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Natural Convection Cooling of PCB Equipped with Perforated Fins Heat Sink including Inclination and Vibration Effects

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Abstract

A numerical simulation is proposed to investigate the thermal behavior ofa Central Processer Unit (CPU) as a single electronic component placed on Printed Circuit Board (PCB) equipped with a heat sink. Two types of heat sinks were used; the first is with solid fins and the other with perforated fins. Natural convection cooling is considered, with the inclusion of vibration and inclination effects. The power dissipated from the electronic component is (30W). In order to study the thermal behavior during the vibration effect, a frequency values of (0,2,5,9,16HZ) with constant amplitude (3 mm) was considered. The inclination effect is investigated with and without the vibration effect. The results showed that the vibration causesa decrease in the temperature of the component. The temperature of the component decreases with increasing the angle of inclination, Verification of the results gave good agreement.

Keywords : PCB, Perforated Fins Heat Sink, Inclination, Vibration, Natural Convection.

I. Introduction

The cooling of electronic equipment is one of the most important topics. The natural convection is one way for heat transfer. It is important to keep electronic device in safe temperature by controlling the temperature by removing heat. The heat transfer from high space temperature to low space temperature in natural convection is caused bygravity[IV].

Vibration is considered as one of the factors that cause the failure of the electronic equipment [IX].Many electronic systems are subjected to vibration and inclination in many applications such as submarine, missiles, airplane and so on. Thus the objectives for study the effect of vibration and inclination on heat for components is important. Many researches studied the effect of increasing heat transfer rate from any unit,but researches are little in study the effect of vibration in heat transfer.The problem arises in missiles directed the researchers to study the effect of vibration,most of researches focus on the mechanical and structural effects of vibration.Rodrigo .etal[XI] investigated experimentally and numerically natural convection heat transfer from a vertical plate made from aluminum subjected to heat flux,placed in water enclosure,the researchers found that the Nusselt number doesn't depend on the heat flux for laminar flow. Wu-Shung .etal [XV] studied the effect of vibration on heat transfer on the heated surface in a vertical channel during natural convection,this study used the finite element method to analyze the two dimension problem. The study focused on the frequency, amplitude, and Rayleigh number. Results showed that the value of the Rayleigh numberfor the plate with vibration is less than for stationary case.Also, the larger the frequency and amplitude the larger heat transfer rate. Baxiet al.[III] studied the effect of vibration on free and forced convection from spheres,the spheres were made from copper and this investigation done experimentally. The range of frequency and amplitudes (150-930CPM) and (4-25.5)mm respectively. In this study obtained that the effect of vibration on the Nusselt number under Reynolds number less than 200 is so small and can negligible the effect.Nag. et al[X]investigated the effect of vibration on a finexperimentally and the results showed the heat transfer increased with increased the vibration.When the velocity of vibration is greater than (15mm/s) the effect on heat transfer was significant.The effectof vibration on cylinder studied numerically by B.Keshavarzian.etal [II].Dhanawade.et al[VII]investigated experimentally the enhancement in heat transfer for fin arrays with circular perforation under forced convection.Rajput.et al [VI]investigated the convection heat transfer from fin with circular perforation analyzed by finite element. Fins with different number of perforation and hole diameters are studied. The results showed that the heat transfer rate increased with increased perforation and then starts decreasing. The enhancement in heat transfer increased with increase in number of perforation and diameter of the perforation.Abbas et al [I]investigated experimentally the enhancement in heat transfer rate for fins with circular perforations under free convection with steady state conditions. The temperature distribution and heat transfer coefficient were obtained at different perforations area and heat generations. The results showed that perforations increase lead to increase theheat transfer coefficient.Thamir et al [XIII]investigated the effect of geometry and shape for the perforation on heat transfer in the perforated fins, with rectangular, circular, triangular and also solid fins.Comparison between different types of fins satisfied the best shape and geometry of perforation for the fins;the circular one.Gdhaidh.et al [V] investigated the cooling of central processing unit (CPU) placed in a rectangular enclosure on vertical walls. Water used as the working fluid under natural convection cooling. The power dissipated from (CPU) was taken in the range (15-40W).The researchers studied the effect of dimensions for the enclosure and the value of power dissipated from (CPU).Results showed that the heat transfer coefficient increased when the power dissipated increased, and the decrease in temperature became very small when the width for enclosure is greater than (50mm). The used water reduced the temperature by (38%). Staliulionis.et al [XVI] investigated experimentally and mathematically the cooling for electronic component by using heat sink. Diode and transistor placed on the base for heat sinkwere considered. The investigation focused on studying the distance between the two components.Also studied the best position for the component on the heat sink. Results showed large dissipated power evaluated when the electronic component is in the center of the heat sink. Shrikant et al [XII] studied the cooling of the electronic equipment by natural convection. The investigation done experimentally by using transformer, resistor,and relay.These components were placed ona rectangular heat sink. The experiment done with and without using an enclosure. Also the placement of grill on the wall of the enclosure was studied.Results showed that the grill increased the cooling by increasing the ventilation inside the enclosure.

