

Analysis of heat transfer in a triangular lamella (fin) with triangular housing

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Summary: *The convective heat transfer between a surface and the surrounding liquid can be increased by bonding with the surface called fins. Heat conducted through solids, walls, or boundaries must be continuously released to the environment or environment to keep the system in a stable state. In many technical applications, it was necessary to dissipate large amounts of heat from small areas. The fins increase the effective area of a surface, which increases convective heat transfer. The rectangular and triangular fins are straight fins. The triangular louvers are attractive because the same heat transfer requires much less volume than the rectangular louvers. Therefore, the fins are of practical importance, since they offer a maximum heat flow per unit mass with ease of manufacture. In an air-cooled engine, rectangular and triangular ribs are provided around the circumference of the engine cylinder. The analysis of the heat transfer takes place by placing rectangular and then triangular lamellae. The analysis is carried out by varying the temperatures at the surface of the cylinder from 200 °C to 600 °C and the length from 6 cm to 14 cm. Input parameters such as density, heat transfer coefficient, thermal conductivity and fin thickness are used and output parameters such as heat flow rate, heat flow per unit determined by mass, efficiency and effectiveness. The comparisons are shown with rectangular fins..*

Key words: *rectangular fin, triangular fin, heat flux, heat transfer coefficient, efficiency and effectiveness.*

I. INTRODUCTION

Heat transfer is a thermal energy which occurs in transits due to temperature difference. The modes of heat transfer are conduction, convection and radiation. Fin is a thin component or appendage attached to larger body or structure. Based upon the cross sectional area type, straight fins are of different types such as rectangular fin, triangular fin, trapezoidal fin parabolic fin or cylindrical fin. Fin performance can be measured by using the effectiveness of fin, thermal resistance and efficiency. Triangular fins have applications on cylinders of air cooled cylinders and compressors, outer space radiators and air conditioned systems in space craft. Several authors paid attention in analyzing the performance of fins. **Thirumaleshwar** [1] in his book provided an introduction to modes of heat transfer. He had given detailed information of extended surfaces such as boundary conditions and analysis. **Arora et al.**[2] in their book provided an introduction to triangular fins and they had given detailed information of triangular fins its boundary conditions and analysis. **Incropera** [3] in his book proposed a correlation for triangular fins. He discussed two dimensional fin analysis participating in heat transfer. **Mahesh et al** [4] in their book

gave practical applications of triangular and rectangular fins. **Kumar et al.** [5] In their article provided experimental investigation to predict the performance of heated triangular fin array within a vertically oriented and air filled rectangular enclosure to analyze the effects of several influencing parameters for their wide ranges; Rayleigh number $295214 \leq Ra \leq 773410$, fin spacing, $25 \text{ mm} \leq S \leq 100 \text{ mm}$ and fin height $12.5 \text{ mm} \leq L \leq 37.5 \text{ mm}$ for constant heat flux boundary conditions at the heated and cooled walls of the enclosure. They developed an empirical correlation relating Nusselt number to several influencing parameters. **Teerakulpisut** [6] in his paper presented application of modified Bessel functions in the analysis of extended surface heat transfer and differential equations are formulated from the fundamentals of conduction and convection heat transfer. **Rahim et al.** [7] in their paper analysed heat transfer through a wall containing triangular fins partially embedded in its volume, Coupled heat diffusion equations governing each constituent are solved numerically using an iterative finite volume method. Numerical and the analytical results are attained in their paper. It is found that the fin-root can act simultaneously as a heat sink and heat source for the wall. The heat transfer rate through the combined system is clearly seen to be maximized at a specific fin-root length. The maximum reported heat transfer rate through the triangular rooted-finned wall is recommended to utilize the triangular rooted-fin as a heat transfer enhancer for high mechanical strength structures exposed to highly convective fluid streams. **Narve et al.** [8] in their paper studied heat transfer characteristics of natural convection heat flow through vertical symmetrical triangular fin arrays. They studied experimentally and results are compared with equivalent rectangular fin arrays. Average and base Nusselt numbers and Grashoff number are calculated. They observed that with increase in Grashoff number, average and base Nusselt number increases, Similarly average Nusselt number increases with spacing whereas base Nusselt number increases to maximum value.

