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THERMAL MANAGEMENT OF A DIRECT ATTACH CHIP OF A LAPTOP COMPUTER

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ABSTRACT: - This work presents an analytical and computational investigation of the effect of fins length and fin height at different volumetric flow rate of fan on the performance of heat sink. The facility have been adapted by using ANSYS15 and EES software to study the heat transfer characteristics for cross flows air cooled in single processors (chip) in modern laptop and study the effect of the fins in enhancement in heat transfer phenomena and study all variables which have effect on heat transfer phenomena. We make ten different readings of volumetric flow rate of fan from [0.05to 0.25] m^3/s and three different reading of height and length at 21 Was heat load from the chip and we find that volumetric flow rate increases heat transfer coefficient and that will decrease junctions temperature from 55.74oC to 43.95oC as volumetric flow rate increase five times.

The theoretical and computational results showed good agreements between them as the junction temperature was decreasing when volumetric flow rate of fan increase and fins length increase as a results for additional surface area which dissipated more heat transfer and the fin effectiveness increasing in a results of increasing of volumetric flow rate of fan and fin height.

Nomenclature:-

Symbol	Title	Units
A_{fin}	Active area of the fins	m^2
$A_{unfinned)}$	passive area of the fins, unfinned area	m^2
A_{TIM}	The TIM area	m^2
A_B	The board area	m^2
$TIM_{thickness}$	Thickness of the interface TIM	m
$B_{thickness}$	Thickness of the board	m
R_{TIM}	Thermal resistance of TIM	C^o/W
R_B	Thermal resistance of the board	C^o/W
R_{fin}	Thermal resistance of the fins	C^o/W
$R_{unfinned}$	Thermal resistance of the unfinned	C^o/W

R_{HS}	Thermal resistance of the heat sink	C^o/W
R_{total}	Total thermal resistance of the package	C^o/W
h	heat transfer coefficient	$W/m^2.^oC$
k_{TIM}	Thermal conductivity of the interface TIM	$W/m.^oC$
k_B	Thermal conductivity of the board	$W/m.^oC$
k	Thermal conductivity of the heat sink	$W/m.^oC$
η	Fins efficiency	-
T_j	The junction temperature	^oC
T_s	Surface temperature of the fins	^oC
$\dot{Q}$	Rate of heat transfer	kW
T_∞	Ambient temperature	^oC
N_u	Nusselt number	-
R_e	Reynolds number	-
P_r	Prantel number	-
ν	Kinematic viscosity of air	m^2/s
$\dot{m}$	Mass flow rate of the air	Kg/s
$\dot{V}$	Volumetric flow of the air	m^3/s

1- INTRODUCTION

Thermal management of electronic equipment is critical for the continued success of the microelectronics industry. Portable electronic devices, such as notebook computers and cellular telephones, require that the thermal solution be small, light, and energy efficient. The use of high speed processors in modern laptops and other electronic devices leads to higher rates of heat generation that need to be dissipated efficiently. This heat generation can lead to a certain degree of discomfort when using a notebook computer on top of your lap. If heat is not dissipated efficiently it may also shorten electronic components life and cause the fan to operate for longer periods, consuming the battery charge more quickly.

The consumer demand in the electronics industry has been highly advancements in laptopprocessor speed and capabilities, with many laptop central processing units (CPU) of more than 3GHz available as shown in figure (1),especially in alow price, however, asthe total amount of heat generated increases with processor speed. The high temperatures that modern laptops generate are starting to become too significant for common cooling techniquesto handle, and hence alternative cooling techniques are necessary[1].

Heat transfer theory seeks to predict the energy transfer that takes place between material bodies as a result of temperature difference. This energy transfer is defined as heat. The three modes by which heat can be transferred from one place to another are conduction, convection and radiation [2].

It is well known that a hot plate of metal will cool faster when placed in front of a fan than when placed in still air. With the fan, we say that the heat is convected away, and we call the process convection heat transfer. Convection involves the transfer of heat by motion and mixing of a fluid as shown in figure (2)[3].

