Investigating the Fluidisation and Behaviour of Dry Cohesive Powders in Axially Rotating Drums.

Henry Baker* | 170219998 | h.baker4@ncl.ac.uk |Chemical Engineering MEng Honours | Supervisor: Vladimir Zivkovic

Introduction

Powders are classified into four categories, based on particle density and diameter, originally introduced by Geldart (1973). Geldarts class C powders are fine and cohesive. Fluidisation is the process by which a gas is pumped through a powder overcoming the weight of the particles causing them to float and the powder to behave like a liquid.

Normally it is very difficult to fluidise fine cohesive powders without aids like mechanical stirring or ultrasonic vibration, however it has been shown that in an axially rotating drum the fine powders can be fluidised as described by Huang et al. (2009).

The behaviour of a fine powder in a drum has stages that are recognisable by characteristic behaviours, the behaviour of cohesive powders change with angular velocity.

Aims

- To fluidise fine cohesive powders in a rotating drum and then investigate the effect of fill ratio on the aeration and deaeration of the powder
- To map the behaviour of a fine cohesive powder from low to high angular velocity

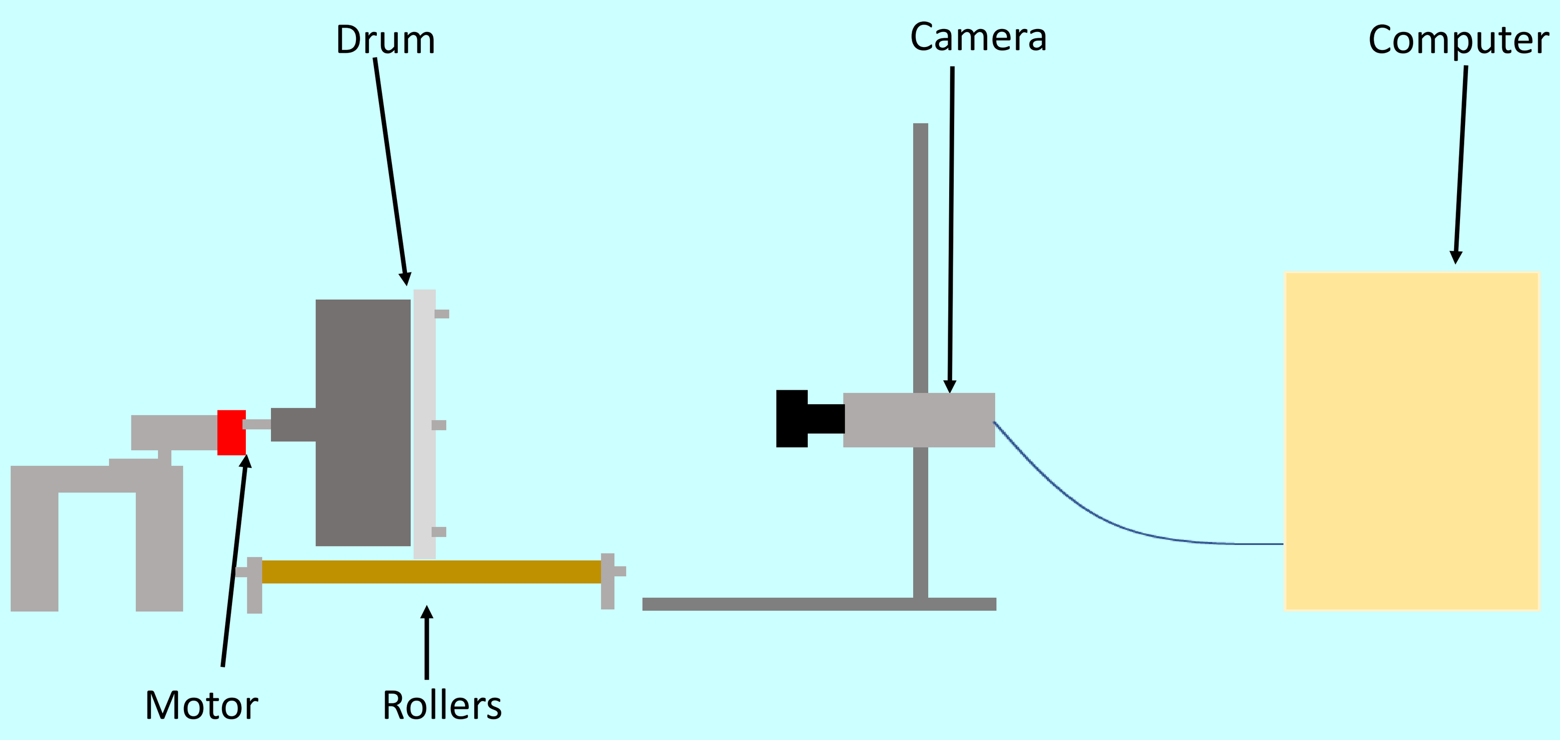

Figure 1: The equipment set up for the experiment.

Method

The powder was placed in the drum apparatus shown in figure 1 and rotated at various angular velocities. The movement was recorded on a high speed camera and then visually analysed on the computer. The drum was rested on the rollers for stability.

