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Ian Villaroman-Team Member

MECH 420-02 FALL 2016

Instructor: Dr. Gianfranco DiGiuseppe

"Utilization of MATLAB to solve heat transfer problem"

Date: December 13, 2016

Abstract

In this project, the team wanted to analyze what would happen to the heat rate of a cylindrical rod when two of the variables are changed. The variables we changed were Tsurr and

the diameter of the un-insulated pipe. The team created a MATLAB script to do this with ease. We used 295K, 345K and 395K for temperature of surface, Tsurr, and used diameters in the interval 0.1 meter to 1 meter, in increments of 0.1 meters. After running the script and plotting what we found, we saw that the graphs were linear.

Team Member Roles and Contribution to the Project (Bulleted)

- Name: Clayton Schultz
  - Role: Mathematician and aid to problem formulation
  - Work done: Executed MATLAB script, designed system variables and aided in writing of completed results.
  - Per cent of project: 50%
- Name: Ian Villaroman
  - Role: Scribe and aid to problem formulation
  - Work done: Creation of heat transfer problem, writing of project, and hand calculations
  - Per cent of project: 50%

Problem

A un-insulated pipe is routed through a building. The un-insulated pipe has a diameter of **100 millimeters** and a length of **20 meters**. The pipe's diameter is **0.10 meters** The pipe's outer surface temperature is maintained at **175°C** and the natural convection coefficient is **5 W**$/m^2K$ The exposed pipe surface emissivity is **0.7.**

What is the total rate of heat loss from the pipe when the buildings walls and air are at 22°C.

Known:

$$q''_{rad} = \varepsilon\sigma(T_s^4 - T_{surr}^4)$$
$$q_{rad} = A[\varepsilon\sigma(T_s^4 - T_{surr}^4)]$$

$$q''_{conv} = h(T_s - T_\infty)$$
$$q_{conv} = A[h(T_s - T_\infty)]$$

$$q = q_{conv} + q_{rad}$$

Pipe known
(*** Values **bolded** and underlined are the independent variables changed throughout the experiment, see Plotted chart below.*)

L= 20 m
D= 0.10m dia
ε= 0.7
$\sigma = 5.67 * 10^{-8} \frac{W}{m^2 * K}$

Walls & Air

T_∞=22°C
T_∞= 295 K

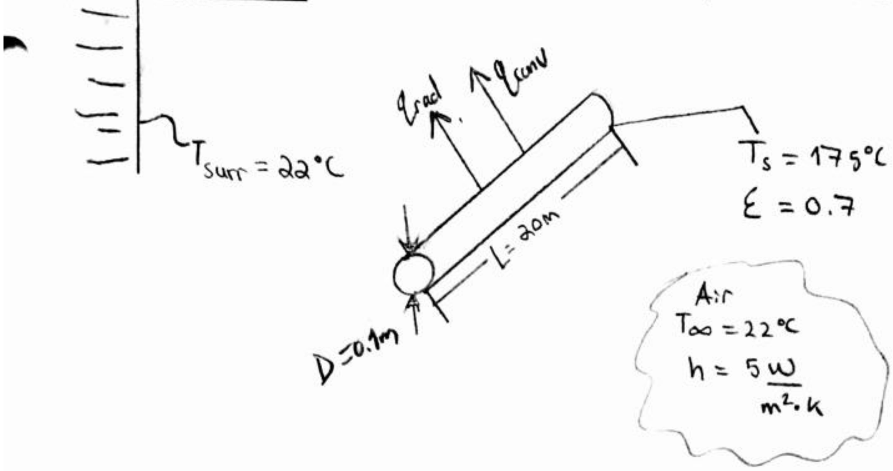
Surface

T_s=**175**°C
T_s= 448 K
h= $5\frac{W}{m^2 * K}$

Hand Calculations

Clayton Schultz
Ian Villaruman

Note
Walls & Air = $T_\infty = 22°C$



$\sigma = 5.67 \cdot 10^{-8} \frac{W}{m^2 \cdot K^4}$

Area of cylinder $= \pi D L$

$A = \pi \left(\frac{0.1m}{1}\right)(20m)$

$A = 6.283\ m^2$

Assume
- Steamline is constantly being used
- Net radiation is between Steamline & walls

