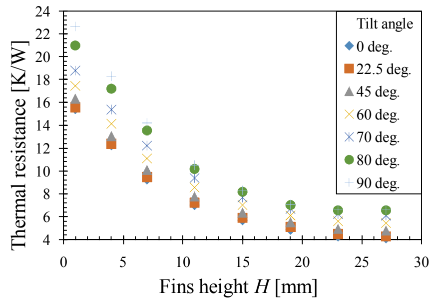


Fig. 3 Change in thermal resistance by changing fins height.

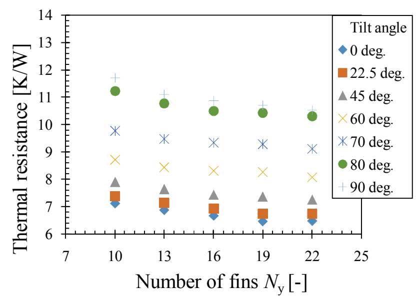


Fig. 4 Change in thermal resistance by changing N_y.

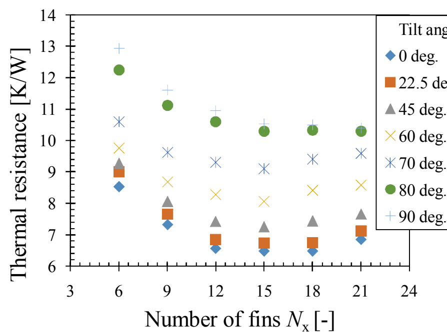


Fig. 5 Change in thermal resistance by changing N_x.

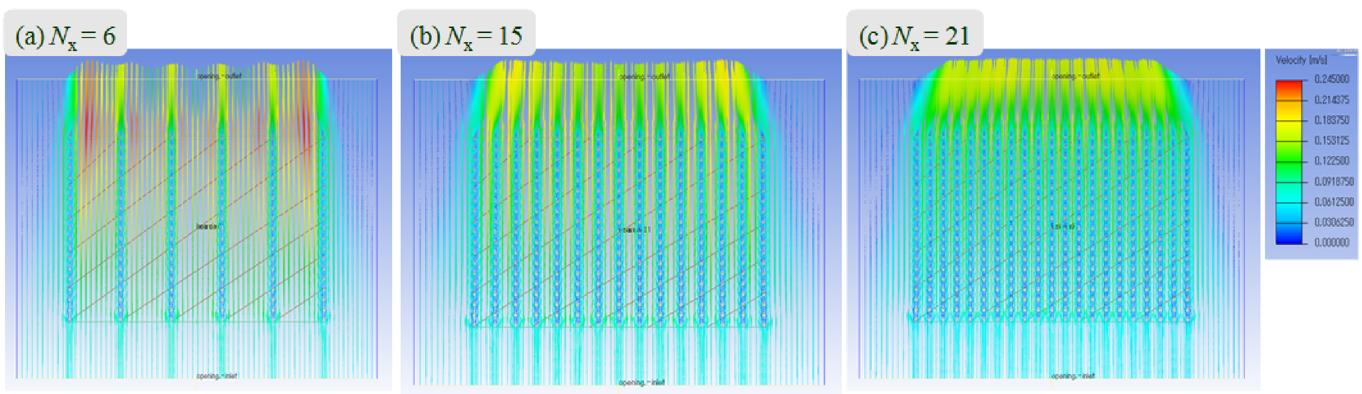


Fig. 6 Difference of flow pattern in the case of changing N_x

Fig. 5 shows the result of changing the number of fins in the x direction and tilt angle with the number of fins in y direction fixed at 22.
In below 70deg.,the best cooling capacity is Nx =15.but over 70deg. ,the best is Nx=21.so optimum value of the number x direction varies depending on the tilt angle.
The number of fins in the x direction decreases from the value cooling capacity getting worse even though the flow velocity becomes faster.
The space more than necessary cause decrease in surface area and heat transfer area.
The number of fins in the x direction increases from the value cooling capacity getting worse.
the number increased the fins spacing is too narrow, this cause decreasing the flow velocity and heat transfer does not occur, the cooling capacity deteriorates.
From FIG. 7, when the tilt angle is 45 degrees or less, there is almost no influence of clearance, but it exceeds 70 deg., the cooling capacity is deteriorated due to the narrowing of the clearance. when the heat sink is downward (θ = 90 deg.) air flow in a form from the tip side of the fin toward the base, and flow with a narrow clearance is restrained.

