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The Numerical study of thermal flow characteristics for piezoelectric fan on rectangular channel

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Abstract: This study used the commercial CFD software ANSYS CFD / Fluent, for simulating the transient flow field and investigating the radiator heat effects of radiator for single piezoelectric fan in a single rectangular flow channel, respectively, for two kinds of heat devices, which were flat and square columnar types placed horizontally or vertically in order to find the optimum cooling radiator position; the numerical simulation study of the parameters, including the distance from the tip of fan blade to the front edge of the radiator (Lg), the center of piezoelectric fan to the flow channel plate height (Hw), and fin column (n). The results of heat flux were from the solver and in these configurations of piezoelectric fans, Niu Saier number (Nu) and the coefficient of performance (COPv), which should be applied to prove the results, respectively. Piezoelectric fan was placed in front of the radiator flow channel; the cooling air was imported in the radiator and produced the vortex flow which enhanced the mixture capabilities for cooling and hot air around the radiator. As piezoelectric fan activated, the blade upper and down parts or left and right direction of blade had a strong impinging flow on the stream, so the impact flow which happened closer to the piezoelectric fan hadthe better results of cooling effects. And the piezoelectric fan was reciprocated, that conformation impinging flow damaged the temperature of boundary layer; in the direction of the actuating blade tip, the fluid was reciprocated, and the direction of flow pulled the blade tip, generated vortex, and formed entrained flow, which effectively mixed hot and cold ambient air simultaneously.

Keywords: piezoelectric fan, radiator, impinging flow, computational fluid dynamics.

I. INTRODUCTION

As semiconductor producing process and technology progress and develop, the design concept for electronic components is turned to slim and light, and the challenges face overheating problems gradually increases. In the same sizes, CPU (Central processing unit)internal integrated circuit manufacturing process increases, which also represents the same size wafer'sheat, will increase. According to Morre's Law, for the same size in integrated circuits which will be double its efficiency in every eighteen months; it represents the same size wafer's heat will also increase. Because the heat will influence electronic components operation, so the heat per unit area for electronic components operation will raise constantly. As integrated circuits is getting smaller, So making a wide range of portable consumer electronics product innovated, especially in mobile phones, notebook products, and the co-design philosophy is to enhance user comfort with low noise, And that can be operated in low power conditions in order to extend the operation time and the life of products. Research and develop such products as radiator design criterion, and therefore in order to meet high power and high density electronics equipment era, and enable them to work under either a safety or normal operation temperature, and thence how to effectively enhance the thermal performance of electronic components equipment in recent years become a very important research topic.

Acikalin and Garimella [1] used the piezoelectric fan in three different forms to display at the top of the heat source, changed amplitude of piezoelectric fan, changed the distance between piezoelectric fan to the heat source, changed the length of piezoelectric fan in the offset of resonance frequency. The offset of the resonant frequency of piezoelectric fan and the heat center was applied as a parameter of heat transfer effect. So the amplitude piezoelectric fan blades became smaller, airflow becomes weaker, that the overall heat transfer performance became degraded. Acikalin et al. [2] Analyzed and Forecasted piezoelectric fan cooling performance , the piezoelectric fan was placed in front of the heating of stainless steel sheet, used infrared thermal imaging measurement techniques to do the experiment, and the piezoelectric fan which was placed in the acrylic plate container, and then particle image velocimetry (PIV) was applied for flow visualization, simulated and studied the space relationship from amplitude to the wall of piezoelectric fan for flow analysis and thermal effects. The results showed the effect of heat transfer for amplitude piezoelectric fan became better; the simulation and experimental results for the ratio between the two errors was around 17%.Acikalin et al. [3] applied the piezoelectric fan in electronic components, and the fan had small size, low noise and low power consumption and other advantages, but the piezoelectric fan is not purposely used to replace the current axis rotary fan. As in the regional and local hyperthermia rotating fan cannot meet the cooling effect requirement, So the piezoelectric fan can be used to provide effective cooling effect. Experimental results showed that the piezoelectric fan placed vertically at central position in the mobile phone had a better heat transfer coefficient than that was placed in the horizontal position. Liu et al. [4] studied the vertical and horizontal pressure fan placed on the surface of the heat transfer plate to investigate the heat effect, And the experimental methods used six different geometries piezoelectric fans, heat transfer results showed an increase effect because each cycle in the pressure was generated by the fan blade tip and sides of the jet stream was caused by entrained air flow , fan blades was placed vertically in the best position at the center of the heat transfer symmetrical distribution. When the fan was placed horizontally, the heat transfer performance decreased quite large, because the entrained air flow was blockaded. Fan placed horizontally heat transfer performance is not overall lower than that placed vertically, which will be related with the flat surface of the distance. Acikalin et al. [5] applied the flow visualization experiments to approach and evaluate piezoelectric fan which used in electronic cooling system feasibility, and the study showed that the three groups of piezoelectric fan placed vertically and a set of piezoelectric fan placed horizontally, which investigate the heat transfer coefficient of piezoelectric fan, And the piezoelectric fan was used to evaluate the thermal performance of the feasibility of electronic components. Abdullah et al. [6] put piezoelectric fan on the horizontal position for two-dimensional numerical simulation and flow visualization experiments in order to observe the phenomenon and discuss swing piezoelectric fan flow field formed by its heat transfer coefficient. And discussed the length between the height of heat source and piezoelectric fan. The optimum cooling efficiency will be reduced 68.9 ° C, and the experimental and numerical analysis results error was approximately 11%.