Solution

recall $q''_{rad} = \varepsilon\sigma(T_s^4 - T_{surr}^4)$

$\hookrightarrow q_{rad} = A[\varepsilon\sigma(T_s^4 - T_{surr}^4)]$

recall $q''_{conv} = h(T_s - T_\infty)$

$\hookrightarrow q_{conv} = A[h(T_s - T_\infty)]$

Radiation requires change to K

$$q = q_{conv} + q_{rad}$$
$$= A\left[h(T_s - T_\infty) + \varepsilon\sigma(T_s^4 - T_{surr}^4)\right]$$
$$= A\left[\left(5 \frac{W}{m^2 \cdot K}\right)(175-22) + (0.7)\left(5.67 \cdot 10^{-8} \frac{W}{m^2 \cdot K^4}\right)\left((448K)^4 - (295K)^4\right)\right]$$
$$= (6.28m^2)\left[765 + 1298.21\right]$$
$$= (6.28m^2)\left[2063.21\right]$$

$$\boxed{q = 12,957\ W} \rightarrow 13\ kW = q$$

Project Description

In this project, we wanted to find the heat rate of a cylindrical rod. The team asked "What if" questions such as "What if changed the diameter of the rod to a value located between 0.1 to 1 meter?"' or "What if we tested three different Tsurface temperatures?" We created a MATLAB script to answer these questions and plotted each heat rate with three different TSurfaces values.

Results and Discussion

Equation for Heat Rate:

q = □□□□□ + □□□□

q = □[□(□□ − □□□□) + □□(□□^{4} − □□□□□^{4})]

MATLAB equation: (taken directly from MATLAB)

```
D = .1:.1:1;
L = 20;
A = (pi*D*L);
E = .7
r = 5.67*10^-8
Ts = 448
Tsurr1 = 295
Tsurr2 = 345
Tsurr3 = 395
Tinf = 295
h = 5

q_doublep_rad1 = A*(E*r*(Ts^4-Tsurr1^4));
q_doublep_conv1 = A*[h*(Ts-Tinf)];

q1 = q_doublep_rad1 + q_doublep_conv1;

q_doublep_rad2 = A*(E*r*(Ts^4-Tsurr2^4));
q_doublep_conv2 = A*[h*(Ts-Tinf)];

q2 = q_doublep_rad2 + q_doublep_conv2;
```

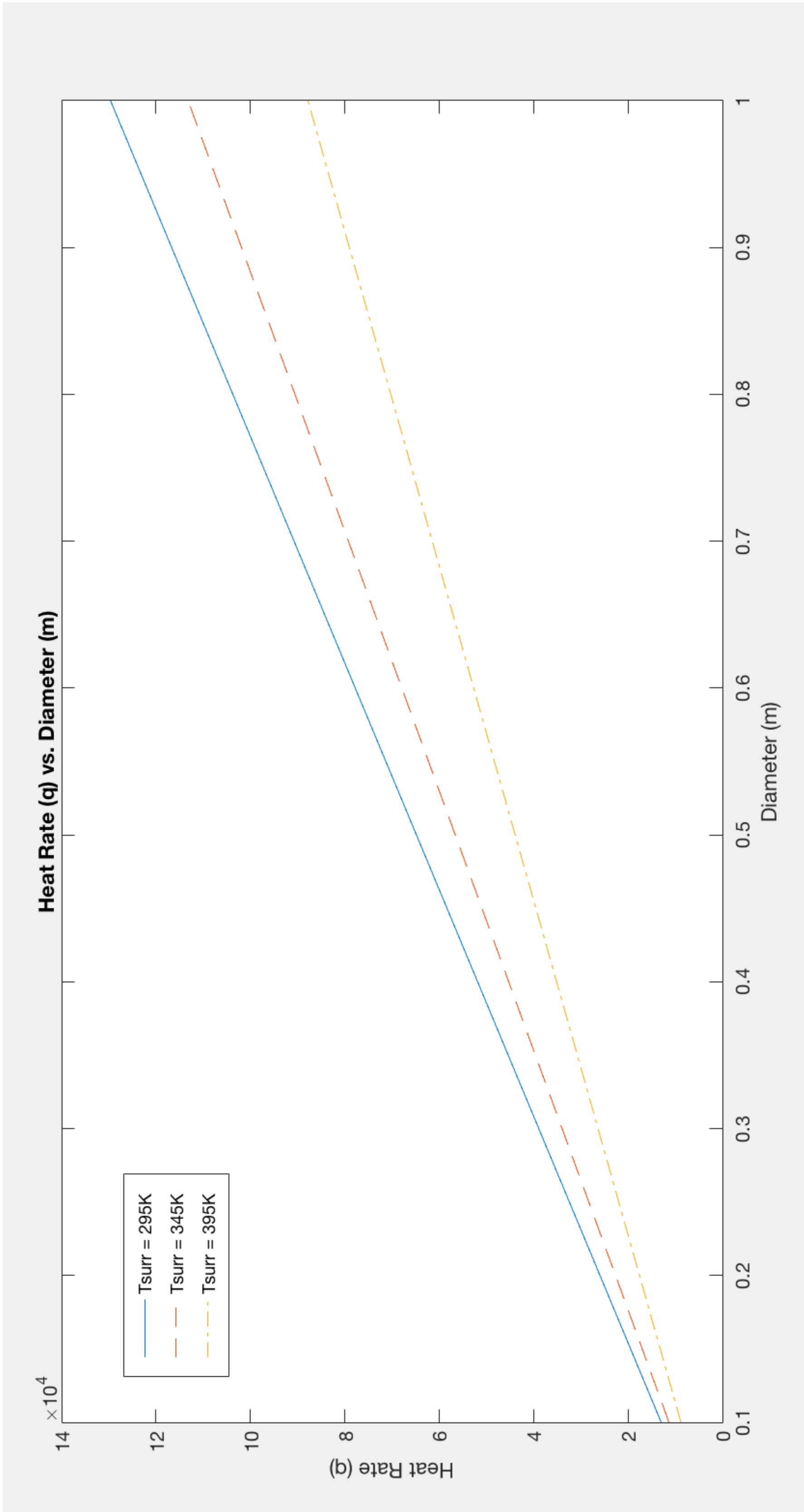
```
q_doublep_rad3 = A*(E*r*(Ts^4-Tsurr3^4));
q_doublep_conv3 = A*[h*(Ts-Tinf)];

q3 = q_doublep_rad3 + q_doublep_conv3;

plot(D,q1,D,q2,D,q3);
```

