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Modeling of Heat Transfer from Finned Surface

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Abstract: ***Numerical determination of temperature distribution T (x) and fin heat transfer rate of a rectangular and triangular fin is presented. The shooting method is used which converts the boundary value problem into an initial value problem. Numerical results at different step sizes are compared to the analytical solution. The shooting method starts the solution from a guessed value at the boundary with initial data and produces the final boundary value at the end. The major downside is that the shooting method is computationally time expensive. Calculated the heat transfer for both RECTANGULAR and TRIANGULAR geometry to get the desired output value. Heat transfer rate, efficiency and effectiveness along the length are increased from the tip to the base for all cross section. All the results are plotted in the form of graph.***

Keywords: Shooting Method, Fin, Temperature distribution

1. Introduction

Fins are used in a large number of applications to increase the heat transfer from surfaces. Typically, the fin material has a high thermal conductivity. The fin is exposed to a flowing fluid, which cools or heats it, with the high thermal conductivity allowing increased heat being conducted from the wall through the fin. The design of cooling fins is encountered in many situations and we thus examine heat transfer in a fin as a way of defining some criteria for design.

Fins can be of a variety of geometry rectangular, triangular, parabolic, and hyperbolic and can be attached to the inside, outside or to both sides of circular, flat plate. Fins are most commonly used in heat exchanging devices such as radiators in cars, computer CPU heat sinks, and heat exchangers in power plants [1] .

- Heat transfer through triangular fin array per unit mass is more than that of heat transfer through rectangular fin array. Therefore, the triangular fins are preferred for automobiles, central processing units, aero-planes, space vehicles etc. where, weight is the main criteria.
- At wider spacing, shorter fins are more preferred than longer fins.
- The aspect ratio for an optimized fin array is more than that of a single fin for both rectangular and triangular profiles [4] .

Types of Fin

Fins can be broadly classified as:

1) Longitudinal fin - Rectangular, Trapezoidal and Concave profile.
2) Radial fin - Rectangular and Triangular profile.
3) Pin fin - Cylindrical.

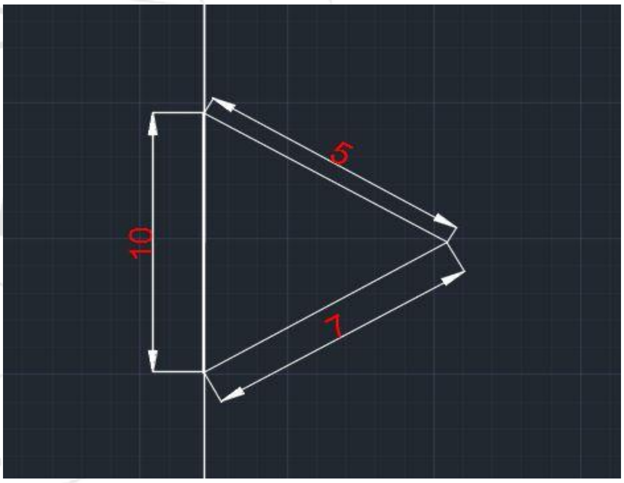
Rectangular Fin:

Figure 1.1: Dimensions of Rectangular fin

The rectangular fin as shown in Figure-1.1, with L, as the length of the fin, as thickness of the fin and B breadth 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.

Base temperature,
T_b = 40 °C
Ambient temperature,
T_∞ = 20 °C
Length of fin=10cm, Breadth of fin =5cm

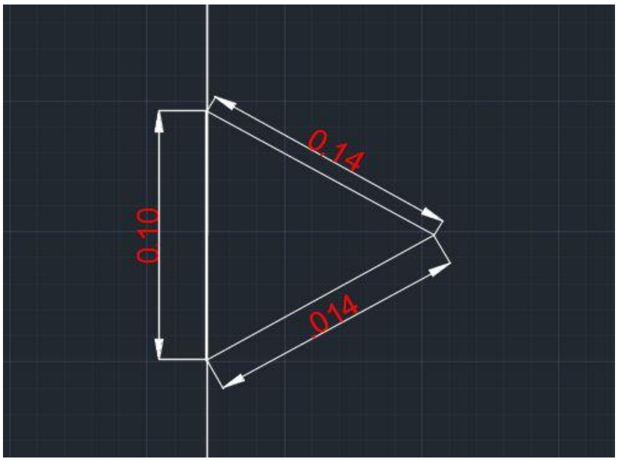
Triangular Fin:



Distance AB=5cm, BC=10cm, CA=7cm
Figure 1.2: Dimensions of Triangular Fin (Scalene)

The triangular fin as shown in Figure-3, with the dimension of AB=5cm, BC=10cm and CA=7cm having unequal distance from all the 3 sides.

