Radiation Heat Transfer in a Rotary Drum

Particulate Process and Product Design Group

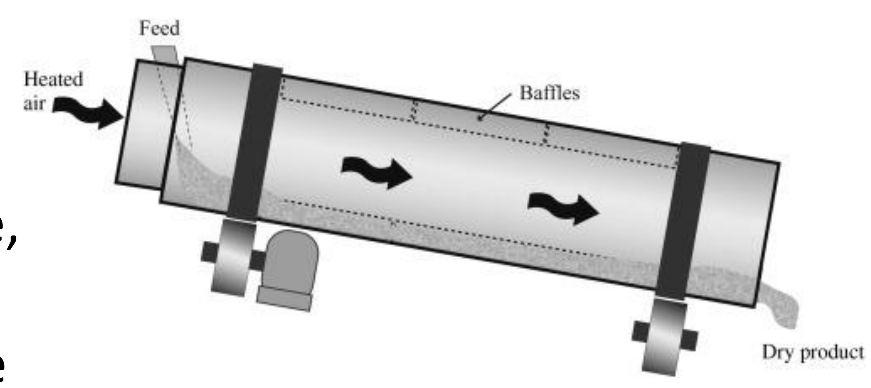
Joel Tronstad, Chemical Engineering
Mentor: Dr. Heather Emady
School of Engineering of Matter, Transport, and Energy

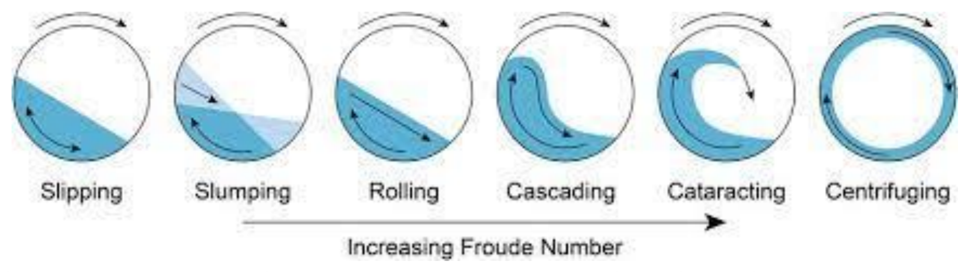
The current research is focused on experimental investigation of conduction and radiation heat transfer mechanisms at high temperatures (>500°C) in a 6" diameter and 3" long stainless-steel rotary drum. This work serves to bridge the gap in literature for experimental validation of simulation-based research. Experiments were performed to test the effect of rotation rate on the heat transfer rate at 25% and 17.5% fill level, and 4 mm particles. Rotation rates of 2, 5 and 10 rpm were tested.

Heat Transfer in Rotary Drums

Rotary drums are used to manufacture pharmaceuticals, cement, food, and other particulate products because of their high heat and mass transfer rates[1].

- Particulates have properties of solids, liquids, and gasses
- Particulate parameters: particle size, particle distribution, and shape
- Operating parameters: rotation rate and drum fill level





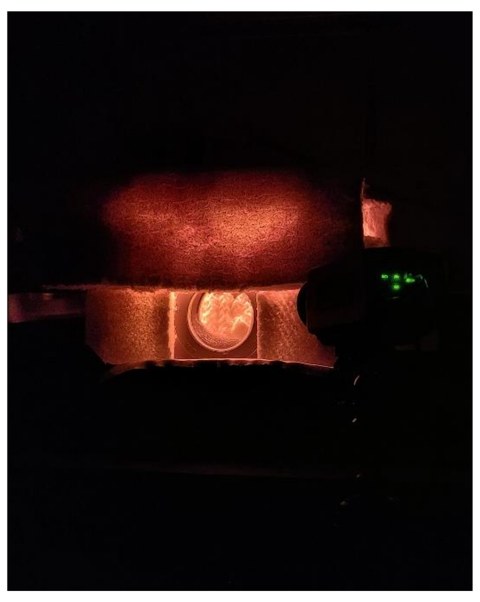
- Rolling motion most applicable to industry standards as it maximizes the surface area of the material in contact with the heating element while not damaging the particulates[2]

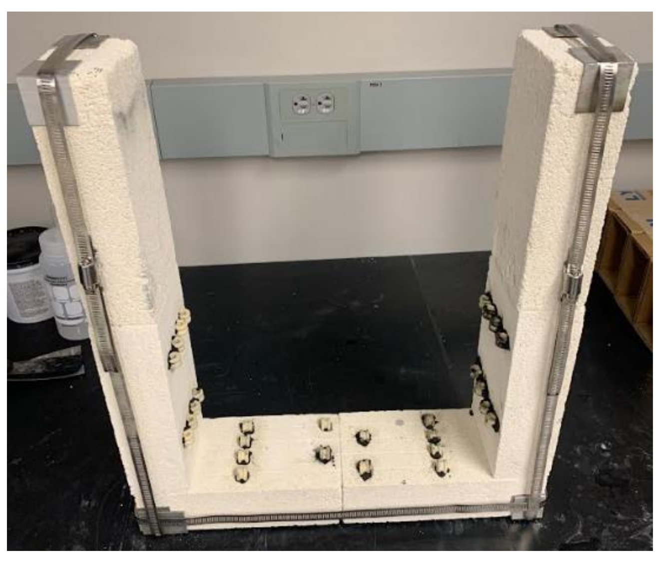
- Conduction, convection, and radiation are the three forms of heat transfer present.
- Radiation heat transfer occurs at temperatures above 500 °C
- Heating element, drum wall, and particulates all begin to emit radiation at these temperatures