Wait et al. [7]used three sets of different lengths of piezoelectric fan to do the numerical simulation and flow field visualization analysis. Took three groups piezoelectric fan model to do visualization analysis, and authenticate with the numerical simulation analysis to explore the high resonance frequency of driven piezoelectric fan in all modal characteristics and analyzed. The results showed that the piezoelectric fan at higher resonance mode, the electro mechanical coupling coefficient can provide a better performance, and the practical application of electron cooling have to consider commercial specifications. Naik et al. [8] studied the heat transfer characteristics in the flat rib of rectangular flow channel, the experimental results showed larger quantities of ribbed strip can effectively enhance the heat transfer rate, and the optimized space of rib would be increased. And the longer rib will reduce heat transfer rate, increased the distance between the flows channels' top plate to the rib's roof, the velocity distribution will increase along the rib's roof, and caused heat transfer coefficient varied considerably at portion of the rib's roof. In this study, use of piezoelectric fan device placed horizontally (Horizontal piezoelectric Fan) and vertically (Vertical piezoelectric Fan), and in flat (Plate-fin) and needle- type (Pin-fin) of cooling fins which is at the top or in front of the fins, the use of piezoelectric fan flow arising from the impact of cold air will pass through the radiator fin's mixing air, and the destructed the temperature boundary layer of cooling fins, the use of this method for lateral fins structural changes in the flow field and to enhance heat transfer performance. Most of the current study, no matter how domestic or international research for improved shape and piezoelectric fans were mostly used in research without fin heat exchanger's heat transfer effects, there were very few relative research in piezoelectric fans erected that were enhanced the radiator heat transfer effects. In this study, the use of piezoelectric fan would have expectations for reducing the thermal resistance of the heat sink module design, and more hope for the present cooling fins could provide good design recommendations.

2. Geometric Modeling

2.1 Calculation region and parameter settings

This paper mainly discussed the piezoelectric fan on the radiator heat flow characteristics, the research tools used ANSYS / Fluent CFD-Post with two sets of software to simulate the flow field analysis, and calculated data for Fluent results, including the relationship between pressure and velocity versus time. Before used the Fluent we should write a user -defined function (UDF) to calculate the flow field for speed and pressure distribution, and in the Fluent software exported each node position on the x-axis, y-axis and x-axis velocity, and y-axis velocity and pressure values, and later imported the data into CFD-Post-processing software for calculation. The Main function was to deal with the information of pressure, speed, temperature and radial lines (Path lines) that can be solved by post-processor solver, and discussed by this feature piezoelectric fan with different parameter configuration properties for heat sink effects. This study can be described as below for the ways to set the model and each condition should be set.

Numerical simulation of the Schematic geometric model range was set to be 300cm × 50cm × 100cm (X × Y × Z), and the Schematic geometry as shown in Figure 1,

(a) Case-1 horizonta lpiezoelectric fan on the flat radiator fan,
(b) Case-2 vertical piezoelectric fan on the flat radiator fan,
(c) Case-3 horizontal piezoelectric fan on the needle- type radiator fan,
(d) Case-4 vertical piezoelectric fan on the needle- type radiator fans.

To comply with the real environment in the area of numerical calculations, the initial value at inlet and outlet pressure value was set as the operating temperature of 300˚K, the working fluid is air. Gambit was established by the calculation model of grid construction and preliminary definition of the model boundary conditions, saved as a file and import mesh for grid computing software for Grid check.

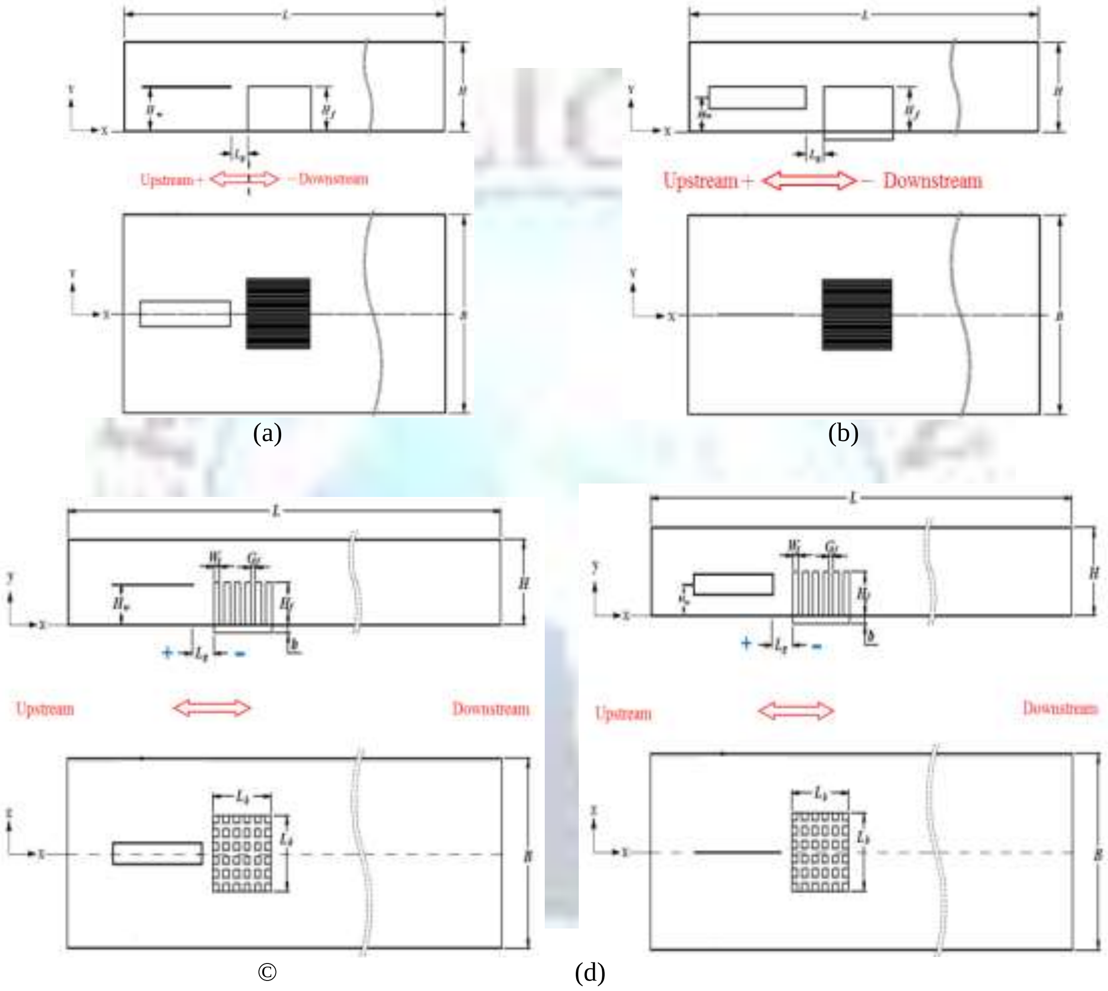
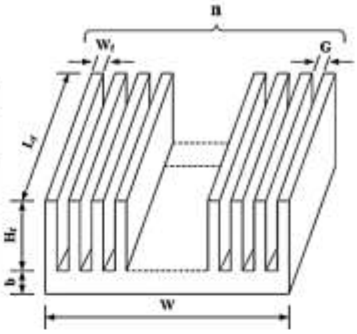