Base temperature,
T_b = 40 °C
Ambient temperature,
T_∞ = 20 °C



Distance AB = 0.14cm, BC = 0.10cm, CA = 0.14cm
Figure 1.3: Dimensions of Triangular Fin (Isosceles).

The triangular fin as shown in Figure-3, with the dimension of AB=0.14cm, BC=0.10cm and CA=0.14cm having 2 equal distance and an unequal distance from all the 3 sides.
Base temperature,
T_b = 40 °C
Ambient temperature,
T_∞ = 20 °C

2. Literature Review

2.1 Introduction

The literatures regarding the numerical and analytical solution for fins are presented below.

2.2 Literature Surveys

The following are the few literatures regarding the heat transfer from the surface of the fin.

Giulio Lorenzini and Simone Moretti [15] solved the problem of heat removal is a major issue in modern industry. They faced the problem of optimizing fins to enhance heat removal. Initially, they investigated the system numerically using a CFD code. They investigated Y-shaped profiles which consequently examined, obtained by varying the angle between the two arms of the original T. They observed that width reduction, typical of Y-shaped profiles with respect to T-shaped ones, enhance efficiency significantly. This new approach to heat removal optimization suggested the realization of arrays with multiple Y-shaped fins. Each array had the same width of the corresponding optimized T-shaped fin. This choice allowed immediate comparisons, so as to evaluate the actual performance enhancements typical of multiple-fin configurations, with respect to previous configurations.

Jacob *et al.* [6] have analyzed that natural convection heat transfer from triangular fin arrays experimentally and theoretically. They found that fin optimization is useful to go through the exercise of optimizing a fin in order to achieve the high rate of heat transfer per volume of fin material. The result of this optimization provides general guidelines relative to the dimensionless characteristics of a well designed fin.

Sandhya Mirapalliand Kishore P.S. [7] conducted research assuming that the heat conducting through the solids, walls or boundaries has to be continuously dissipated to the surroundings or environment to maintain the system in a steady state condition. They have carried out analysis by varying temperature son the surface of the cylinder from 200ºC to 600ºC and varying length from 6 cm to 14 cm. Input parameters such as density, heat transfer coefficient, thermal conductivity and thickness of fin are taken and output parameters such as rate of heat flow, heat flow per unit mass, efficiency and effectiveness are determined. Comparisons are presented with rectangular fins. They observed that heat transfer is maximum in triangular fins.

Saurav Kumar and M.K. Singh [2] studied rectangular and triangular fin for investigating experimentally and theoretically in free and forced convection to find out temperature and heat transfer coefficient of both fins. Analysis of both fins has been made for heat transfer rate, efficiency and effectiveness. The equation of temperature distribution of triangular fin is solved using Laplace transformation.

Vinay Kumar *et al.* [3] made an attempt to enhance the heat transfer in a rectangular fin plate by different perforations heat sinks (i.e. circular, triangular, square). The patterns of perforations including 24 perforations (holes) for the first fin and the number of perforations increased 8 for every fin until reached to 56 in the fifth fins. These perforations were distribution on 6-14 columns and 4 rows.

Lokesh Aurangabadkar *et al.* [4] analyzed the thermal heat dissipation of fins by varying its geometry. Parametric models of fins have been developed to predict the transient thermal behavior. Thereafter models are created by varying the geometry such as rectangular, circular, triangular and fins with extension. After determining the material the final step is to increase the heat transfer rate of the system by varying geometrical parameters such as cross sectional area, parameter, length, thickness, etc which ultimately leads to fins of varying shape and geometries.

Dogonchi A.S. & Ganji D.D. [5] have solved a heat transfer problem of convective-radiation heat transfer through a moving fin with internal heat generation using temperature dependent thermal coefficient. The heat transfer coefficient, thermal conductivity and heat generation rate are variable and supposed to be temperature dependent. The heat transfer in fin with longitudinal rectangular profile was carried out by using the Differential Transformation Method (DTM). They observed that the temperature increases with an increase in the heat generation gradient and a decrease in the Peclet number and the radiation–conduction parameter. Also, the optimal temperature distribution for a longitudinal rectangular fin is accomplished at stationary fin with heat generation-without radiation case.

Mosayebidorcheh.S. *et al* [8] have considered an optimum design point for fin geometry, so that heat transfer rate reaches to a maximum value in a constant fin volume. They assumed that the thickness of longitudinal fins varies with length. In this study temperature dependent heat generation, convection and radiation are considered and analytical techniques based on the least square method were presented. They observed that heat transfer rate decreases with increase of the fin thickness ratio.

