OPTIMIZING DIMENSION OF HEAT SINK'S PLATE FIN WITH THE EFFECT OF WIND VELOCITY IN SITE ROUTER TECOMMUNICATION SYSTEM

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Abstract - Nowadays, heat dissipation for electronic chips, microprocessors in electrical and electronic equipment, especially in Site Router telecommunication equipment when operating at high intensity is an urgent process to increase life expectancy, productivity and performance. Many telecom providers such as Huawei, Ericsson, Cisco etc have offered solutions for liquid cooling, cold air, heat pipes. However, the complexity, the cost and the effect are not high. Furthermore, there is shortage in optimal parameters of design and operation [1-5]. Derived from the above fact, the author has calculated and modeled a Site Router equipment using extruded blast heat exchanger with a large heat exchanger structure which withstands pressure when falling, combining airflow from fans to speed up the dissipation of heat. In this paper, the author presents the optimal calculation and control process of the size of the heat sink and the contact plate under the influence of actual operation conditions at the specified velocity of the air flow from which the model is built directly to determine the number and the size of the heat sink's plate fins.

Key words - Airflow; cooling process; heat dissipation; optimal control; SiteRouter equipment.

1. Nomanclature

A: Surface area in m^2.

A_c: Cross-sectional area in m^2.

A_f = H.W: Total frontal area of heatsink.

A_p: Fin profile area.

α: The convective heat transfer coefficient depends on a number of parameters determined by experiment ($W/m^2.K$).

b: Fin spacing in m.

C=120: Sutherland's constant for air.

F: surface area of heat exchanger (m^2).

H: Fin height in m.

k= 209: Thermal conductivity of Al6063-T5 (W/m.K).

θ_b: Temperature excess = T_b- T0(K,^{0}C).

λ: Thermal conductivity of the material (W/m.K).

L: Fin length in m.

μ: Dynamic viscosity at input temperature T0.

μ0= 18,27x10^{-6} Viscosity reference at standard temperature T0.

$N = \dfrac{W-t}{b+t} + 1$: Number of fins.

Q_x: X- axis heat transfer for 1 second (W).

Q: Heat dissipates in a second of the object (W).

q_x: The density of the heat transfer current in the direction x (W/m^2).

R_e: Thermal resistance (K/W).

R_{sink}: Thermal resistance of heatsink.

R_{fin}: Thermal resistance of each fin.

T: The absolute temperature of the object (K).

$\Delta T = T_1 - T_2$: The difference in wall thickness (K).

T_w: Average temperature of the object (K,^{0}C).

T_f: Average temperature of the gas or liquid (K,^{0}C).

T0=291,15: Standard temperature of air (K).

T_0=273+55: Absolute temperature environment (K).

t: Thickness of fin.

t_b: Thickness of base.

W: Width of heatsink.

2. Introduction

Today's thermal technology evolves from material to heat dissipation for liquid, nitrogen, gas or heatpipe applications such as "Laser-cooling Brings Large Object Near Absolute Zero" by Hänsch and Schawlow [7].

The variety of solutions offers great efficiency for devices that require large amounts of heat dissipation. However, the complex structure and the need for external power sources such as heat pumps have increased costs and are difficult to implement for limited-sized devices such as SiteRouter. One of the studies: "Design and Optimization of Horizontally-Finished Plate HeatSink for High Power LED street lamps" by Xiaobing Luo and Wei Xiong [6] launched in 2009 has reduced the complexity of liquid-liquid heat sinks as well as the use of extruded extruded heatsinks to optimize heat dissipation.The study has created the premise for the placement of heatsinks in telecommunication equipment with optimal size compact. However, the new study stops at passive heat dissipation through radiation and convection without impact from wind flow.

Based on the research on extruded bladed heat exchanger, the team combined the airflow through the layout solution of the blower in the SiteRouter, calculating the fin height adjustment and the distance between the fins. heat dissipation to reduce the heat at specified values of wind speed, increase the ability to dissipate heat to the environment. The obtained results are achieved through using NLP solve optimization function on Maple for the heat dissipation of Site Router's Mathematic model [8].