Fig. 1. Schematic geometry model

In this study, plate-type heat sink, the floor shape was rectangular, and the dimensions of length (Lf) was 45 mm, width (W) was 40 mm and the bottom plate thickness (b) was 2 mm; rectangular radiator was used needle plate, and the dimensions of Length and width (Lb) both were 40 mm with the base plate thickness (b) 2 mm. Radiator schematic and dimensions were shown in Fig. The property of Aluminum heat sink material for its thermal conductivity was 168 W/m-K. And in this case, radiators and heating surface of periphery and the bottom plate of the radiators, heating surface were all regarded as insulation, made the direction of heat transfer can transmit from the bottom to the fins. Bottom heating radiator surface dimensions was set to be 31 mm × 31mm, and the thickness was ignored when numerical simulation, the heating power (calories)was raised up to 35 W.

Plate-fin heat sink

Fin number: n	14	10
Fin height: H_f	10 mm	10 mm
Fin width: W_f	1 mm	1 mm
Fin-to-fin gap: G	2 mm	3 mm
L_f=45 mm	W=40 mm	b=2 mm



Pin-fin heat sink

Fin number: n	14	10
Fin height: H_f	12 mm	12 mm
Fin width: W_f	1 mm	1 mm
Fin-to-fin gap: G	2 mm	3 mm
L_f=45 mm	W=40 mm	b=2 mm

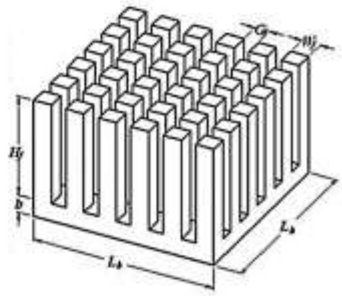


Fig. 2. Schematic diagram and dimensions of radiators

2.2 Boundary Conditions

Before analyzed, did the following basic assumptions in order to easily studied and researched questions:

(1) The working fluid was air.

(2) Transient (Transient) flow field.

(3) The flow field had no passive terms.

(4) Ignored the effects of gravity.

(5) All material parameters did not change with temperature and time.

(6) Laminar flow. This left amplitude equation as,

$$F(x) = -42.3402x^2 + 33587.5x^3 - 2.7317*10^6x^4 + 9.05342*10^7x^5 - 1.2653*10^9x^6 + 6.34496*10^9x^7 \quad (1)$$

The piezoelectric fan equation could be written as, $f(x,t) = f(x) \times \sin(2\pi \times fr \times t)$,where f (x)was the blades swing amplitude, fr was the beat frequency, t was the swing time. Heating surface and solid heat conduction boundary : the surrounding of Radiator bottom floor was set to be insulated, heating surface of the heating power was 35W, heat sink thermal conductivity was 168 (W / m-K),heated 40 seconds, then turned on the piezoelectric fan for 2 seconds . After setting the basic assumptions, the computational domain included establishment the conditions for the movement of objects should be totally controlled. In this case, Fluent provided a dynamic mesh model (Dynamic Mesh), and could be written in C language of user- defined function module (user-defined function) in order to embed the problem needs. In calculating the rule of law for the pressure, the standard term was used. The x, y, z direction, speed and pressure were initialized, and then set three-axis speed, the energy equation, and the convergence condition value of continuity equation [8].Numerical simulation of the convergence criteria was set as the momentum equation residuals (Scaled Residual) was less than 10-8 and the value of the rest of the convergence equation was below 10^{-6}.

2.4 Setting the data acquisition line

As shown in Figure 3, the four forms of radiator which was placed horizontally along the flow channel, and at front, rear, right, and left direction set the data acquisition line, and at the same direction depicted top-line, mid-line, and bottom-line. This line represented the distance for the data acquisition center to base plate of the piezoelectric (H_w), the distance between fan front to the radiator end (L_g), and speed changed in the Z-axis and X- axis position surrounding the radiator.