R.K.Rajput [11] considered three types of fins. He considered analytical method for solving the fin problems. He has given analytical formulation for solving heat transfer rate along the length.

Hyung Suk Kang [14] considered about the optimization of a triangular fin with variable fin base thickness. There, he used two dimensional analytical methods for analysis. He observed that the optimal heat loss increased whereas the corresponding optimum fin effectiveness decreases with increase in fin volume.

Worachest Pirompugd and Somchai Wongwises [9] have considered partially wet fin efficiencies for the longitudinal fin of rectangular, triangular, concave parabolic, and convex parabolic profiles. They considered two methods to derive partially wet fin efficiency that depend on a set of boundary conditions. According to the derivation, the fin efficiencies are the function of the length of the dry portion. Thus, the equations for calculating the length of the dry portion must also be presented. They found that the fin with larger section had a higher conduction heat transfer rate and fin efficiency. Also found that the partially wet fin efficiencies decreased with increased in relative humidity.

R. J. Moitsheki [12] considered a heat transfer problem of a longitudinal fin with triangular and parabolic profiles. Both thermal conductivity and heat transfer coefficient are assumed to be temperature-dependent and given by power laws. In other case, classical Lie symmetry techniques are employed to analyze the problem. He obtained exact solution to satisfythe realistic boundary conditions. The effects of the physical applicable parameters such as thermo-geometric fin parameter and the fin efficiency are analyzed.

Mohsen Torabi et al [10] considered the performance characteristics of convective–radiative longitudinal fins of rectangular, trapezoidal and concave parabolic profiles with simultaneous variation of thermal conductivity, heat transfer coefficient and surface emissivity with temperature. Calculations were done using the differential transformation method (DTM). The accuracy of the DTM is confirmed by comparing its predictions with the results from an analytical solution and a well-tested numerical procedure. Results were presented to illustrate the effects of thermal conductivity parameter, emissivity parameter, convection–conduction parameter, radiation–conduction parameter, and dimensionless convection and radiation sink temperatures on the performance of fins.

E .M. Mokheimer [16] considered about the effect of locally variable heat transfer coefficient on the performance of fin subjected to natural convection. Fin of different profiles like straight and pin fin with rectangular (constant diameter), convex parabolic, triangular (conical) and concave parabolic profiles and radial fins with constant profile with different radius ratios. The local heat transfer coefficient was considered as a function of the local temperature. Results show that there is a considerable deviation between the fin efficiency calculated based on constant heat transfer coefficient and that calculated based on variable heat transfer coefficient and this deviation increases with the dimensionless parameter ***m***.

2.3 Limitations from the Literature Surveys:

The literature survey shows the calculations relating to limiting the maximum heat transfer rate from the fin surface but remains silent which method is most effective for computation.

2.4 Objective of the research

1) To calculate the temperature profile along the length of the fin with variable cross sectional area for different geometrical sections.
2) To calculate the efficiency, effectiveness and maximum heat transfer from the varying finned surface.
3) To compare the performance of fins.

2.5 Conclusion

The present chapter provides the detail information to the fin problem. The literatures have been studied related to the problem. Accordingly, the objective of the present work has been formulated. The necessary formulation for the fin is presented here for computation.

3. Methodology

3.1 Introduction

The shooting method is used to solve initial value problems. An ordinary differential equation is converted to many first order differential equations. The known boundary values are converted to initial values of the solution. With guess value of unknown boundary value; using trial and error method or some other scientific approach, these one dimensional equations are solved simultaneously.

3.2 Formulation

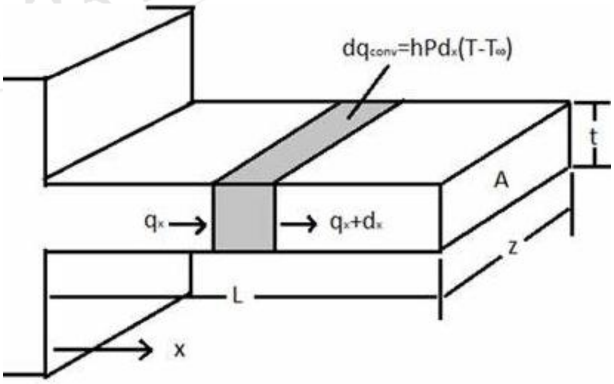


Figure 3.1 Geometry of rectangular fin

Applying the energy balance on the rectangular fin:

$$Q_x = Q_{x+dx} + Q_c$$

Where:
Q_{x+dx} = Energy leaving the control volume.
Q_x =Energy entering the control volume.