II. DESCRIPTION AND WORKING OF FINS

As fins are introduced to enhance heat transfer from a base which is at high temperature, rectangular fins and triangular fins are considered for analysis on two stroke air cooled engine. Engine life and effectiveness can be improved with effective cooling. The cooling mechanism of the air cooled engine is mostly dependent on the fin size. The heat is conducted through the engine parts and convected to air through the surfaces of the fins. Insufficient removal of heat from engine will lead to high thermal stresses and lower engine efficiency. As air-cooled engine builds heat, the cooling fins allow the wind and air to move the heat away from the engine.

Considering an air cooled petrol engine with two stroke, at no load condition engine does not generate power. When load increases on an engine, the upward movement of a piston causes compression of the previously available charge inside the cylinder. Thus, during upward stroke, suction and compression of charge takes place simultaneously, and both transfer port and exhaust port remain closed. At the end of compression stroke, the charge is ignited by a high voltage electric spark. After ignition of charge, hot high pressure gases expand. The piston goes downwards and compresses the charge drawn in the crank case. At the end of expansion stroke, exhaust port which is slightly placed higher than the transfer port, opens releasing the burnt gases from cylinder to the atmosphere. Fins are provided on a periphery of engine. Exhaust heat is exposed to outside of engine cylinder. Air cooled engines have fins to radiate heat to surrounding air. Cylinder is made of cast iron and fins are made of stainless steel.

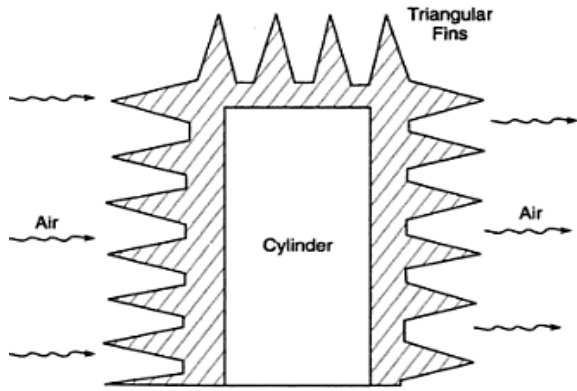


Fig.2 Air cooled cylinder with triangular fins

Fig.1 and Fig.2 below gives a layout of an air cooled cylinder provided with rectangular and triangular fins.

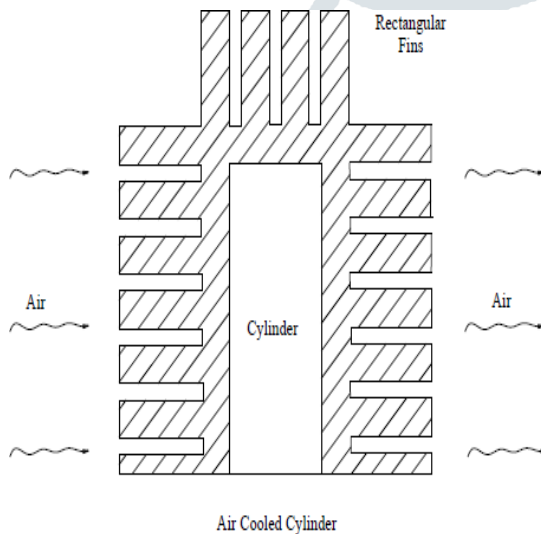


Fig.1 Air cooled cylinder with rectangular fins

Fig.1 shows rectangular fins placed around the cylinder. These fins are made of stainless steel of thickness 2.5 cm. Fig.2 shows a single cylinder fitted with triangular fins of thickness 2.5 cm. As the heat developed inside a two stroke engine cylinder is more, the heat has to be dissipated to surroundings by fins. These fins fitted are having an appropriate surface area to take away the heat to surroundings.