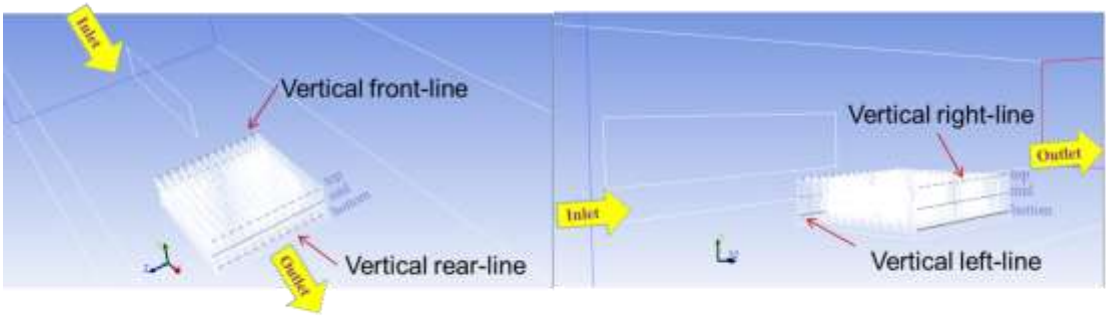


Fig.3. The theoretical model of data acquisitionline

3. Theoretical model

As applied the first law of thermodynamics, you should define the space contained in a controlled surface area and allow this energy and matter could enter and leave the surface, this area was called the controlled volume. Using the heat transfer rate equation to represent the conservation of energy, the formula could be written as

$$\dot{E}_{in} + \dot{E}_g - \dot{E}_{out} = \dot{E}_{st} \quad (2)$$

Generated heat $\dot{E}$ gwas in the controlled volume, the energy conversion heat generated during this study. There was no energy conversion, and therefore this was ignored. $\dot{E}_{in}$ And $\dot{E}_{\mathbf{out}}$ represented heat and mechanical energy reacted in and out of the controlled volume, Storage Term $\dot{E}$ **st** meant storing energy within the physical changed. From (2) the energy per unit volume of the time rate of change could be rewritten as,

$$\iiint_{C.V} \rho c_p \frac{\partial T}{\partial t} dxdydz + h_c A_t (T_{ave} - T_\infty) - \dot{E}_{in} = 0 \quad (3)$$

where ρ is density and Cp was specific heat, the product was known as volumetric heat capacity, $\frac{\partial T}{\partial t}$ was the energy per unit volume within the object of the time rate of change, dxdydz represented the control volume, A_t was the total cooling area of radiator, h was the average heat transfer coefficient, (T_{AVE}-T_∞) was for the temperature difference of controlled surface and volume of the fluid. Cop_v expressed the coefficient of performance, this amount represented the dimensionless unit of time which took away the heat and power consumption , cop_v could be written as $Cop_v = R_{th,\ nc} / R_{th,pzf}$, where $R_{th,pzf}$ was the piezoelectric fan thermal resistance , $R_{th,nc}$ was the case of natural convection heat sink thermal impedance. This impedance ratio obtained from piezoelectric fan which reflected indicators of the overall thermal performance. Grid computing model was for independent verification the validity of the accuracy and numerical methods. Setting numerical simulation piezoelectric fan and radiator front side of the columnar distance (L_g) was 0 mm, the height (H_w) of piezoelectric fan was 10 mm, the radiator fin width (W_f) was 1 mm, the radiator fin height (H_f) was 10 mm, and the fin number (n) was 14.Since the study was to investigate the heat impact effects under the fan swung, so took the grid points surrounding the radiator fan and the fan swung area manually encrypted, and through piezoelectric fan started every 20 cycles, took an x shaft speed data for analysis. Data acquisition line was set at the 22.5 mm point front of the piezoelectric fan. In this study, we chose the grid respectively 8e +4, 1.4 e +5, 1.7 e +5, 2 e +5, 3.1 e +5 and 3.8e +5. The results showed the lease number of grid points would cause larger error values, but the number of grid points would result in excessive computation time, so in order to meet both simulation accuracy and simulation time requirement, the grid points approximately 2e +5was used in this study.

4. Results and discussion

This study was heating on the bottom of the radiator and heating surface (31mmm × 31mm) the heating power was set at the condition of 35W, in order to simulate transient heating situation for central processing unit of desktop, heated and raised the Temperature for 40 seconds, and then opened the fans, and cooled the fans for 2 seconds. And investigated the cooling efficiency of fins under different parameter configuration within these 2 seconds. The evaluation process was set to ignore the fin temperature gradient. And applied total energy balance of the object to determine the transient temperature distribution, and at this energy balance that was affected by surface heat loss rate and the rate of change of internal energy. In this study, the following parameters was applied and discussed: the distance L_g was the front point of piezoelectric fan to the front point of radiator, the height (H_w) was the center point of piezoelectric fan to the bottom plate flow channel, and the number of fins was n.

4.1the height of center point of piezoelectric fan to the bottom plate of flow channel-H_w

Case-1, when the number of fin was 10, and the height of the single piezoelectric fan was 15mm which was placed 5mm in front of the radiator, single piezoelectric fan speed could be introduced into the flow path center of the radiator, the radiator and the speed distance between the flow channel became larger, the side effects accelerated the flow rate of fluid. But as the fluid flew into the radiator flow channel, the flow was confined and the speed was less diffused by the radiator fin, and therefore in the middle of the radiator back had less energy loss rate, so the cooling effect increased significantly. In the temperature field, the temperature changed by the heat sink , and thus affected the flow temperature of the wake zone dramatically, and the tail position of the bottom flow area changed inconsistently, and moreover the speed could effectively flew into the radiator inside and cause rapid changes in heat transfer more evidently, and also resulting in changes in the larger heat on both sides of the position, and then on the rear wall of the heat shock to both sides had diffusion effects, resulting in the outlet position presented two formations of non-caloric change area.

Case-2, when the distance between piezoelectric fan centers to the flow channel plate e (H_w) was less, the thermal resistance degraded was followed by. The highest thermal value was occurred at the position of the distance between fan center to the flow channel base Hw = 21mm, and the distance (L_g) between the front end of piezoelectric fan to the front end of radiator fan (L_g) were 5 mm and 10 mm, the thermal resistance raising trend is not obvious during the flow channel (H_w) which is the distance between center of piezoelectric fan to the bottom of flow channel is (H_w) lower than 16 mm , but at the channel distance which increased height to 21 mm , the thermal resistance of a single piezoelectric fan rose vigorously.