Q_c = Heat transfer due to convection.

$$Q_x = -kA(x)\frac{dT}{dx} \qquad (3.1)$$

By Using Taylor Series Expansion

$$Q_{x+dx} = Q_x + \frac{d}{dx}(Q_x)\Delta x + Q_c \quad (3.2)$$

$$Q_c = hP(x)\Delta x(T - T_\infty) = 0 \quad (3.3)$$

Using equation (3.1) and (3.3) in (3.2) we get,

$$\frac{d}{dx}(-kA(x)\frac{dT}{dx})\Delta x + hP(x)\Delta x(T - T_\infty) = 0$$

$$\frac{d}{dx}(A(x)\frac{dT}{dx})\Delta x - \frac{hP(x)}{k}(T - T_\infty) = 0 \quad (3.4)$$

This is the governing differential equation for an extended surface.For constantarea of cross-section:

$$\frac{d^2T}{dx^2} - \frac{hP}{kA_c}(T - T_\infty) = 0 \qquad (3.5)$$

where, $m^2 = \frac{hP}{kA}$

Let$\theta = T - T_\infty => dT = d\theta$

$$\frac{d^2\theta}{dx^2} - m^2\theta = 0 \qquad (3.6)$$

General solution to the differential equation is:

$$\theta(x) = C_1e^{-mx} + C_2e^{mx}$$

$$= C_1 \cos h(mx) + C_2 \sin h(mx) \quad (3.7)$$

Where C_1 and C_2 are two arbitrary unknown constants. The boundary conditions are:

$$x = 0,\ T = T_b(\text{Base temperature}) \quad (3.8)$$

Boundary conditions at fin tip:

1.Heat dissipation from an infinitely long fin.

$$(x \to \infty, T = T_\infty)\text{.....................} (3.8)\ a$$

2. Heat dissipation from a fin insulated at the tip

$$(x = L, -k\frac{dT}{dx} = h_t(T - T_\infty))\text{..} (3.8)b$$

3. Heat dissipation from a fin losing heat at the tip

$$(x = L, \frac{dT}{dx} = 0)\text{..................}(3.8)c$$

Heat lost by rectangular fin,

$$Q = \frac{kA_cm\theta_0 hcoshmL + k\ m\ sinhmL}{k\ m\ coshmL + hsinhmL}$$

Where,

θ_0 = Temperature difference, K.

k = thermal conductivity, W/MK.

m= Fin parameter, $\sqrt{\frac{hL}{kA_c}}$............... (3.9)

A_c = cross sectional area of fin, m^2.

h = heat transfer coefficient/m^2K.

Rate of heat flow per unit mass

$$(q_r) = \frac{kA_cm\theta_0}{2\delta\rho L}\frac{hcoshmL\ +kmsinhmL}{kmcoshmL\ +hsinhmL}.$$

Efficiency of rectangular fin:

$$\eta_r = \frac{-kA_cm\theta_0\frac{hcoshmL + km\ sinhmL}{kmcos\ hmL + h\ sinhmL}}{2WLh\theta_0}$$

Effectiveness of rectangular fin:

$$\epsilon_r = -kA_cm\theta_0\frac{h\ coshmL + km\ sinhmL}{km\ coshmL + h\ sinhmL}/hA_c\theta_0$$

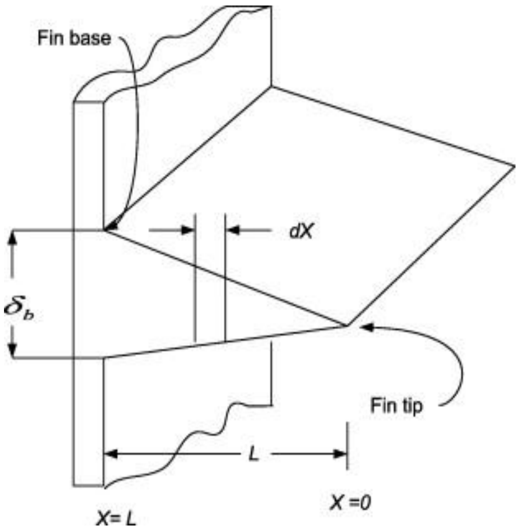


Figure 3.2: Geometry of triangular fin.

For a triangular fin representing length of fin L, thickness 2δ, 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.

Heat lost by triangular fin,

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

Where,

θ_0 = Temperature difference, K.

k = thermal conductivity, W/MK.

B = Fin parameter, $\sqrt{\frac{hL}{k\delta}}$.............. (3.10)

I_1=Bessel function of second kind.

I_0=Bessel function of first kind.

