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RESEARCH ARTICLE

THE EFFECT OF FIN HEIGHT ON FREE CONVECTION HEAT TRANSFER FROM RECTANGULAR FIN ARRAY

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ABSTRACT

Experimental study has been investigated to study the free convective heat transfer from a vertically rectangular fin array. It fabricated from Aluminum which is having six fins. Each Finhas thickness and fin spacing were 4 mm and 10 mm respectively. The fin length is 300 mm. Fin height was selected 10 mm, 25 mm and 45 mm respectively. A Rayleigh number ranging from $7.6 \times 10^6 - 1.5 \times 10^8$ were used. Heat input was varied from 68 W to 716 W were supplied for all fin configurations. The base and the ambient temperatures were measured in order to evaluate the heat transfer rate from fin arrays. The effects of fin heights with different heat input on the performance of fin arrays were observed. The results show the convection heat transfer coefficient, convection heat transfer rate, Nusselt number (Nu) and the Rayleigh Number (Ra) from fin arrays depends on fin height and reach to maximize value with fin height 45 mm. Otherwise, it has a minimum value at 10 mm fin height, the opposite behavior of average temperature decreases. The enhancements in the convection heat transfer coefficient and the base to ambient temperature difference (decreases), were 44% and 41%due to increase fin height from 10 mm to 45 mm. An empirical correlation relating Nusselt number to the influencing parameters (Rayleigh number and fin height) has also been suggested with a maximum variation of ±10% and as follows.

$Nu = 7\, Ra_{0.3} H_{0.7}$

INTRODUCTION

The generated heat from an electronic device is causing damage it, unreliable and incompatibility operation. Therefore, this generated heat necessary to dissipate as soon as immediately when the temperature of device is high. The researcher found more technique to solve this issue. One of these techniques is used fins. The fins havethe capability to transfer heat and it protects the device as a result suitable operation will occur. Natural convection is played as a vital solution to the above issue with the help of natural circulation of air. This cooling procedure plays a key role in the electronics cooling system, such as cooling engine, transformer etc. Experimental studies on vertical rectangular fin arrays was carried by **Guvenc A. and Leung C. [1 , 2]**. Numerical studies on vertical rectangular fin arrays was investigated by **Nancy D and Saikhedkar N. [3, 4]**.**Golnoosh Mostafavi, *et al*. [5]**, studied experimental and analytical approached which it employed in order to find the optimized interruptions fin's length. The results show the enhancement of thermal performance of rectangular fin due to add interrupted fins when compare with continuous fins. **Burakyazicioğlu, *et al*. [6]**, used data based on experimental results of the rectangular fin array was exposed to natural convection. The work covered a different parameter range of fin spacing, fin length, fin height, fin thickness, width of rectangular base plate and base to ambient temperature difference. They concluded the heat transfer rate from fin arrays is larger from vertical plate and it's dependent on fin height, fin length and base to ambient temperature difference. **Yazicioglu, B., *et al*. [7],** investigated experimentally from altered fin configurations with 250 and 340 mm fin length. They tested aluminum rectangular fins to get Optimum fin spacing of on vertical base. The difference temperature was used 30-150 K. The fin height and fin spacing from 5 to 25mm and 4.5 to 85.5 mm, respectively. The well fin space was found between 6.1 and 11.9mm.Further the larger fin height results in a higher convective heat transfer from fin array, but for low base-to-ambient temperature difference, it was insignificant. **Gaurav Kumar, *et al*. [8]**, analyzed experimentally the effects of several influencing parameters for their wide ranges; Rayleigh number $295214 \leq Ra \leq 773410$, fin spacing $25\, mm \leq S \leq 100\, mm$ and fin height $12.5\, mm \leq H \leq 37.5\, mm$ for constant heat flux boundary conditions atthe heated. An empirical correlation is also developed relating Nusselt number to several influencing parameters.**YuncuH., G. Anbar [9]** studied the free convection heat transfer of the rectangular fin with a different fin configuration, such as fin spacing between 6-26 mm and fin height from 6.2-83 mm. The fin thickness and fin height were constant 100 and 3 mm respectively. The result shows the ratio of fin spacing to gain height was effected on convection heat

