Assignment 01: Fin Design

Focus: Fin Design as an Application of Computational Heat Transfer
Deadline : **29th January, 2022, 23:59 hrs.**

Problem Statement 1: [Computational & Graph based visualisations]

Aim: To analyse, discover & compare temperature profile and heat transfer rates with varying x. (1D flow, Variability in shapes)

A unifin model needs to be installed on a cylindrical pipe within which a constant heat flux of (**1600 W/m^2**)is generated. In order to do that, a chemical engineer tried to study for two distinct designed fins namely **rectangular prismatic fin** (triangular in 2D), as well as **cuboidal fin model** (rectangular in 2D). To begin with his steady state analysis, he tried to assume certain assumptions which includes 1D flow of heat, surrounding air temperature being maintained constant at **25°C** alongwith the adiabatic fin tip assumption. He chose copper as the reasonably good material for fin installation, due to its good conductivity coeff. (**398W/m.K**) and better thermal properties.

In order to solve the above mentioned problem, you are required to use some computational skills described in ESO208 using a finite difference approach. Try to use the **Central difference method**, for resolution of both first and second derivative terms (except end nodes)and a suitable **approach** at end nodes and obtain the temperature profile through the length dimension along with the heat transfer through fin.

Description:

Material Used for fin: Copper(Cu)

Dimensions

(1) **Rectangular prismatic model**: Length= 5m (x); width = 5cm (y); thickness = 2cm (z)

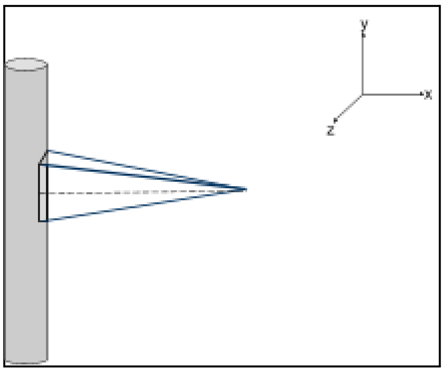

Fig 1: Rectangular prismatic model illustrated

(2) **Cuboidal model**: **Length**= 5m (x); **width** = 5cm (y); **thickness** = 2cm (z) (as usual discussed in Discussion)

Note: 1) Properties of surrounding air, thermal conductivity are to be referred from literature, wherever required and assume them to be constant for this particular problem.

2) Assume some suitable step size along x. (May be in order of 10^{-3}) + If any another assumption required to solve the problem, feel free to assume those (Also, mention them accordingly)

Problem Statement 2: [Graph based visualisations and Numerical analysis]

Aim 2.a: To study annular uni-fin loading on a cylindrical pipe.

A cylindrical pipe with inner and outer radii of R1 & R2 (order of metres) respectively, are used in an industry to carry superheated vapour to manufacturing plants. The pipe with thermal conductivity of 'k' W/m.K is attached with an annular fin with thickness 't' (order of mm) and outer diameter as R3 (order of metres). The surrounding temperature is somehow controlled at '25°C' and has convection heat transfer coefficient being constant as 'h'W/m^2.K. Additionally, the surface temperature of the pipe is maintained constant at 145°C. Deduce an expression of Temperature profile and plot it with varying 'r' as a parameter along with heat loss through pipe.

[Recall MTH102 for Bessel functions of first and second kind (0 order)]

Note: (1) Assume the steady state and 1D flow(radial) + any necessary assumption taken need to be stated as well.

(2) Use the convention of corrected radius.

Aim 2.b: To study annular multi-fin loading on a cylindrical pipe & Using Efficiency curves.

Steam in a heating system flows through tubes (Circular, **Outer diameter 5cm)** and whose walls are maintained somehow at a temperature of **130°C**. Circular aluminium alloy modelled (2024-T6) annular fins of outer diameter **6cm** and constant thickness of **1mm** are attached to the tube. The space between the regular fins is **3mm** and thus there are **250** such fins installed per metre length of the tube. Heat is transferred to the surrounding air maintained at its ambient condition of **25°C**, with a heat transfer coefficient of **40 W/m².K**. Determine increase in heat transfer from the tube per metre of its length as a result of installation of multifin. Also, compare it with the unifin & no fin installation.

Note : Try to use an efficiency chart provided below for this problem.