Rate of heat flow per unit mass, $(q_t) = \frac{b\theta_0\sqrt{(2hk\delta)}I_1\ (2B\sqrt{x})}{I_0\ (2B\sqrt{L})}$

Efficiency of triangular fin: It is the ratio between actual heat transfer rate from the fin to the ideal heat transfer rate from the fin.

$$\eta_t = \frac{1}{L}\sqrt{2kW/h}\frac{I_1}{I_0}\frac{(2B\sqrt{x})}{(2B\sqrt{L})}$$

Effectiveness of triangular fin: It is the ratio between heat lost with fin to the heat lost without fin.

$$\epsilon_t = \sqrt{2k/h\delta}\frac{I_1(2B\sqrt{x})}{I_0(2B\sqrt{L})}$$

3.3 Solution of the differential equation:

Solution of the Eq. (3.6) is obtained using analytical method and numerical method.

3.3.1Analytical method

Using the boundary condition Eq. (3.8) and (3.8)a in Eq. (3.7); the solution obtained is:

$$\theta(x) = \theta_b e^{-mx} \ldots\ldots\ldots\ldots\ldots\ldots. (3.10)$$

Using the boundary condition Eq. (3.8) and (3.8)b in Eq. (3.7); the solution obtained is:

$$\theta(x) = \theta_b\frac{e^{m(l-x)} + e^{-m(l-x)}}{e^{ml} + e^{-ml}} \ldots\ldots\ldots\ldots. (3.11)$$

Using the boundary condition Eq. (3.8) and (3.8)c in the Eq. (3.7); the solution obtained is:

$$\theta(x) = \theta_b \frac{\cos hm(l-x) + \frac{h}{km}[\sin h\{m(l-x)\}]}{\cos hml + \frac{h}{km}[\sin h(ml)]} \quad (3.12)$$

Fin efficiency: The efficiency of a fin is defined as the ratio of the actual heat transferred by the fin to the maximum heat transferable by fin, if entire fin area were at the base temperature.

$$\eta = Q_{fin}/Q_{max} \ldots\ldots\ldots\ldots\ldots\ldots (3.13)$$

3.3.2 Numerical method

For solution of the Eq. (3.6), the shooting technique is used. From Eq. (3.6),

$$\text{Let } z = \theta - - - - (3.14)$$
$$and\ y = z' \ldots\ldots\ldots . (3.15)$$

The boundary conditions are:
$\text{At } x = 0, \theta = \theta_b \text{ and at } x = L, \theta(L) = 0$

The solution of Eq. (3.13) is:

$$z_{i+1} = z_i + f_1(x_i, \theta_i, z_i)h$$
$$\text{or } z_{i+1} = z_i + m^2\theta h \ldots\ldots\ldots . (3.16)$$

And the solution of Eq. (3.14) is:

$$\theta = \theta_0 + f_2(x_i, \theta_i, z_i)h$$
$$or \quad \theta = \theta_0 + zh$$
$$or \quad \theta_{i+1} = \theta_i + zh \ldots\ldots\ldots\ldots \quad (3.17)$$

The solution starts from x=0, $\theta = \theta_b$ and guess value of z and ends at x=L, $\theta = 0$ using Shooting techniques. Here h is the step size. That is calculated according to the number of points used along the fin surface. So h = L/n, where n is the number of points along L.

3.4 Shooting Technique

Shooting technique is applied for the Eq. (3.15) and (3.16). Using the value of ɵ and guessed value of z as initial value, these values are calculated at different points along the length of the fin till x=L. The solution is said to be converged when for a particular guess value of z; ɵ becomes 0. The initial guess value is obtained using heat and trial method.

3.5 Conclusion

The differential equation for the fin has been solved using analytical and numerical method. So, the solution procedure has been discussed. Then both the solution must be matched to get the accuracy of the solution.

4. Results and Simulation

4.1. Introduction

The formulation to the fin for varying cross sectional area has been derived in the previous chapter. The Eq. (3.6) has been solved using analytical and numerical method. The numerical method of solution consists of Shooting techniques. The results and the required graphs for the said equation are presented below. .

4.2 Results

Eq. (3.12) for analytical result and also Eq. (3.16) and (3.17) for numerical results obtained for different values of x are presented in table.4.1.

1. For Isosceles triangle cross section fin surface:
The geometrical dimension of isosceles triangle ABC is: AB = 5cm, BC = 5cm, CA = 2cm. The temperature profile for uniform fin having isosceles triangle cross section is shown in table 4.1 below.