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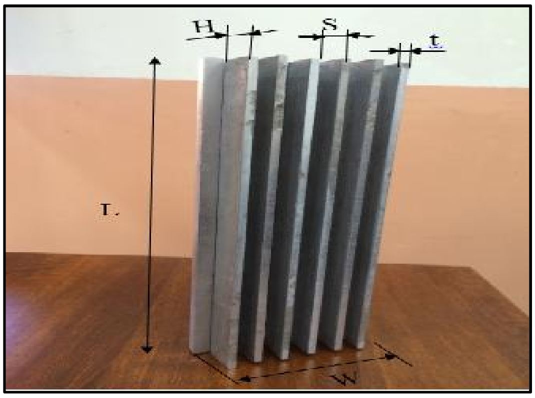
transfer. The fine spacing was decreased when the fin height increase. The optimum fin spacing was 11.6 and 10.4 mm when the fin height range between 16 to 26 mm respectively. **Kamil MertÇakar [10]** presented numerically and experimentally studies on rectangular fins to select the best fin spacing. The model investigated by using the CFD program. They concluded convection heat transfer increase with fin height. Also experimentally determined that the optimum fin spacing value for vertical fin arrays is approximately 10 mm. The goal of the present study to investigate the effects of fin heights with different heat input on the performance of fin arrays protruding from a vertical rectangular base.

Experimental setup and fin design

A test bed of the heat sink and vertical plate with rectangular fins was prepared. Base plate dimensions were the same, but the fin height was different.The design of test bed has been conducted, to evaluate the rate of heat transfer by natural convection when used the finned heat sink, as shown in Fig 1. It was manufactured from square cast iron material with the height of 320 mm and cross sectional area 100 mm^2.It insulated with a layer of wool thermal with thickness of 15 mm. The reflector sheet with thickness 0.5 mm was used inside it.Three heater were used each one has power of 600 W. The fins are installed on the test section by a sliding channel as shown in the Fig. 1.

Fig.1 The Test Device Component

The fin configurations were produced by milling longitudinal grooves in one of the faces of rectangular bar. The fin arrays were produced from rectangular bars with the dimensions of the base plate are L × W × H, where L = 300 mm is the length in the stream wise direction, W = 100 mm is the width, and



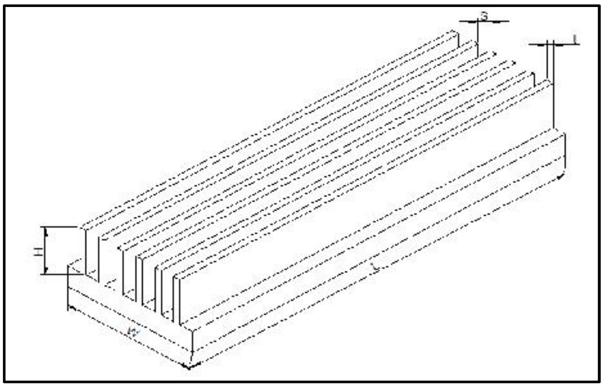


Fig. 2 The fins Geometry

different H = 10, 25 and 45 mm is the height. Fins were kept integral with the base plate of thickness 7 mm while, fin thickness was kept constant, t = 4 mm, fins spacing S=10 mm and the six numbers of fin was used. Geometry of in-line continuous rectangular fins heat sink is shown in the Fig. 2.

Experimental Procedure

Particle experiment was connected for various heat fluxes through the control of the heater voltage which supplies heat flux to the test section by a voltage regulator (50, 75, 100, 125 and 150 V). The ambient temperature was measured in order to calculate bulk temperature.A thermometer has been used to measure the ambient temperature. Eight points were chosen to measure the base-plate temperatures of fin arrays are shown in Fig.3.

