Journal of Engineering Sciences
& Information Technology
Issue(II) , Vol. I - June 2017
ISSN: 2518-5780

المجلة العربية للعلوم و نشر الأبحاث
Arab Journal of Sciences & Research Publishing
AJSRP

Investigation of Maximum Heat Transfer from an Aluminum Alloy Extended Surfaces

Raad Muzahem Fenjan
Al-Mustansiriyah University - College of Engineering - Materials Engineering Department- Baghdad - Iraq

Abstract: The aim of this research is to obtain the maximum steady state heat transfer used aluminum alloy extended surfaces which obtain the optimal design for these fins. For three cases, (according to both dimension and direction of the extended surfaces): vertical fins extended from horizontal base, vertical fins extended from vertical base , and horizontal fins extended from vertical base, the natural convective, conductive and radiative heat transfer was studied experimentally and respectively the comparison between these cases were achieved. The parameters studied were distance between fins, fin length fin thickness and fin protrusion.

Keywords: optimal design, heat transfer, fins, rectangular base.

1. Introduction

The paper deals with enhancing heat loss from the metal bases to the surrounding used aluminum alloy fins which widely used for many engineering applications. On the other side the fins are cheap and simple construct parts. Forced convection applications are not always appropriate because we required to extra space to accommodate the fan unit, besides additional operational costs, and a possible source of noise are incurred. Bernardin J. D. and Mudawar I., [1], studied the curve of cooling for aluminum alloy. The researchers conclude that the increase of surface roughness will resulted the repeated of the cycles of heat quench of this alloy samples and there is shift occurring in curve of temperature-time. These shifts cause shorter period of overall quench. D.W. and Abu-Mulaweh H.I., [2], reported theoretical and experimental values of fin temperature caused by natural and radiation heat transfer along this fin. The fin was horizontal geometry with circular cross section; also the fin one end had a constant temperature with neglected heat transfer at the other hand. The results comparison shows very good agreement and the percentage of loss in heat due to radiation was (15-20%). Rao V. D. et al., [3], formulate theoretically, the natural heat transfer problem for fin in horizontal orientation with suppose adjacent fins as enclosure for two fins. The equations of continuity, momentum and energy were solved numerically for fluid flow into this enclosure. As a result, the calculations include the fluxes heat from base and fins. Azarkish H. et al., [4], investigate numerically the optimal geometry for fin with longitudinal orientation, the heat generation was existence. Many parameters used in this research like the temperature of base, the coefficient of heat transfer, the surface emissivity, and fin heat generation. Asadi M. and Khoshkho R. H., [5], investigate numerically the interaction of convection with ion radiate. They present numerical solution for distribution of fin temperature. They investigate the radiation effect on generation of entropy and some dimensionless heat transfer numbers. They conclude that the distribution of temperature was uniform and increasing the fin convection heat transfer. Gawai U. S.et al., [6], concluded that protrusion base surface could be taken infinite geometry variation to improve the heat transfer over the surface. Also, they conclude that the spherical dimples which used as a roughness surface give good characteristics of heat transfer. Sorathiya A. S., et al., [7], studied the effects of many parameters for extended surfaces on the rate of heat transfer. Parameters include fin cross sectional area, pitch of fin, material of fin thickness of fin, velocity of air and exposed angle of air. The useful of this survey show the improvement of both geometry and material fin. Sonawane R. and Palande D.D., [8], concluded that the borer pin fin could be give heat transfer rate higher than fin of solid pin. This process achieved with variation of different parameters like geometrical shape, bore diameter and cribriform number. Balpande A., et al, [9], studied the obtaining of optimal fin size and shape to obtain the maximum heat transfer. Various parameters used like, configuration fin, thickness fin, length fin and number of fins. Lee J. B., et al., [10], Investigate experimentally the heat transfer from cylinder in vertical direction used inclined fins. Various angles inclination, various fins numbers and various temperature of base were used. Nusselt number was suggested from the experimental data. The results of inclined and radial fins were compared. They found the resistance of heat transfer with inclined fins was (30%) lower than that of radial fins.

2. Experimental work

For the experiments, there were three fin array directions showed in fig. (1). The construction for each array could be shown in fig. (2). Fins and spacer bars thermal conductivity of ($160 Wm^{-1}K^{-1}$) and surface emissivity (0.1 at 25 °C) used in these experiments. To hole fin with spacers, the studs and screws are used. The parameters for each fin could be shown in fig. (3), where (W) is the width, (L) is the length, (b) is the fin protrusion, (S) is the uniform space between fins and (δ) is fin thickness. Also, for any particular geometry; assembly width of (200 mm), fins had a uniform thickness and uniform separation between two adjacent fins. The strip elements used for heating sources were fixed at the rear of the vertical base. The same width of four heater plates is (200 mm) but and with different length of (175, 275, 375 or 500 mm). The heater plates were manufactured with each one was backed by a number of strip heating elements of (100 W) each, as shown in fig. (4). For (500 mm) long plate, there were six strip heating elements used, also for (375 and 250 mm) long plate, there were five and four respectively. The wooden base manufactured from solid wood of (20 mm) thickness and this base area slightly larger than fins assembly. The electrical power supplied to heater by a constant electric current and regulated used the wattmeter for a period specified the steady state until (12 hours). The layer insulates of (25 mm) thickness separating the two heaters, ensure the no temperature difference occurred across the layer insulate. The three fins directions used in the experiments. The same type of thermocouples used to measure the fin surface and the ambient temperatures. The room temperature maintained at (15°C). From the fin temperature (θ), the fin heat rate loss ($\dot{Q}$) could be measured. For vertical fins, there are four effect parameters, space separation between fins (S), fin length (L), fin thickness (δ) and fin protrusion (b). For the vertical fins on a vertical base, the parameters values (5 mm$\leq S \leq$75 mm; L= 175,275, 375 or 500 mm; $\delta =$ 2, 4 6, 8 or 20 mm; b= 25, 50 or 100 mm; W=200 mm and θ =25°C and 50°C) and the test rig shown in fig. (5). Also the parameters values of vertical fins on a horizontal base (5 mm$\leq S \leq$75 mm; L= 175,275, 375 or 500 mm; $\delta =$ 2, 4 6, 8 or 20 mm; b= 25, 50 or 100 mm; W=200 mm, θ=25°C and 50°C) as shown in fig. (6). For the horizontal fins extended from vertical base, only the fin separation (S) effect is taken because it is virtually influenced into heat loss enhancing. The parameters values of horizontal fins were; thick of (4 mm) and long of (250 mm), protuberance of (75 mm) perpendicularly extended from a vertical base of (250 mm x 200 mm) as shown in fig. (7).

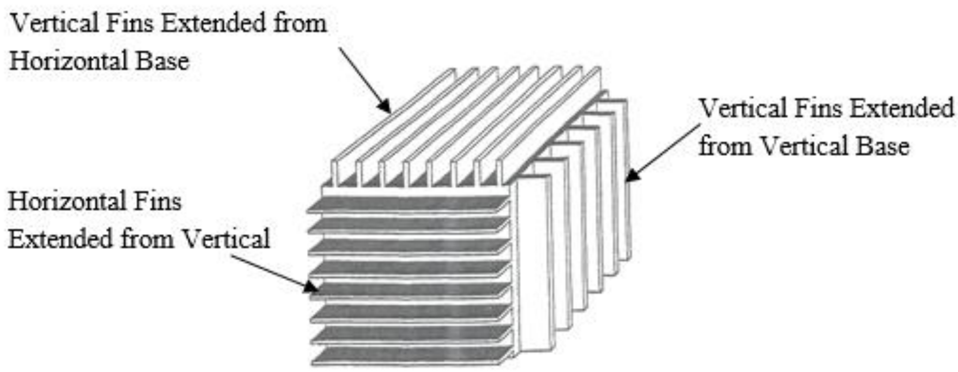

Fig. (1): Three fin orientations arrays.