Table 4.1: Temperature profile along the length of the fin (Isosceles triangle cross section)

X (in cm)	ɵ (Analytical)	ɵ (Numerical)
0	20	20
2.3	8.83	3.47
4.6	3.9	0.6
6.9	1.72	0.1
9.2	0.7	0.02
11.5	0.3	0.003
13.8	0.1	0.001
16.1	0.06	0.0002
18.4	0.03	0.00018
20.7	0.01	0.0001
23	0	0

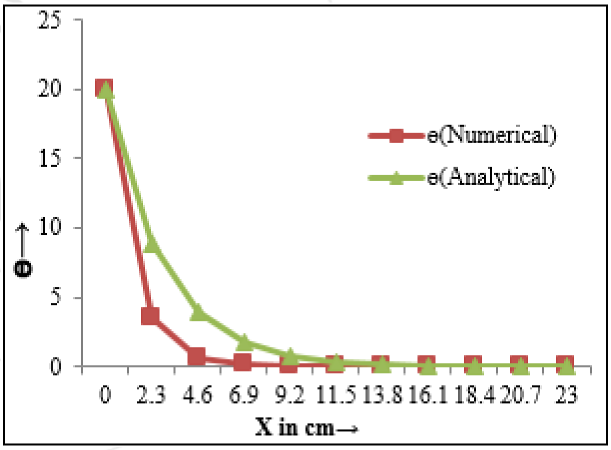


Figure 4.1: Graphical representation of temperature profile along the length of the triangular fin (isosceles)

Fig.4.1 shows that the numerical and analytical solution for the temperature profile gradually decreases along the length of the fin. The numerical result shows greater loss of the temperature than the analytic solution temperature values. Both results show good match at both ends of the fin but there is large difference between these two at the central portion of the fin. However the fins temperature profile of triangular fin (Isosceles) shows good mathematical validity with each other.

2. For Scalene triangle cross section fin surface:
The geometrical dimension for scalene triangle ABC is: AB = 5cm, BC = 4cm, AC = 3cm. The temperature profile for uniform fin having scalene triangular cross section.

Table 4.2: Temperature profile along the length of the triangular fin (Scalene).

X (in cm)	ɵ (Analytical)	ɵ (Numerical)
0	20	20
2.3	8.83	5.7
4.6	3.90	1.30
6.9	1.72	0.30
9.2	0.70	0.10
11.5	0.30	0.02
13.8	0.10	0.01
16.1	0.06	0.0020
18.4	0.03	0.0011
20.7	0.01	0.0010
23	0	0

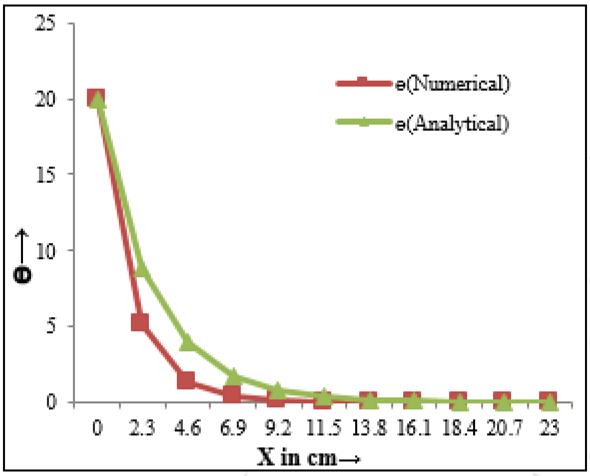


Figure 4.2 Temperature profile along the length of the fin (Scalene triangle cross section) with uniform cross section.

Fig.4.2 shows that the numerical and analytical solution for the temperature profile gradually decreases along the length of the fin. The numerical result shows greater loss of the temperature than the analytic solution temperature values. Both results show good match at both ends of the fin but there is large difference between these two at the central portion of the fin. However the fins temperature profile of triangular fin (Scalene) shows good mathematical validity with each other.

3. For Rectangular cross section fin surface:

The geometrical dimension for the rectangular cross section: length=18cm, width =0.1cm. The temperature profile for uniform fin having rectangular cross section is presented in the table 4.3 below.

Table 4.3: Temperature profile along the length of the Rectangular fin.

X (in cm)	ɵ (Analytical)	ɵ (Numerical)
0	20	20
1.8	8.85	3.7
3.6	3.92	0.68
5.4	1.74	0.12
7.2	0.77	0.023
9.0	0.34	0.004
10.8	0.15	0.001
12.6	0.07	0.00022
14.4	0.03	0.00020
16.2	0.01	0.00010
18.0	0	0

