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experiment 8: Drying

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**Synopsis**

In this experiment, it was found that the fluid bed dryer could be modelled by a drying process with three distinct periods consisting of a warming-up period, a constant-rate period and a falling-rate period.

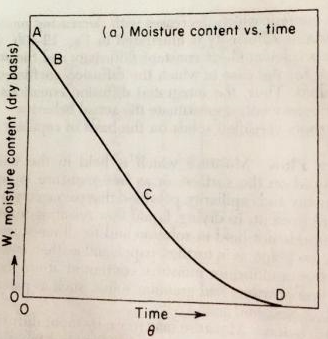
**Introduction**

The aim of the experiment is to determine a model that predicts how the moisture level in a material that is being dried changes during the drying process by drying a material using a Sherwood Tornado M501 Fluid Bed Dryer. [1]

**Theory**

Drying is an important unit operation in the chemical industry but is a particularly complex one due to the heterogeneous nature of the material to be dried. [1]

In a fluidised bed dryer such as the Sherwood Tornado M501, the solid bed exists in a fluidised condition. This is a condition in which the solid particles are supported by drag forces caused by the drying gas phase passing through the spaces between the particles at a critical velocity. However, the condition is unstable as the gas velocity is insufficient to entrain and pass around all of the solid, causing particles to rise and fall again. Also, eddy currents that exist within the gas can lift particles temporarily. This can be described as the gas and solid phases being intermixed and acting as a boiling fluid. [2] Such conditions offer high rates of heat and mass transfer that allow for much faster and more homogeneous drying than conventional drying methods such as oven and vacuum drying. [3] The fan speed and the heating element temperature of the dryer are both controllable to control the speed at which the material is dried.



[4]

When a solid is dried, data is obtained that shows that the drying process is not a smooth continuous process in which a single mechanism can be seen, but is in fact subject to time and moisture content, causing distinct periods in the drying process to be observed.

**A-B ¦Warming-Up Period:** As the material warms, the drying rate increases.

**B-C ¦ Constant-Rate Period:** Moisture movement within the solid is rapid enough to maintain a saturated condition at the surface, and the rate of drying is controlled by the rate of heat transferred to the evaporating surface. Vapour diffuses from the saturated material surface across a stagnant air film into the environment. This is analogous to the evaporation of a body of water, and is independent of the nature of the solid. [2]

**C ¦ Critical Moisture Content:** The average moisture content when the constant rate period ends. [2]

**C-D ¦ Falling Rate Period:** Once the initial moisture content is below the critical moisture content, the evaporating surface can no longer be maintained to be saturated by moisture content within the solid. The drying rate decreases in the unsaturated area and hence the total rate decreases. Once the entire evaporating surface becomes unsaturated, the drying rate becomes totally governed by internal moisture movement. [2]

**Experimental Technique**

Equipment

* Sherwood Tornado M501 Fluid Bed Dryer
* Generic material for drying
* Beaker
* Spatula
* Water
* Thermocouple
* Aluminium boats
* Scale
* Drying oven

Diagram

 [1]

Methodology

1. The instructor mixed an unknown amount of water with an unknown amount of the material to be dried in a beaker and mixed it thoroughly with a spatula.
2. The aluminium boats were placed in the drying oven for 15 minutes, then their weights were measured and recorded.
3. The dryer was programmed to a fan speed of 50rpm, a temperature set-point of 80˚C and a time of 195 minutes. The thermocouple was placed on top of the dust screen on top of the dryer.
4. An initial sample of the wetted material was weighed in an aluminium boat and then labelled and placed in the drying oven.
5. The wetted material was placed in the dryer and the drying process was started.
6. Every 15 minutes a small sample was weighed in an aluminium boat and then labelled and placed in the drying oven. The temperature was also recorded. This step was repeated until 195 minutes had elapsed.
7. The samples were left to dry overnight, and their dry weights were determined the following day.