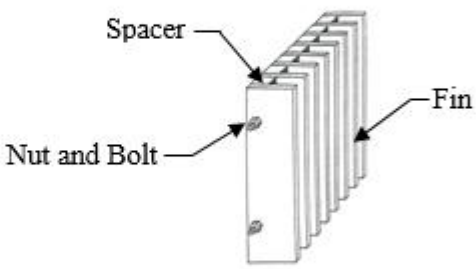

Fig. (2): The fin array construction.

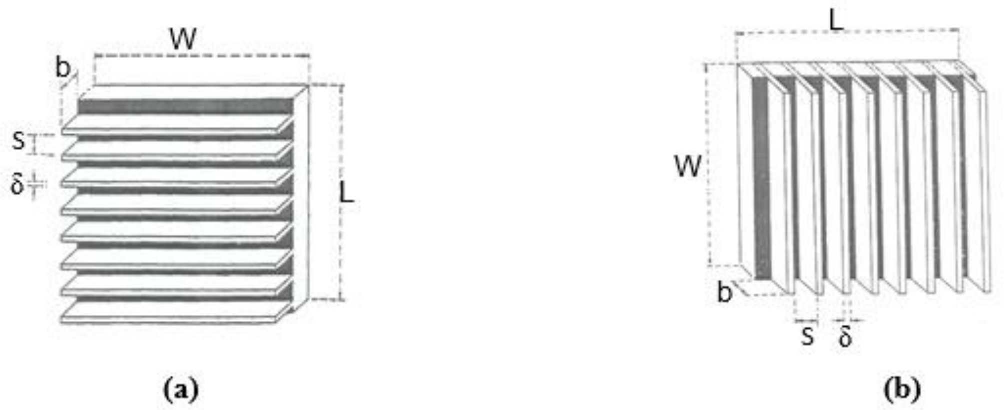

Fig. (3): Parameters of (a) horizontal fins and (b) vertical fins.

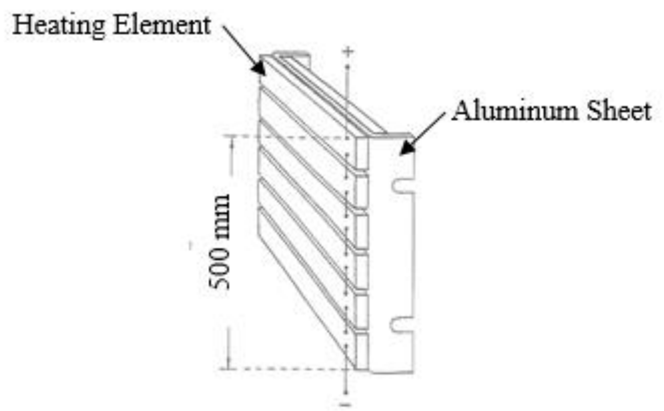

Fig. (4): Main heater for a heating plate of (500 mm) long.

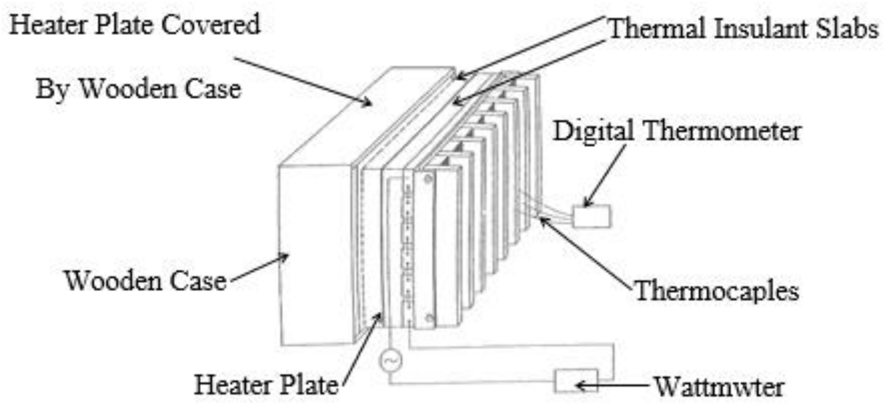

Fig. (5): Test rig for vertical fins based on a vertical base.

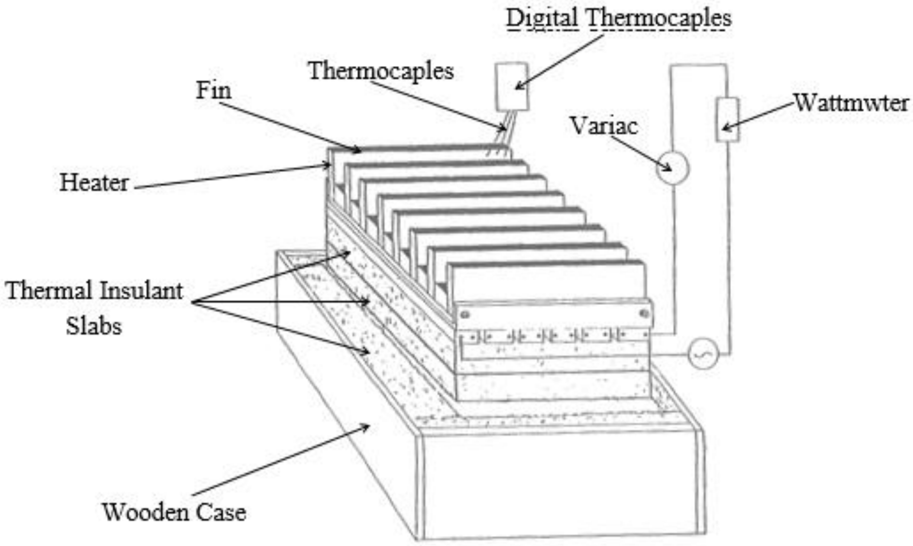

Fig. (6): Test rig for vertical fins based on a horizontal base.

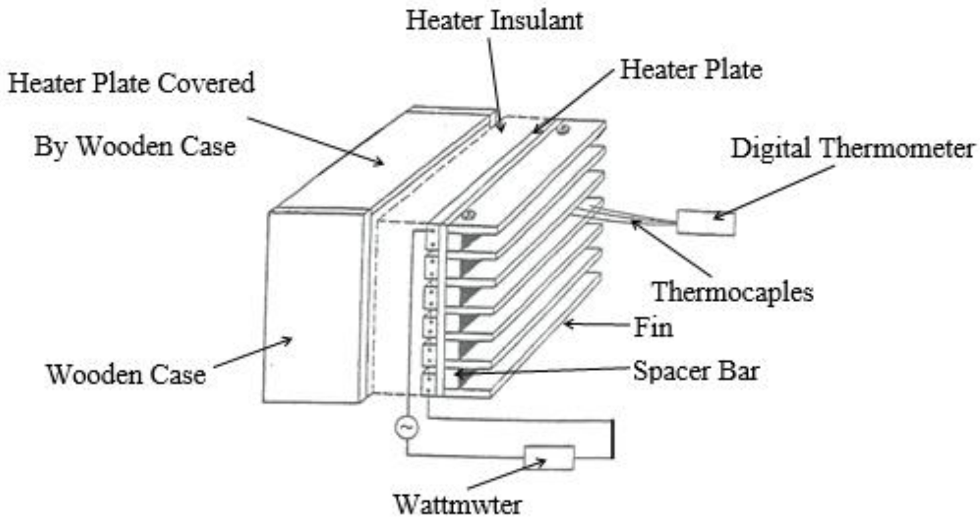

Fig. (7): Test rig for horizontal fins based on a vertical base.