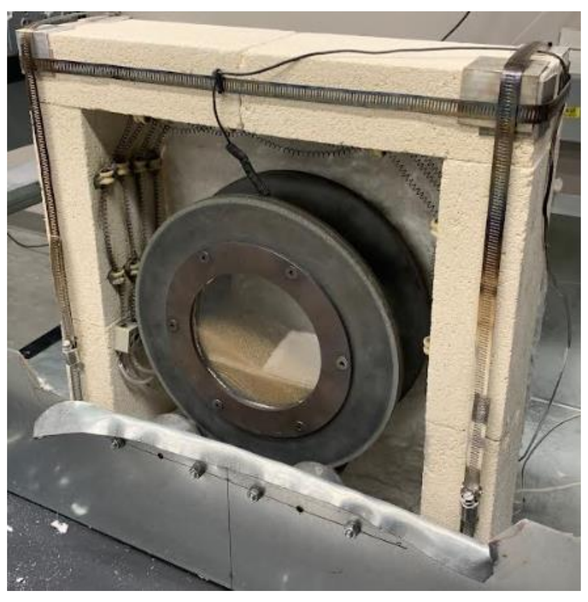
Experimental Setup

The experimental setup makes use of the existing rotary drum with a newly designed radiation heating system.

- The stainless-steel core of the rotary drum is 6" in diameter and 3" long, attached to 11" titanium wheels for assisting in rotation.
- The new radiation heating system is designed using Ni-Cr heating element coils, held in ceramic insulators attached to the firebricks using furnace cement.
- The temperature of the PID controller was set to **700°C**, with the coils heating up to **600°C** instantaneously and reaching a maximum temperature of **1000°C** .
- The rotary drum and heating system is covered with kaowool insulation to improve heating and prevent heat loss

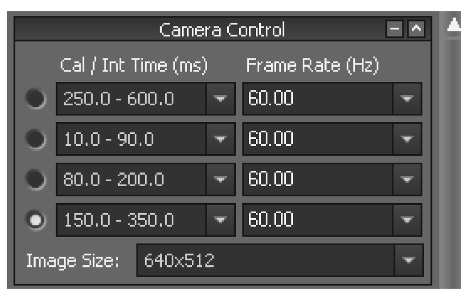


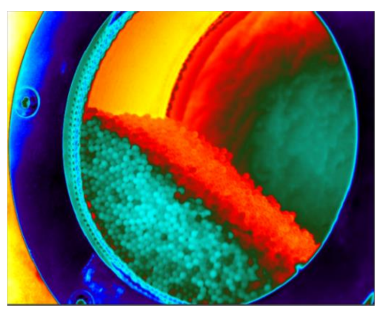




Temperature Measurement

An infrared camera is used for continuous non-invasive temperature measurement of the system. The IR camera can be operated for temperatures from 10°C – 1200°C.(ND2 filter required for temp >250°C).



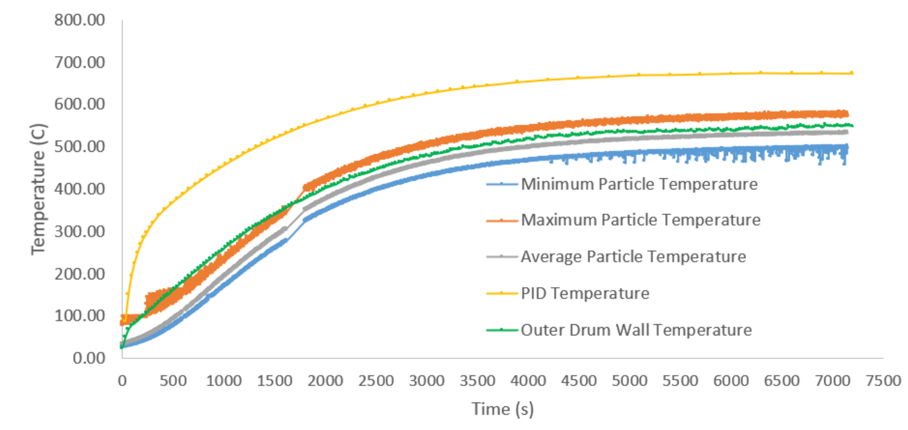


Results

Completed runs for 2, 5, and 10 rpm were conducted and analyzed.