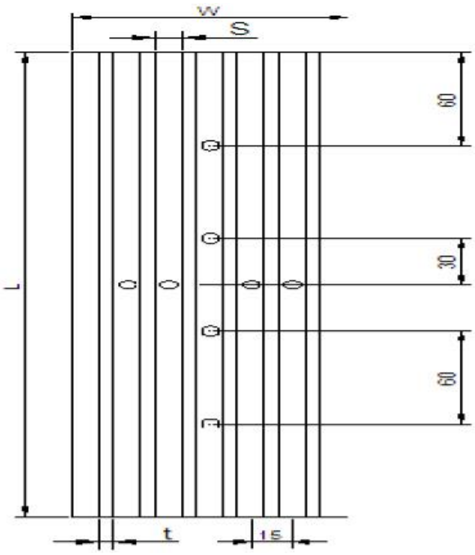


Fig.3 Site of Thermocouples

The temperature scanner thermometer (8 channel thermocouple) manufactured by Altop Industries Ltd,India has been used to measure the average temperature along the base-plate. The experimental RIG as shows in the Fig.4.The heater inputs were adjusted with the help of dimmer stat. The temperatures of the fine array with different positions and ambient temperature were recorded at the time intervals of 30 min. Steady state condition was reached about four hours during the experimental work. Arrival of steady state was assumed as temperature reading does not vary by 0.5°C.

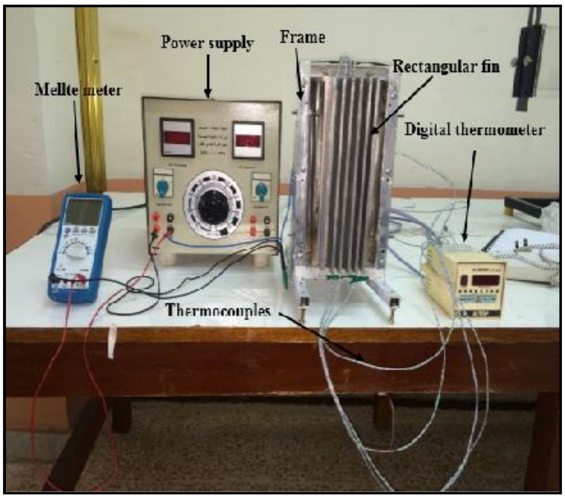


Fig.4 Photograph of the experimental RIG with the measuring instruments

Calculation Procedure

The total quantity of heat generated in the electric heater ($Q_{gen.}$) was converted to heat. The different mode of heat transfer through the fin was conduction, convection and radiation. The equation of these heat is below:

$$Q_{gen.} = Q_{conv.} + Q_{rad.} \quad (1)$$

The generating heat was:-

$$Q_{gen.} = V \times I \quad (2)$$

The heat transferred by radiation is calculated as follows:-

$$Q_{rad.} = \sigma \times \varepsilon \times S_{sur} \times A_t (T_{av.}^4 - T_{air}^4) \quad (3)$$

Therefore, the heat transferred is calculated by convection as follows:

$$Q_{conv.} = Q_{gen.} - Q_{rad.} \quad (4)$$

Therefore, the heat transfer coefficient in free convection was calculated from the equation which is known as Newton cooling law as follows:

$$h = \frac{Q_{conv.}}{A_t \Delta T} \quad (5)$$

$$A_b = l * W \quad (6)$$

Exposed fin area

$$A_f = (l * H * 2) + (t * H * 2) + (l * t) \quad (7)$$

Totally exposed area $A_t = n * A_f + l * s * (n-1)$ (8)