**Results**

Aluminium boat weight = 1.59g

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sample | Gross Weight (Dryer), g | Gross Weight (Oven), g | Net Weight, (Dryer), g | Net Weight (Oven), g | Moisture Content, g | Moisture Content, dimensionless | Temperature, ˚C | Time |
| 1 | 2.87 | 2.43 | 1.28 | 0.84 | 0.44 | 0.34 | N/A | 0 |
| 2 | 3.30 | 2.95 | 1.71 | 1.36 | 0.35 | 0.20 | 48.8 | 15 |
| 3 | 2.07 | 1.99 | 0.48 | 0.40 | 0.08 | 0.17 | 50.0 | 30 |
| 4 | 3.33 | 3.31 | 1.74 | 1.72 | 0.02 | 0.01 | 51.6 | 45 |
| 5 | 2.72 | 2.72 | 1.13 | 1.13 | 0.00 | 0.00 | 52.9 | 60 |
| 6 | 2.87 | 2.87 | 1.28 | 1.28 | 0.00 | 0.00 | 54.1 | 75 |
| 7 | 2.25 | 2.25 | 0.66 | 0.66 | 0.00 | 0.00 | 56.8 | 90 |
| 8 | 2.83 | 2.83 | 1.24 | 1.24 | 0.00 | 0.00 | 59.2 | 105 |
| 9 | 2.87 | 2.87 | 1.28 | 1.28 | 0.00 | 0.00 | 61.3 | 120 |
| 10 | 2.97 | 2.97 | 1.38 | 1.38 | 0.00 | 0.00 | 61.5 | 135 |
| 11 | 5.49 | 5.49 | 3.90 | 3.90 | 0.00 | 0.00 | 60.9 | 150 |
| 12 | 4.27 | 4.27 | 2.68 | 2.68 | 0.00 | 0.00 | 61.5 | 165 |
| 13 | 7.47 | 7.47 | 5.88 | 5.88 | 0.00 | 0.00 | 60.7 | 180 |
| 14 | 4.02 | 4.02 | 2.43 | 2.43 | 0.00 | 0.00 | 61.5 | 195 |

A

B

C

D

**Discussion of Results**

The moisture content of the material under the drying conditions selected was shown to mimic the predicted conditions as discussed in the **Theory** section. Three distinct areas are visible representing the predicted different drying processes as the moisture content of the material decreases. The accuracy of the collected results is further reinforced by the correlation coefficient of 0.9602, representing a strong positive correlation between moisture content and time. Furthermore, a strong positive correlation was also observed between moisture content and temperature. Hence, the model described in the **Theory** section models the drying in the fluid bed dryer very well.

During the experiment, we encountered several issues and sources of error. Firstly, the thermocouple was very faulty, several times reporting temperatures that were clearly incorrect. This was rectified by using common sense to replace these temperatures with more sensible values. The thermocouple was also very difficult to hold in the same position each time, possibly causing further errors. Secondly, the drying vessel seal was found to not be perfect, as hot gas could be felt to be escaping from around the seal at the bottom, potentially causing drying to be less effective than expected.

However, due to the results otherwise being as expected, the collected data can be assumed to be correct.

**Conclusions**

In conclusion, it was found that the fluid bed dryer could be modelled by a drying process with three distinct periods consisting of a warming-up period, a constant-rate period and a falling-rate period.

**Appendix I: Calculation Formulae**

Net weight (dryer)

Net weight (oven)

Moisture content

Moisture content (dimensionless)

**References**

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| [1] | Heriot-Watt University School of Engineering & Physical Sciences, Drying, Edinburgh: Heriot-Watt University, 2017. |
| [2] | R. H. Perry and D. W. Green, “Solids-Drying Fundamentals,” in *Perry's Chemical Engineers' Handbook (7th Edition)*, New York, McGraw-Hill, 1997, pp. 1225-1236. |
| [3] | Sherwood Scientific, Ltd., “Model 501 Fluid Bed Dryer,” [Online]. Available: http://www.sherwood-scientific.com/fbds/501.html. [Accessed 3 February 2019]. |
| [4] | R. H. Perry and D. W. Green, “12-41a The periods of drying,” in *Perry's Chemical Engineers' Handbook (Seventh Edition)*, New York, McGraw-Hill, 1997, p. 1232. |