Most of researches studied the effect of perforation for single fin not as a heat sink.Also researches dose not focus on using the perforated fins heat sink for cooling electronic components with and without vibration and inclination effects. In the presentwork,a heat sink with perforation is used to increase the exposed area,with the effect of vibration and inclination,fora single electronic component (CPU).

II. Description of physical model

The problem that is used for analysis in this study is shown in (fig.1). Three dimensional analysis with three casesare considered. The first case, electronic component on PCB,the second case, electronic component on PCB with solid fins heat sink, and the third case electronic component on PCB with perforated fins heat sink.The parts are placed in a computer case. These three cases were studied under the vibration and inclination effects. The electronic component considered dissipates heat of 30 W. The physical model for all parts is shown in table 1,and the properties of materials are shown in table2.

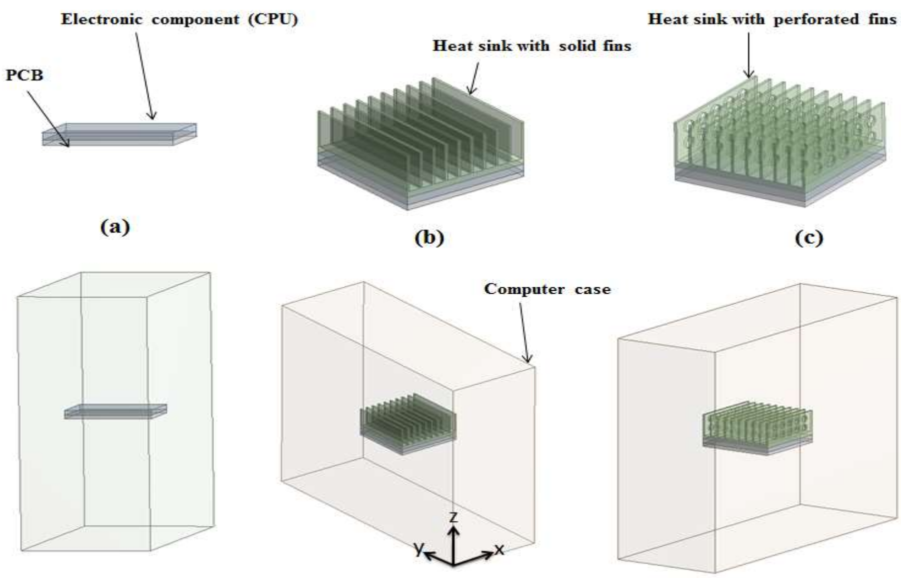


Fig.1 The schematic diagram for models

Table 1: Dimensions for physical model (cm)

Components	Length	Width	Height	Material
Electronic component (CPU)	10	10	0.7	Silicon
PCB	10	10	0.5	Fr-4
Heat sinks	10	10	4	Aluminum
Computer case	41	15	36	Aluminum

Table 2: Properties of materials

Material	Thermal conductivity [w/m.k]	Specific heat [j/kg.k]	Density [kg/m^3]
Aluminum	202.4	871	2719
Silicon	150	710	2300
Fr-4	0.35	1300	1250

The air flow inside the computer case is considered as the working fluid in this study.The properties of the fluid with thermal conductivity (0.0282 w/m.k), specific heat (1008.2 j/kg.k), density (1.16 kg/m^3) and viscosity ($1.78*10^{-5}$kg/m.s).The first heat sink with solid finsis of type PR182 with dimensions (10*10*4cm) and ten fins array, the base having a thicknessof (5.5mm),the thickness for each fin is (2 mm),and the number of fins array in the heat sink is (10). The second type of heat sinkis with fins of circular perforation. This type of perforation is used based on experimental study [11],which concluded this type of perforation. The general specifications for heat sink with solid and perforated fins is shown in (fig.2)