The average temperature was:

$$T_{av.} = \frac{(T_1 + T_2 + \cdots + T_n)}{n} \quad (9)$$

While the average film temperature (T_f) is calculated as follows:

$$T_f = \frac{T_{s_{av.}} + T_{air}}{2} \quad (10)$$

The Nusselt number may be defined asthe ratio between the convection heat flux to the conduction heat flux and written as follows

$$Nu = \frac{h\,L}{K_f} \quad (11)$$

Rayleigh number was calculated as:

$$Ra = \frac{L^3\, g\, \beta\, (T_{av.} - T_{air})}{v^2} Pr \quad (12)$$

RESULT AND DISCUSSION

The free convection heat transfer from the vertical rectangular fin having six fins. The main dimension of fin model was the fin length 300 mm, fin spacing 10 mm, fin thickness 4 mm and different fin height 10, 25 and 45 mm. The different heat generated is supplied were 413, 930, 1680, 2630 and 3792 W/ m^2. The experimental results with discussion show the effect of fin height on Nusselt number, RayleighNumber and heat transfer coefficient.

Temperature Distribution

The Explaining of the temperature gradient of the fin surface by using Fluke Ti32 thermal image device. This image reveals different colors to display the temperature gradient of it as shown in Fig. 5.

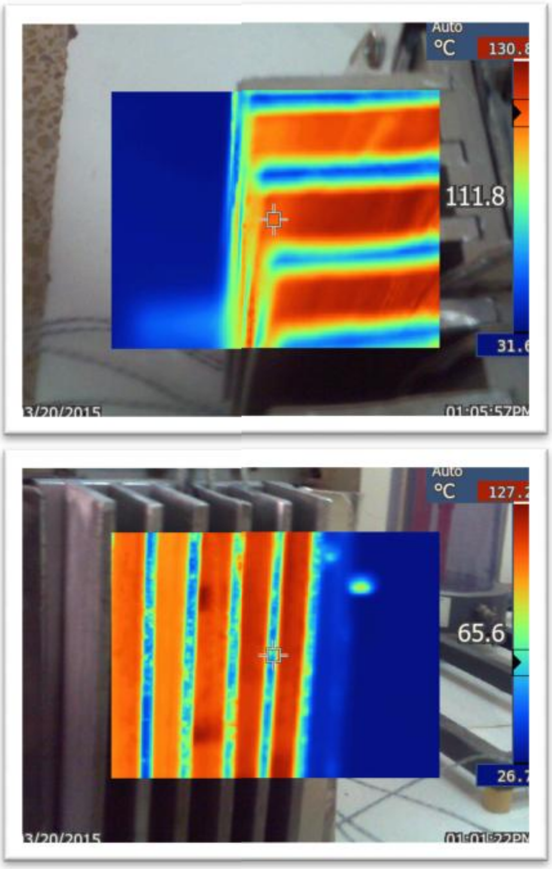


Fig.5 Temperature distribution imager

The Variation of Temperature Different

The relationship between the temperature difference and fin height of different convection heat transfer is presented in Fig. 6. It reveals the inverse relationship between the temperature difference and fin height. In other words, the temperature difference was decreased when the fin height increases at different convection heat transfer due to increase the surface area and thereby increase the heat transfer coefficient. As well as can be observed the temperature difference was increased with convection heat transfer rate. The minimum value of the temperature difference is at fin height (H = 45 mm) where the maximum value at (H = 10 mm) in all cases.

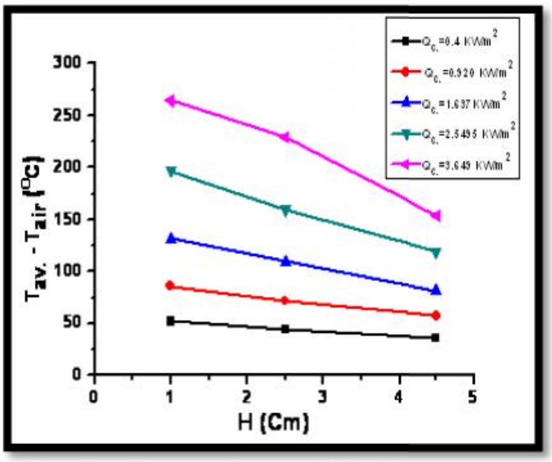


Fig. 6 The effect of heat transfer rate on fin base to ambient temperature difference at different fin height