Two separate motors were used with different gear ratios. To use voltage control the motors were calibrated producing the calibration curve shown in figure 2. A range of angular velocities were chosen and the motors set to the appropriate voltage.

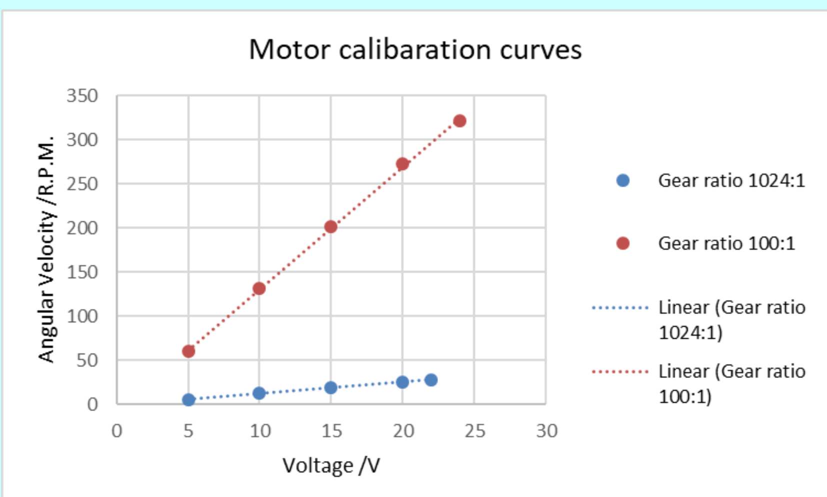

Figure 2: The two motor calibration curves for the different gear ratios.

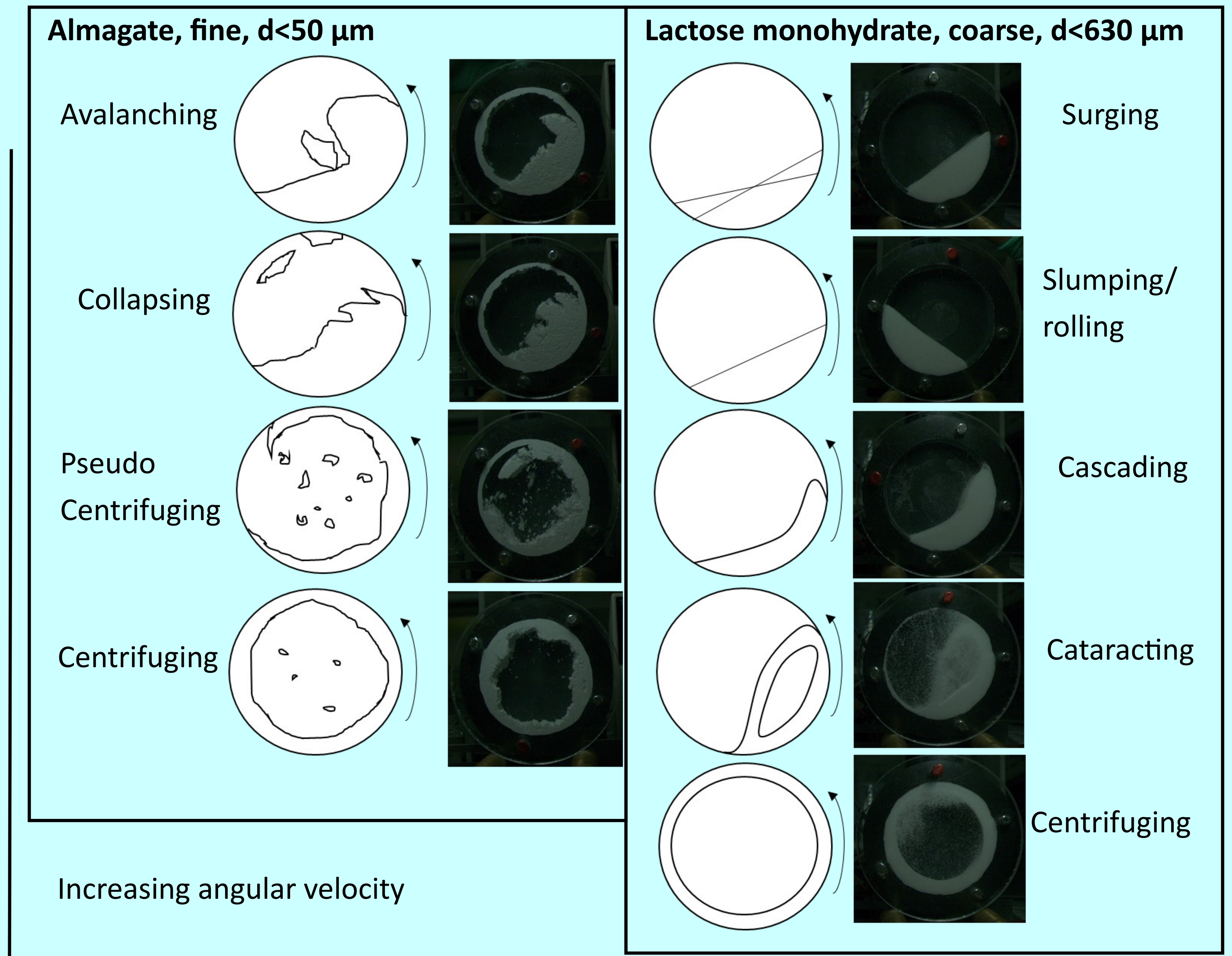

Figure 3: A comparison of the behaviours of a fine cohesive to a coarse powder as shown in Huang et al. (2010) in an axially rotating drum.