The processor is designed to meet a specific thermal design power (TDP), but thermal solution is required to dissipate this TDP at maximum power consumption of aprocessor although the value represents the worst case real application which is veryrarely attained by an average user[4]. The ultimate goal of thermal management is todissipate the TDP and maintain the processor below its maximum operating temperature. Thermal monitoring of the hottest location on the die determines the maximumjunction temperature (Tj). Major laptopmanufacturers have successfully employedthermal management techniques for mobile processors with an average TDP of 20 W[5].Most recently Intel Corporation introduced the Intel Celeron M processorfor mobile computers with a TDP of 24.5 W [6]. The cooling solutions for notebook computers are usually more complex, with limitedspace and varying design layouts, than for desktop systems

2. THEORETICAL ANALYSIS

Forced convection is a mechanism, or type of transport in which fluid motion is generated by an external source like fan. It should be considered as one of the main methods of useful heat transfer as significant amounts of heat energy can be transported very efficiently. This mechanism is found very commonly in everyday life, including central heating, air conditioning, steam turbines and in many other machines. Forced convection is often encountered by engineers designing oranalyzing heat exchangers, pipe flow, and flow over a plate at a different temperature than the stream.

Although the cooling solutions may vary among manufacturers, all notebook computers employ passive and/or active cooling methods with either air or liquid coolants. A basic passive cooling method is natural convection within the laptop cabinet whereas an active cooling method employs fans to aid airflow over the devices in the laptop cabinet.

By using EES software (Engineering equation solver) which is a general equation-solving program that can computationally solve thousands of coupled non-linear algebraic and differential equations. The program can also be used to solve differential and integral equations, do optimization, provide uncertainty analyses, and perform linear and non-linear regression. The required heat sinks are designed, the effect of volumetric flow rate on heat transfer is appeared by forced convection on heat transfer coefficient and it could be decreased temperature of junction and it should be calculated Reynolds number to determine flow laminar or turbulent, then the total resistance of the system can be determined as.

$$R_{TIM} = \frac{TIM_{thickness}}{A_{TIM} \times k_{TIM}} \quad \ldots\ldots (1)$$

$$R_B = \frac{PCB_{thickness}}{A_B \times k_B} \quad \ldots\ldots (2)$$

The thermal resistance of the heat sink is given by

$$R_{fin} = \frac{1}{h * \eta * A_{fin}} \quad , \quad R_{unfinned} = \frac{1}{(h * A_{unfinned})}$$

$$R_{HS} = \frac{1}{\frac{1}{R_{fin}} + \frac{1}{R_{unfinned}}} \quad \ldots\ldots (3)$$

$$R_{total} = R_{TIM} + R_{PCB} + R_{HS} \quad \ldots\ldots (4)$$

Then heat transfer coefficient, Nusselt number and Reynolds number will be determined.

$$R_e = \frac{VL}{\nu} \quad \ldots\ldots (5)$$

$$N_u = 0.664 {R_e}^{0.5} {P_r}^{1/3} \quad \ldots\ldots (6)$$

$$h = \frac{N_u k}{L} \quad \ldots\ldots (7)$$

The rate heat transfer between surface of the fin and environment can calculate as

$$\dot{Q} = \dot{m} C_P (T_s - T_\infty) \quad \ldots\ldots (8)$$

Where $\dot{m} = \rho \dot{V}$ ……(9)

Finally the maximum allowable temperature at the heat sink attachment surface, T-junction, it will be determined .

$T_{j=}T_s + \frac{\dot{Q}}{\eta A_s h}$…………………………..……… (10)

Where A_s is the total surface area of the system. We use 10 different reading of volumetric fan flows rate at three different reading of fins length and three different fins height as shown in table(1)and comparison between the theoretical and computational ones.

