**Design of a Heat Sink**

As a highly qualified Mechanical Engineering graduate you have been employed by a large multi-national company in their design team. The company produces a wide range of electrical and mechanical equipment and one particular piece of equipment has caused the company extensive problems as it continually fails due to excess heat causing the electrical circuitry/components to fail. After many years of trying to solve the problem, and failing, they have realised that only an MMU Engineering graduate is up to the job and thus you have been assigned the task.

A heavy duty piece of electrical switching equipment, generates a tremendous amount of heat. To prevent the equipment failing it is essential that a heat sink is designed to remove this heat. Using the windage of the electrical equipment it is possible to blow air over the heat sink so that the forced convection may increase the effectiveness of the heat sink.

Effectively the equipment has a heat sink footprint that measures 20cm x 20cm. Onto this square flat surface fins may be attached.

You quickly decide that there are two possible shapes the fins may take.

a) Flat plate fins (minimum fin thickness = 2.0mm, maximum fin thickness = 5.0mm minimum gap between fins = 5.0mm)

b) Circular Pin fins (minimum fin diameter = 5.0mm, maximum fin diameter = 10.0mm, minimum gap between fins = fin diameter

For both types of fin there also exists 2 important restrictions. No fin can be longer than 200mm and the maximum mass the heat sink can be is 2.0kg (mass of the fins only)

Given the constraints of the problem you quickly realise that an aluminium alloy is likely to be the material of choice. An extremely effective material to use as a fin in terms of thermal properties (kAL = 202 – 249 W/mK), you also recognise that it has a relatively low density (ρAL = 2700 kg/m3) that also makes it a desirable material for a low weight solution.

For the heat loss using thin flat plate fins you realise that standard fin theory will be relevant and the only difficulty will be knowing what value to use for “h”. However, you know that various correlations for flow over flat plates are given in Chapter 5 of Holman. (Heat Transfer, McGraw-Hill)

For the heat dissipation calculations for pin fins you immediately realise that the work of Grimson and Zukauskas (Holman, Chapter 6) on flow over tube banks may be used (with a few assumptions?) for flow over a bank of pin fins.

The heat transfer characteristics of staggered and in-line tube banks were studied by Grimson and on the basis of a correlation of the results of various investigators, he was able to represent data in the form

$\overbar{Nu}=\frac{hd}{k\_{f}}=C Re\_{f}^{n} Pr\_{f}^{1/3}$ (1)

Properties for use with Eqn (1) are evaluated at the film temperature as indicated by the subscript *f*.

The values of the constants *C* and *n* are given in Table 1, below, and are valid to tube banks having 10 or more rows in the direction of flow. For fewer than 10 rows the ratio of *h* for *N* rows is given in Table 2. The Reynolds Number is based on the maximum velocity occurring in the tube bank, i.e., the velocity through the minimum-flow area. This area will depend on the geometric tube arrangement.

In-line Arrangement $u\_{max}= u\_{\infty }\left(\frac{S\_{n}}{S\_{n}-d}\right)$

Staggered Arrangement $u\_{max}= \frac{u\_{\infty \left(S\_{n}/2\right)}}{\left[(\frac{S\_{n}}{2})^{2}+S\_{p}^{2}\right]^{1/2}-d}$

Where u∞ is the free stream velocity entering the bank and *Sn* and *Sp* are parameters of the geometry.



|  |
| --- |
| Sn/d |
|  | 1.25 | 1.5 | 2.0 | 3.0 |
| Sp/d | C | n | C | n | C | n | C | n |
| In Line |
| 1.25 | 0.386 | 0.592 | 0.305 | 0.608 | 0.111 | 0.704 | 0.0703 | 0.752 |
| 1.5 | 0.407 | 0.586 | 0.278 | 0.620 | 0.112 | 0.702 | 0.0753 | 0.744 |
| 2.0 | 0.464 | 0.570 | 0.332 | 0.602 | 0.254 | 0.632 | 0.220 | 0.648 |
| 3.0 | 0.322 | 0.601 | 0.396 | 0.584 | 0.415 | 0.581 | 0.317 | 0.608 |
| Staggered |
| 0.6 | - | - | - | - | - | - | 0.236 | 0.636 |
| 0.9 | - | - | - | - | 0.495 | 0.571 | 0.445 | 0.581 |
| 1.0 | - | - | 0.552 | 0.558 | - | - | - | - |
| 1.125 | - | - | - | - | 0.531 | 0.565 | 0.575 | 0.560 |
| 1.25 | 0.575 | 0.556 | 0.561 | 0.554 | 0.576 | 0.556 | 0.579 | 0.562 |
| 1.5 | 0.501 | 0.568 | 0.511 | 0.562 | 0.502 | 0.568 | 0.542 | 0.568 |
| 2.0 | 0.448 | 0.572 | 0.462 | 0.568 | 0.535 | 0.556 | 0.498 | 0.570 |
| 3.0 | 0.344 | 0.592 | 0.395 | 0.580 | 0.488 | 0.562 | 0.467 | 0.574 |

Table 1 – Modified correlation of Grimson For Heat Transfer in tube banks of 10 rows or more.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| N | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Ratio for Staggered Tubes | 0.68 | 0.75 | 0.83 | 0.89 | 0.92 | 0.95 | 0.97 | 0.98 | 0.99 | 1.0 |
| Ratio for in line Tubes | 0.64 | 0.80 | 0.87 | 0.90 | 0.92 | 0.94 | 0.96 | 0.98 | 0.99 | 1.0 |

Table 2 – Ratio of h for N rows deep to that for 10 rows deep.

**SECTION1: Heat Transfer Rate Calculations (50%)**

1) Design a heat sink that will dissipate as much heat as possible – if it is assumed that the base plate is kept at a constant temperature of 380K.

2) Assume the temp of the ambient air, at inlet, used to cool the heat sink is T∞ = 300K

Assume the velocity of the air, at inlet, is 1.0m/s. State fully any assumptions you make.

**This part of the assignment should be no more than 10 pages long.**

**SECTION2: CFD (50%)**

In this section, you are supposed to produce a comprehensive report to present to your line manager investigating the possibility/feasibility of modelling the above problem using the latest version of the commercial Computational Fluid Dynamics (CFD) code, Ansys-Fluent. Provide details on the following aspects of your CFD analysis (i.e. use these headings in your report):

a) Method: Advantages and disadvantages of using CFD as opposed to other methods for this project.

b) Computational Domain: How to generate appropriate CAD files and what the optimum computational domain would be by using appropriate figures.

c) Boundary Conditions: The type of boundary conditions you would need to use for such a problem by using appropriate figures to show details.

d) Mesh: The choice of mesh and the software to use to generate your mesh.

e) Post-processing: The type of figures you would see appropriate to show your results and the software you would use to generate the figures.

f) Feasibility: Estimated cost and time to conduct your simulations, assuming you only have access to a standard HP Z840 workstation with the latest Windows and Microsoft office already installed on the machine. You need to include the costs of all the specialist software, programs that you would need for this task. Use appropriate tables, figures, Gantt Chart, etc to represent a feasibility analysis for simulating this task using CFD.

g) References: You should use ‘Harvard style’ referencing throughout your report in this section.

General Information: This report requires significant amount of research from different sources, and you should produce a professional report, well-structured, all typed using Microsoft Word Document (or Latex) and include all relevant figures and tables. **The CFD part of assignment (including the main text and all the relevant figures, tables, references, etc) must be no more than 6 pages long**. Anything more than that is not going to be marked and you may even be penalised. This page limit would mean that you should restrict your attention to the key aspects of this study and should avoid including figures, data or information which are not essential.