3. Results and Discussions

3.1 Optimum Design of Vertical Fins Based on the Vertical Base

3.1.1 Optimum Separation Distance(S) Values

The surface area of heat transfer increased when the number of fins increase, therefore the heat transfer coefficient over fins decreased. The lines passed from maximum values of separation distance (S) indicate optimum separation distance(S). The effects of varying fin length (L) on the steady state heat loss

($\dot{Q}$) through the air for ($\theta = 25$ or 50°C) base temperature respectively could be shown in figures (8-9) where the longer fin length cause higher rate of heat transfer.

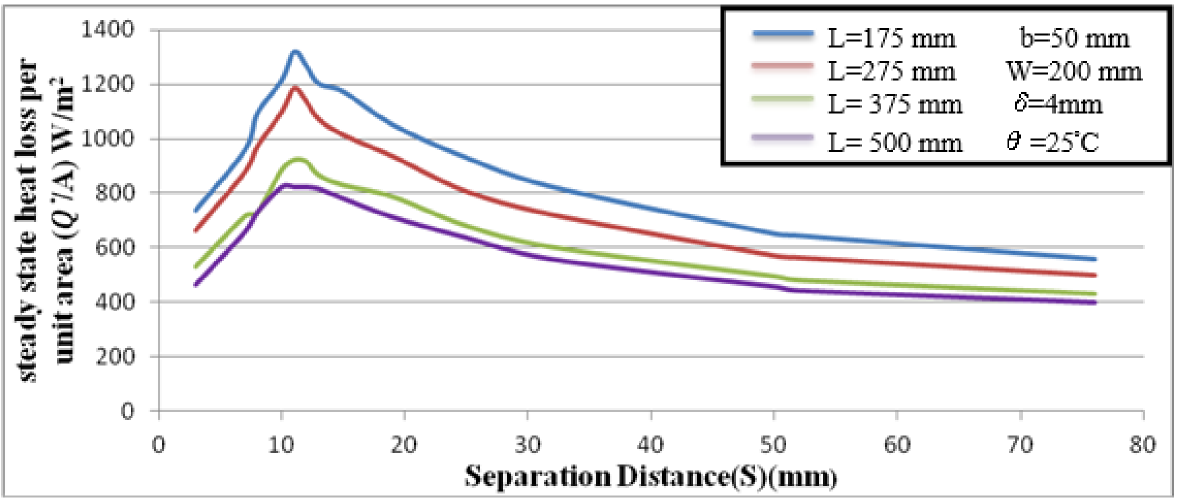

Fig. (8): Varying effects of fin length on the heat loss for θ =25°C.

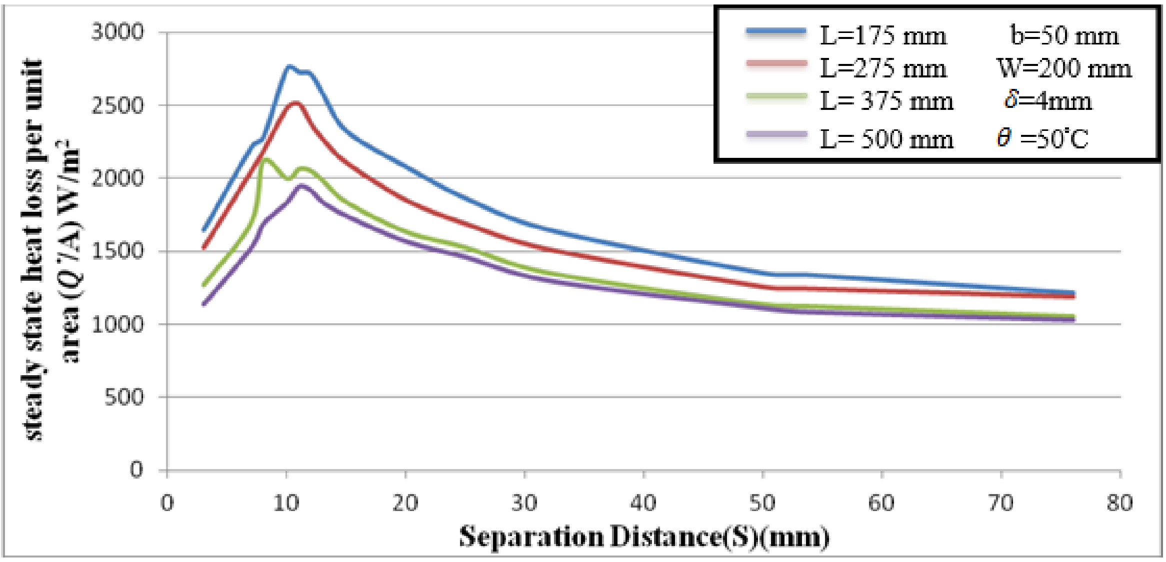

Fig. (9): Varying effects of fin length on the heat loss for θ =50°C.

3.1.2 Optimum Fin Length (L) Values

When the boundary layer decreased then the coefficient of heat transfer decreased, also this coefficient takes the minimum value at the fin upper edge. When fin length increased then the heat transfer area, the boundary layer thickness and resistance of air flow increased. Fig. (10) shows the reducing in the heat transfer coefficient.

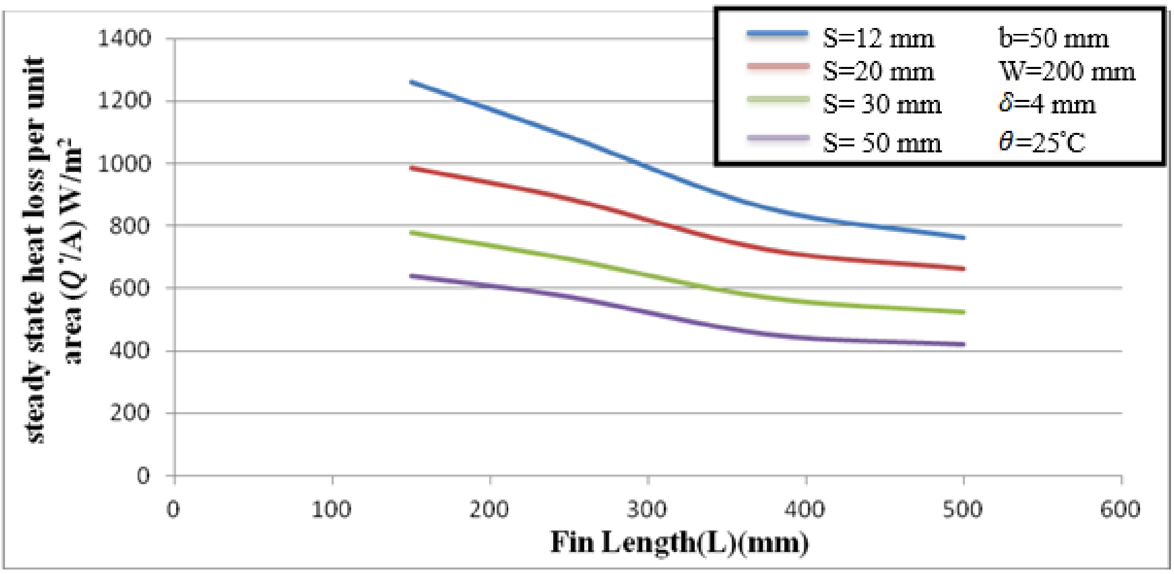

Fig. (10): Fin separation distance varying effects on the heat loss for θ =25°C.