V. CONCLUSION

In order to predict the performance of natural convection cooling in the thin enclosure, the influence of varying the tilt angle on the fin height, the number of fins, the distance from the tip of the fin to the enclosure wall, and the base size was examined by numerical analysis. As a result, the following knowledge was obtained.
(1) The influence on the cooling performance changes largely depending on the tilt angle of the fin height. The higher the fin height, the smaller the effect of the tilt angle, and the cooling performance saturates at 19 mm regardless of the tilt angle.
(2) The larger the number of fins in the depth direction of the flow is, the higher the cooling performance is, and the influence of the tilt angle is small.
(3) The optimum value that does not become the resistance of the flow exists in the number of fins in the vertical direction of the flow, and it takes different values depending on the tilt angle.
(4) The distance from the tip of the fin to the casing wall is almost unaffected when the tilt angle is 45 deg. Or less, but the influence on the cooling performance is large at 70 deg.
(5) The base size is affected when the tilt angle is large. When the base length in the opening direction is long, the cooling performance is good.

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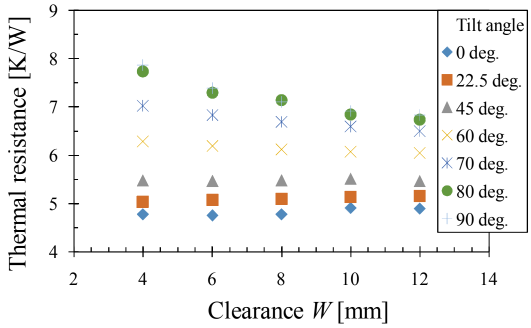

Fig. 7 Change in thermal resistance by changing clearance.

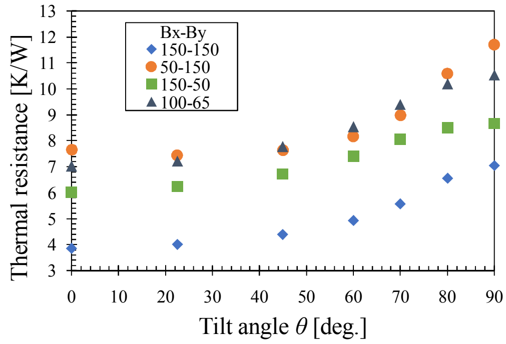

Fig. 8 Change in thermal resistance by changing base dimensions.

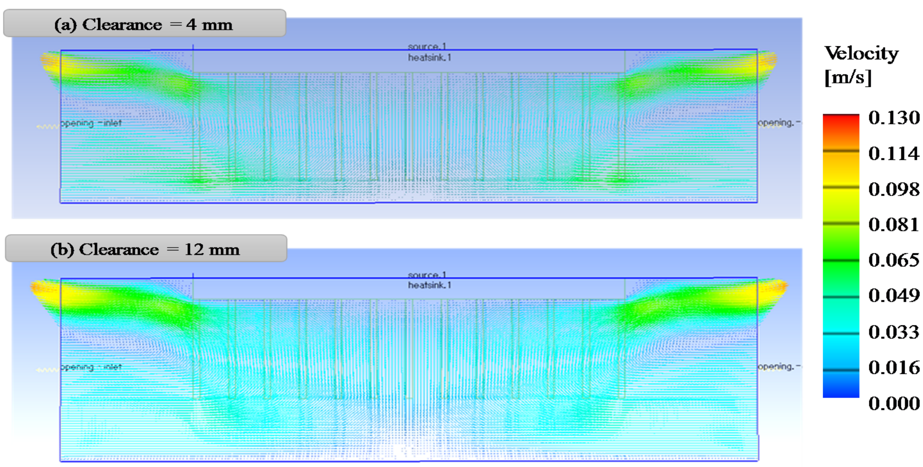

Fig. 9 Difference of flow pattern in the case of θ = 90 deg.