Lakehead University - Department of Mechanical Engineering

ENGI-3454-WA: Applied Heat Transfer (Winter Term 2016)

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Term Project

Thermal Performance Characteristics of an Electrical Power Transmission-Based Heat Sink Using Fin Array Under Various Operating Conditions, Design and Material Characteristics –

1-D Steady-State Heat Transfer Modeling & Simulations

Project Statement: A heat sink composed of a fin array is proposed to effectively enhance heat dissipation from an electrical transmission system (e.g. electric transmission cable). In this term project, it is required to model, analyze and simulate the 1-D steady-state thermal performance of a fin array system with different materials, design aspects, and operating conditions in order to characterize their detrimental effects.

Material/Theory for Study related to this Project Assignment:

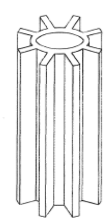
Study textbook chapter 3, section 6 (i.e. 3-6).

Fins Array Specifications:

Consider a fin array composed of a number (N_{fin}) of longitudinal straight fins that have uniform rectangular profiles with constant width (w=1m) and variable finite length L. The fins extends from a surface enclosing a cylindrically shaped electrical transmission system of constant diameter D=50 mm. The heat generated from the system is to be dissipated from its surface, which is maintained at 150 ^oC, using the proposed fins array-based heat sink. The array is made of a certain material with thermal conductivity k and exposed to the surrounding medium at T_∞ with a uniform convection coefficient h.

Heat Sink (Finned) System Thermal Performance Indicators (to be determined for each simulation):

1. The total heat transfer rate from the finned system, $\dot{Q}_t$ (in W)
2. The maximum heat transfer rate from the finned system, $\dot{Q}_{\max}$ (in W)
3. The efficiency of a single fin, η_{fin} (in %)
4. The overall efficiency of the finned system, η_o (in %)
5. The overall effectiveness of the finned system, ε_o
6. The overall thermal resistance of the finned system, $R_{t,o}$ (in $^oC/W$)
7. The fin tip temperature T_L (in ^oC)



A. Simulation based on varying the operating convection coefficient, h: Vary h from 10 to 160 $W/m^2.K$ with an increment of 15. Study the effect of varying h on the heat sink thermal cooling performance. The following parameters are fixed for this simulation: thickness t=0.75mm, N_{fin}=12, L=25mm, material is stainless steel with k_{ss}=75 W/m.K, T_∞ =40^{o}C and the fin tip is convective type (call it **Case A**). In your modeling and simulations, use (i) the accurate fin convective tip-based heat transfer solution, (ii) the approximate corrected length method, to determine the above performance indicators (1 to 7). Compare your results (using % difference).

B. Simulation based on varying the operating cooling fluid temperature, T_∞: Vary T_∞ using 5, 10, 25, 30 and 40 ^{o}C. Fix the following: h=23.3 $W/m^2.K$, thickness t=0.75mm, N_{fin}=12, L=25mm, material is stainless steel with k_{ss}=75 W/m.K, and the fin tip is convective type. In your modeling and simulations, use the approximate corrected length method. Study the effect of varying T_∞ on the above thermal performance indicators (1 to 7).

C. <u>Simulation based on varying the design length, *L*:</u> Vary *L* using 15, 25, 35, 45, and 50 mm (with fixed conditions as in Part B above, with T_∞ =25ºC). Study the effect of varying *L* on the 7 indicators above.

D. <u>Simulation based on varying the fin material type:</u> Perform your simulations based on (i) aluminum fins (k_{AL}=237 W/m.K), (ii) copper fins (k_{cu}=386 W/m.K), and stainless steel fins (k_{ss}= 75 W/m.K). Fix conditions as in part B above with T_∞ =25ºC. Study the effect of changing the fins material on the 7 indicators. Compare your results (use % diff).

E. <u>Simulation based on varying the number of fins N_{fin}:</u> Perform your simulations with varying N_{fin} from 2 to 50 fins with increment of 2. Fixed conditions as in part B, except use aluminum fins and T_∞ =25ºC. Study the effect of changing N_{fin} on the 7 indicators.

F. <u>Simulation based on varying the fin thickness, *t*:</u> Perform your simulations with varying *t* =0.75, 1.0, 1.25, 1.5, 1.75, and 2.0 mm. Fixed conditions as in part B, except use aluminum fins and T_∞ =25ºC. Study the effect of changing *t* on the 7 indicators.

<u>General Methodology:</u>

It is required to perform one detailed and full sample of calculation. Equations recalled from the lecture notes should be numbered as given in the notes. Print an Equation (with a number matching that in the lecture notes) then show numerical values substituted in the Equation with final answers (in **bold** format).

<u>Note:</u> Calculations & numerical simulations should be performed using MS Excel software.

<u>RESULTS:</u>

Effectively and appropriately show and compare your simulation results mostly in graphical and in certain cases Tabulation forms. You need to figure out how you want to effectively represent your data graphically. Number your figures and Tables accordingly and appropriately. The size of a figure should be within 1/3 of the paper size. Table size is flexible depending on contents.

<u>Discussion:</u> Discuss your results in an effective & insightful manner using the above figures. Present a Figure and discuss it then move to the next Figure, repeat for this for all Figures and Tables.

<u>Report Components:</u>

The project report should be submitted in hard copy bound using a spiral-type (or thermal) binder. The page setup should be the standard US letter size. Use Font size 11, Times New Roman font, and line spacing 1.5. The report should be typed using MS Word and the curves in the graphs should be distinguished by color and appropriate legends should be used. The sheets in the report should be double-sided (i.e. use both sides of the sheet) and pages should be numbered. The total number of pages <u>should not exceed 40 pages (max # of sheets in the report = 20)</u> without missing any of the required parts and results. The report should contain the following sections:

1. Cover page (includes Dept. Name, course code and name, term project title, student name & ID#, seat # (circled), professor name, and submission date)
2. Acknowledgement (student learning benefits/outcomes from this project)
3. Introduction (include project problem statement and detailed schematic, and project objectives & requirements)
4. Methodology and detailed sample of calculations as required (in the body of the report)
5. Results & discussion (effectively discuss your results)
6. Conclusion (Briefly highlights your findings and key results)
7. References used (Dr. Basel Ismail's lecture notes ENGI-3454: Applied Heat Transfer Design)
8. Appendix (attach a copy of this handout to your report as an appendix and one sheet from Excel showing some of your results as a proof). It should be noted that you could be asked, in case needed, to submit your excel document as a verification of your work.

Submission Deadline (without penalty): by Wednesday, March 30th, 2016 (at the start of the class 1pm)

Deadline for late submission with penalty (-20%): No later than Monday, April 4th, 2016 (Start of the class 1pm). Any submission after this late deadline will not be marked (get zero mark)

Project mark:
As to the course outline, this term project constitutes **15%** of the total course mark.

Academic Misconduct & Dishonesty

Projects must be completed independently (the students should perform their projects independently in their own). Any violations may result in giving zero mark for those who engaged in this misconduct! The University takes a most serious view of offences against academic honesty such as plagiarism, cheating and impersonation. Penalties for dealing with such offences will be strictly enforced. A copy of the "Code of Student Behavior and Disciplinary Procedures" including sections on plagiarism and other forms of misconduct may be obtained from the Office of the Registrar and can be found in the University Calendar. http://mycoursecalendar.lakeheadu.ca/pg39.html