3.1.3 Optimum Fin Protrusion (b) Values

The surface area of heat transfer increased when the fins protrusion (b) increased. Figs. (11-12) show the fin Protrusion (b) effectiveness of on the ($\dot{Q}$) therefore the heat transfer rate will increase with increasing of fins protrusion also fig. (13) shows cross plots from figs. (11-12). Fig.(13) shows clearly the increasing of heat transfer rate with the increasing of fin protrusion with higher fin base temperature due to convection heat transfer process.

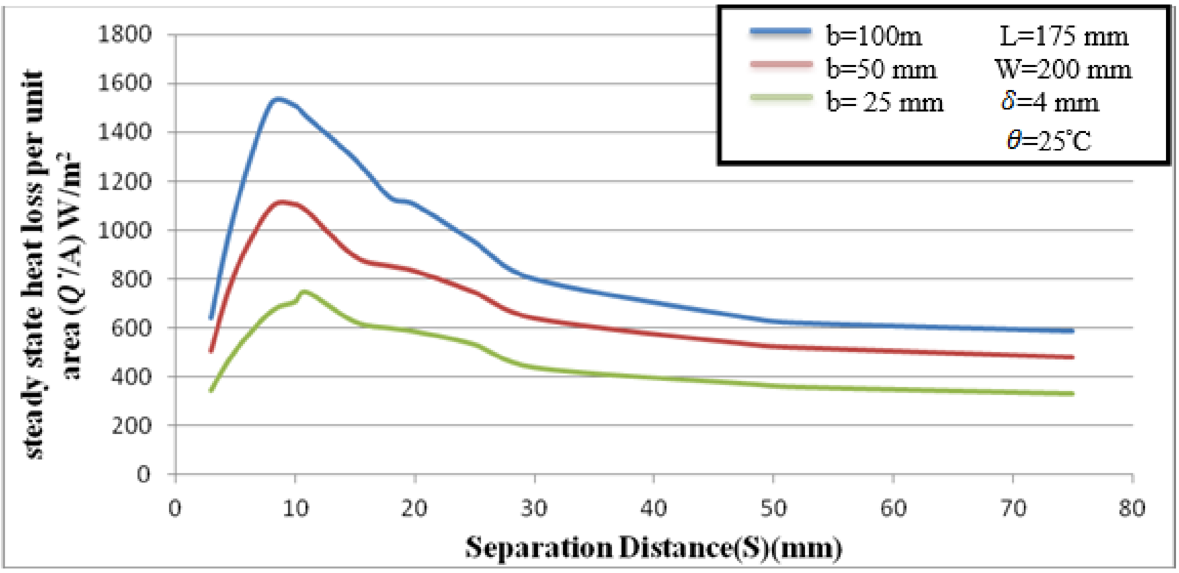

Fig. (11): Fin protrusion varying effects on the heat loss for θ =25°C.

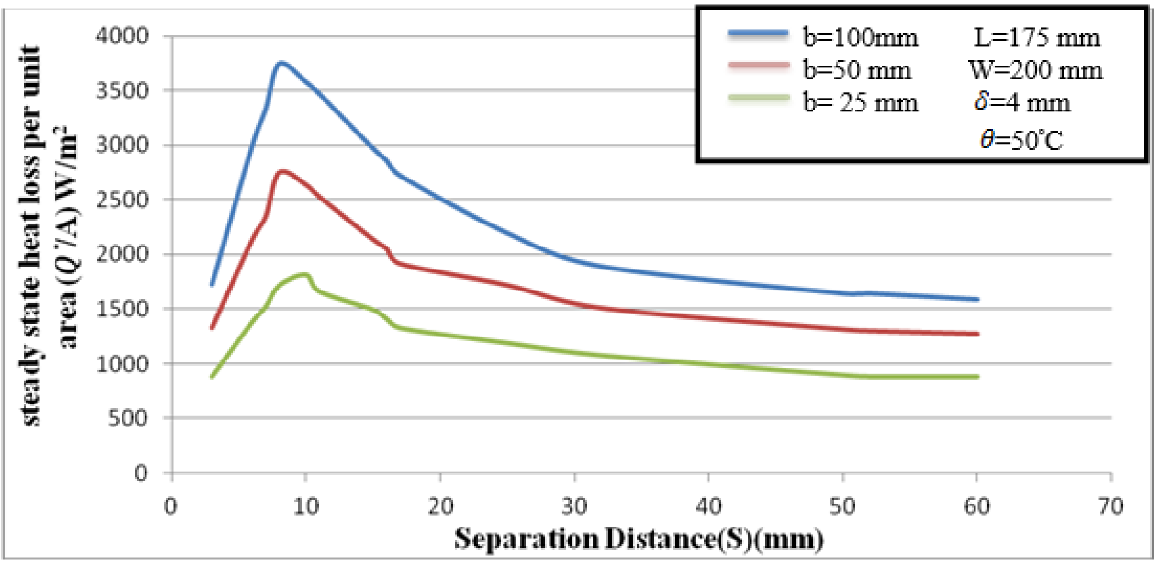

Fig. (12): Fin protrusion varying effects on the heat loss for θ =50°C.

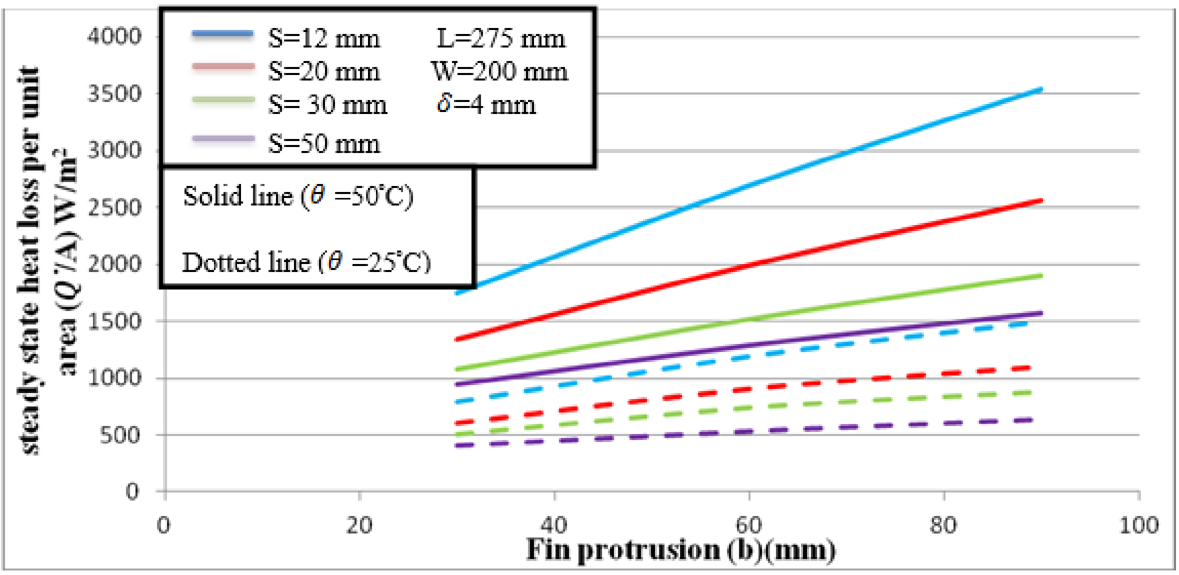

Fig. (13): Cross plots from the Figs. (11) and (12).