3. Method

SiteRouter equipment is modeled by using built-in fan housings on the air flow bushes directly into the extruded-fins heatsink. At fixed velocities of 1 m/s, 5 m/s the authors calculate the thickness of profiles of the fins as well as the distance between the adjacent fins from which the number of heat sink flutes is matched for the highest heat dissipation effect

3.1. Thermal conductivity

Thermal conductivity occurs due to the difference in temperature between regions in a solid or between two solid objects in contact. General heat conduction [4, 5] is:

$$Q_x = -\lambda F \frac{\partial T}{\partial x} \ (\mathrm{W}) \rightarrow q_x = \frac{Q_x}{F} = -\lambda \frac{\partial T}{\partial x} \ (\mathrm{W/m^2}) \quad (1)$$

in case of flat wall (application of heat dissipation calculation)

$$Q = \lambda F \frac{\Delta T}{\delta} = \frac{\Delta T}{R_\theta} (\mathrm{W}) \ \rightarrow R_\theta = \frac{\delta}{\lambda F} \ (\mathrm{K/W}, {}^0\mathrm{C/W}) \quad (2)$$

with λ: Thermal conductivity of the material (W/m.K).

Diamonds, silver and copper have very good thermal conductivity (see table 1). However, most manufacturers use aluminum as their primary material. The main reason is that aluminum is available, cheap and easy to make. Besides, another important factor affecting the heat dissipation quality is the ability to radiate (Copper is able to emit less heat than aluminum).

In this paper, the main purpose is to analyze geometric parameters of heatsinks and based on the thermal conductivity and manufacturing capability. The author uses the Al 6063-T5 aluminum for the heatsink of SiteRouter equipment.

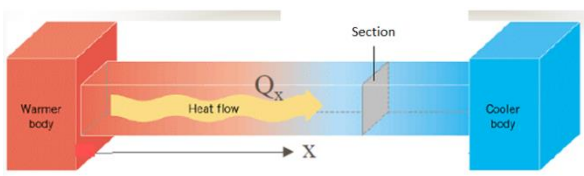

Figure 1. *Conduct heat from high temperature to low temperature*

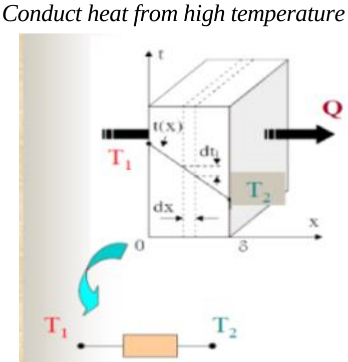

Figure 2. *Heat conduction through flat wall and equivalent heat*

Table 1. *Table of thermal conductivity of some heat dissipation materials*

Material	Thermal Conductivity W/(m.K)	Microhardness Mpa	Surface Roughness µm
Al 5052	140	745	6.9
Al 6061	180	705	0.7
Al 6063 -T5	201	1094	0.4(flycut)
Al 6065	170	680	
…..			
Alumium Nitride	160	10044	0.45
Alumina(96% Al2O3)	20.9	3100	1.3(Ground)
Copper(Cu)	397	924.1	0.45(milled)
Silver(Ag)	429		
Gold(Au)	310		
Diamond	2200		
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3.2. Convection

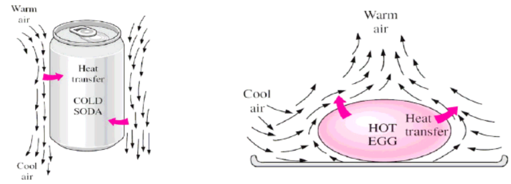


Figure 3. *Convection process*

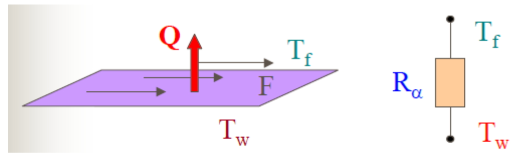


Figure 4. *Thermodynamic model*

Convection is the process of heat exchange that occurs when a surface of a solid comes into the contact with a liquid or gaseous environment at different temperatures.