3. COMPUTATIONAL ANALYSIS

The computational models included forced convection heat transfer and the residual of first operation shown in figure (3). As the package increased in temperature this parameter became more significant. Forcedconvection was based on the Boussinesqapproximation; Radiation was neglected in the models because of the low temperature ranges and also based on an analytical calculation for the radiative [7-13].

4.RESULTS AND DISCUSSION

The ANSYS, ICEPAK 15 in our study was implemented ,this models included forced convection heat transfer and the mesh configuration and boundary condition of the system was shown in figure (4) with mesher –HD types ,the number of elements are (13,052,000) and number of nodes are (13,220,172) and maximum elements size in X,Y and Z directions is 0.002m. The fins and fins base was made form aluminum with density 2800 kg/m^3 and thermal conductivity is 205 W/m^{0}C.

The simulation results are compared with the theoretical heat sink temperatures in order to verify that the simulations are representing the conditions of the theoretical state. For the first reading at 0.05m^3/s the maximum junction temperature is 55.74^{0}C with velocity arraydistribution in y- direction as shown in figure (5).

When doubled the volumetric fan flow rate to 0.1m^3/s, the maximum junction temperature is decrease by 6 degrees as 49.53^{0}C for suitable length of heat sink which we computed.

While figures (6), and (7) represent the temperatures and velocities array distribution in ydirections for laptop cabinet and the temperatures are continuously decreases by two degrees for each reading when increase volumetric fan flow rate at 0.15 ,0.25 m^3/sand the minimum junction temperature is 43.95^{0}C.

Figures (8) shown four views the temperatures and velocities contour in the laptop package at volumetric flow rate 0.1 m^3/s.

The junction temperature was decreasing as volumetric flow rate of fan increase and fins length increase from 40mm to 60mm as a result for additional surface area which dissipated more heat transfer as shown infigure (9).

Finally,figure (10) shown the increasing in fin effectiveness as a results of increasing of volumetric flow rate of fan and fin height.

4-CONCLUSION

Demand for high power, compact, the laptop computers are increasing the heat that is generated by laptops.Forced convection cooling can prolong component lifetime and reduce thetime that the cooling fans operate. Less power will be consumed, and less noise generated. Ten different readings of volumetric air flow rate from 0.05 to 0.25 m^3/s was performed to calculate different junction temperatures at three different fins length and height respectively and we find the lowest temperature at maximum volumetric air flow rate at the same heat load as 21Watt.

The analytical and computational results showed good agreements in calculate the performance of heat sink.

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Table (1) Fins dimensions and readings

Volumetric fan flows rate [m^3/s]	fins length [mm]	fins height[mm]
0.05, 0.055, 0.06, 0.07, 0.08, 0.1, 0.12, 0.15, 0.2, 0.25	L1=40 L2=50 L3=60	H1=8 H2=12 H3=15

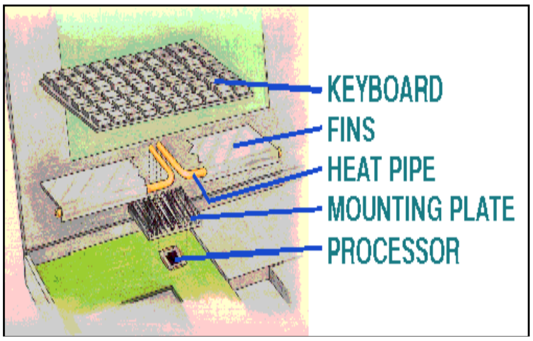

Figure (1) laptop components

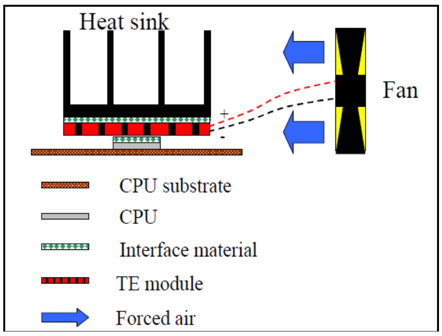

Figure (2) Forced convection of aluminum heat sink [5]