The convective heat transfer rates has been plotted as a function of fin base to environment temperature different.The proportional relation between temperature differences and convection heat transfer rate at different fin height as shown in Fig. 7. This figure shows that convection heat transfer rate from fin arrays is dependent on fin height. Essentially, fin heat transfer rate increases with fin height. The rate of heat transfer are closer to each other when fin base to environment temperature different was low and spaced at higher temperature differences. The enhancement in the base to ambient temperature difference (decreases) due to increase fin height and reach to 41% when H = 45 mm compared with H = 10 mm.

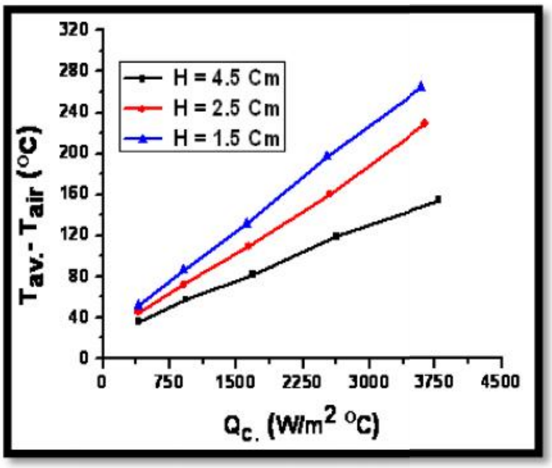


Fig.7 The effect of fin height onbase to ambient temperature difference at different heat transfer rate

Variation Heat Transfer Coefficient

The relation between heat transfer coefficient and several variables such as temperature differential, average base temperature, convection heat transfer rate and Nusselt number with different fin height, it can show in Fig. 8 to 12. The proportional relation between heat transfer coefficient and temperature different and average temperature as shown in Fig. 8 and 9. These figures illustrated that the average temperature and fin base to environment temperature difference decreases when fin height as increased and reach a minimum at fin height 45 mm, but it gets the opposite when the fin high decreases and becomes a maximum of 10 mm.The reason can be attributed to the increased surface area of heat transfer, and it can be seen this Phenomenon clearly with higher heat flux.For the same reason and approach will be notice an increase in the convection heat transfer coefficient.The enhancement in the convection heat transfer coefficient due to increase fin height and reach to 44% when H = 45 mm, compared with H = 10 mm.

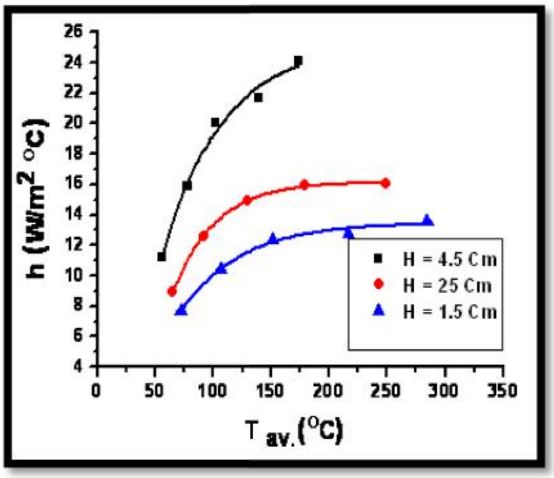


Fig. 8 The effect of fin height on heat transfer coefficient at different averagetemperature

