Analyzing the Effects of Conduction, Convection, and Radiation in a Rotary Drum

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Research Overview: Altering and improving ASU's rotary drum setup to allow for experimental heat transfer tests using radiation

Introduction:

Rotary drums are important tools used in multiple manufacturing industries for heating and transporting particulate products. By studying the different methods of heat transfer in a rotary drum and analyzing how operating conditions impact the heat transfer efficiency, industrial models can be improved, and required energy consumption can be reduced.

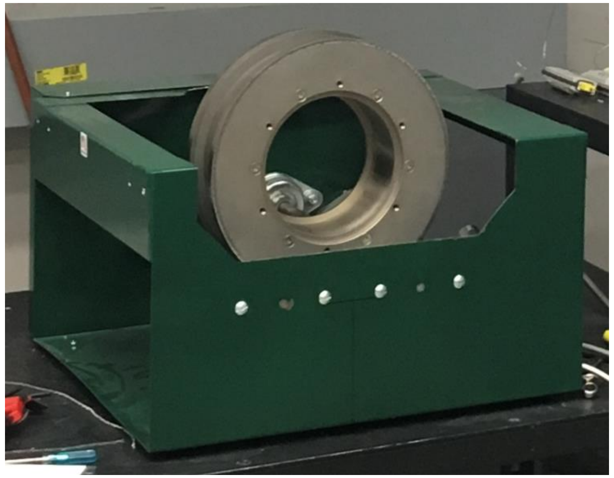


Figure 1. Original Rotary Drum Setup

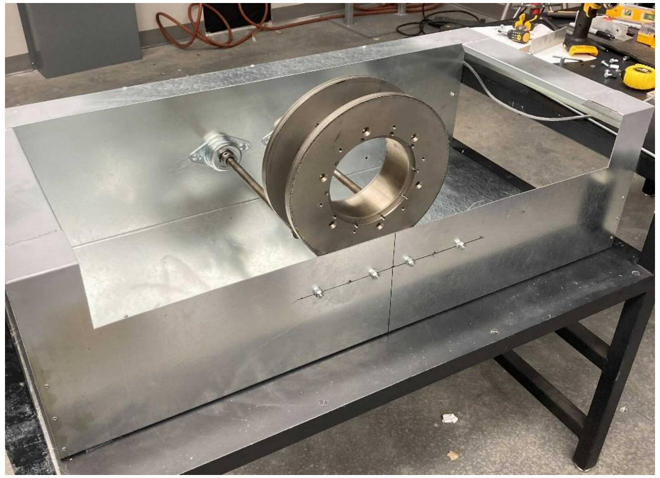


Figure 2. Reconstructed Rotary Drum Setup

Analysis - *Focused on Heat Transfer Rate*

$$\dot{Q}_R = e\sigma A(T^4 - T_c^4)$$

Where $\dot{Q}_{cv}$ = heat transfer rate from radiation [W],

e = emissivity of the heat source (e = 1 for an ideal radiator),

σ = Stefan-Boltzmann constant = 5.6703×10^{-8} watt/(m^2*K^4), A = radiating area [m^2],

T = temperature of radiator [K], T_c = temperature of surroundings [K]

Developments:

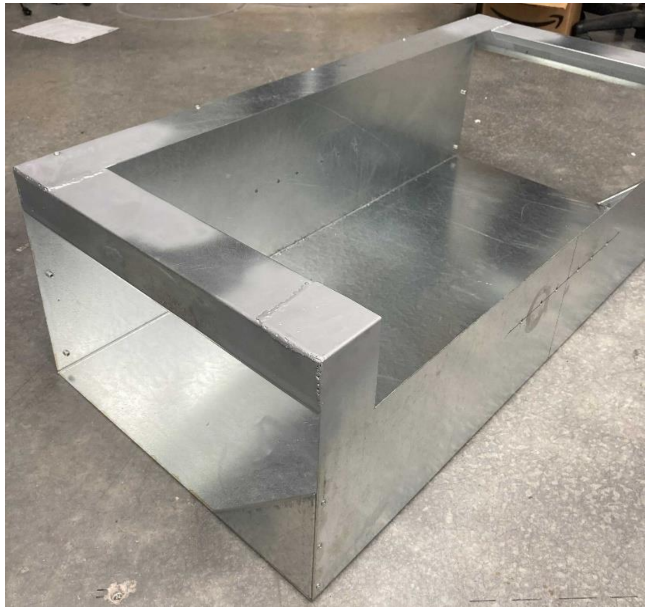
This semester, the following milestones have been achieved.