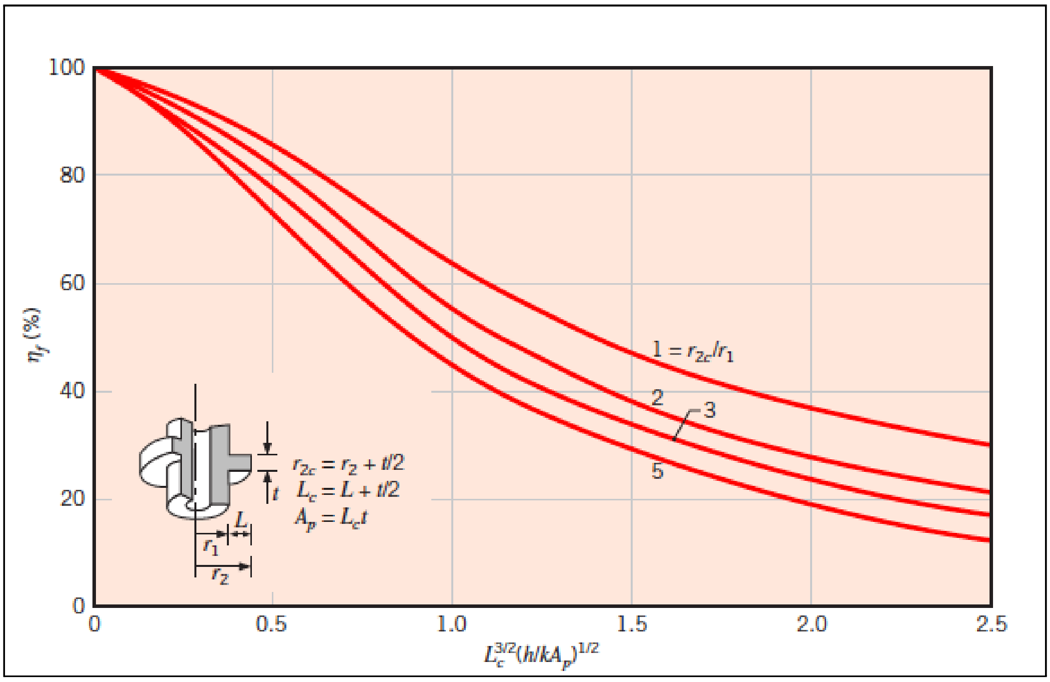

Fig 2: Efficiency chart for annular profiles fin.

Problem Statement 3: [Data analysis & comparison]

Aim 3: Using data provided and variability mentioned, carefully analyse the data firstly, do some logical filtration wherever required and check for the dependency of thermal conductivity for varying temperature. Having the correlation of 'k' with temperature, in order to operate for a steady state condition,

Necessary Information:

D = 5mm

Surface Temperature = 100°C

$h_{\_surrounding}$=100 W/m^2K (constant)

Ambient temperature = 25°C

Case 1: What should be the temperature distribution of the **pin fin** (cylindrical) required for the variability in materials and infinitely long fin assumption.

(a) Cu (k = 398W/mK (constant)) ;

(b)2020-Aluminium (k=180W/mK (constant))

(c)ASI Stainless Steel (k=14W/mK (constant))

(d) Material 'A' whose k is a 'variable' and manipulated as stated below.

Case 2: What should be the **optimum length of pin fin** required for heat transfer for all stated materials above? [Optimality in length is defined in terms of temperature being 99.99% attainment of $T_{\_surrounding}$!!]

Temperature	k (W/m.K)
373	618
423	448
473	677
523	707
565	731
615	761
665	997
715	820
758	777
808	875
858	2986
908	2005
958	963
1008	983
1058	823
1173	1140

Table 1: T v/s k

Problem Statement 4: [Computational & Graph based visualisation]

Aim 4: Transient Heat transfer (Most realistic condition & determination of when the fin is really operational?) Consider a large Uranium plated rectangular fin of (**L = 4cm, w=1cm, th = 0.04mm**), thermal conductivity of **28W/mK** and thermal diffusivity as **12.5x10^{-6} m^2/sec**(Google about thermal diffusivity), that is initially at a uniform temperature of **200°C**. Heat is generated uniformly in the plate at a constant rate of e'(gen) as **5 x 10^6 W/m^2**. At time **t=0**, one side of the plate is brought into contact of running iced water and is maintained at **0^{0}C** at all times, while the other side is subjected to convection to environment at **T_∞= 30°C** with a heat transfer coefficient of **h= 45W/m^2.K**. Considering a total of **15** equally spaced nodes in the medium two inclusive of boundary nodes, estimate the exposed surface temperature of the plate after **2 mins**. After the start of cooling using (a) Algebraic Formulation [Explicit method (i.e using Temperature at (p)th time.)] (b) Matrix Formulation [Implicit method (i.e. using Temperatures at (p+1)th time.)]

Assumption : (1) 1D heat transfer, for each first derivative term either use backward difference approach or may be forward difference approach. (Also, Choose wisely the boundary conditions such that nodes at boundary may also get covered.)

(2) Maybe you can also use a suitable approximation of w>>>th and proceed.

Note: You may assume necessary assumptions wherever required in addition but properly mention about the same.

1) Generate the temperature profile w.r.t x for each half a min. duration. Use a time step of 10 seconds for the most accurate calculation.
2) Also, generate the temperature profile for x= L with variation of time.

E.O.D

Deliverable: Prepare a zip folder which contains solutions to the problems of Assignment 01 & all matlab files used during computation and to be submitted through Google form (link will be shared later)

(Note: All plots must be computed and not drawn manually)

Advisory: Try to give 1 or 2 hrs. for each problem and I am pretty much sure, you all can rock it!