III. ANALYSIS OF RECTANGULAR AND TRIANGULAR FIN

Rectangular Fin:

The rectangular fin as shown in Fig.3 with L as the length of the fin, 2δ as thickness of the fin and W width of fin and assuming the heat flow is unidirectional and it is along length and the heat transfer coefficient (h) on the surface of the fin is constant.

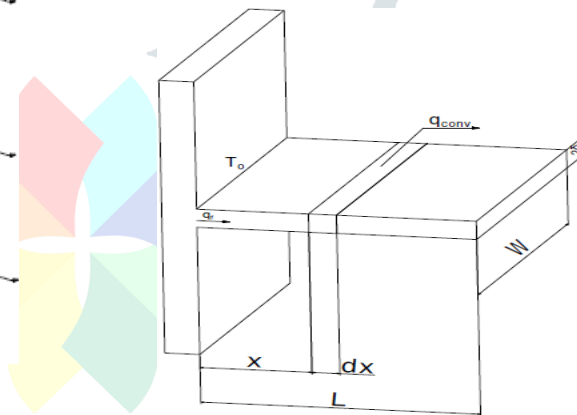


Fig.3 Rectangular fin attached to cylinder

Heat lost by fin, (Q_r)

$$KA_c m \theta_0 \frac{h \cosh mL + km \sin h mL}{km \cos h mL + h \sin h mL} \dots\dots\dots (1)$$

where,

k = thermal conductivity, W/mK
 A_c = cross section area of fin, m^2

$m =$ fin parameter, $(\sqrt{hP/kA_c})$

P = perimeter of fin, $(2W + 4\delta)$, m

$\theta_0 =$ temperature difference, K

h = heat transfer coefficient, W/m^2K

Mass of rectangular fin, (m_r) $2\delta \times \rho \times L \dots\dots\dots (2)$

where,

ρ = density of fin material, kg/m³

Rate of heat flow per unit mass through rectangular fin,

$$q_r = \frac{KA_c m \theta_0 \frac{h \cos h mL + km \sin h mL}{km \cos h mL + h \sin h mL}}{2\delta \times \rho \times L} \dots\dots\dots (3)$$

Efficiency of rectangular fin, (η_r)

$$\eta_r = \frac{\text{Heat lost with fin}}{\text{Heat lost from the fin if entire surface maintained at room temperature}} = \frac{-KA_c m \theta_0 \frac{h \cos h mL + km \sin h mL}{km \cos h mL + h \sin h mL}}{2WL \cdot h \theta_0} \dots\dots\dots (4)$$

Effectiveness of rectangular fin, (ϵ_r) = $\frac{\text{Heat lost with fin}}{\text{Heat loss without fin}}$

$$\epsilon_r = \frac{-KA_c m \theta_0 \frac{h \cos h mL + km \sin h mL}{km \cos h mL + h \sin h mL}}{h A_c \theta_0} \dots\dots\dots (5)$$

Triangular Fin:

For a triangular fin representing length of fin L, thickness, 2 δ and width of fin, W and assuming the heat flow is unidirectional and it is along length and the heat transfer coefficient (h) on the surface of the fin is constant.

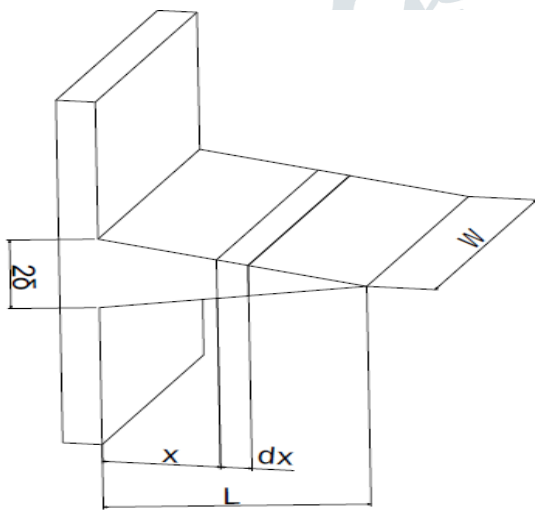


Fig.4 Triangular fin attached to cylinder

Heat lost by triangular fin,

$$Q = 2W\theta_0 \sqrt{(hk\delta)} \left[\frac{I_1(2B\sqrt{L})}{I_0(2B\sqrt{L})} \right] \dots\dots\dots (6)$$

where,

θ_0 = temperature difference, K
 k = thermal conductivity, W/mK
 B = fin parameter, ($\sqrt{hL/k\delta}$)