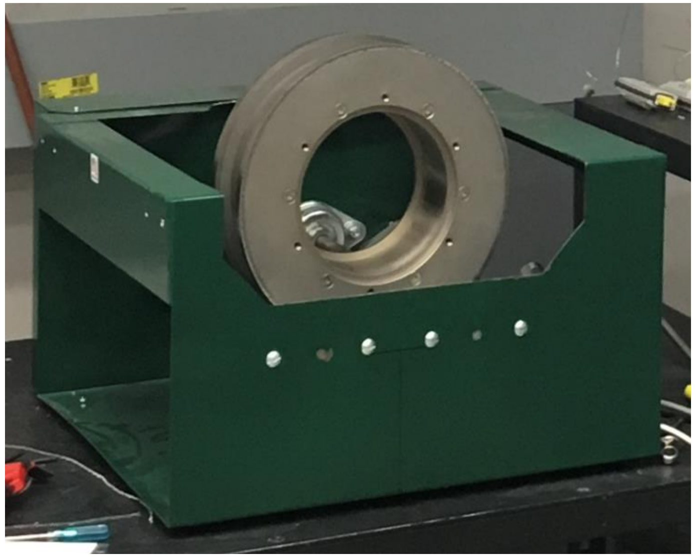
- Completed physical alteration of the rotary drum setup
- Reassembled rotary drum setup mechanisms onto new drum box

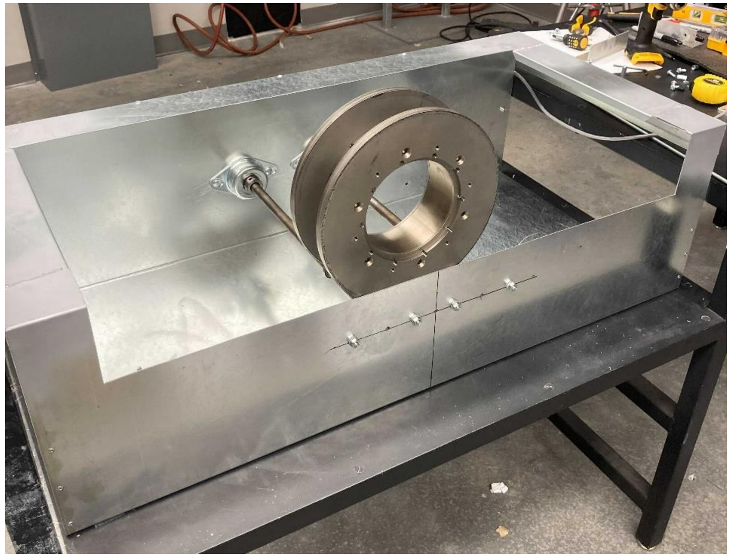
Conclusions and Future Work:

- Design and construct the support structure for the drum's heating system
- Calibrate the thermal camera and plan out experimental heat transfer tests
  - Design Factors: fill level, rotation rate, and particle size

Photos







Equations:

$$\dot{Q}_R = e\sigma A(T^4 - T_c^4)$$

Where $\dot{Q}_{cv}$ = heat transfer rate from radiation [W],

e = emissivity of the heat source (e = 1 for an ideal radiator),

σ = Stefan-Boltzmann constant = 5.6703*10^{-8} watt/(m^2*K^4), A = radiating area [m^2],

