Design and Testing of Fluid Flow Through a Porous Particulate Bed

Theo Yih[1], Jack Shaughnessy[2], Wilson Ng[2], Shae Godwin[1]

[1] Department of Chemical Engineering, University of Washington

[2] Department of Material Science & Engineering, University of Washington

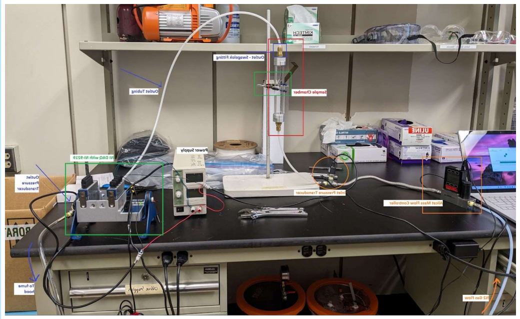
Abstract

Vapor deposition has become a highly useful process in the production of nano materials used in modern batteries. The flow of gas through a porous bed of particles during the vapor deposition process, however, is difficult to characterize, and current models do not fully capture the complexities of many real systems. Generally, engineers use the Ergun equation to describe fluid flowing through packed beds. Group14 is interested in determining whether the modified Ergun equation can be further modified to describe nitrogen gas flowing through packed beds of their proprietary material for the purpose of scaling up battery anode production. Using a testing chamber designed and built by the investigators, this study finds that the Ergun equation is not a valid model for describing fluid flow as-is, and large discrepancies exist between measured and calculated pressure differentials when using the Ergun model. Further investigation will continue to quantify this discrepancy in a correcting factor.

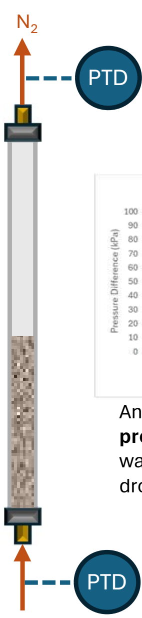
Motivation

Lithium-ion batteries are one of the most broadly utilized types of batteries, used in devices ranging from cell phones to electric vehicles. Group14 specializes in anodes for lithium-silicon batteries, which can be used for the same applications as lithium-ion, but with better energy storage capabilities and faster charging. Li-Si batteries are desirable for electric vehicles, in particular. There is a large vested interest in scalability of fast EV production to reduce the carbon produced by driving, since about 1/3 of all carbon emitted in the US is from combustion of fuels used in vehicles. Improving the viability of producing Li-Si battery anodes at the industrial scale requires the accurate characterization of processes used in their production, such as flowing gases through particles that will yield nano particles used in batteries.

Experimental Approach

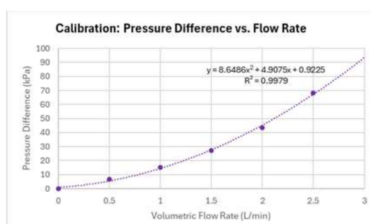


The **Sample Chamber** allows for the variance of bed depth, sample mass, and packing density. **Nitrogen gas** mass flow was controlled using an **Alicat Mass Flow Controller.** Pressure transducer readings on each end of the Sample Chamber were collected using a **NI DAQ NI-9219 Input Module**.



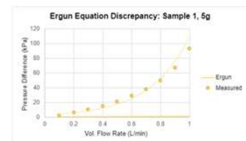
$$\frac{\Delta P}{L}\frac{d_a}{\rho u s^2}\frac{\phi^3}{1-\phi} = k_1\frac{1-\phi}{N_{Re}} + k_2$$

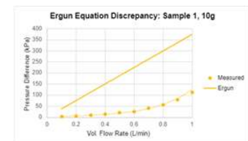
Modified Ergun Equation

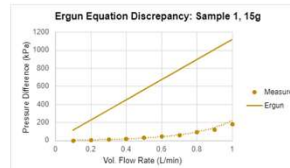


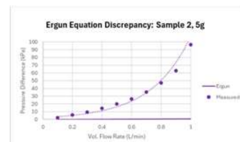
An **empty sample chamber pressure characterization** curve was created to find only the pressure drop due to the packed bed

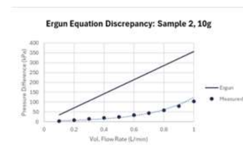
Results



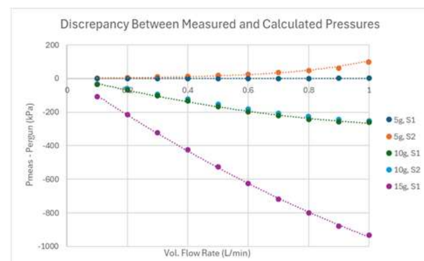








The different particulate bed materials tested thus far, Sample 1 (S1) and Sample 2 (S2), have varying pore density and particle size. Bed heights correspond with sample mass, and the relationship between the bed height and pressure discrepancy has yet to be explored.



$P_{measured} - P_{Ergun}$:

- Sign inverts between 5g and 10g
- Absolute value increases with flow rate exponentially
- More testing necessary to determine relationship quantifiably

Conclusions

There are large discrepancies between the pressure drop values measured in the lab and those calculated using the Ergun equation. The discrepancy seems to get smaller as the mass of the sample increases, and the discrepancy may decrease to negligible levels as the mass of particles in the bed approaches industrial scale values. Further investigation will continue to quantify the discrepancy with a correcting factor or term.

Recommendations & Future Work

The experiment will continue, and more data will be collected to determine the correction factor necessary to accurately describe the packed bed's pressure drop.

After completion of this portion of the experiment it is recommended to continue testing on a larger scale to confirm the findings of the investigators. If a correction factor is found its application to larger scales must be tested.

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