Case-3, Because most of the impinging stream was generated at the X-axis, and the vortex flow would divert under the Z-axis direction, vortex of the impact tip of flow which just intensively effected front side of cylindrical speed as shown inFig.4- (a), and the rear side of cylindrical had the effects of pressure difference and the frictional stress, and thus caused flow to the rear side had larger resistance, and thus could not create an effective velocity field as shown in Fig. 4-(b), and in the meantime at the distance (Hw) of piezoelectric fan center position to the flow channel plate bottom was 30mm,the impact could be effectively flow into the cylindrical cooling fins, and thus the flow can be effectively entrained into the Z-axis direction with opening , and at the same time followed with the impact flow to the X -axis direction to the rear side columnar cooling fins for effective heat dissipation. In piezoelectric fan placement in higher -shaped case, the impact flow was formed at blade tip position directly on the square columnar cooling fins chip rather than in the front, however, the impact flow homeopathically flew and impacted the back side, and the activity caused the front flow field of square columnar fins the pulled flow field backward, and thus the velocity of the front end of the square cylindrical fin was measured slower, as shown in Fig. 5.

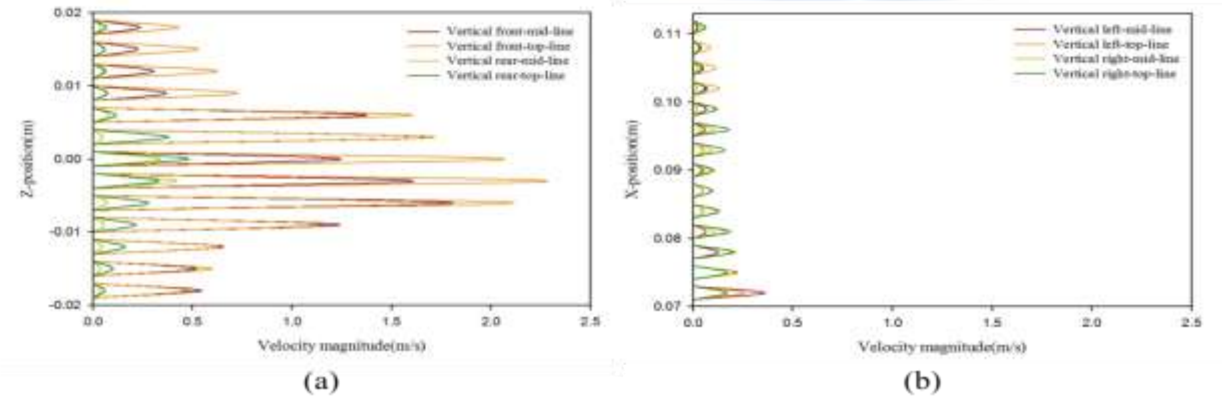


Fig. 4.The Z -axis and X- axis speed change map asflow channel H_w = 15 mm

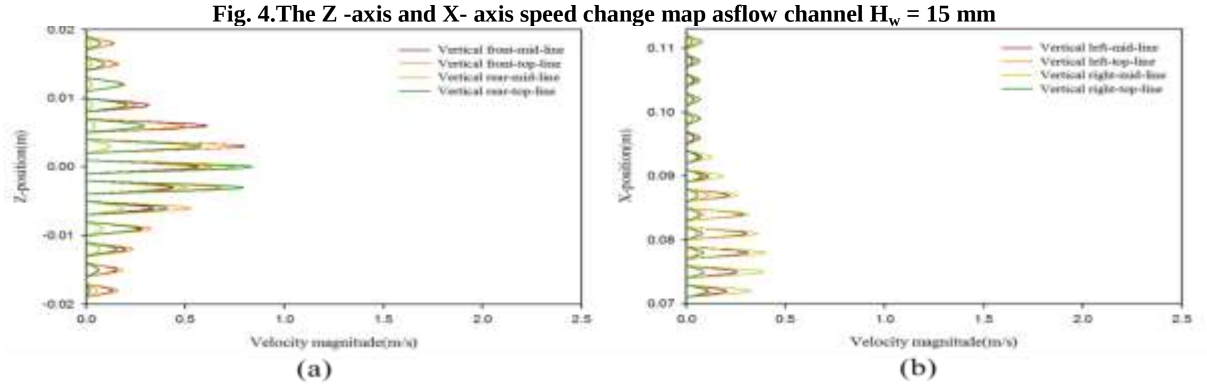
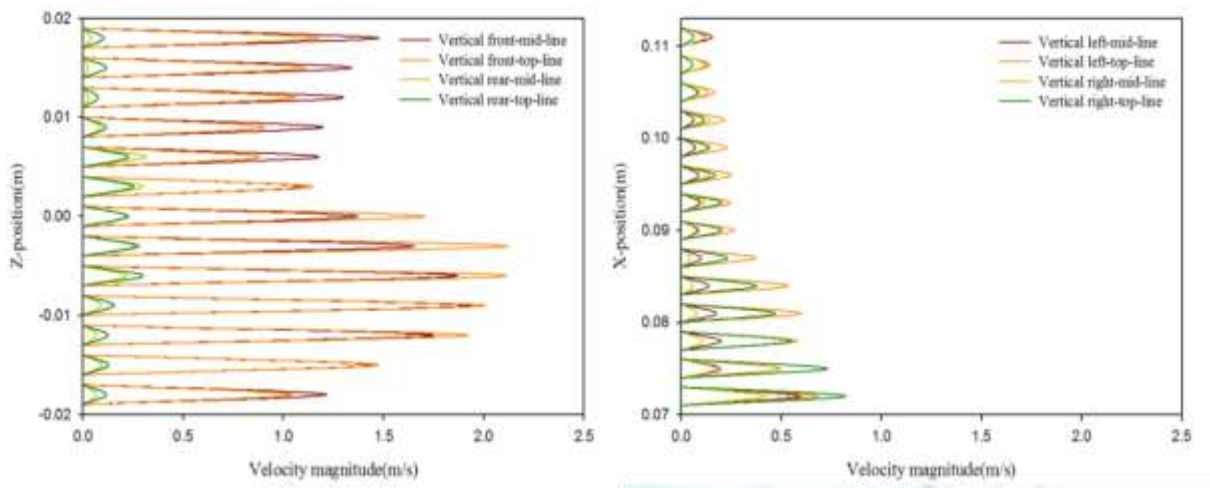