I_1 = Bessel function of first kind

I_0 = Bessel function of first kind

The mass of triangular fin,

$$(m_t) = \frac{1}{2} \times 2\delta \times L \times W \times \rho \dots\dots\dots (7)$$

ρ = Density of fluid kg/m³

Rate of heat flow per unit mass (q) = $\frac{\text{Heat flow through fin}}{\text{mass of fin}}$

$$q = \frac{2W\sqrt{hk\delta}\theta_0 \frac{I_1(2B\sqrt{L})}{I_0(2B\sqrt{L})}}{\frac{1}{2} \times 2\delta \times L \times W \times \rho} \dots\dots\dots (8)$$

Efficiency of triangular fin (η_t)

$$\eta_t = \frac{2W\sqrt{hk\delta}\theta_0 \frac{I_1(2B\sqrt{L})}{I_0(2B\sqrt{L})}}{2WL \cdot h \theta_0} \dots\dots\dots (9)$$

Effectiveness of triangular fin, (ϵ_t) = $\frac{\text{Heat lost with fin}}{\text{Heat loss without fin}}$

$$\epsilon_t = \frac{2W\sqrt{hk\delta}\theta_0 \frac{I_1(2B\sqrt{L})}{I_0(2B\sqrt{L})}}{h A_b \theta_0} \dots\dots\dots (10)$$

where,

A_b = base area of triangular fin, ($W \times 2\delta$), m²

IV. RESULTS AND DISCUSSION

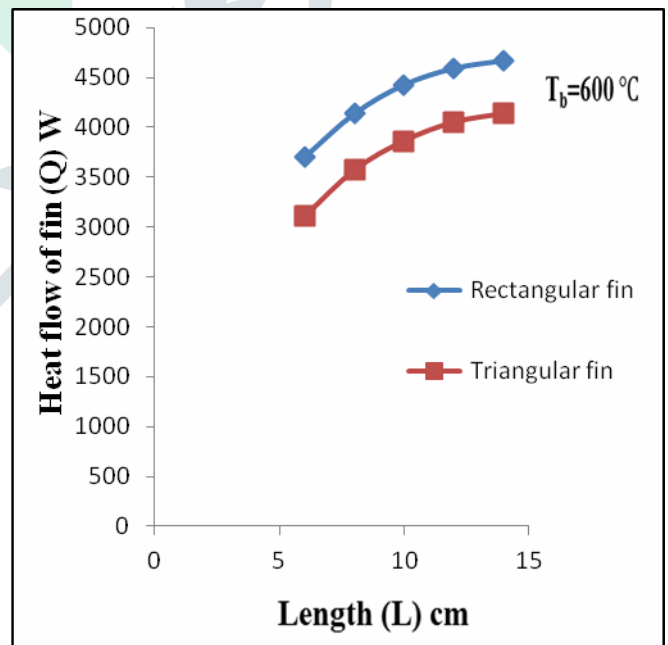


Fig.5 Variation of heat flow of the fin (Q) with length (L)

Fig.5 shows the variation of heat flow through fin to length of the fin. It is noted that as a length is increased, heat flow increases. The increase of the two fins varies as the same

curve, however at any point of length rectangular fins gives more heat transfer rate compared to triangular fin.