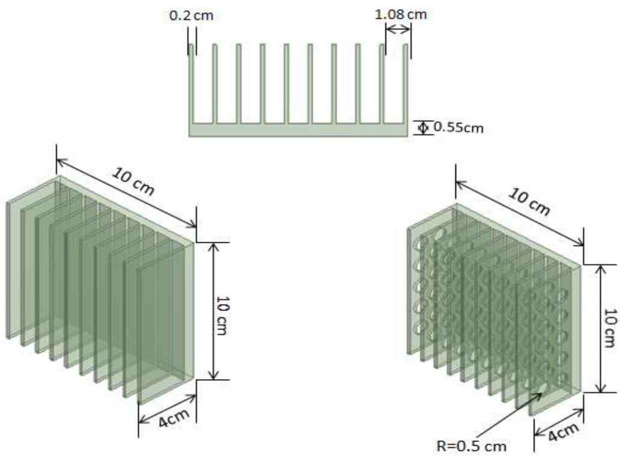


Fig.2Schematic diagram for heat sinks

The amplitude of vibrationsis (3 mm) with (0,2,5,9,16HZ) as the frequency values. The magnitude of the velocity of vibration is evaluated from Wu-Shung [XV] and [XIV] as;

$$V_v = 2\pi f \mathrm{a} \cos(2\pi f t) \quad (1)$$

At (t=0)steady state condition

$$V_v = 2\pi f \mathrm{a} \quad (2)$$

Where (f) isthe frequency of vibration ,(a)is the amplitude and (t) is the time .The three cases with and without vibration,and with three angles of inclination (0°,45°, and 90°) for all cases,were investigated.

III. Mathematical Modelling

The mathematical model assumes steady,three dimensions, laminar flow, incompressible, air as ideal gas,the density follows Boussinsque approximation, and negligible radiation effect. With these assumptions, the governing equationsof continuity, momentum, and energy will be as follows:

Continuity equation;

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z} \quad (3)$$

u, v, w are the velocity component in x, y, and z direction.

Momentum equation;

$$\rho\,(V.\nabla V) = g - \nabla p + v\nabla^2 \mathrm{V} \quad (4)$$

Where ρ is the density of air ,V is the velocity component ,p is the pressure and v is the kinematic viscosity.

Bossinisque approximation;

$$\rho = \rho_\infty[1-\beta(T-T_\infty)] \quad (5)$$

Where ρ_∞ is the density of air at the ambient temperature, and $\beta$is the thermal expansion coefficient. The gravity in this simulation in z-direction has the componentsg[0,0,-g].

Energy equation;

$$V.\nabla T = \alpha\,\nabla.(\nabla T) \quad (6)$$

Where α is the thermal diffusivity.

The boundary conditions at the walls of computer case are assumed isothermal at temperature 303 K and stationary (u,ν, w=0). Also, the CPU placed on PCB with a heat sink have a velocity of vibration (w=V_{v}).

IV. Numerical Procedure and Results Validation

Numerical solution of the mathematical model was made by using ANSYS software. The geometry of the model is created,and an independence test for the mesh was done to perform the solution with good accuracy and low computational cost. The effect of the number elements was examined with time and the optimum results were with a number of elements (313980) without a heat sink and (814625) with heat sink, see fig .3, the time required for solution for all cases was in the range (145-215)minute.

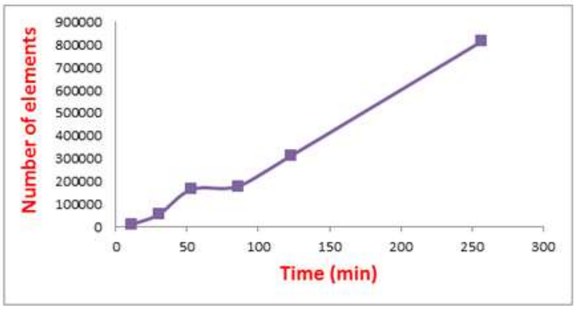


Fig .3 The relation between the number of elements and computational time

The residual monitors for continuity and momentum equations was chosen as 10^{-4}, and for energy equation, it was 10^{-6}.The numerical solution was validated with Amin Rana [VIII] and shows good agreement, the percentage difference was (0.90), see fig.4a&b.

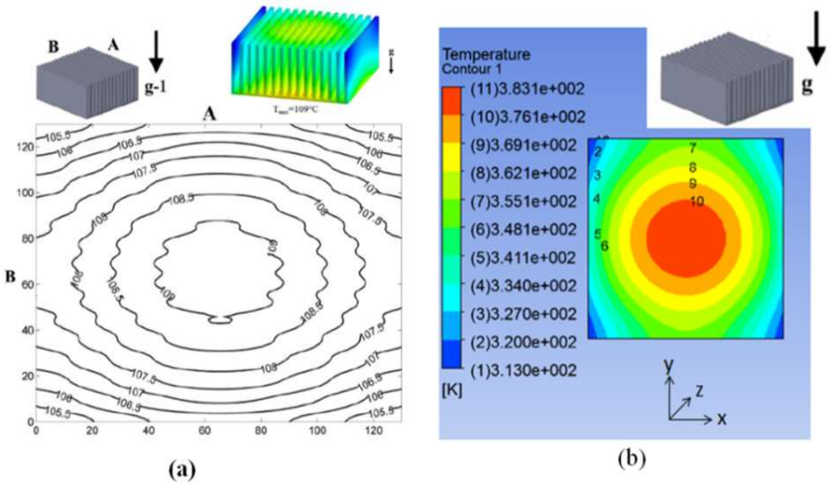


Fig.4 Comparison between (a) Results of Md Ruhul Amin Rana [VIII] (b) Numerical results of the present work