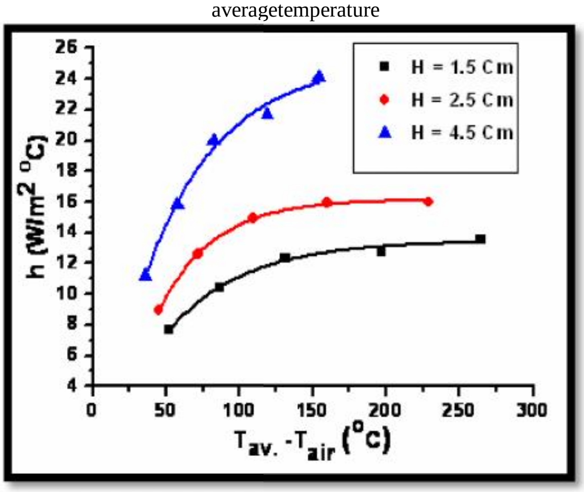


Fig. 9 The effect of fin height on heat transfer coefficient atbase to ambient temperature difference

Figure 10 and 11 describe the relation between heat transfer coefficient with convection heat transfer and Nusselt number. The rate of convection heat transfer and Nusselt number was increased with fins high, in all cases "due to a lower thermal resistance resulted from the increased heat transfer surface area created by the incremented fin height". The enhancement in the convection heat transfer rate reaches 5% when H = 45 mm, compared with H = 10 mm. Figure 12depicts that the heat transfer coefficient increases as the heat flux increases and arrive at maximum value with the fin height increases.

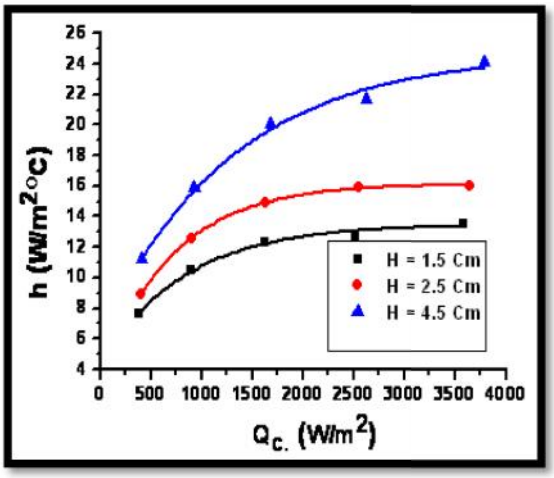


Fig. 10 The effect of fin height on heat transfer coefficient at differenceheat transfer rate

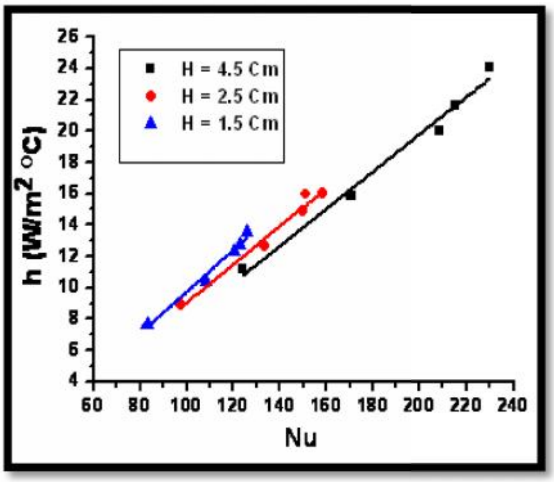


Fig. 11 The effect of fin height on heat transfer coefficient at differenceNusselt number

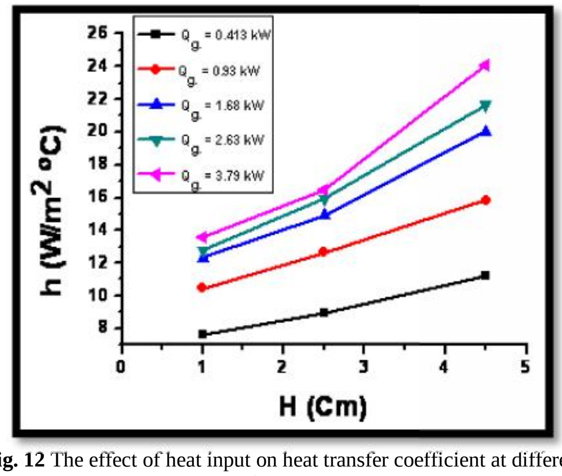


Fig. 12 The effect of heat input on heat transfer coefficient at difference fin height