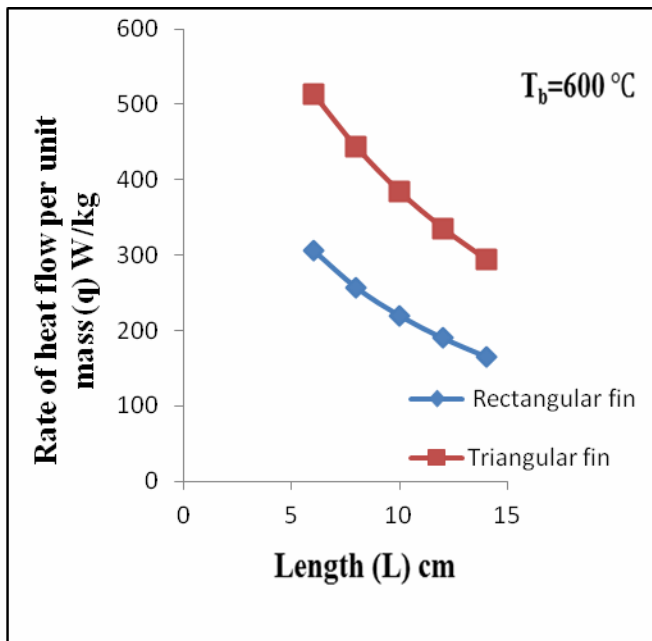


Fig.6 Variation of rate of heat flow per unit mass of fin (q) with length (L)

Fig.6 shows a variation between rate of heat flow per unit mass to the length of fin. It is observed that the heat flow of a triangular fin is more when compared to rectangular fin at any point of length hence it is utilising most of the material for dissipation of heat.

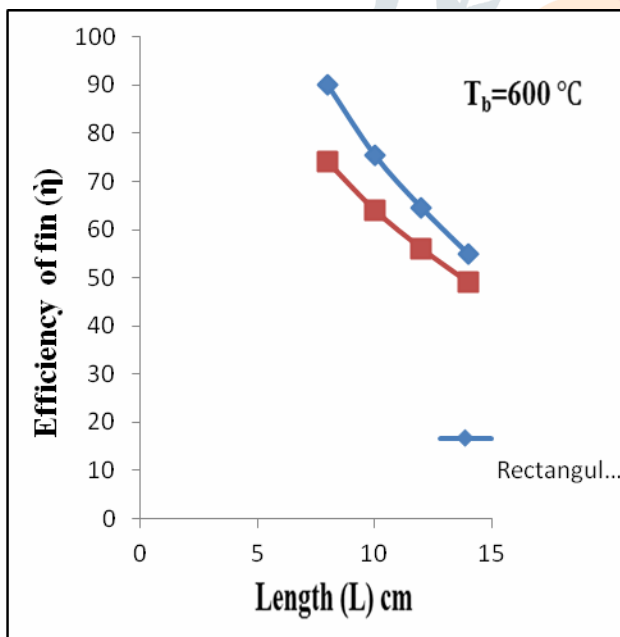


Fig.7 Variation of efficiency (η) with length (L)

Fig.7 shows the variation of efficiencies of fins. Efficiencies of fins are for more for shorter length compared to long length of fins. However it is understood that rectangular fins exhibits more efficiency than triangular fins.

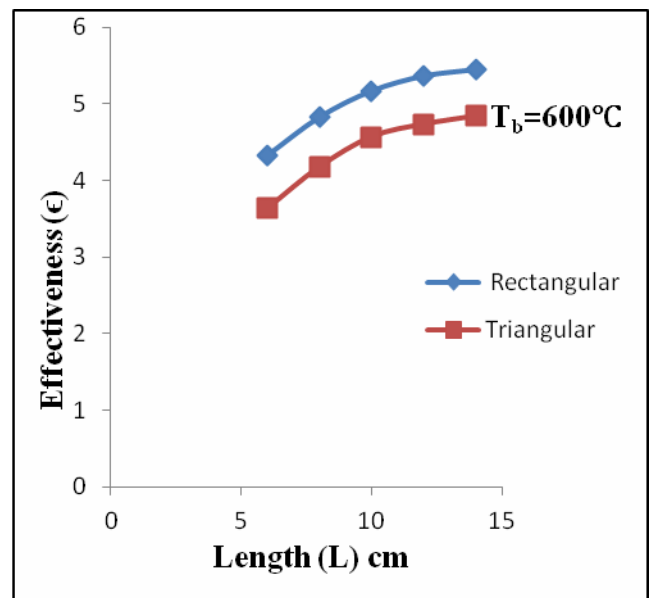


Fig.8 Variation of effectiveness (ε) with length (L)

The graph Fig.8 shows variation of effectiveness of a fin. The effectiveness of a fin increases with increase in length of a fin. In general rectangular fins, give more effectiveness than triangular fins.