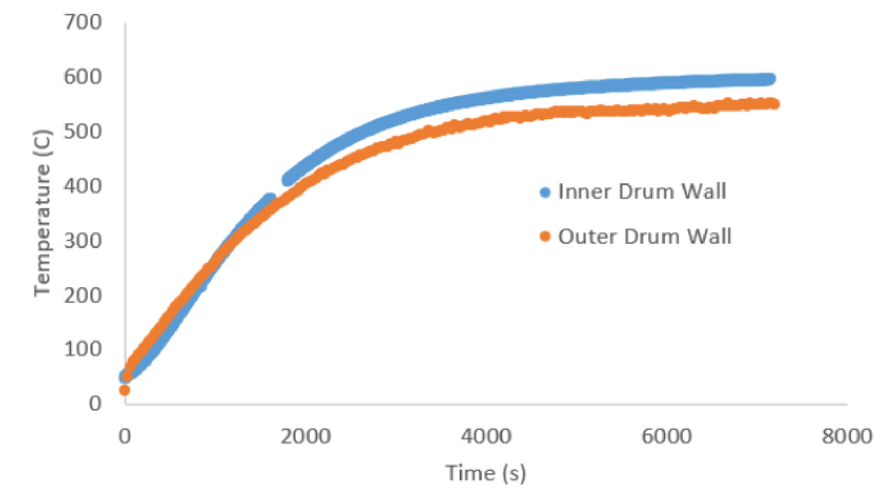
5 RPM Temperature Analysis

- PID Largest Temp
- Steady State around 4500s
- Inconsistencies in rapid heating
- Max Particle Temp hotter than outer drum wall

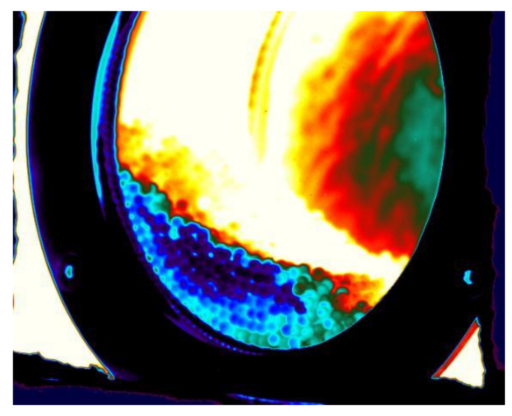


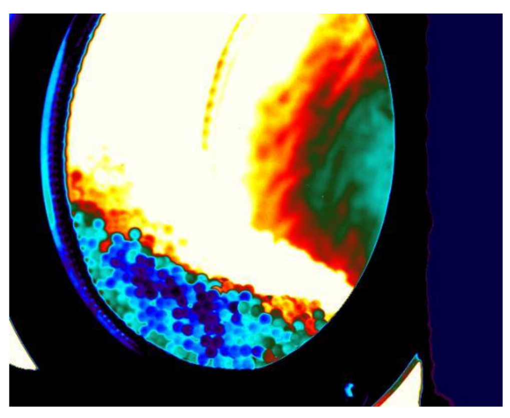
Inner vs Outer Drum Wall

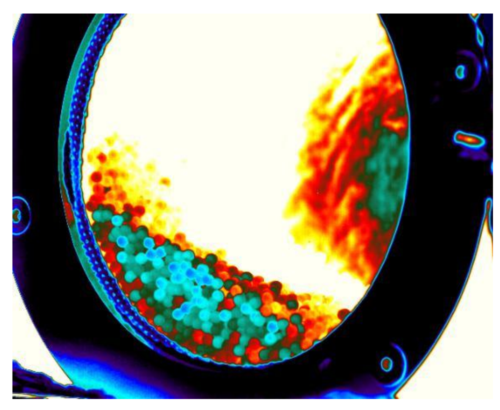
- Inner wall temp higher at 2000s
- Heat transfer properties of steel change at high temperatures
- As temp increases absorbance decreases and transmittance increases for steel
- Heat trapped inside drum



17.5 FL with 4MM Particles


2 RPM


5 RPM


10 RPM

- Core size calculated using imageJ looking at 15 minute segments starting once steady state is achieved

Time (min)	Total Area	Area Core	Core Size %
30	5.086	1.609	31.64
45	5.086	1.435	28.21
60	5.086	1.637	32.19
75	5.086	1.389	27.31
90	5.086	1.879	36.94
Average			31.25

- Average core size was calculated for three rotation rates

Fill Level	Rotation Rate	Average Core size %
17.5	2 RPM	31.25
17.5	5 RPM	16.99
17.5	10 RPM	8.46

Conclusions

- Higher temperatures result in greater transmittance for stainless steel resulting in inner drum wall exceeding outer drum wall temp.
- As rotation rate increased, the core size decreased leading to more uniform heating of the particle bed.
- As the rotation rate increased, the particle bed temperature distribution narrowed.

Future Goals

- Repeat trials at lower temperatures using new method.
- Conduct repeat experiments to confirm rotation rate has minimal effect on the heat transfer rate.
- Confirm that the heat produced by the coils in each experiment is consistent and is not a driving factor in the results,
- Combine all parameters into radiation heat transfer equation.

Acknowledgments

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1. Richard, P., Nicodemi, M., Delannay, R. *et al.* Slow relaxation and compaction of granular systems. *Nature Mater* 4, 121–128 (2005).
2. Mellman, J. The transverse motion of solids in rotating cylinders–forms of motion and transition behavior.Powder Technology.2001, 118

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