Fig.5. The Z -axis and X- axis speed change mapsas flow channel H_w = 30 mm,

Case-4, Figure 6 shows the fan actuated for two seconds , As H_w = 10 mm Z-axis and X- axis position speed change maps; Since piezoelectric fan was vertical configured, in the meantime, the closer the floor, the greater cooling area caused by the tip of the radiator. Figure 6 (a) showed the results which were displayed in front of the radiator, at the top-line, mid-line with the energy went on, the impact of flow velocity on the front was more strongly than that on the rear end, monitoring line was set at the rear of the radiator by monitoring the fluid through the cylindrical side fins, Since pressure difference and the friction effect, that fluid flow to the rear caused greater resistance, the performance speed is also relatively slower. Figure 6 (b) showed the radiator left and right side monitoring line, the speed close to the front end of the piezoelectric fan was faster, in swung process of piezoelectric fan, the fins top had less resistance, the speed has been measured at the position of the top-line from monitoring line is faster than that has been measured at the mid-line, but the overall performance was still not as good as that had been measured at the front end of the monitor line.Fig.7 presented the relationship between H_w and $N_u$for the first 42 seconds. Contrary then that, N_u would show the opposite trend [9-10] at the radiator plate.



(a) (b)

Fig. 6. The Z -axis and X- axis speed change maps as flowchannel H_w = 10 mm

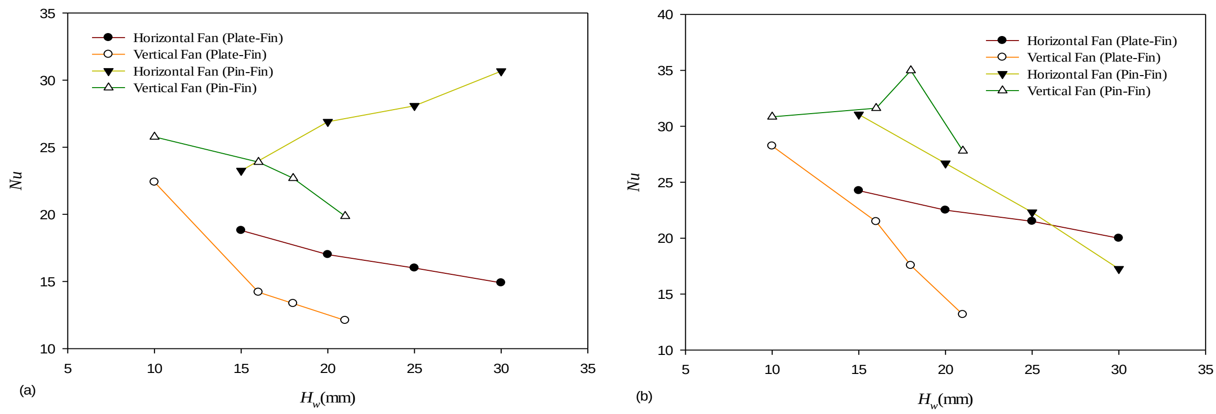


Fig.7. The relationship between H_w and N_u, (a) n = 14; (b) n = 10

4.2 The distance between the front ends of piezoelectric fan blade to the front end of radiator (L_g)

Case-1, Flow of the fan came from the upper part of the central location, this flow would produce vortex at the lower part of the central location, and the vortex would guide the flowing fluid at this moment. And then during the fan swung down,the vortex at the top swing position would flow down, that was contrary to the direction of flow which was caused by the upper part of the fan. The counter-clockwise flow caused the impact flow phenomenon, and thus caused the wall had a negative speed. Case-2, at the distance between the front end of piezoelectric fan to the front end of radiator was (L_g) 5 mm, the thermal resistance was lower than that at L_g=0mm and L_g= 10mm, at the position of L_g = 0mm , the impact flow caused by piezoelectric fan hit the front end of radiator , induced the less wind flew inside the fins , and at the position of L_g= 10mm , the front end of radiator was less affected by the front end of work fluid, which made the rear of the radiator Waste heat was not easy to rule out , and induced the heat accumulation, which was the reason for conformation the higher thermal resistance. At the position of the piezoelectric fan center to floor distance (H_w) was 21mm, piezoelectric fan was placed at L_g = -22.5 mm could get the lowest thermal resistance , but the less or larger distance between the font end of piezoelectric fan to the front end of radiator could not get better cooling effect. Case-3, at a fixed distance between the front ends of piezoelectric fan to the point of 5mm before the end of radiator. Changed distance between the center of piezoelectric fan to the base of flow spacing(H_w), at column number, n= 14 the thermal resistance significantly have little change, while the column n = 10,and the Hw had larger value that meant the pressure fan placed farther away from the base plate , the higher the thermal resistance was. And then selected a row column n = 10 and n = 14 in order to study, which at the greater value of thermal difference, that was at the location of piezoelectric fan base center to the flow channel spacing H_w = 30 mm. Case-4, if the thermal resistance was getting smaller, which meant that each placement of cylindrical piezoelectric fan had greater cooling impact and effects, At the position of the L_g= -22.5 mm had minimum thermal resistance, As piezoelectric fan under the vertical position, the impingement flow of the blade tip was moving above the floor of bottom plate. So the impingement flow had heat dissipation for the other columnar cooling fins, that the heat dissipation was more obvious; Otherwise at the position of L_g = 5 mm and L_g = -45 mm, the blade floor heating tip center was farther away, the greater the thermal resistance became greater. Figure 8described the relationship between L_g and N_u, the time is at the 42_{nd} second.