3.1.4 Optimum Fin thickness (δ) Values

Optimum fin thickness(δ) leads to maximum heart rate transfer. If the heat transfer area base area and the distance between fins are constants, then the number will be increased when the fins thickness is reduced. Temperature gradient along fin will be greater for the thinner thickness fin, therefore the optimal value of fin thickness (δ) will decreased when reduced fins separation. The optimum value is smaller than (3 mm) as shown in fig. (14).

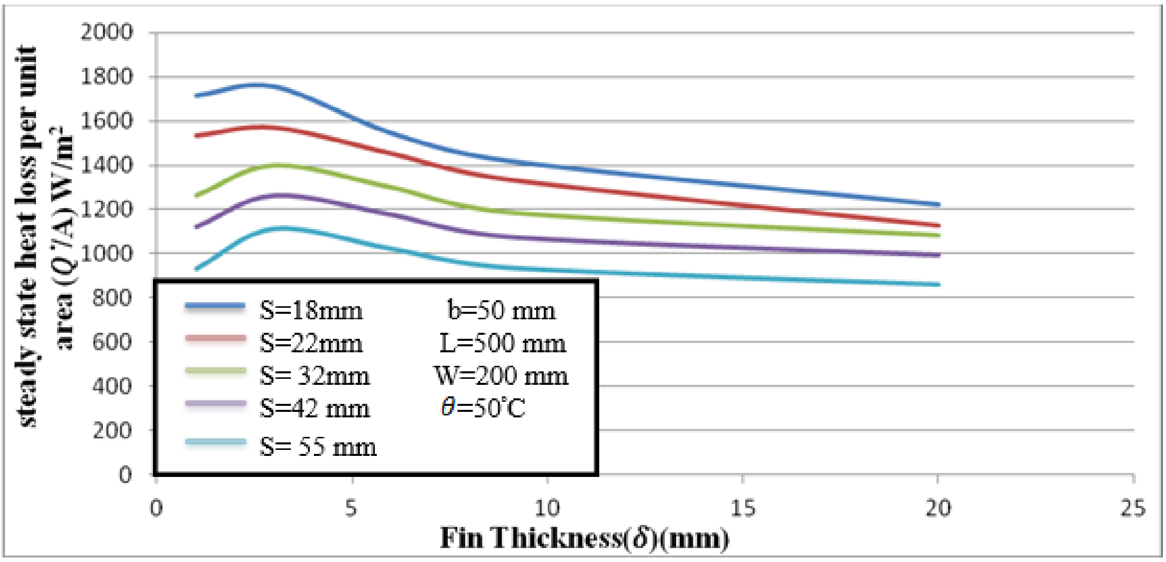

Fig. (14): Fin separation distance varying effects on the heat loss for θ =50°C.

3.2 Optimum Design for Vertical Fins Based on the Horizontal Base

3.2.1 Optimum Separation Distance(S) Values

If the base width was constant, then the heat transfer rate increased with increased of the number of extended from this base therefore the decreasing into separation distance cause a decrease into heat transfer rate coefficient. Thus, the optimum separation distance (S) values with respect to the maximum heat dissipation could be shown in figs. (15-16).

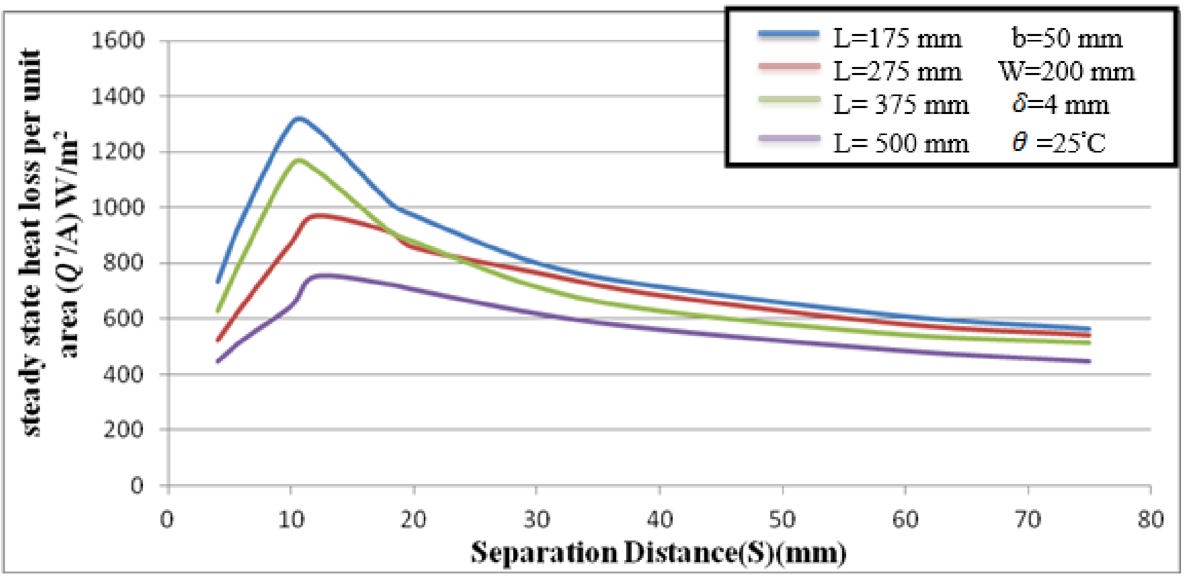

Fig. (15): Fin length varying effects on the Steady-state heat loss for θ =25°C.

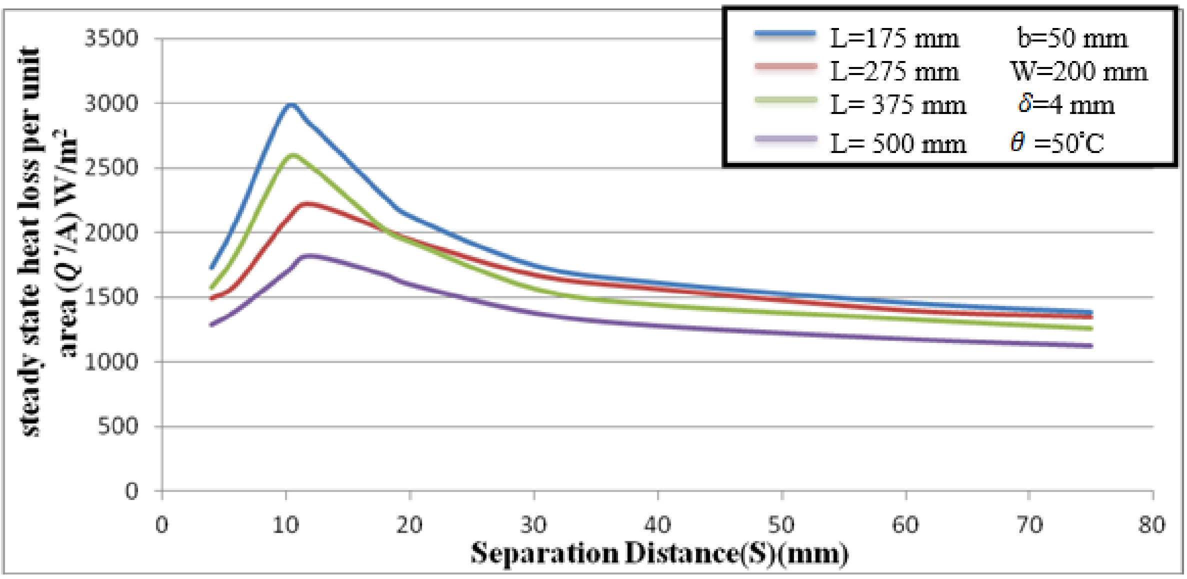

Fig. (16): Fin length varying effects on the Steady-state heat loss for θ =50°C.