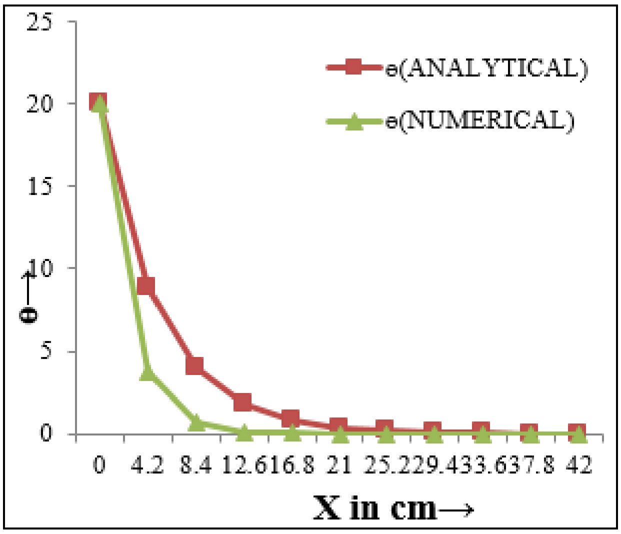


Figure 4.3: Temperature profile along the length of the fin with uniform rectangular cross section

Figure 4.3 shows that the numerical and analytical solution for the temperature profile gradually decreases along the length of the fin. The numerical result shows greater loss of the temperature than the analytic solution temperature values. Both results show good match at both ends of the fin but there is large difference between these two at the central portion of the fin. However the fins temperature profile shows good mathematical validity with each other.

4.3. Conclusions

Both results show good match at both end of the fin but there is large difference between these two at the central portion of the fin. The numerical result shows greater loss of the temperature than the analytic solution temperature values. In Rectangular fin the guess value taking in the numerical method is -20.57672.Whereas in triangular fin for both scalene and isosceles surface the value taking in the numerical method is -6.48885 for scalene finned surface and -7.18769 for isosceles finned surface.

5. Conclusions and Future Work

5.1 Introduction

The heat transfer from the fin surface having uniform cross section along the length of the fin is presented. The uniform cross sections were rectangular and triangular (isosceles, scalene). The following summaries are deduced from the analytical and numerical results.

5.2 Summary

The following summaries were obtained during the analysis of the results.

1. Temperature of rectangular fin increases along the length from the tip to the base of the fin.

2. Temperature of triangular fin increases along the length from the tip to the base of the fin.

3. In case of shooting method, maximum heat transfer rate is increased along the length from the tip to the base.

5.3Future Scope of Work

1) Fin analysis can be carried out by considering two dimensional heat transfer rate.
2) Fin analysis can be carried out by applying heat transfer rate due to radiation from the finned surface.
3) Non-homogeneous and anisotropic materials can be used for analysis of different fin material.

5.4 Conclusion

The overall conclusion from the analysis of the fin of uniform cross section is that the temperature profile decreases with increase of length of the fin. The programming for the present work is obtained using ‘C’ programming language and the operating system is windows-10. All the graphs are plotted using Microsoft excel sheet. The computation is done in Mechanical Engineering laboratory, Centre for Advanced Post-Graduate Studies of Biju Patnaik University of Technology Odisha.

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Appendix <A>
<Software Details>

1. For calculating temperature distribution of rectangular fin using numerical (shooting) method:

```
#include<stdio.h>
#include<math.h>
int main ()
{
int count, n;
float m, h, p, k, a, x, y, yi, L, b, thetai, xi, theta, h1;
count = 0;
n = 10;
L = 18;
b = 0.1;
h = L/n;
k = 380;
h1 = 20;
a =L*b;
p = 2 (L+b);
x = 0;
printf ("Enter the value of xi, yi, thetai:\n");
scanf ("%f  %f  %f\n", &xi, &yi, &thetai);
while (count<=n-1)
     {
     m = sqrt ( (h1*p)/ (k*a) );
     y = yi + m*m*thetai*h;
theta = thetai + yi*h;
     x = xi + h;
yi = y;
xi = x;
thetai = theta;
```

```
printf ("value of x, theta, y is: x=%f y=%f theta=%f m=%f\n", x, y, theta, m);
count++;
      }
return 0;
}
```

2. For calculating temperature distribution of triangular fin (Isosceles)using numerical (shooting) method:

```
#include<stdio.h>
#include<math.h>
int main ()
{
int count, n;
float m, h, p, k, A, a, x, y, yi, L, b, c, thetai, xi, theta, h1;
count = 0;
n = 10;
L = 23;
h = L/n;
k = 380;
h1 = 20;
a = 5;
b = 5;
c = 2;
A=4.89;
p =12;
x = 0;
printf ("Enter the value of xi, yi, thetai:\n");
scanf ("%f  %f  %f\n", &xi, &yi, &thetai);
while (count<=n-1)
      {
      m = sqrt ( (h1*p)/ (k*A) );
      y = yi + m*m*thetai*h;
theta = thetai + yi*h;
      x = xi + h;
yi = y;
xi = x;
thetai = theta;
printf ("value of x, theta, y is: x=%f y=%f theta=%f m=%f\n", x, y, theta, m);
count++;
      }
return 0;
}
```