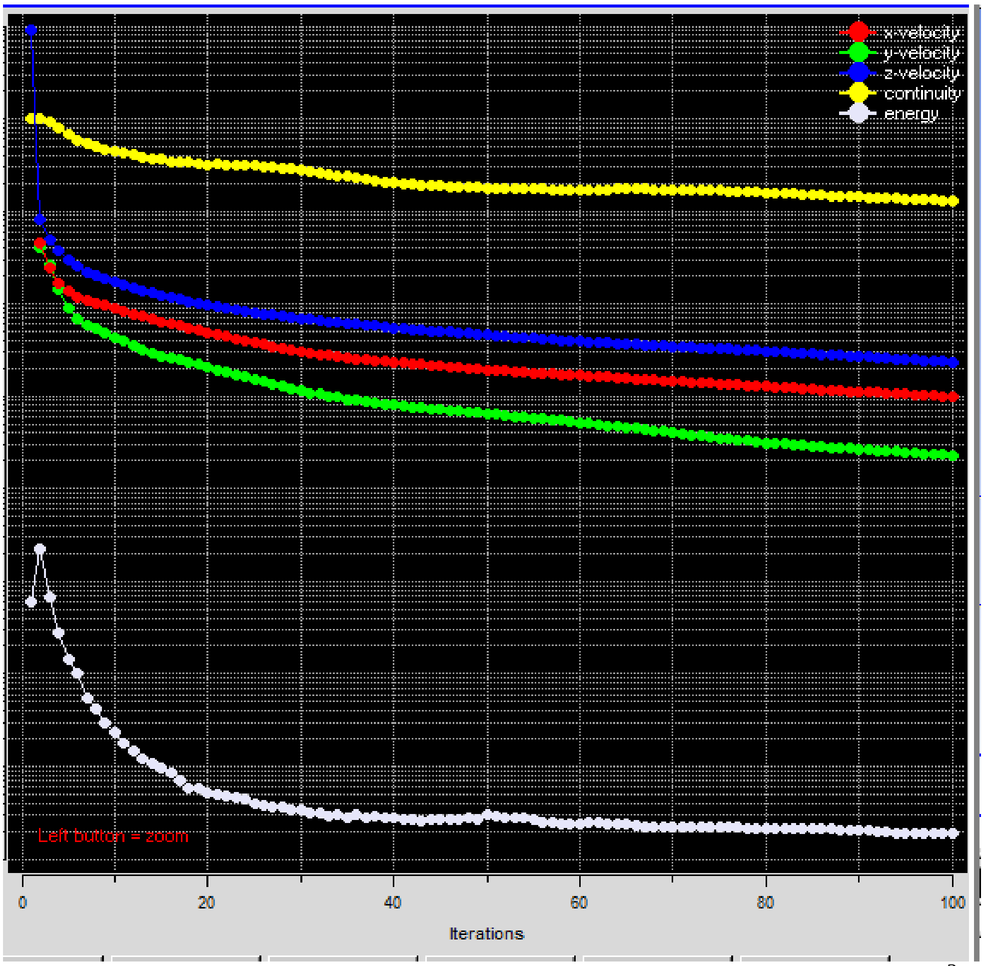

Figure (3) the residual of the operation at volumetric flows at 0.05m^3/s.