3.2.2 Optimum Fin Length (L) Values

Figs. (17-18) shown that the circulating air currents depend on the values of (L, S,b, and θ)therefore the larger value of (b) give the optimum (L).Also these figs. show the increasing of heat transfer rate with decreasing of separation distance and increasing of base temperature values due to the heat transfer convection.

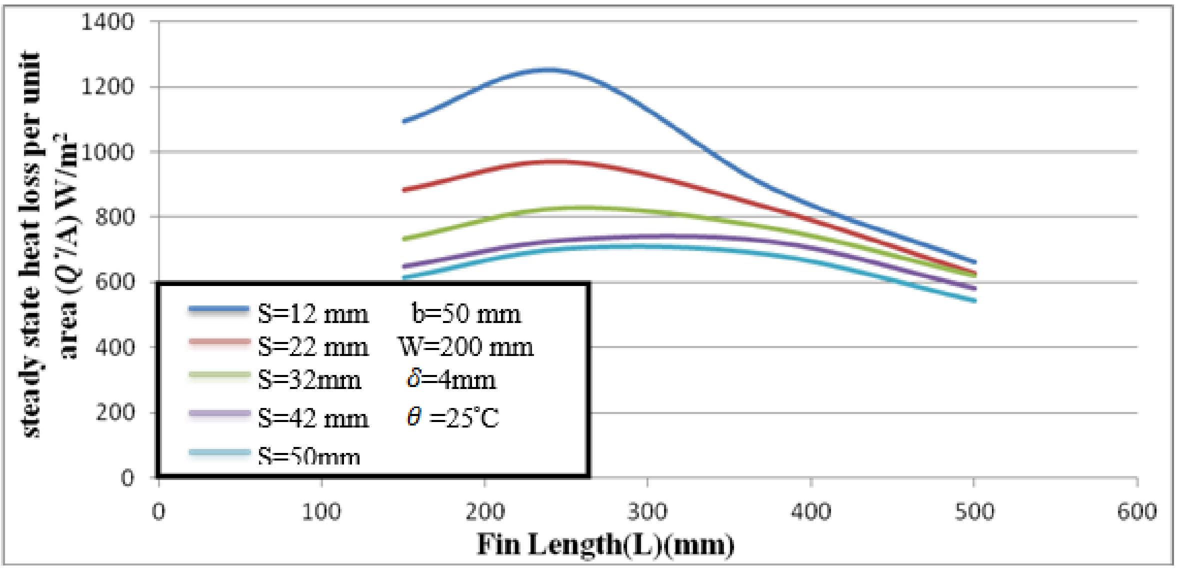

Fig. (17): Optimum fin length variation with θ =25°C.

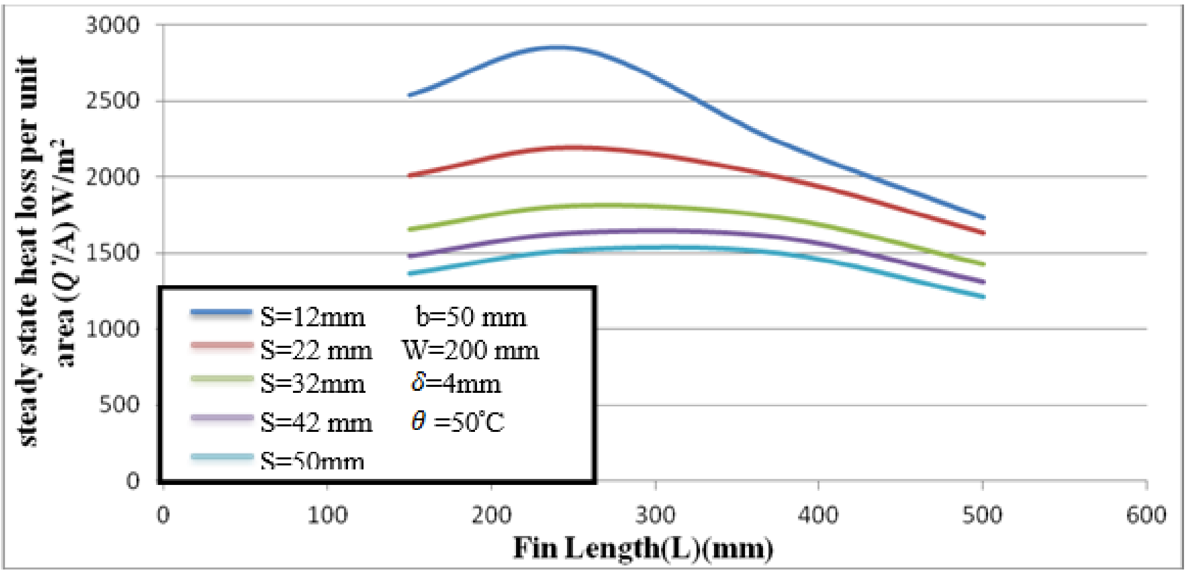

Fig. (18): Optimal fin length variation with θ =50°C.

3.2.3 Optimum Fin Protrusion (b) Values

Larger fin protrusion gives additional area exposed to heat transfer with lower heat transfer coefficient due to increasing into air flow resistance. Also the fin surface temperature declined toward the fin tip due to fin material resistance, therefore fig. (19) shows that the small protrusion not economic to use because there is a small increase in the heat dissipation rate compared with the base surface therefore no optimum value of (b) obtained from heat transfer view.

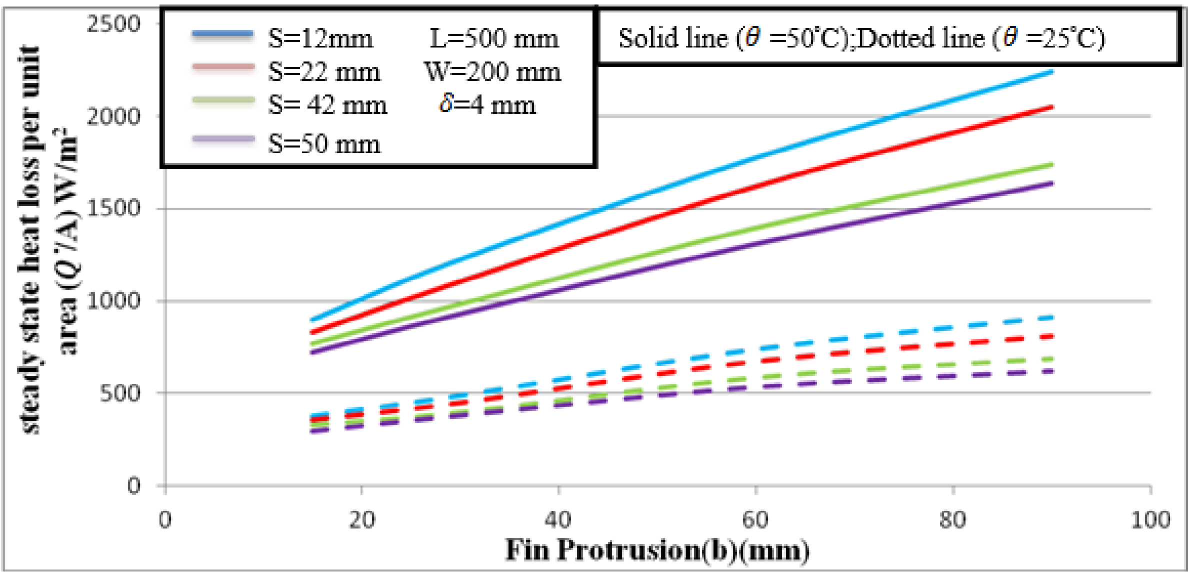

Fig. (19): Variation of heat loss with fin protrusion.