Fig.9 shows variation of heat flow of fin when length is fixed at 10 cm. It is observed that there is a steep increase of heat flow of fin. Heat flow of rectangular fin is more than triangular fin.

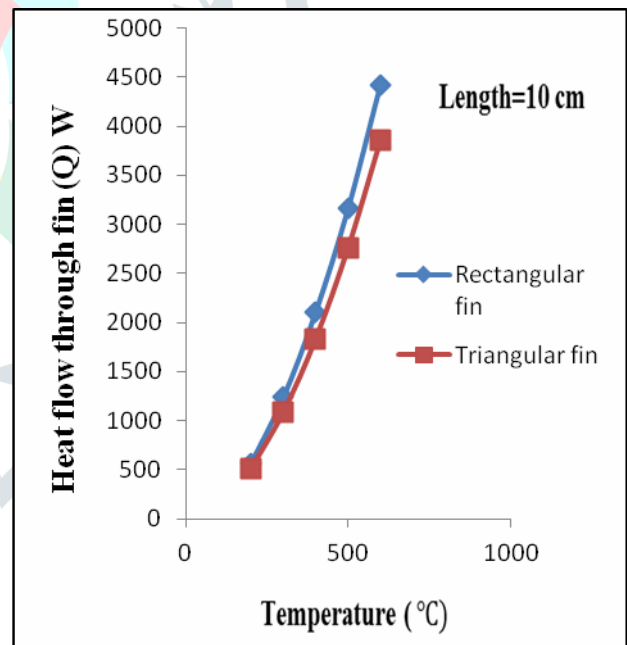


Fig.9 Variation of heat flow (Q) with temperature (°C)

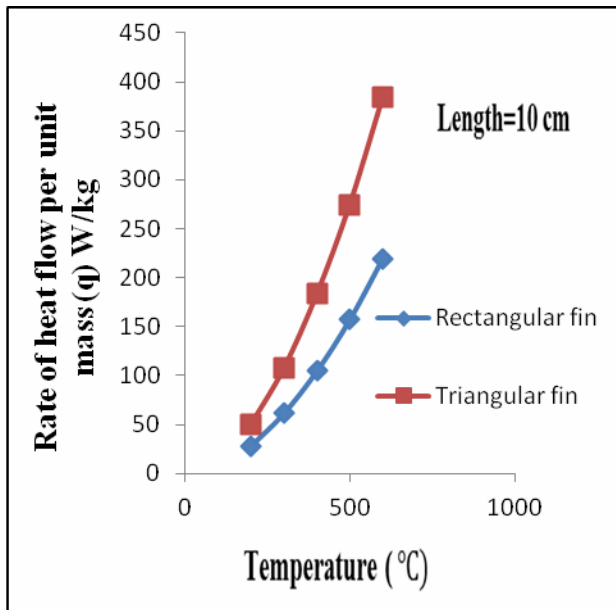


Fig.10 Variation of rate of heat flow per unit mass of fin (q) with temperature °C)