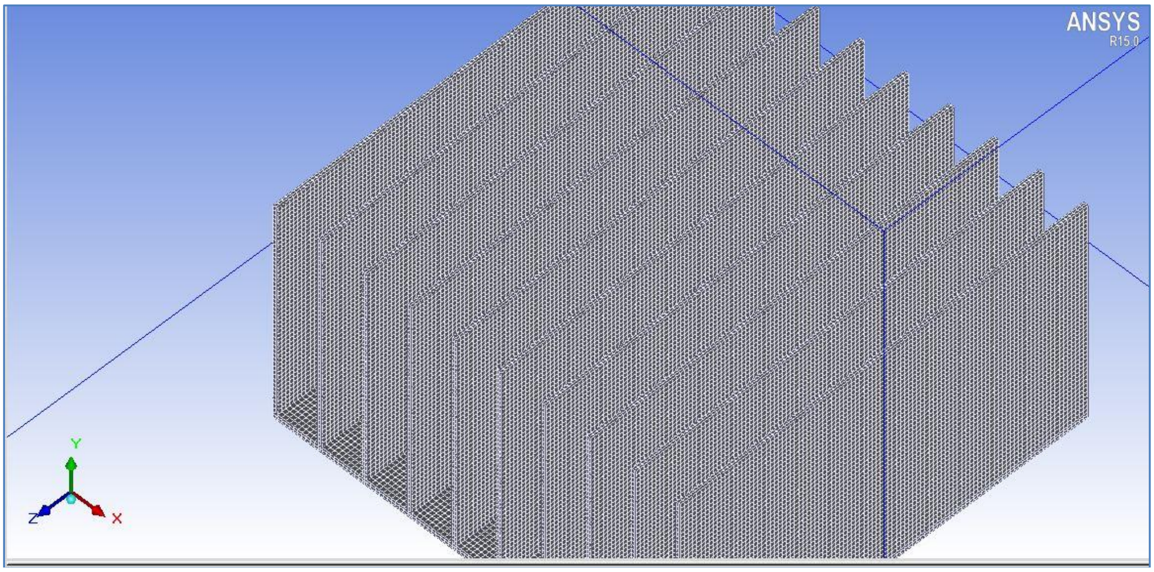

Figure (4) the mesh configuration of the system

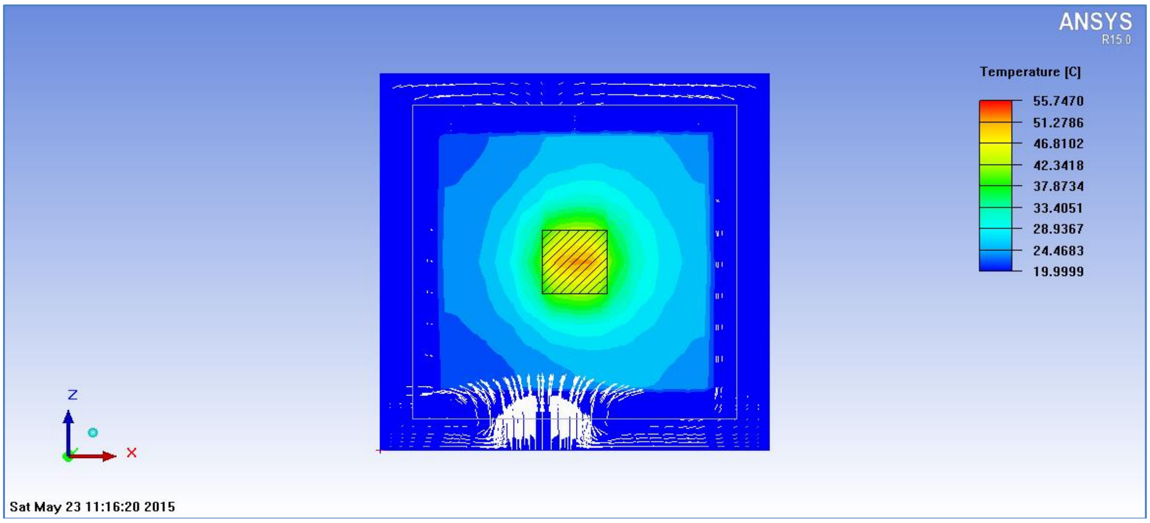

Figure (5) temperature and velocity array distributionsin laptop cabinetat volumetric flow rate $0.05 m^3/s$