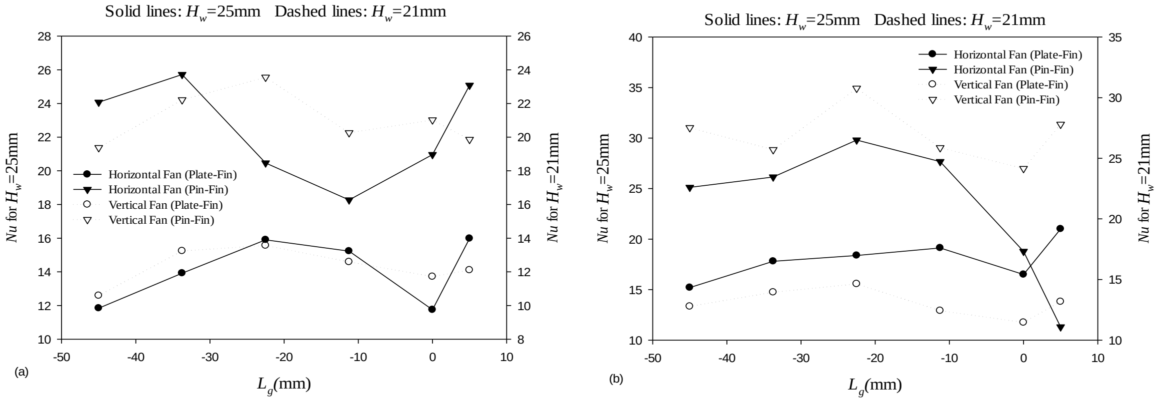


Fig.8. Therelationship between L_g and N_u (a) n = 14, (b) n = 10

4.3 The impact of change fin number (n)

Case-2, Figure 8 showed the two columns n=14 and n=10, the minimum coefficient of performance parameter value was the same as at the distance between the front end of piezoelectric fan to the front end of radiato was (L_g) 10 mm, that was the farther distance of the front end of piezoelectric fan, and at this position the fin column was n=10, whose coefficient of performance is greater than the coefficient of performance of the fin column n=14. Under fin column n= 10,the kinetic energy generated by the piezoelectric fan over the front end could be more easily transmitted to the internal of radiator, and which caused the internal liquidity of radiator was relatively stronger. After integrated the heat flux of radiator surface, and defined the average convection coefficient, we could have the convection coefficient is also greater than the number of fin column n=14.The four cases Characteristic analysis could be seen from Fig.7 and 8.

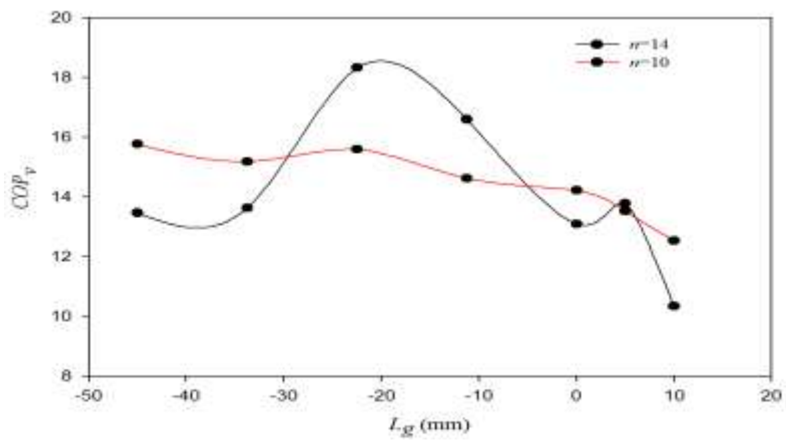


Fig. 9. Changed L_g impacted on COP_v(H_w = 21 mm, t = 42s)

Case-3 As shown in figure10 (a),atn=14 the distance between fin column center to the piezoelectric fan base H_w=30 mm, pitch velocity vector and fins heat flux distribution were shown in this figure, and during the fan tip swings, the generated impact flow made velocity boundary damage which was in the front end side of the fin. When the impinging stream flew to the top of cooling fins, due to the fin retarding effect, it could not effectively influence the other flow path to the heat sink fin of the flow field, the speed drew heat out only in the front end of the heat sink. As the fin column n = 14, the distal end of fin had high heat flux, he overall view was shown in Fig.10 (c).

Case-4 as shown in Fig.10(b), at the position of fan placed vertically down, the fin column n= 14,the space between fan center to the bottom plate of channel was H_w= 10, the heat flux in the front of the fin was the most obvious, due to piezoelectric fan placed closer to the cooling fins, the fin spacing (G) is relatively smaller, fin reaction force applied to the surface of the impact of fluid flow generated by the impact of the front fin blockade, after that fluid will pushed towards the Z axis direction . The X- axis and Z -axis angle was shown in Fig. 10 (d), the influence of the flow field became fan extends, the transmission effects had limitation, and at the fan-shaped outer end position, the fin heat flux became lower, that was caused by heat accumulation.