V. Results and Discussion

- Effect of vibration

Figures 5to7show the effect of vibration on three cases;without vibration, the temperature of component decreases when using heat sink, the best effect is when using heat sink with perforated fins. The figures indicate that increasing the vibration velocity leads to decrease in temperature for all cases.This may be referred to the increase in inertia force caused by vibration which makes the boundary layer near the surface unstable.The perforated fins heat sink decreases the temperature of the componentdue to increase in the surface area that is exposed to air,and due to the flow disturbance occurs.

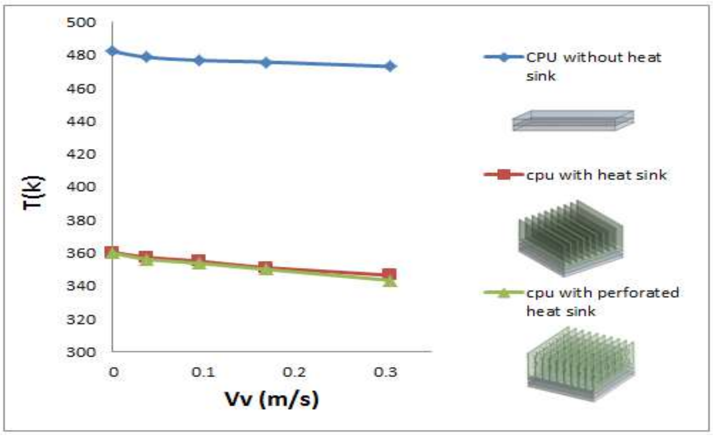


Fig. 5Temperature vs.vibration velocity at 0°angle of inclination

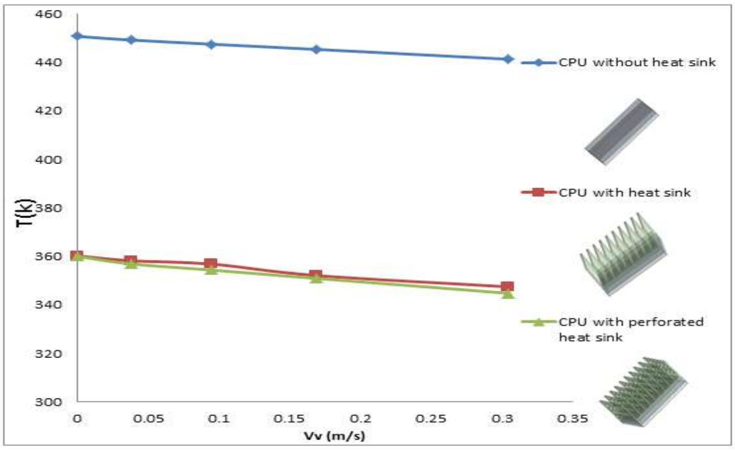


Fig .6Temperature vs. vibration velocity at 45°angle of inclination

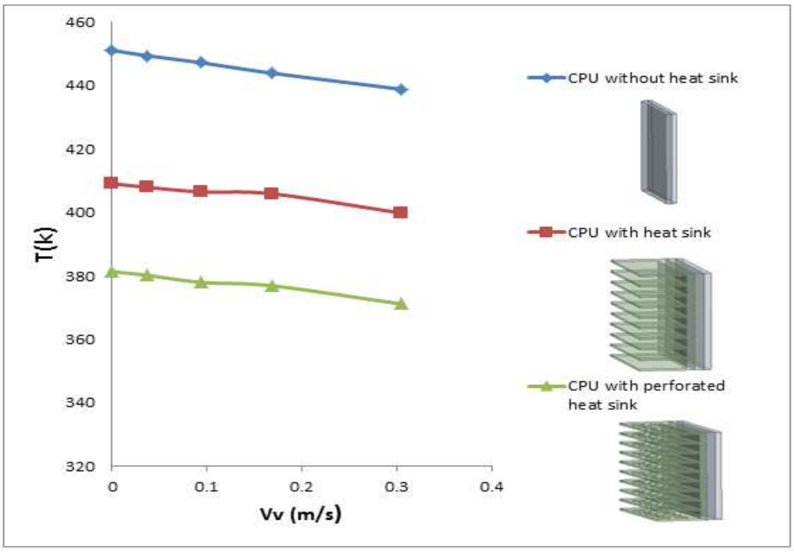


Fig. 7Temperature vs. vibration velocity at 90°angle of inclination

- Effect of inclination

Figures8to12show the decrease of temperature with increasing the inclination angle. This happens in case of single component without a heat sink.When using heat sink, the temperature increase with inclination, this returnsto the position of the fins of the heat sink.