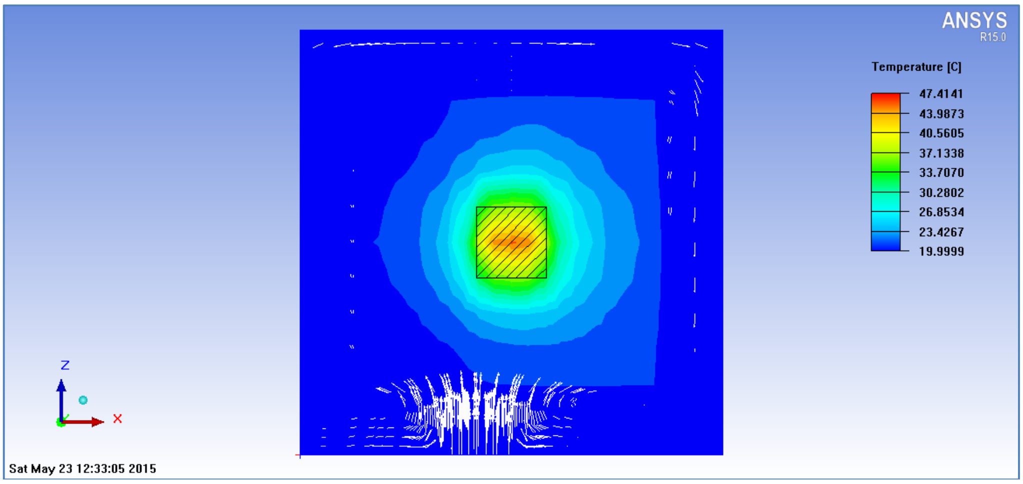

Figure (6) temperature velocity array distributionin laptop cabinet at volumetric flow rate $0.15\ m^3/s$.

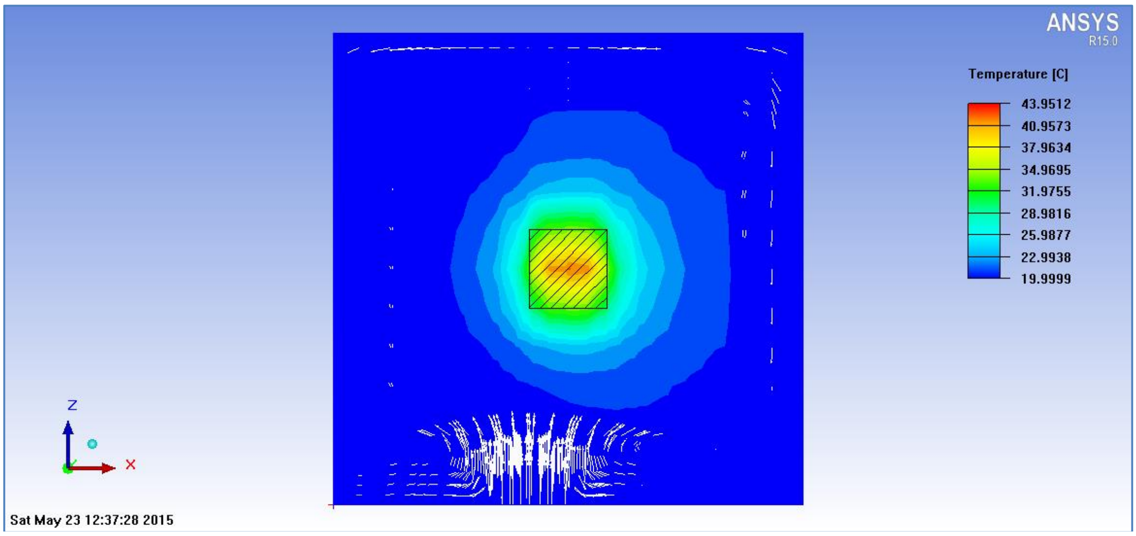

Figure (7)temperature and velocity array distributionin laptop cabinet at volumetric flow rate $0.25\ m^3/s$.