3.2.4 Optimum Fin Thickness (δ) Values

The optimum separation distance (S) is unaffected by changes in the fin thickness (δ) for $\theta = 25$ °C as shown in fig. (20), and fig. (21) for $\theta = 50$°C. When the values of other parameters remain constant, then the optimum (δ) values decreased where (S) reduced. When (W) and (S) are constant values, then the minimum fin thickness used due to increasing in fins number and increasing in heat transfer rate.

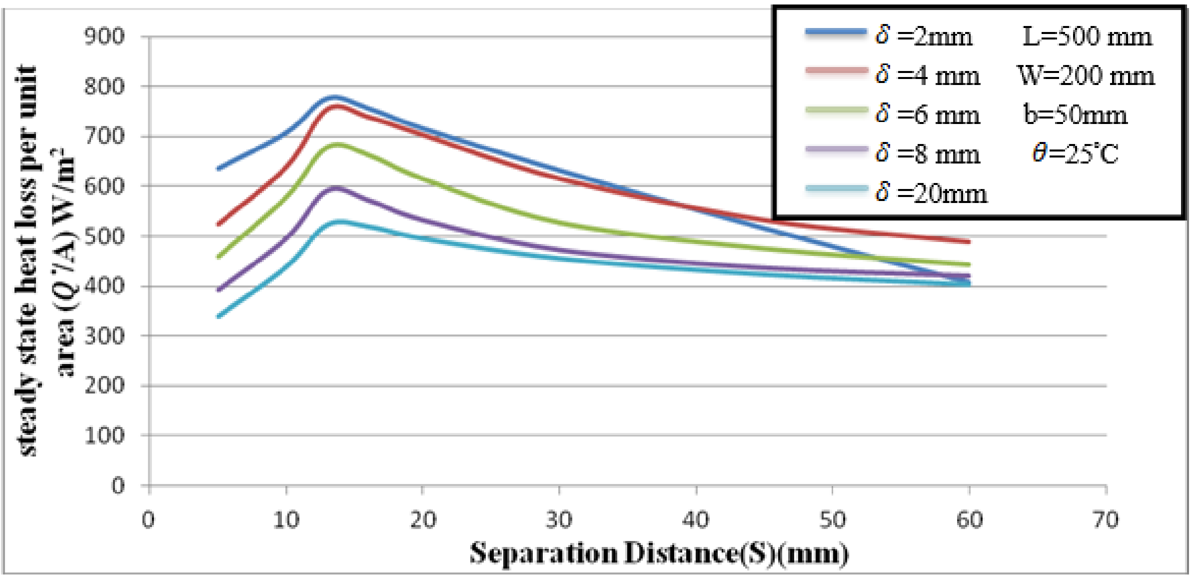

Fig. (20): Optimum separation distance with θ =25°C.

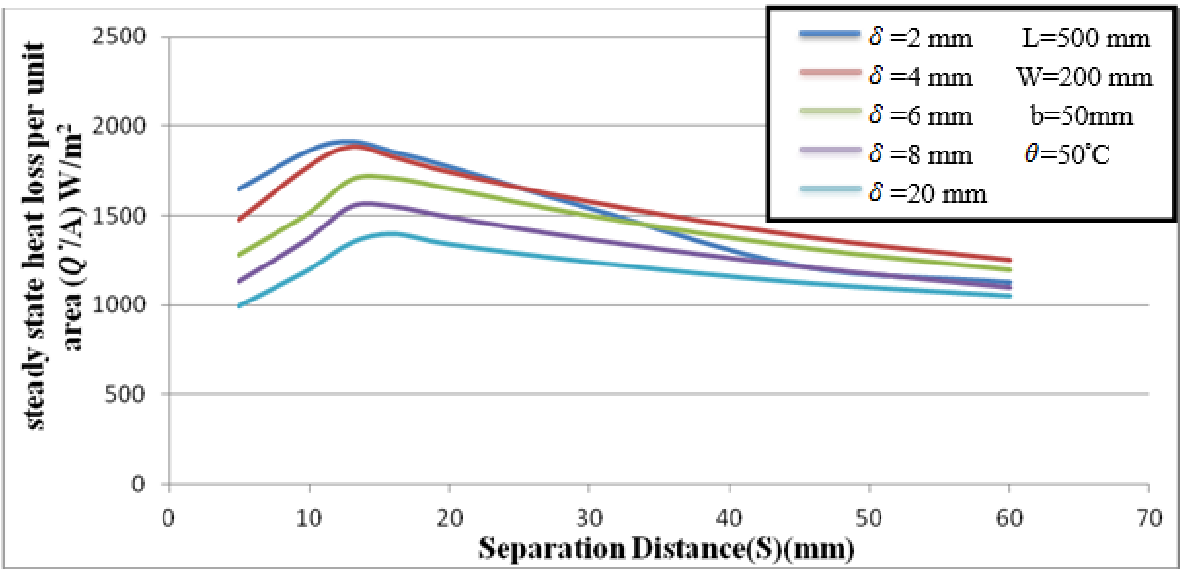

Fig. (21): Optimum separation distance with θ =50°C.

3.4 Comparison Between Vertical and Horizontal Fins on a Vertical Base

The comparison achieved using same geometrical dimensions and the same base temperature. The vertical fin was more rapid loss of heat. Fig. (22) shows the comparing between vertical and horizontal fins based on vertical bases. The temperatures of the base and room were 80°C and 25°C respectively.

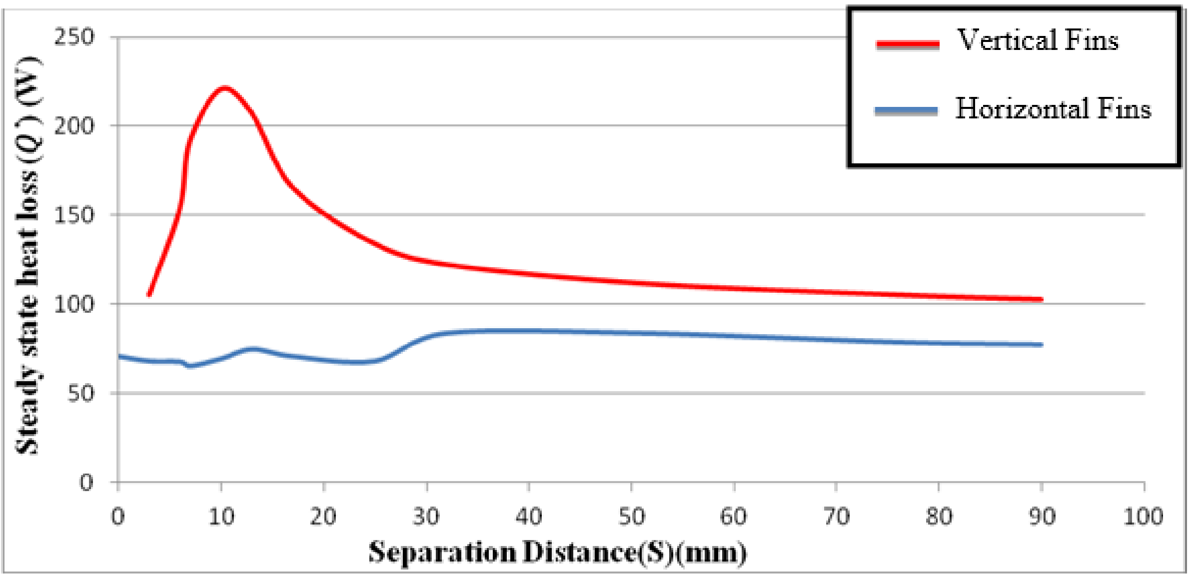

Fig. (22): Heat transfer performance for vertical and horizontal fins extended from vertical base.