To calculate the heat in the convection process we use the Newton formula as follows:

$$Q = \alpha F (T_w - T_f) = \frac{T_w - T_f}{R_\alpha} \ (\mathrm{W})$$
$$\rightarrow R_\alpha = \frac{1}{\alpha F} \ (\mathrm{K/W}, {}^0\mathrm{C/W}) \quad (3)$$

3.3. Influence of geometric parameters of heat dissipation to heat dissipation

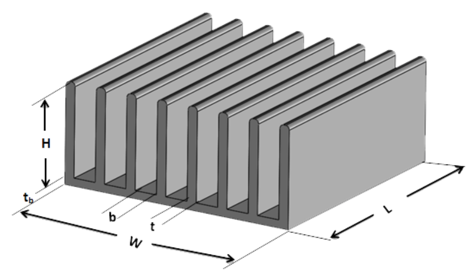


Figure 5. *Structure of Heatsinks*

The energy equation for the heat exchanger has the effect of the external air flow of the heat sink [3]:

$$\dot{S}_{gen} = \frac{Q\theta_b}{T_0^2} + \frac{F_d V_f}{T_0} \quad (4)$$

While $\theta_b = Q.R_{sink}$ (5)

From (4) and (5): $$\dot{S}_{gen} = \frac{Q^2 R_{sink}}{T_0^2} + \frac{F_d V_f}{T_0} \quad (6)$$

Thermal resistance of the heatsink:

$$R_{sink} = \frac{1}{(\mathrm{N}/R_{fin}) + \mathrm{h(N-1)\,bL}} + \frac{t_b}{kLW} \quad (7)$$

Thermal resistance of each fin:

$$R_{fin} = \frac{1}{\sqrt{hPkA_c}\ \tanh(\mathrm{mH})} \quad 8)$$

With: $m=\sqrt{\dfrac{hP}{kA_c}}$ (9)

Force acting on the heatsink surface under the effect of air flow:

$$\frac{F_d}{(1/2)\rho V_{ch}^2}=f_{app}N(2\,\mathrm{HL}+\mathrm{bL})+K_c(\mathrm{HW})+K_e(\mathrm{HW}) \quad (10)$$

Free flow velocity: $V_{ch}=V_f(1+\dfrac{t}{b})$ (11)

For laminar flow:

$$f_{app}Re_{D_h}=\left[\left(\frac{3.44}{\sqrt{L^*}}\right)^2+fRe_{D_h}{}^2\right]^{1/2} \quad (12)$$

with: $L^*=\dfrac{L}{D_h R_{eD_h}}$ (13)

$$fR_{eD_h}=24-32.527(\frac{b}{H})+46.721(\frac{b}{H})^2 \quad (14)$$
$$-40.829(\frac{b}{H})^3+22.954(\frac{b}{H})^4-6.089(\frac{b}{H})^5$$

$$K_c=0.42(1-(1-\frac{N.t}{W})^2) \text{ and } K_e=(1-(1-\frac{Nt}{W})^2)^2 \quad (15)$$

The equation of heat transfer coefficient:

$$Nu_b=\left[\left(\frac{\mathrm{Re}_b^*\,\mathrm{Pr}}{2}\right)^{-3}+\left(0.664\sqrt{\mathrm{Re}_b^*}.\mathrm{Pr}^{1/3}\sqrt{1+\frac{3.65}{\sqrt{\mathrm{Re}_b^*}}}\right)^{-3}\right]^{-1/3} \quad (16)$$

$$\mathrm{Re}_b^*=\mathrm{Re}_b\left(\frac{b}{L}\right) \quad (17)$$

$$h=\frac{kf.Nu_b}{b} \quad (18)$$

Reynolds factor: $\mathrm{R}_{eD_h}=\dfrac{D_h.V_{ch}}{\nu}$; $D_h=2.b$.