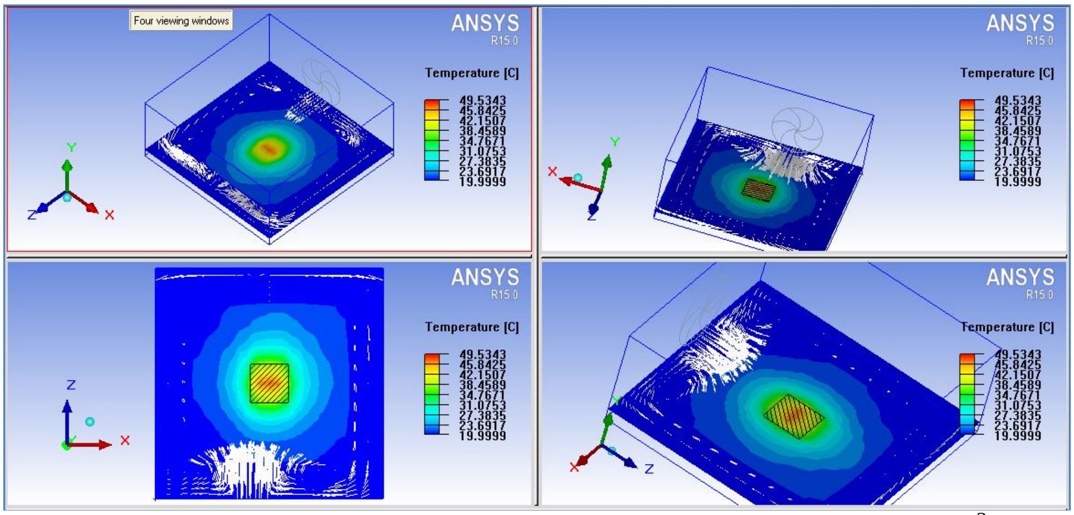

Figure (8) velocity contour in the package at volumetric flow rate 0.1 m^3/s.

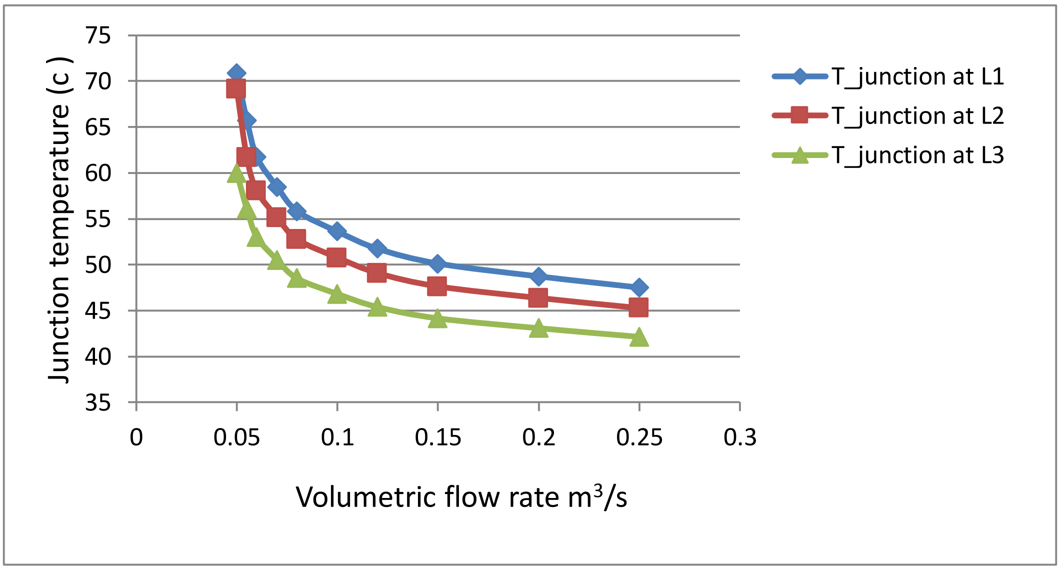

Fig (9) junction temperature with different volumetric fan flows rate at different fins length