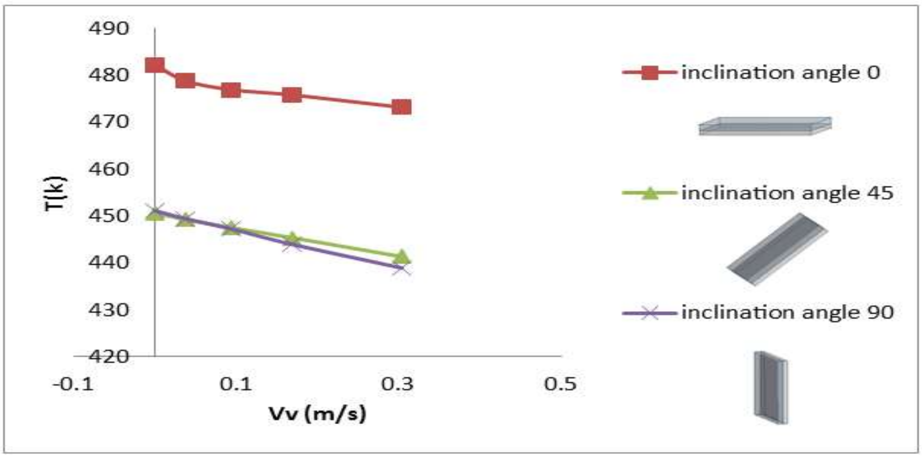


Fig. 8Temperature vs. vibration velocity with different inclination angles

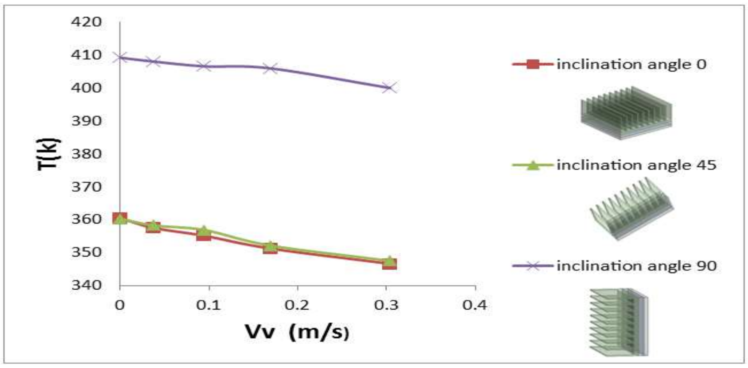


Fig. 9Temperature vs. vibration velocity with solid fin heat sink with different inclination angles

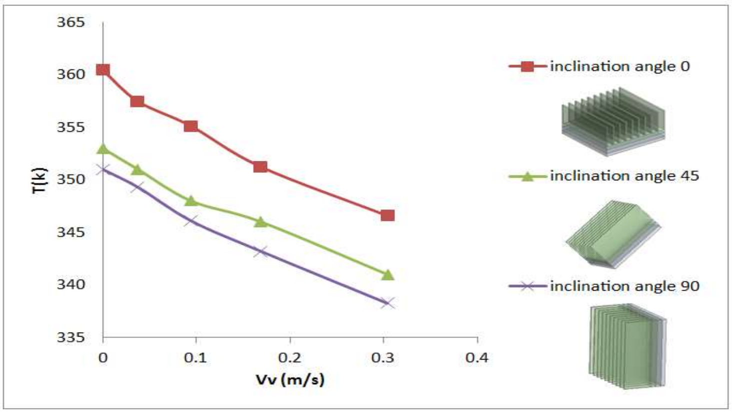


Fig. 10 Temperature vs. vibration velocity for electronic component with rotating 90° solid fin heat sink with different inclination angles

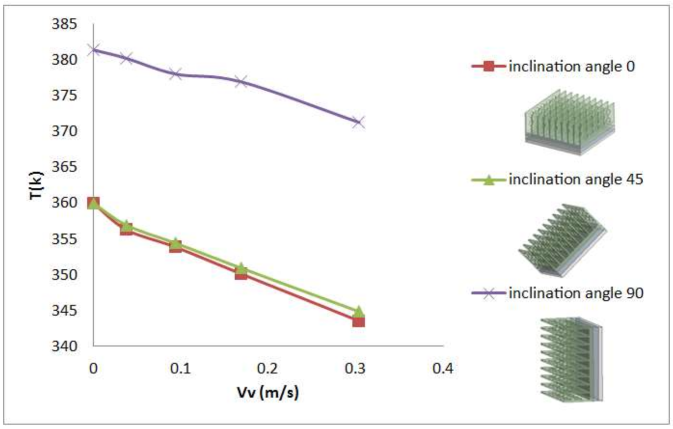


Fig. 11 Temperature vs. vibration velocity for with perforated fin heat sink with different inclination angles