Therefore: $\mathrm{R}_{eD_h}=\dfrac{2.\mathrm{b}.V_{ch}}{\nu}$ (19)

Kinematic viscosity:

$$\nu=\frac{\mu}{\rho};\ \mu=\frac{\mu_0(T0+C)}{T_0+C}.\left(\frac{T_0}{T0}\right)^{3/2} \quad (20)$$

4. Parameters optimized with empirical model

Based on the energy equation Entropy (4), we can optimize any of the parameters for the size of the heat sink:

$$\frac{\partial \dot{S}_{gen}}{\partial x}=0 \quad (21)$$

$$\dot{\mathrm{S}}_{\mathrm{gen}}=\dot{\mathrm{S}}_{\mathrm{gen}}(\mathrm{L},\mathrm{H},\mathrm{t_b},\mathrm{W},\mathrm{b},\mathrm{t}\ldots)=\dot{\mathrm{S}}_{\mathrm{gen}}(\mathrm{x_1},\mathrm{x_2},\mathrm{x_3},\ldots)\to\min$$

$$\mathrm{R_{sink}}=\mathrm{R_{sink}}(\mathrm{L},\mathrm{H},\mathrm{t_b},\mathrm{W},\mathrm{b},\mathrm{t},\ldots)=\mathrm{R_{sink}}(\mathrm{x_1},\mathrm{x_2},\mathrm{x_3},\ldots)\to\min$$

Because the size and working space of the device is limited, the parameters L, H, W are fixed. Therefore, the optimal performance of heat dissipation based on optimizing the remaining parameters of the heatsink includes: b, t, t_b.

Apply with practical parameters for experiment: $Q=25\mathrm{W};\ L=60.10^{-3}\mathrm{m};\ W=60.10^{-3}\mathrm{m};\ H=25.10^{-3}\mathrm{m};$ $t_b=2.10^{-3}\mathrm{m}$ with condition: $\frac{b}{H}\geq 0.28$ to remove the radiation directly from the surface of the heatsinks to the opposite heatsinks surface.

Case 1: At wind speed of 1 m/s

The NLP Solve command solves a nonlinear program (NLP), which involves computing the minimum (or maximum) of an objective function, possibly subject to constraints [8]. Therefore, using the NLP solve optimization function on Maple, we obtain the optimal solution b, t for heat dissipation:

$solve := NLPSolve(R_{sink}, RB, assume = nonnegative);$

$Solve=[2.26046585938925793,\ [b=0.00545000000000002,\ t=0{,}000779266948589301]]$

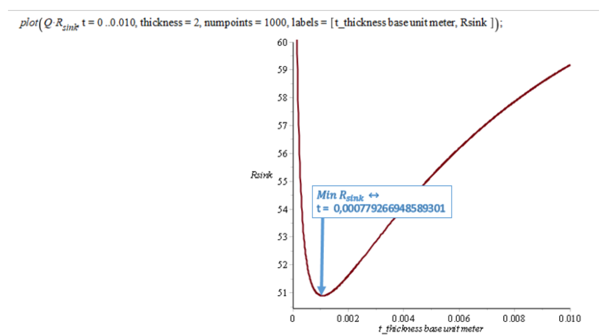


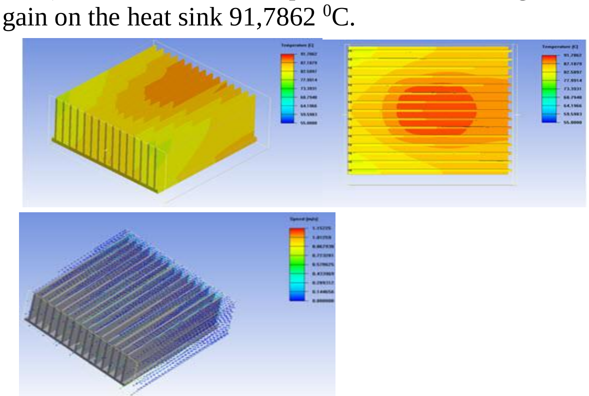
Figure 6.** The graph shows the relationship between Rsink heat dissipation with fin's thickness t **at wind speed of 1 m/s.

