Test 4 Reflection

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MET 440 Heat Transfer

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Learning Objectives

Test 4 focused on the following course objectives:

- Explain the physical meaning of dimensionless parameters and their relation to different heat transfer problems
- Differentiate between forced and natural convection heat transfer
- Solve forced convection problems using different experimental correlations

Test 4 had a single problem, and it was the same problem assigned for Test 1. This time, we were tasked with solving the problem without having the convective coefficients defined from the beginning, requiring us to solve for those parameters ourselves using more advanced analysis methods like logarithmic mean temperature difference, Nusselt and Reynold's number analysis, and complex iteration. The problem also included both natural convection and forced convection within the system, requiring different approaches to solve for each area. The use of experimental data was necessary to define the parameters of the fluid flowing in the pipes when defining the Nusself and Reynold's numbers for that area.

Grading

Problem 1

This was the exact same problem as Problem 1 on Test 1. The problem proved to be complicated then and was only more complicated this time around as all the *h* values for convective heat transfer were left out and had to be derived before a final answer could be arrived at.

Finding issues with this problem is difficult as the answers to the prompts will always have very small windows of acceptability. Comparing the new answers gained from this attempt to those from the first attempt on Test 1, there is only a 2% difference in the amount of heat collected by the water in each tube and the water flow rate according to the given solutions. Comparing my answers for Test 4 to the solutions for Test 4, there is only a 0.2% difference between my solution and the given solution, with both of my answers being slightly smaller.

Initially, this would look like a great result, but checking deeper into the process, there was a mistake made that created some issues within the iteration. The methodology between the solution I reached and the provided solution are very similar. Both approached the issue by assuming the missed convective heat transfer coefficients, solving for the missing parameters of the system, and then comparing those assumed results to results provided by experimentally backed equations for the same set of properties. By performing this process a few times, the assumed values would closely match the experimental ones and the final answers would be acceptable.

When comparing my attempt to the solution, there are a couple of small discrepancies which lead to interesting differences in the calculated values on the tables, even if the final answers were very similar. The first issue arises when calculating the Nusselt number for the water flow. In my attempt, I assumed the pipes the water flowed through to be of a constant heat because the system was steady-state. In the solution, the pipes are of a variable heat, and that meant using a different value for the Nusselt number, 4.36 rather than 3.66. Another difference in the analysis of the flowing water stems from a very different result for Reynold's number. The range of Reynold's numbers I calculated were between 19 and 20, which is an absolutely tiny number. I kept the results as they were associated with an incredibly small flow rate, and so a very low Reynold's number made sense. In the solution, the Reynolds number is still very small, but is in the range of 120 to 130. This difference caused a larger difference in the *h* value for the flowing water. In my system, the smaller Reynold's mean that the *h* for the water was around 170 W/m^2K while the solution has it more than seven times higher at nearly 1300 W/m^2K. This discrepancy carried forward.

For the ambient air and the air in the insulated air gap, the shift in the *h* value for water made an impact on how large these resistances were in order to counteract that difference and still maintain the same heat absorption. Both the ambient air and the insulated air gap in my answer had *h* values around 4 W/m^2K while the solution has both around 2 W/m^2K. Though the difference in *h* value is small for both the water and the air boundaries, relative to the answers, they are fairly far from correct. Carrying forward the error in the Reynold's number impacted the values calculated using the mass flow rate, but largely cancelled out with regards to the final answers as the convective transfer of the water was reduced, but the convective transfer of all of the air interfaces was subsequently increased. Instead of using an average temperature for the air gap, the top and bottom were treated separately. Though this method is functional, it did not provide the correct average temperature for the gap and therefore complicated the process while also reducing the efficacy of the LMTD method in that area.

Grade

Following the provided rubric, the grade I would give my attempt is a 90%.

- The purpose is clearly stated and contains all the relevant information that must be found in the solution. **5/5**
- The drawings and diagrams are clearly labeled, there is a full diagram, a zoomed in area for inspection and an included resistance circuit for the system. **10/10**
- Three sources are listed in MLA format that provide all the sources used for this test. **5/5**
- The design considerations set the boundaries for the problem clearly. **10/10**
- The data and variables section outlines all the information provided from the problem statement along with easily attainable properties for the materials involved. **5/5**
- The procedure section clearly outlines the steps that will be taken to solve the problem in as concise a manner as possible. Due to the length of the procedure needed to solve for all the missing variables, it is longer than the single paragraph called for on the rubric, but each step is necessary to complete the problem and the length is like the procedure section on the provided solution. **25/25**
- The calculations portion shows some errors. Though the final results do not differ largely from those given, the underlying math has issues. A flaw with the Reynold's number caused large discrepancies for the final *h* values for all parts of the system. Using the separate surfaces of the air gap instead of an average temperature also impacted results. For the most part, the correct equations are used and no errors were made in calculation. Choosing incorrect equations/parameters lead to the errors in this section. **10/20**
- The summary is concise and contains the answers from the purpose section. **5/5**

- The materials section lists all the materials in the system. **5/5**
- The analysis comments on the aspects of the system that make it unique and compares the initial assumptions to the final answers. **10/10**

Discussion

Revisiting a problem from Test 1, which I found very difficult at the time, proved to be just as stressful this time. Examples we had worked in class were not nearly as complex, and increasing the scale of those tactics to encompass such a large system was a challenge. Having access to the worked-out answer from Test 1 was very helpful as it allowed me to check any new answers against them, but the increased complexity introduced by the last few chapters made for a much more difficult problem.

I made several attempts at creating an Excel spreadsheet that could neatly and concisely solve for all the variables necessary for this test, but continually struggled to find something could do everything necessary at once. Eventually I settled for much smaller groups of variables and manually shifted later sections to incorporate new answers. Though this method proved slower than those used in class, it was also effective.

From a professional standpoint, it is easy to see how these concepts would play an important role in the design of any system where heat transfer would be important. Having the skills to setup a procedure which can incorporate so many variables is valuable. My past working in an injection mold shop makes me consider how useful this sort of analysis would be when building new mold designs, as the heat transfer problems between the mold, the hot plastic, the air trapped in the various cavities and the air outside the mold surface would all need to be accounted for when considering how long to keep the mold closed to set the plastic and how difficult it would be to separate the plastic from the mold when the process is complete. Failing to analyze all these factors prior to building the mold could result in a very poor final product that fails to accomplish what it was designed to do.

This test stretched my ability to use Excel effectively, and I learned a lot because of it. Having to account for so many shifting variables meant crafting the spreadsheet slowly and carefully, and restarting the process more than once to make sure the end result was readable and usable. It made me appreciate what a powerful tool Excel can be when it is used with care by knowledgeable people.

All told, I spent more than 12 hours on this test. Two hours were spent poring over tables and charts, finding proper polynomial equations for all the properties of air and water that needed to be calculated, and gathering all the different equations necessary to analyze all the materials into one, easy to read place. Actually building a procedure to utilize all those tools took another four, as I had a hard time visualizing how the different missing information would need to be used together to get final answers and I could not directly apply that to the examples in class without getting confused. The final 6 hours were spent making the Excel and test documents. I restarted the Excel process 2 separate times with many edits in between trying to find ways to make the information work for me the way I needed it to. Writing up that process in Word with MathType was also very time consuming, as there were many equations and some of them were quite long and involved.

If I were to take this test again, I would focus more on making the Excel document as clear and concise as I could as early in the process as possible. Once I had that setup, working with the massive amount of numbers involved was much easier and less daunting. Had I started there instead of working out the first iteration completely by hand first, I would have saved time and felt less overwhelmed by the scale of the problem.