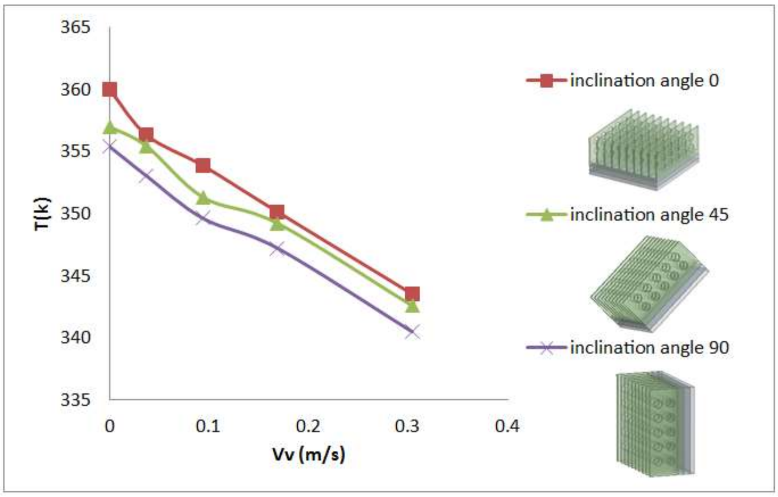


Fig. 12 Temperature vs. vibration velocity for electronic component with rotating 90° perforated fins heat sink with different inclination angles

Figures13 and 14show comparison between two types of orientation for finned heat sink with inclination effect.The figures show that the temperature decreases when orienting the heat sink 90° over the component, this position is suitable to make the air passing between the spacing of the heat sink.In other words, the orientation of fins heat sink 90° over the component offers less resistance for the air than the first position.

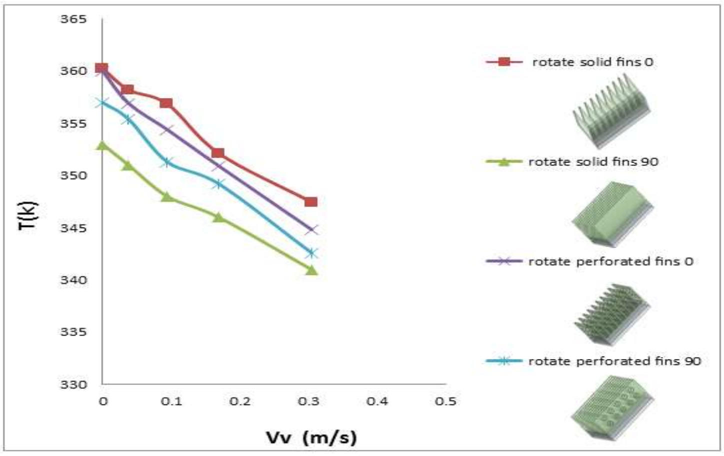


Fig. 13Comparison between heat sink with perforated fins and solid fins with two types of rotating fins 0° and 90° under angle of inclination 45°