The following optimal number of heat sink's fin optimizes t parameters:

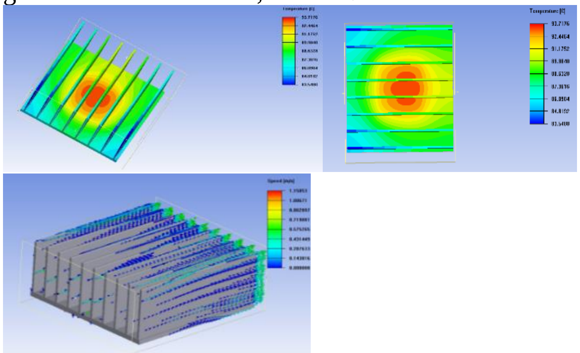
$$N=\frac{W-t}{b+t}+1=\frac{60.10^{-3}-0{,}000779}{5{,}45.10^{-3}+0{,}000779}=10(\,fins) \quad (22)$$

Use Ansys IcePack to simulate 3 cases with other fin's number:

a) N= 15, ambient temperature 55^{0}C, the highest heat gain on the heat sink 91,7862 ^{0}C.



b) N=8, ambient temperature 55^{0}C, the highest heat gain on the heat sink 93,7176 ^{0}C.



c) Optimized parameters N=10, ambient temperature 55 ^{0}C, the highest heat gain on the heat sink 90,1244^{0}C.

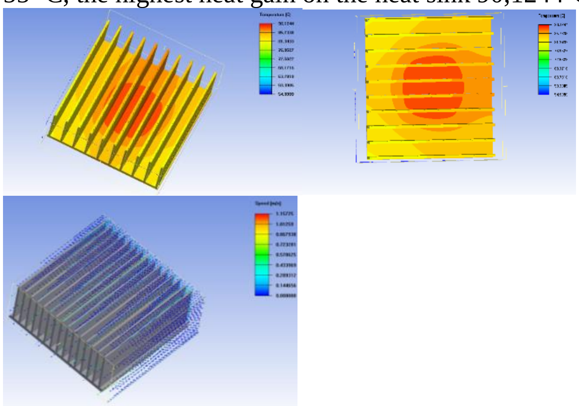


Figure 7. *The comparison about the highest heat gain between the different N of heatsink at ambient temperature 55^{0}C*

Combining the calculated resuslt of eq. (22) with the experiment simulation, at the N=10 at the fixed ambiend temperature 55ºC, the best highest gain on the heat sink is 90,1244ºC. The obtained result is compared with the number of fin N=15 (is larger than 10) and N=8 (is smaller than 10). Thus, the optimized parameter N is 10 which is really suitable with the theory calculation in (22).

Case 2: At wind speed of 5 m/s:

Using the NLP solve optimization function on Maple we obtain the optimal solution b, t for the heat dissipation:

$$solve := NLPSolve\left(R_{sink}, RB, assume = nonnegative\right);$$

$$Solve = [1.36539969526120397,\ [b=0.00700000000000009,\ t=0{,}00137701437586191]]$$

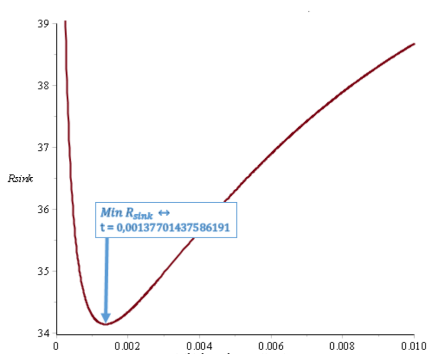


Figure 8. *The graph shows the relationship between Rsink heat dissipation with fin's thickness t at wind speed of 5 m/s*

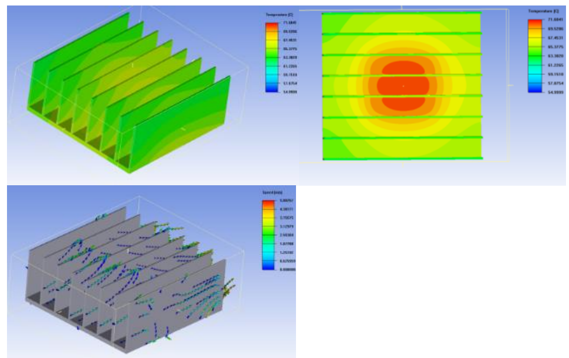
The following optimal number of heat sink's fin optimizes t parameters:

$$N = \frac{W-t}{b+t} + 1 = \frac{60.10^{-3} - 0,00137}{7.10^{-3} + 0,00137} = 8(\,fins)$$

