Midterm Design Project

Report and Presentation Due: Monday, April 2nd 6:00 pm
Progress Presentation: Monday, March 19th 6:00 pm

1 Overview

You have been asked to design a heat exchanger which will be used as an oil cooler in a gasoline IC engine. This heat exchanger you will be designing will be used to ensure that the lubricating oil does not thermally breakdown. The heat exchanger will be an oil cooler with the rejecting medium being air that will be delivered via a duct. The duct and the heat exchanger comprise your device.

Your goal is to optimize the efficiency of the heat exchanger using CFD as a tool to find the optimal geometry. The primary drivers of your design will be to reduce the size and weight of the heat exchanger to keep costs reasonable.

2 Performance Requirements

Your heat exchanger design will utilize a separated flow design, whereby your hot fluid is light oil (motor oil), and your working cold fluid is air. Both fluids will be under forced flow conditions, the oil via a pump, and the air driven by the vehicle speed. The specific requirements of the project are as follows:

- The heat exchanger shall be capable of rejecting the required heat when the air temperature is 108^{o}F and the vehicle is traveling at a minimum of 25 mph (it does not have to work below this speed).
- The heat exchanger inlet face must be less than 36” in width or height. The inlet size (face area) to the heat exchanger must be 250 in^2 or less. The device may be as deep as required.
- Due to packaging constraints, the heat exchanger is mounted 60” downstream of the inlet of a supply duct.
    - The air inlet side of the duct on the front of the vehicle has a section of 22” x 12” (height x width).
    - The duct may transition in cross section over its length, or at the outlet, but must exactly fit the inlet of the heat exchanger at the outlet location of the duct.
- The specification of oil temperature at maximum load is:
    - Entering: 350^{o}F
    - Exiting: 195^{o}F maximum
- The flow rate of oil at maximum operating load is to be between 3.5 gpm and 5.5 gpm.

2.1 Assumptions

- You may assume the oil has the following properties:
    - SG = 0.86
    - μ = 34.5 cP
    - k = 0.15 Btu/hr-ft-^{o}R

- c_p = 0.5 Btu/lbm-^oR

3 Project Requirements

The project's design criteria are multifaceted. They include the following:

- Meeting the design performance requirements and limit specifications.
- Be of compact design.
- All work should be reported in I-P units.

3.1 Items of non-responsibility

You will not be responsible for engineering or reporting the following beyond common sense assumptions:

- Material compatibility / costs
- Manufacturing methods / costs

4 Deliverables

Your design needs to be presented in several ways and needs to fully convey the manner in which it works. These items should include the following:

4.1 Progress Presentation (5 minutes)

Halfway through the design period you will be required to give a brief presentation () to show progress on your project. You should present at a minimum:

- Design concept
- Initial hand calculations
- Any preliminary simulations or models

4.2 Final Report

The report should be typed and submitted on time by the final delivery date and time. Your report should be of a professional level meeting the standards discussed in class and shall be submitted in paper and electronic form (PDF). In general color or black and white images are acceptable as long as they are legible and clearly explain the results.

Your final report should include:

- Design assumptions.
- Statement of design concept.
- Scaled sketches illustrating the conceptual design.
    - The basic design of each of your device should be illustrated in clear scaled sketches. All components used should be sized and called out in your drawings. Do the anticipated geometric complexity of your components the use of 3D CAD is strongly recommended.
    - It is not necessary to draw every view of every component that is to be designed. Drawings should only be included if they show meaningful information that cannot be illustrated on another drawing.
- CFD simulations that demonstrate the following:
    - The simulated entrance and exit temperatures for both working fluids

        - Air entering the duct through exiting the heat exchanger
        - Oil entering and exiting the heat exchanger
    - The simulate pressure drop for both fluids across the overall device
        - Air pressure drop across the duct and heat exchanger
        - Oil pressure drop across the heat exchanger
    - Temperature contour plots showing fluids under steady state conditions across the device
    - Pressure contours showing the distribution of both working fluids under steady state conditions
    - Velocity / streamline plots that demonstrate the flow patterns through the heat exchanger
- Hand verification calculations for the major elements of your design, including:
    - Approximations for entrance and exit temperatures for the oil and the air based on fluid, heat transfer and thermodynamic theory
    - Approximations for pressure drop for the oil flow
- The operating conditions of your design at the specified conditions, including:
    - Oil flow rate
    - Summarized overall temperature difference for both working fluids across the entire device
    - Summarized overall pressure drop for air and oil sides
- The efficiency of the heat exchanger based on simulation results
- Overall size of the unit, length, width and depth
- A dry weight estimate
- Design time estimate, cumulative number of hours spend developing your design
- Statement of design benefits.

4.3 Final Presentation (8 minutes)

Your final presentation should provide the audience with an overall summary of your design and the key analyses that were used to arrive at it. This should include:

- The design concept
- Your heat exchanger performance, i.e. temperature differentials, pressure drops, efficiency, size weight, etc.
- How CFD simulations helped influence your design
- Design time estimate
- Design benefits.

5 Suggestions

The following is a list of suggestions that may be helpful in getting a jump start on your design submission.

5.1 Basic design

Start with the big picture and work your way down to the details. Once you have a basic design concept the details will be much easier to formulate. CFD models are very good at not only determining detailed flow parameters for a final design but also at providing general system behavior.

5.1.1 Material properties

You may use material properties from a text book, Mark's Handbook or Fluent's material library. Check to see that the figures you have make sense.

5.1.2 Starting points

There are many resources out there for how heat exchangers work. Use them to get a basic idea as to who you want to design your system. Make sure the design is realistic; i.e. material properties used are reasonable and within normal limits. The following are recommended readings to get you started in your work:

- http://en.wikipedia.org/wiki/Heat_exchanger

- Mark's Standard Handbook for Mechanical Engineers – Section 4.4 heat transfer via conduction and convection (10^{th} Ed.)

5.2 Modeling in general

Use the modeling tools at your disposal to your advantage. Use symmetry, sub-modeling and other modeling techniques to reduce your efforts and make a simplified model. If you can model something simply and prove your concept works that will be sufficient assuming you can back it up. Large very complicated models used upfront are often a very inefficient way of getting to a good solution.

Be aware of the limitations we have discovered in class and through assignments. Be critical of the results you generate. Check all simulations with a basic hand calculation.

5.3 Presentation of results

As in the rest of your careers you will find the best design will never be chosen if the person who is buying it does not understand or trust it. Try and make all the hard work you put into you thoughts about how to solve this problem as clear as possible. Use images and schematics to illustrate things and put time into making graphics clear and presentable.

5.4 Time

It is strongly suggested that you begin work on your design early. Design work coupled with CFD analysis can be time intensive. Ensure that you will have sufficient time to properly prepare your presentation and report.