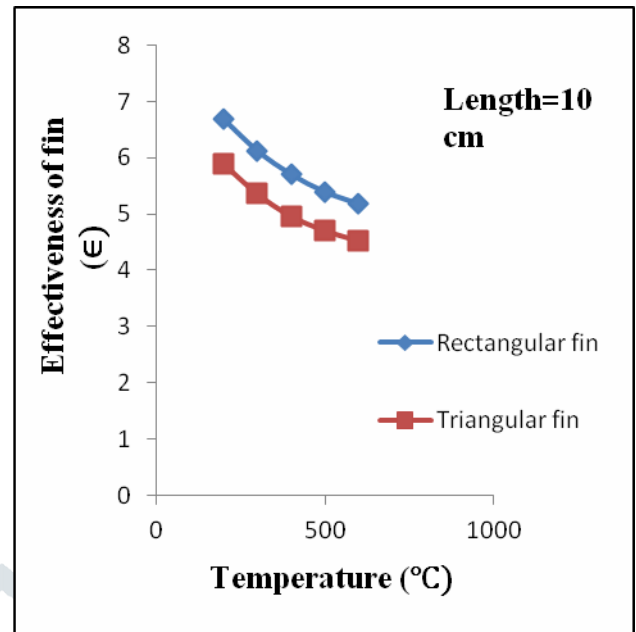


Fig.12 Variation of effectiveness ε) with temperature °C)

The above diagram Fig.10 shows variation of heat flow per unit mass with respect to the increase in base temperature. For a fixed length of a fin it is seen that there is a large variation heat dissipation per unit mass from the base when compared to rectangular fin. Hence triangular fins are preferred for better heat dissipation per unit mass.

Fig.12 shows the variation of effectiveness with respect to base temperature. It was made clear that the effectiveness of rectangular and triangular decreases when base temperature increases and rectangular fin exhibits more effectiveness.

V. CONCLUSIONS

The following conclusions are arrived when the air cooled petrol engine is fitted with rectangular and triangular fins.

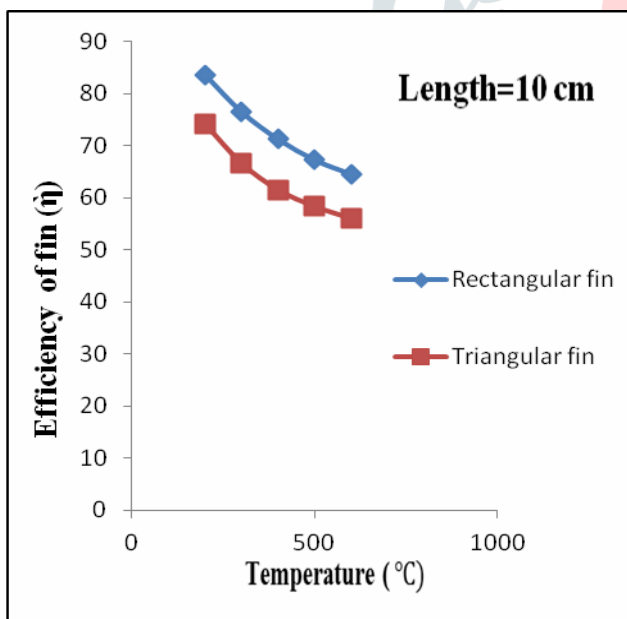


Fig.11 Variation of efficiency (η) with temperature °C)

Here shows Fig.11 for variation of efficiency (η) with base temperature variation at a fixed length. There is a gradual decrease in efficiency (η) as base temperature increases.

1. Varying the length of fin from 6 cm to 14 cm and maintaining base temperature at °C,
 - a) Heat flow from triangular fin is increased by 33.14% compared to rectangular fin of 25.97%,
 - b) Rate of heat flow per unit mass of rectangular fin is decreased by 46% compared to triangular fin of 42.9%,
 - c) Efficiency of triangular fin is decreased by 41.89% compared to rectangular fin of 45.8%,
 - d) Effectiveness of triangular fin is increased by 33.14% compared to rectangular fin of 25.8%.
2. Varying base temperature of fin from 200°C to 600 °C keeping the length fixed at 10 cm.
 - a) Heat flow of triangular fin is increased by 87.9% compared to rectangular fin of 87.14%.
 - b) Rate of heat flow per unit mass of triangular fin is increased by 86.78% compared to rectangular fin of 87.14%.
 - c) Efficiency of triangular fin is decreased by 24.52% compared to rectangular fin of 22.72%.
 - d) Effectiveness of triangular fin is decreased by 23.45% compared to rectangular fin of 22.6%.

3. From the above, it can be concluded that triangular fins are preferred when maximum material of fin is to be utilised for best heat dissipation.

VI. REFERENCES

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