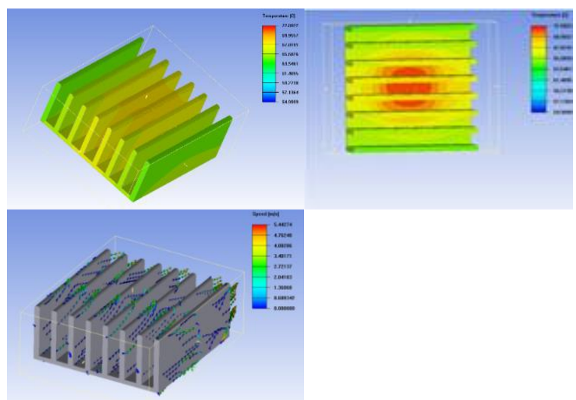
Number of fins is a positive integer, so in the low velocity range from 1 ÷ 10 m/s the number of fins changing 10 ÷ 8 fins does not clearly show the change of temperature when the velocity adjustment amplitude is small.

Therefore, based on the calculation of the thickness of the fin, we compare the temperature when the fins have different thicknesses.

a) t= 0.8 mm, ambient temperature 55^{0}C, the highest heat gain on the heatsink 71,6041^{0}C.



b) t= 2,5 mm, ambient temperature 55^{0}C, the highest heat gain on the heatsink 72,0922^{0}C.



c) Optimized parameters t = 1 mm, ambient temperature 55^{0}C, the highest heat gain on the heatsink 70,1067 ^{0}C.

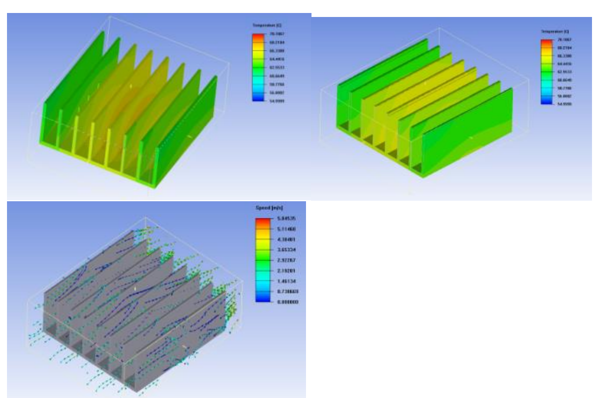


Figure 9. *The comparison about the highest heat gain between the different fin's thicknesses at ambient temperature 55^{0}C*

The results show the relationship between the geometric parameters of the extruded bladed heatsinks and the effect of magnetic force from the wind, thus providing the most suitable and effective thermal dissipation for Site Router equipment at the certain velocity values of the wind. Obtained achievements should extend the radiated energy of the heatsink when the wind velocity condition is constant. The work finds out optimal parameters for the profile, heat sink and fan speed control that help the device to achieve the highest thermal dissipation efficiency.

5. Conclusion

Derived from the obtained results of module Al 6063-T5 heatsink of the Site Router, the author has calculated and modeled Site Router equipment using extruded blast heat exchanger with a large heat exchanger structure which withstands pressure when falling, combining the airflow from the fans to speed up the dissipation of heat. In this paper, the author discusses optimal process of size of the heat sinks and the contact plate is calculated under the influence of actual operating conditions at the specified velocity of the air flow from which the model is built directly to determine the number and the size of plate fin heatsinks. Using the NLP solve optimization function on Maple, we obtain the optimal solution b, t for heat dissipation. Finally, the author has completely defined experimental relationship of characteristic lines between Rsink heat dissipation with wing thickness t in Figures 7 and 8 with the obtained optimized parameters.

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