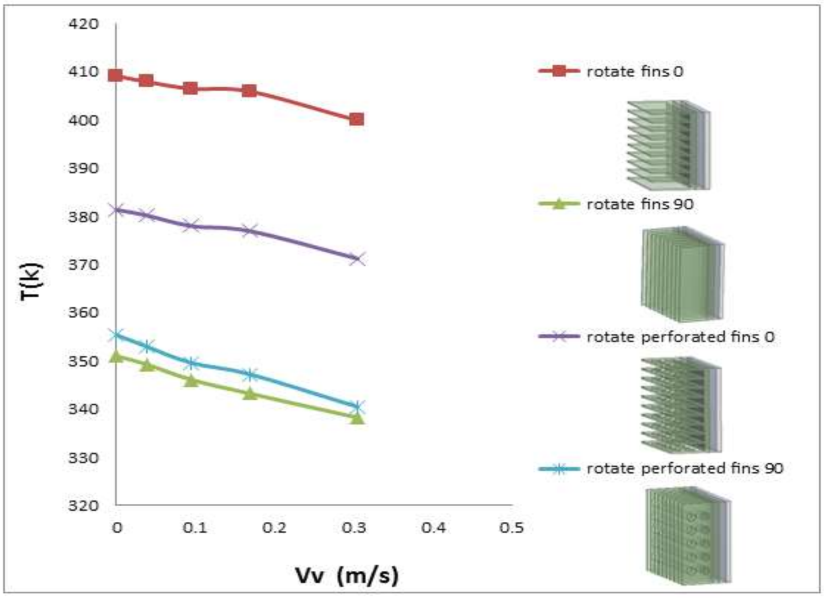
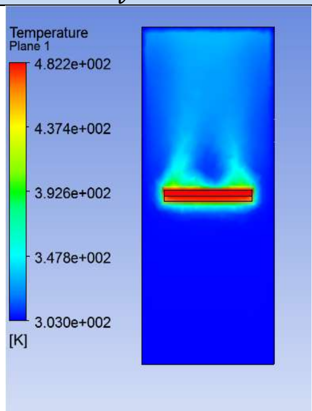
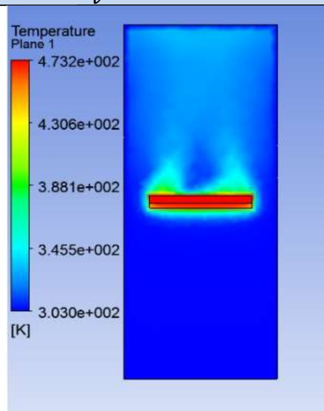
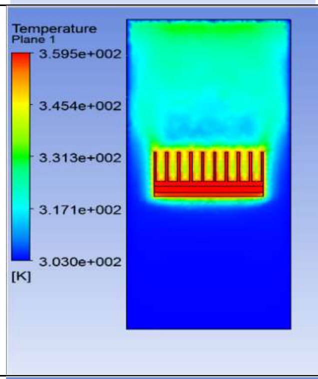
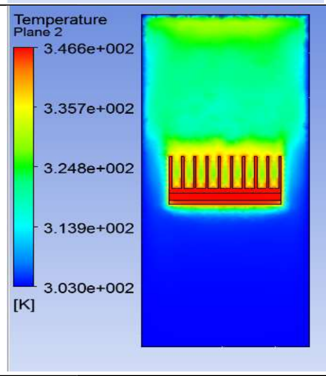
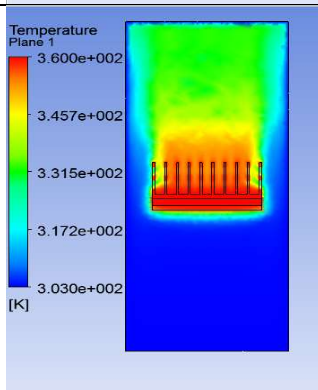
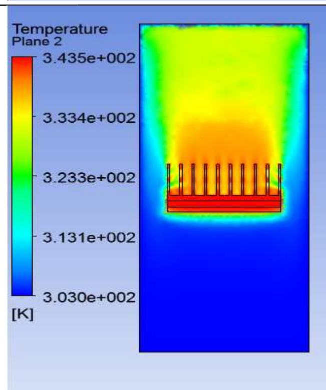
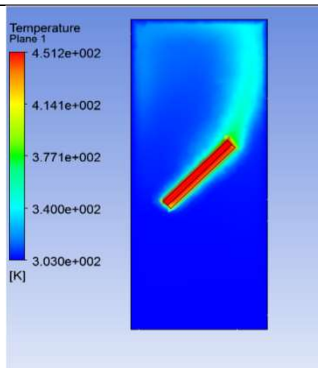
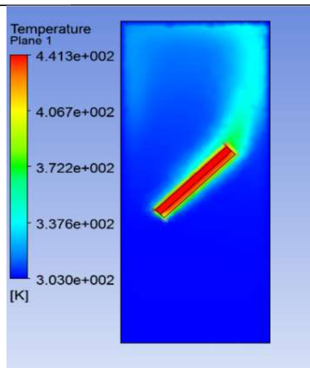
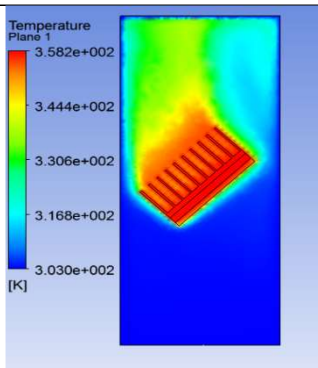
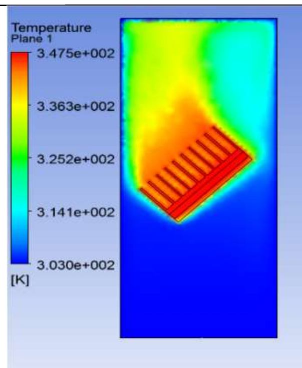
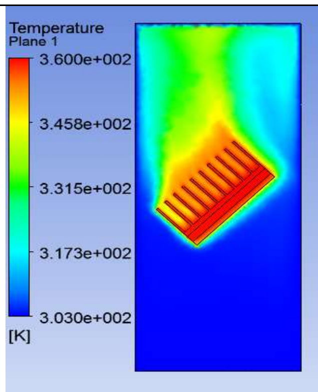
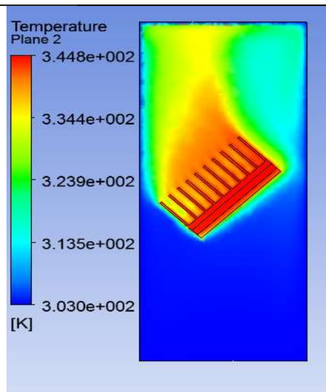
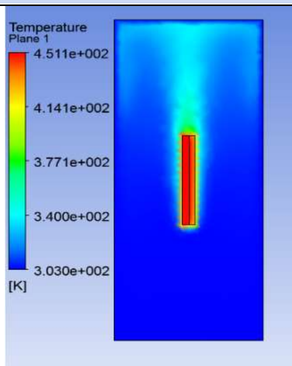
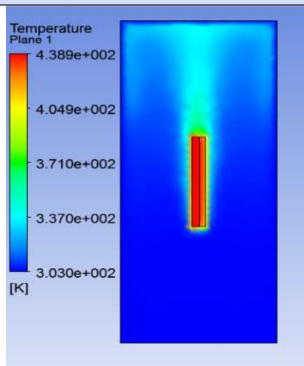