Variations of Nusselt number

The variations of the Nusselt number with fin height have been illustrated in Fig. 13 at a 10 mm fin spacing value. As it can be seen continuously increased in Nusselt number for all the Rayleigh number values due to increase in fin height. This result can be attributed to "the increased effective surface area for heat transfer as well as an increased probability of the formation of separate convection cells due to increase in fin height causing enhanced Nusselt number". An Increase in the Nusselt number directly refers to improved convection heat transfer rate. The relation between the Nusselt number (Nu) and Rayleigh number (Ra) cannot be represented by a straight line and as a result logarithmic equations have been used and acceptable results have been obtained is concluded.The general equation of heat transfer by external free convection:

$Nu = C\,(Ra)^n$

The constants are obtained and the equations will be as follows:

$y = a + b * x$

Where

$y = LogNu$

$x = LogRa$

and (b) are constant as shown in the table

H (mm)	A	b
10	**0.5035**	**0.9572**
25	**0.4079**	**0.9505**
45	**0.0532**	**0.9306**

The general equation for the test model becomes with the boundary condition as follows:

$$Nu = 7\,Ra^{0.3}H^{0.7}$$

For (10 mm ≤ H ≤ 45 mm)

Which include the effect of fin height as a function of the Nusselt number (Nu) and Rayleigh number (Ra) and with compensation the value of fin height, their equivalent values given match with an error does not exceed (10 %).

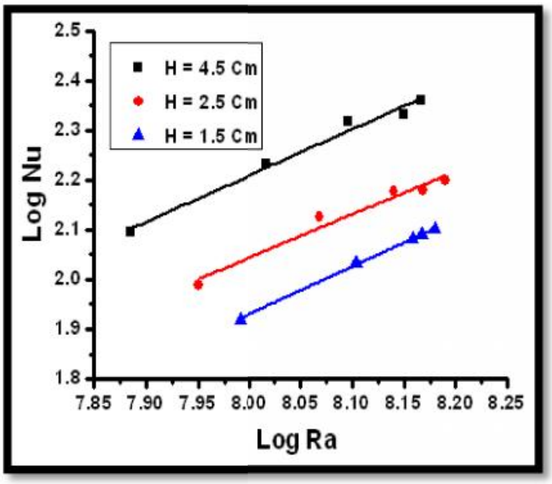


Fig. 13 The effect of fin height onNusselt number at differentRayleigh number

CONCLUSIONS

Free convection heat transfer from vertical fins was investigated experimentally. The effects of different fin height, heat flux and Rayleigh number (Ra) on the heat transfer performance of fin arrays was discussed.

1. The enhancement in the convection heat transfer rate due to increase fin height and reach to 44% when H = 45 mm, compared with H = 10 mm.
2. The enhancement in the fin base to environment temperature difference (decreases) due to increase fin height and reach to 41% when H = 45 mm compared with H = 10 mm.
3. For constant fin spacing, heat transfer rate increases with fin height, base-to-ambient temperature difference and heat flux.
4. The heat transfer rate increases with decrease of average base temperature.
5. The heat transfer coefficient, heat transfer rate and Nusselt number (Nu) was maximum value with fin height 45 mm then decreases to reach a minimum value of 10 mm. The enhancement in the convection heat transfer coefficient due to increase fin height and reach to 44% when H = 45 mm, compared with H = 10 mm.
6. An empirical correlation relating Nusselt number to the influencing parameters (Rayleigh number and fin height) has also been suggested with a maximum variation of ±10% and as follows.

$$Nu = 7\,Ra^{0.3} H^{0.7}$$

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