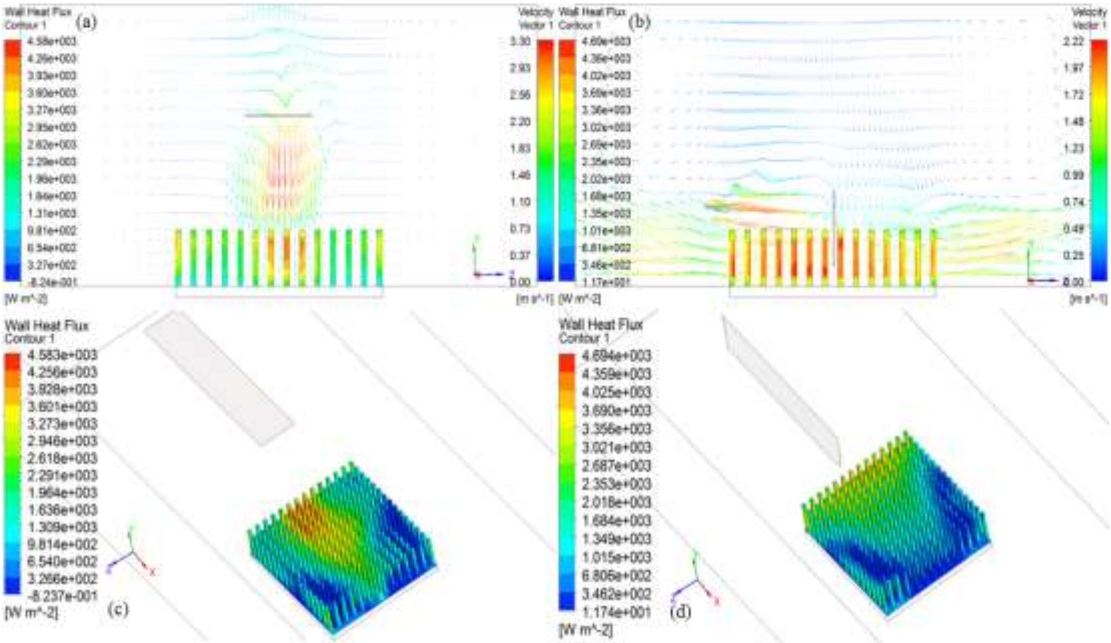


Fig.10. Velocity vector diagram and the heat flux , (a) Case-3 heat flux distribution of the Y-axis velocity vector ; (b) Case-4 heat flux distribution of the Y-axis velocity vector ; (c) Case-3 Radiator surface heat flux (n = 14, H_w= 30, L_g = 5); (d) Case-4 sink surface heat flux (n = 14, H_w = 10, L_g = 5)

5. Conclusion

For the flat radiator: (1) Piezoelectric fan placed vertically, and the piezoelectric fan was placed in front of flat fins. As the piezoelectric fan was placed in different positions, right behind the radiator fluid flow structure was somewhat different, but the impact of piezoelectric fan for the radiator, that was mainly generated by the front end of jet flow and the surfaceof the entrained flow of piezoelectric fan, the two different placement of piezoelectric fan induced the disturbance moving gas for local cooling radiator was obviously different. When the center position of piezoelectric fan was higher than radiator fins, the affected area of entrained flow should be taken as a priority consideration. When the center position of piezoelectric fan was lower than radiator fins, the effect of impact flow area should be taken as a consideration. The cooling performance increased as the fan centers to the flow channel height (H_w) relatively decrease. At the occasion of piezoelectric fan placed at the front of radiator, the closer distance between the centers of radiator to the base plate of flow field, the better cooling performance it was. The piezoelectric fan would decrease it's cooling performance while fan base center to the flow channel height (H_w) lower increased; when piezoelectric fan placed in front of the radiator, the fan should make the fan center to the flow channel height lower, and the distance between the piezoelectric fan front to the radiator fan front the closer the better, But at close range, should be avoided the bypass effect which was generated by the front end of the radiator. (2) The piezoelectric fan was placed in horizontal configuration and in front of flat radiator. Change the height of the piezoelectric fan installed in a rectangular flow channel plate-type heat sink could really reduce the Nusselt value. As the piezoelectric fan placed in front of the radiator height, H_w= 15mm position had overall better performance. The installation of Piezoelectric fan lateral position change with different flow velocity would destruct the flow field structure behind the radiator, so that the inner thermal phenomena of wake region could be improved and increased fluid mixing to enhance the heat transfer effect. The piezoelectric fan Placed in a central location of radiator fan, which would cause vortex flow effects, either increased the flow of side's effects, or enhanced the flow rate.

For square columnar radiator: (1) piezoelectric fan placed vertically, and was placed in front of square cylindrical fin. And during the fan swung, the resulting velocity field caused the radiator velocity boundary layer damage, and with the most efficient way to make the flow field enter into the radiator flow channel. While in cooling performance, the swing forms of the fan disturbed the flow field, it would induce a forward and bottom side impingement flow. The heat accumulation inside the radiator would be taken away. This Phenomenon was the most obvious at n = 10 of the fin, and this Phenomenon were mainly related in the fin adjacent spaceG.(2) piezoelectric fan placed horizontally, and the piezoelectric fan was placed in front of square columnar radiator. At this condition, the jet stream was generated by the front of piezoelectric fan and the entrained flow was mainly generated by surface of piezoelectric fan, at different placement of the piezoelectric which caused the disturbance of flow, and made the heat dissipation significantly different, for the columnar radiator , the entrained flow generated by swing of piezoelectric fan, which would cause the fluid entanglement in each square columns , and would damage the boundary layer for cooling, followed by use of jet stream which was generated by the front end of piezoelectric fan, and that would pull the vortex of entrained flownaway. And therefore made the square columnar radiator easier to achieve the overall average temperature than that of the flat radiator, and the main heat affected area was shown in Fig.11.

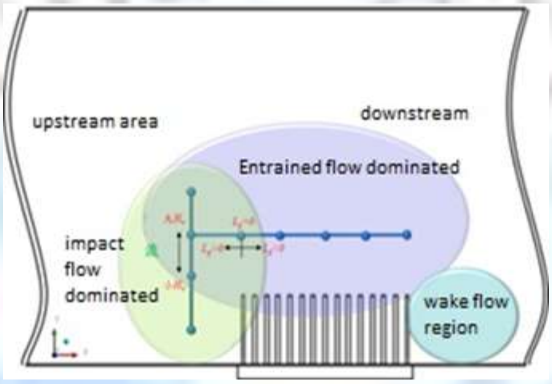


Fig.11. The main heat affected area

7. References

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