Fig. 14Comparison between heat sink with perforated fins and solid fins with two types of rotating fins 0° and 90° under angle of inclination 90°

Some contours from ANSYS for the studied cases arelisted in table 3.

Table 3: Temperature contours in xz-plane with and without vibration (at minimum and maximum value of vibration velocity)

Angle	Case	V_v=0 m/s	V_v=0.3014 m/s
0°	Electronic component without heat sink		
	Electronic component with solid fins heat sink		
	Electronic component with perforated fins heat sink		

<table>
<tr><td rowspan="3">45°</td><td>Electronic component without heat sink</td><td></td><td></td></tr>
<tr><td>Electronic component with solid fins heat sink</td><td></td><td></td></tr>
<tr><td>Electronic component with perforated fins heat sink</td><td></td><td></td></tr>
<tr><td></td><td>Electronic component without heat sink</td><td></td><td></td></tr>
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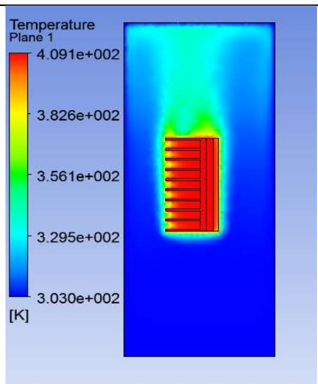
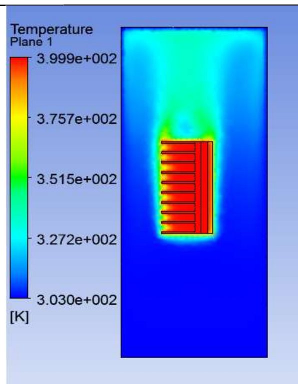
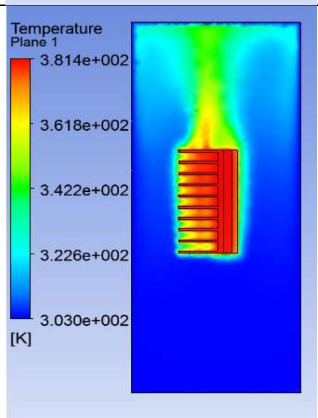
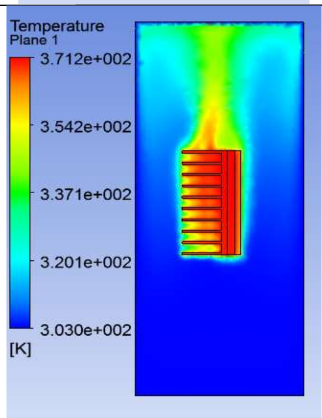
90°	Electronic component with solid fins heat sink		
	Electronic component with perforated fins heat sink		

VI. Conclusions

Natural convection cooling of single electronic component on printed circuit board(PCB)equipped with perforated fins heat sink includingvibration and inclination effects is numerically investigated in the present work.The main conclusions are summarized as follows:

- Vibrating the model leads to decrease in the temperature of the component.
- The heat sink with perforated fins decreases the temperature more than the heat sink with solid fins.
- The angle of inclination leads to decrease the temperature.
- The rotation of fins heat sink 90° leads to decrease in the temperature.
- A good agreement is obtainedinverifying the results.
- The rotation of fins heat sink 90°have less resistance for the flowing air under natural convection than 0°rotation.

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