3. For calculating temperature distribution of triangular fin (Scalene)using numerical (shooting) method:

```
#include<stdio.h>
#include<math.h>
int main ()
{
int count, n;
float m, h, p, k, A, a, x, y, yi, L, b, c, S, thetai, xi, theta, h1;
count = 0;
n = 10;
L = 23;
h = L/n;
k = 380;
h1 = 20;
a = 5;
b = 4;
c = 3;
S= (a+b+c)/2;
A=6;
p =12;
x = 0;
printf ("Enter the value of xi, yi, thetai:\n");
scanf ("%f  %f  %f\n", &xi, &yi, &thetai);
while (count<=n-1)
      {
      m = sqrt ( (h1*p)/ (k*A) );
      y = yi + m*m*thetai*h;
theta = thetai + yi*h;
      x = xi + h;
yi = y;
xi = x;
thetai = theta;
printf ("value of x, theta, y is: x=%f y=%f theta=%f m=%f\n", x, y, theta, m);
count++;
      }
return 0;
}
```

4. For calculating temperature distribution of rectangular fin using analytical method:

```
#include<stdio.h>
#include<math.h>
int main ()
{
int count, n;
float m, h, p, k, a, x, L, b, thetai, xi, theta, h1, m1, m2, m3, m4;
count = 0;
n = 10;
L = 18;
b = 0.1;
h = L/n;
k = 380;
h1 = 20;
a = L*b;
p = 2.0* (L + b);
x = 0;

printf ("Enter the value of xi, thetai:\n");
scanf ("%f  %f\n", &xi, &thetai);
while (count<=n)
      {
            x = xi + count*h;
      m = sqrt ( (h1*p)/ (k*a) );
      m1 = cosh (m* (L-x));
      m2 = (h1/ (k*m))*sinh (m* (L-x));
      m3 = cosh (m*L);
      m4 = (h1/ (k*m))*sinh (m*L);
theta = thetai*[ (m1 + m2)/ (m3 + m4)];
printf ("value of x, theta is:x=%f theta=%f\n", x, theta);
count++;
      m1 = m2 = m3 = m4 = 0.0;
      }
return 0;
}
```

5. For calculating temperature distribution of triangular fin (Isosceles) using analytical method:

```
#include<stdio.h>
#include<math.h>
int main ()
{
int count, n;
float m, h, p, k, A, a, x, L, b, c, thetai, xi, theta, h1, m1, m2, m3, m4;
count = 0;
n = 10;
L = 23;
a = 5;
b = 5;
c = 2;
h = L/n;
k = 380;
h1 = 20;
A = 4.89;
p = 12;
x = 0;
printf ("Enter the value of xi, thetai:\n");
scanf ("%f  %f\n", &xi, &thetai);
while (count<=n)
    {
            x = xi + count*h;
    m = sqrt ( (h1*p)/ (k*a) );
    m1 = cosh (m* (L-x));
    m2 = (h1/ (k*m))*sinh (m* (L-x));
    m3 = cosh (m*L);
    m4 = (h1/ (k*m))*sinh (m*L);
theta = thetai*[ (m1 + m2)/ (m3 + m4)];
printf ("value of x, theta is:x=%f theta=%f\n", x, theta);
count++;
    m1 = m2 = m3 = m4 = 0.0;
    }
return 0;
}
```

6.For calculating temperature distribution of triangular fin (Scalene) using analytical method:

```
#include<stdio.h>
#include<math.h>
int main ()
{
int count, n;
float m, h, p, k, A, a, x, L, b, c, S, thetai, xi, theta, h1, m1, m2, m3, m4;
count = 0;
n = 10;
L = 23;
a = 5;
b = 4;
c = 3;
h = L/n;
k = 380;
h1 = 20;
S= (a+b+c)/2;
A =6 ;
p = 12;
x = 0;
printf ("Enter the value of xi, thetai:\n");
scanf ("%f  %f\n", &xi, &thetai);
while (count<=n)
    {
            x = xi + count*h;
    m = sqrt ( (h1*p)/ (k*a) );
    m1 = cosh (m* (L-x));
    m2 = (h1/ (k*m))*sinh (m* (L-x));
    m3 = cosh (m*L);
    m4 = (h1/ (k*m))*sinh (m*L);
theta = thetai*[ (m1 + m2)/ (m3 + m4)];
printf ("value of x, theta is:x=%f theta=%f\n", x, theta);
count++;
    m1 = m2 = m3 = m4 = 0.0;
    }
return 0;
}
```