3.5 Optimum Design for horizontal fins extended from vertical base

3.5.1 Optimum Separation Distance(S) Values

For very small separation distance and interact of fluid boundary layers occurred and this cause the decreasing into the fin surface heat transfer. Therefore, used of (1mm separation distance lead to vanish the convection heat transfer effect. Fig. (23) shows Variation of separation distance with Variation room temperatures and the optimal separation distance appear when maximum heat transfer rates occur.

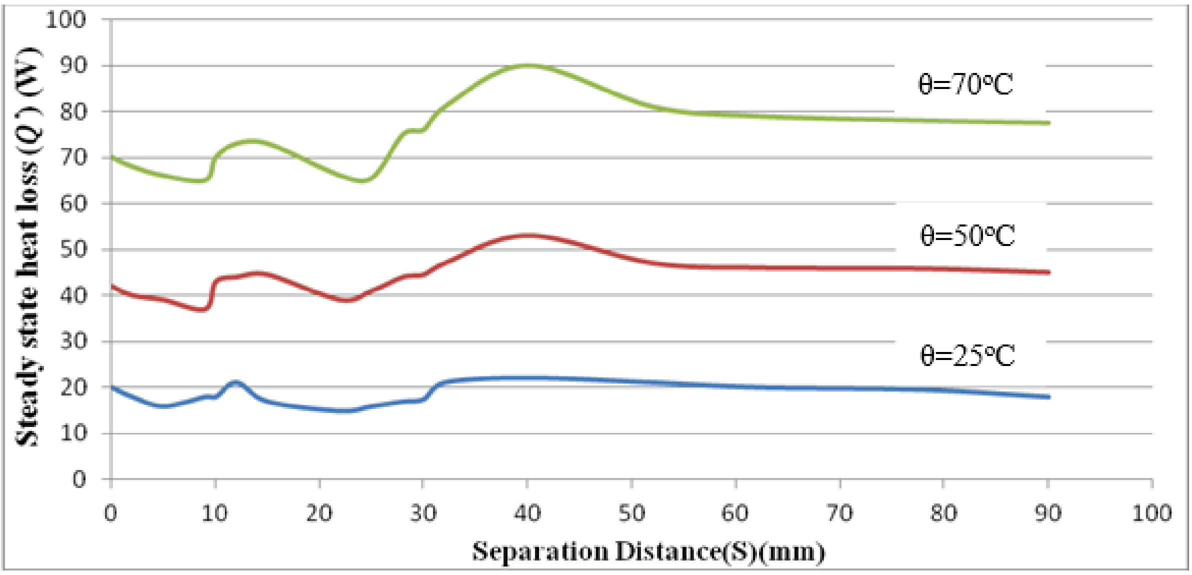

Fig. (23): Separation distance variation with room temperatures variation.

4. Conclusions

1- The changes in fin geometrical dimensions (fin separation, fin length, fin protrusion and fin thickness) lead to rapid variations in the base heat transfer rates therefore optimum fin parameter could be helpful in many applications.

2- For enhancing of heat transfer ratings, it should be taken into account the comparison between fin parameters and it is weight especially for natural convection problems.

3- If surface roughness increased, this lead to increase the natural convection due to increasing the base surface emissivity but, at the other side, the thickness of air boundary layer will be growth (reducing of local coefficient heat transfer).

4- For the vertical fins based on a vertical base, the fin thickness and fin separation distance should be (2 and 10 mm) respectively.

5- For the vertical fins based on a horizontal base, the fins' separation distance and length should be almost (10 mm and 250 mm) respectively, also if fin length was taken longer with lager separation distance, this lead to reduce heat transfer rates.

6- For the vertical fins based on a horizontal base, the steady state heat transfer rate decreased for increasing in the separation of fin.

7- For the horizontal fins extended from vertical base, the maximum base heat loss occurred at (12 ± 1mm) and (38±1 mm) fins separation distances.

8- The horizontal fins extended from vertical base is not the best choice because it's performance was poor with respect to enhancing of heat transfer rate.

References

[1] Bernardin J. D. and Mudawar I., "An Experimental Investigation Into the Relationship Between Temperature-Time History and Surface Roughness in the Spray Quenching of Aluminum Parts", Journal of Engineering Materials and Technology, Vol. 118/127, January 1996.

[2] Mueller Jr. D.W. and Abu-Mulaweh H.I., "Prediction of the temperature in a fin cooled by natural convection and radiation", Journal of applied thermal engineering , Issue 14–15, Vol. 26, pp. 1662–1668, October 2006.

[3] Rao V. D., Naidu S.V., Rao B. G. and K.V. Sharma, "Heat transfer from a horizontal fin array by natural convection and radiation—A conjugate analysis", International journal of heat and mass transfer, Issue 19–20, Vol. 49, pp. 3379–3391, September 2006.

[4] Azarkish H., Sarvari S.M.H. and Behzadmehr A., "Optimum geometry design of a longitudinal fin with volumetric heat generation under the influences of natural convection and radiation", Journal of energy conversion and management, Vol. 51, pp. 1938–1946 October 2010.

[5] Asadi M., Khoshkho R. H., "Temperature Distribution along a Constant Cross Sectional Area Fin", International journal of mechanics and applications, Issue 3, Vol.5, pp.131-137, 2013.
[6] Gawai U. S., Mathew V. K. and Murtuza S. D., "Experimental Investigation of Heat transfer by PIN FIN", International Journal of Engineering and Innovative Technology (IJEIT), Vol. 2, Issue 7, January 2013.
[7] Sorathiya A. S., Hirpara H. P. and Rathod P.P., "An Effect of Different Parameters of Fins on Heat Transfer of IC Engine- Review Study", IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Vol. 11, Issue 3 Ver. 1, pp. 63-71, (May- Jun. 2014).
[8] Sonawane R., Palande D.D., "Heat Transfer Enhancement by using perforation: A Review", International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056 Vol.: 03 Issue 4 Apr-2016.
[9] Balpande A., Bute J. and Sable V., "Theoretical Investigation of Triangular Fin-A Review", International Journal for Engineering Applications and Technology, http: // www.ijfeat.org, MANTHAN-15 ISSN: 2321-8134.
[10] Lee J. B., Kim H. J., and Kim D. K., "Experimental Study of Natural Convection Cooling of Vertical Cylinders with Inclined Plate Fins", Energies 2016, 9, 391; doi:10.3390/en9060391 www.mdpi.com/journal/energies.

الملخص :

الهدف من هذا البحث هو الحصول على اقصى انتقال حرارة في الحالة المستقرة باستخدام سطوح ممتدة من سبيكة الالمنيوم وذلك يؤدي للحصول على أمثل تصميم لتلك السطوح الممتدة. تم إجراء دراسة عملية لانتقال الحرارة بالحمل والتوصيل والإشعاع لثلاث حالات (حسب بعد واتجاه السطح الممتد) وهي لزعانف مستطيلة عمودية على قاعدة مستطيلة أفقية، لزعانف مستطيلة عمودية على قاعدة مستطيلة عمودية و لزعانف مستطيلة أفقية على قاعدة مستطيلة عمودية وبالتالي تم مقارنة النتائج بين تلك الحالات. العناصر الخاصة بالزعانف والتي تمت دراستها هي المسافة بين الزعانف وطول وسمك الزعانف وطول النتوءات للزعانف.

الكلمات المفتاحية : تحقيق – أقصى - انتقال الحرارة - سطوح ممتدة - سبيكة المنيوم