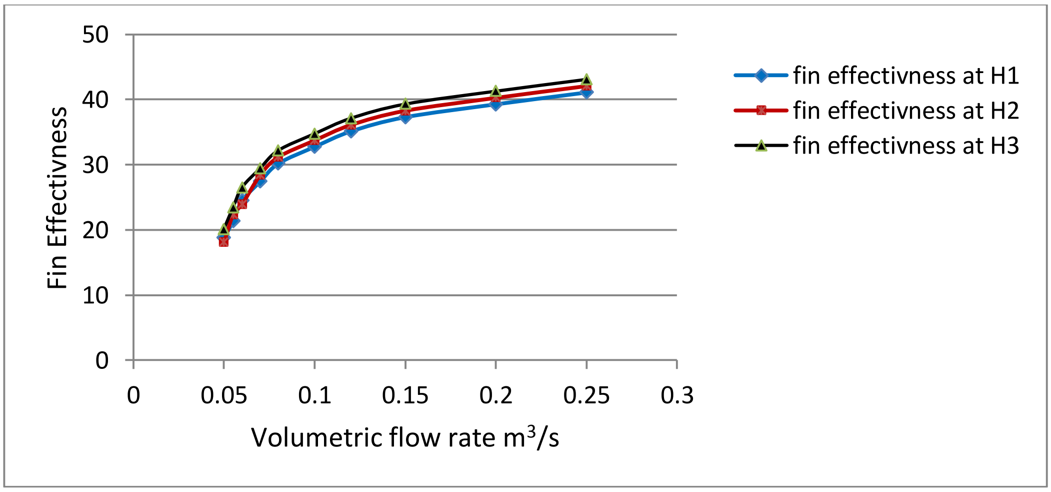

Fig (10) Fin effectiveness with different volumetric fan flows rate at different fins height

الإدارةالحرارية لوحدة المعالجة المركزية موضوعة مباشرة فوق مبدد الحرارة (الزعانف) في جهاز الحاسب المحمول

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الخلاصة :-

في هذا البحث تم اجراء الحسابات التحليلية والنظرية لتأثير طول وارتفاع الزعانف في معدل التدفق الحجمي متغير للمروحة على أداء مشتت الحرارة.

وقد تم تكييف هذه الاجراءات باستخدام برنامج ANSYS 15 وبرنامج EES لدراسة خصائص انتقال الحرارة باستخدام تبريد الهواء في تبريد وحده المعالجة المركزية (رقاقة) في جهاز الكمبيوتر المحمول الحديث ودراسة تأثير الزعانف وغيرها في تعزيز نقل الحرارة.اجرينا في بحثا هذا مجموعة من القراءات المختلفة لعشرقيم مختلفة من معدل التدفق الحجمي للمروحة من[0،05-0،25] م^3/ ثانية وثلاثة قراءات مختلفة من ارتفاع وطول الزعنفه في21واطكحمل حراري من الرقاقة ووجدنا أن معدل التدفق الحجمي يزيد معامل انتقال الحرارة والتي من شأنها تقلل درجة الحرارة الاتصال من55.74درجة مئويةإلى43.95درجة مئوية بزيادة معدل التدفق خمس مرات.

أظهرت النتائج التحليلية والحسابية مقارنة جيدة بينهما حيث تقل درجة الاتصال بزيادة معدل التدفق الحجمي للهواء بزيادة طول الزعنفة كنتيجة لاضافة المساحة السطحية والتي تبدد حرارة اكثر .وكذلك يمكن تعزيز كفاءة الزعنفة بزيادة ارتفاع الزعنفة.