Heat Rate (q) Tsurr = 295K	Heat Rate (q) Tsurr = 245K	Heat Rate (q) Tsurr = 395K	Diameter
12963.53131	11319.22182	8781.322785	0.1
25927.06263	22638.44364	17562.64557	0.2
38890.59394	33957.66546	26343.96836	0.3
51854.12526	45276.88728	35125.29114	0.4
64817.65657	56596.1091	43906.61393	0.5
77781.18789	67915.33092	52687.93671	0.6
90744.7192	79234.55274	61469.2595	0.7
103708.2505	90553.77456	70250.58228	0.8
116671.7818	101872.9964	79031.90507	0.9
129635.3131	113192.2182	87813.22785	1

MATLAB plotted graph of Heat Rate (q) vs. Diameter (m)



Heat Rate (q) vs. Diameter (m)
Heat Rate (q)
Diameter (m)
×10^4
0
2
4
6
8
10
12
14
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Tsurr = 295K
Tsurr = 345K
Tsurr = 395K

Theoretical Analysis

Learning Courses Met:

The following are objectives met for the completion of this project. The complete list is located on Dr. Gianfranco DiGiuseppe's syllabus for the the MECH-420 Heat Transfer course at Kettering University. The numbered list is in reference to the syllabus documentation.

1) Identify the three modes of heat transfer: conduction, convection and radiation for a given energy system. [ABET's A,E,K]
    a) In regards to the hand calculations section, convection and radiation is shown in the FBD of the pipe. Convection and radiation were used thoroughly in our heat transfer course and these basic principles allowed for completion of higher level problems such as chapters 7-9.
2) Analyze physical heat transfer problems by reducing them to workable mathematical models. [ABET's A,E,K]
    a) The team simplified the problem with the use of sketches and free body diagrams (FBD) to allow for easy setup and execution of the heat rate equations.
3) Solve heat conduction problems in steady-state and transient conditions through application of rate equations and the conservation of energy. [ABET's A,E,K]
    a) Use of the heat rate equations for radiation and convection was used throughout the project to find the heat rate of the system.

7) Utilize suitable numerical techniques and computer tools in the formulation and solution of open-ended heat transfer design problems in a project team setting. [ABET's A,E,K]
    a) The MATLAB computer application was used to complete the problem discussed in this project. The team created the problem to allow for future students to take it

and solve it with their own variables. The problem shows no boundaries as their are millions of combinations for variables.

Conclusion

The “Heat Rate (q) vs Diameter (m)” shows that as the surface temperature (Tsurr) and the pipe diameter increases, the heat rate of the system becomes smaller. The problem allowed our group to understand surface temperature is the main component of heat transfer. If the surface is warmer than the rest and the other surfaces, there will need to be less heat transfer. Our experiment shows exactly that. Therefore, our experiment is correct.

The use of our MATLAB code can be used for future generations of heat transfer students trying to understand what will of occur if variables within the project are changed. Theses variables represent the different occurrences that may occur in the real world and the MATLAB code allows students to change the variables within the system quickly and be able to reach variable combination that handheld calculators can only dream about. Use of our MATLAB code would be distributed to heat transfer professors looking for a laboratory exercise for their students to complete.

REFERENCES

DiGiuseppe, Gianfranco. "Surface Energy Balance." MECH-420 Heat Transfer. MI, Flint. 07 Oct. 2016. Lecture.

Incropera, Frank P., and David P. DeWitt. *Introduction to Heat Transfer 6th Edition*. New York: Wiley, 1996. Print.