T = temperature of radiator [K], T_c = temperature of surroundings [K]

$$\dot{Q}_{cv} = h_c A \frac{dT_p}{dt}$$

Where $\dot{Q}_{cv}$ = heat transfer rate from convection (fluid to particle convection) [W],

h_c = convective heat transfer coefficient [W/(m^2*K)], A = heat transfer surface area [m^2],

dT_p = temperature difference between heat transfer surface and the bulk fluid [K]

$$\dot{Q}_c = kA \frac{dT_p}{dt}$$

Where $\dot{Q}_C$ = heat transfer rate from conduction [W],

k = overall heat transfer coefficient [W/(m^2*K)], A = heat transfer surface area [m^2],

T_p = average particle bed temperature [K]

Descriptions/Annotations:

1. Introduction, Abstract, or Background:
2. Methodology, Instrumentation, and Materials:

3. Developments:

   The primary objective this semester is to complete the construction of a new rotary drum setup. Construction of the new drum setup, which utilizes electric induction coils to heat up the drum, is on schedule and many significant milestones have been passed.

   Milestones:

   Completing electrical schematics for the new drum setup – Achieved on September 10th, 2020

   Completing construction of the wiring components with a working loop – Achieved on September 20th, 2020

   Completing necessary modifications of old drum setup – Began on October 15th, 2020 (Ongoing)

   Completing construction of new drum setup box – Achieved on November 2nd, 2020

4. Conclusions and Future Work:

   Currently, construction on the new rotary drum setup is almost complete. In the coming weeks, after the drum setup is built, the next phase in the research process will begin. In this phase, the thermal camera will be calibrated, and the experimental tests with heat transfer will begin. The first set of tests will use conduction, then convection, then radiation and conduction together using fill levels of 10%, 17.5%, and 25% and rotation rates of 2 RPM, 4 RPM, and 6 RPM.

5. References/Literature Cited:

6. Acknowledgements:

7. Research Problem:

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Conclusions and Future Work:

- Design and construct the support structure for the drum's heating system
- Calibrate the thermal camera and plan out experimental heat transfer tests
    - Design Factors: fill level, rotation rate, and particle size

Figure 1. Rotary Drum After Physical Alterations

Developments:

The primary objective this semester is to continue the reconstruction procedure of the new rotary drum setup. The following milestones have been achieved.

- Completed physical alteration of the rotary drum (Figure 1)
    - Entailed thinning out the outer wall of the drum core to reduce the drum heating time
- Reassembled rotary drum setup mechanisms onto new drum box (Figure 2)
- Acquired the required materials for the heating system support structure

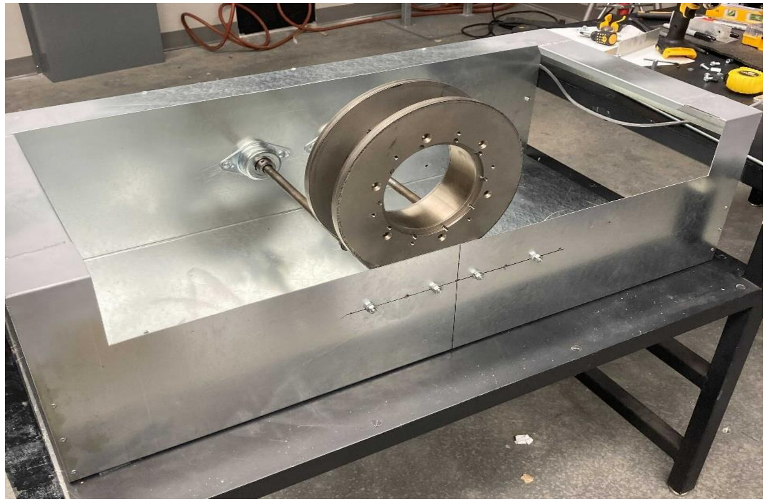

Figure 2. Reconstructed Rotary Drum Setup