Discussion

Four different behaviours were noted in the fine cohesive powders compared to what is seen in coarse powders shown in figure 3, these are:

- Avalanching, characterised by the peak that grows on the rising side of the drum only to collapse when it becomes too heavy, it then rolls down to the bottom of the drum and the cycle restarts.
- Collapsing, characterised by the same movements as avalanching however at a rate that means the peak is constantly collapsing; it looks very similar to a collapsing wave.
- Pseudo centrifuging, characterised by the powder going through several different behaviours changing between them chaotically, a facsimile of cataracting with descending powder containing lumps and the powder sticking together traveling up the wall to fall down near the top of the drum.
- Centrifuging, this is characterised by the powder staying adjacent to the inner wall of the drum for the entire rotation.

The key differences between fine cohesive powders and rough powders were found to be:

- A rough surface which is present in all of the cohesive powders regimes, even in centrifuging which is almost the same as the coarse powders centrifuging, the only difference being the lack of a rough surface.
- The slugs of powder that travel up the drum wall in the cohesive powder as they are not present in the coarse powder, it happens before centrifuging occurs, so the slugs must be caused by powder cohesion to the wall.

Why didn't the fluidisation work?

Fluidisation that was the original area of study did not occur, the experiment failed to produce a gasless fluidized bed. None of the smooth surface, large powder body expansion and change in surface diameter vs. drum diameter ratio as shown in figure 4 occurred. Different powders were tried including maze meal, almagate, cornflour, lactose monohydrate, semolina and potato starch. The reasons for the lack of fluidisation were:

- The lack of additives, in Castellanos et al. (2001), Huang et al. (2009) and Huang et al. (2010) additives were used to reduce the cohesion of the powders, for instance in et al Huang et al. (2009) TiO_2 and SiO_2 nanoparticles were used.
- In Yang et al. (2016) a smooth surface was observed in lactose monohydrate, it is traditionally fluidisable however partial fluidisation was also observed in a drum. Capsulac 60 lactose monohydrate had a similar particle size distribution however no fluidisation was observed, the size distribution could not have been close enough.

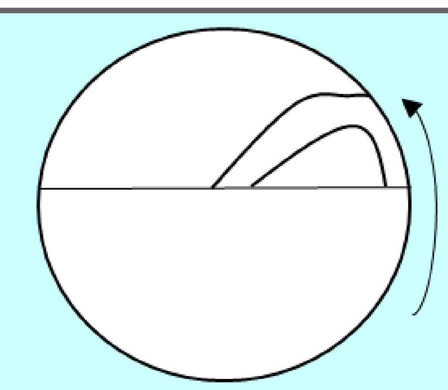

Figure 4: The behaviour of a fully fluidised dry cohesive powder shown in Huang et al (2009).

Future experiments

To improve the experiment in the future a few modifications should be made:

- The drum should be made out of Perspex on both ends and rotated from the rollers in order to allow for back lighting, there were issues with the front layer of powder obscuring the internal behaviour.
- Visual analysis should be done with image analysis software to find out exactly when the regime change happens.
- In order to investigate how the design of the drum wall effects the fluidisation and behaviour a modular system to change the drum wall design should be used.

Conclusion

- There are four regimes dry cohesive powders undergo in a drum; avalanching, collapsing, pseudo centrifuging and centrifuging, the changes between the regimes are caused by a change in the rotational velocities of the drum.
- In order to investigate gasless fluidisation powder additives that reduce particle cohesion should be used, any further attempt with lactose monohydrate should use one with a particle size distribution closer to the one used in Yang et al. (2016).

References

1. Castellanos, A., Sànchez, M.A., Valverde, J.M. (2001) 'The onset of fluidization of fine powders in rotating drums', *Materials Physics and Mechanics*, 3, pp. 57-62.
2. Geldart, D., (1973) 'Types of Gas Fluidization', *Powder Technology*, 7, pp. 285-292.
3. Huang, Q., Zhang, H., Zhu, J. (2010) 'Onset of an innovative gasless fluidized bed-comparative study on the fluidization of fine powders in a rotating drum and a traditional fluidised bed', *Chemical Engineering Science,* 65, pp. 1261-1273.
4. Huang, Q., Zhang, H., Zhu, J. (2009) 'Experimental study on fluidization of fine powders in rotating drums with various wall friction and baffled rotating drums', *Chemical Engineering Science, 64, pp. 2234-2244.*
5. Yang, H., Jiang, G.L., Saw, H.Y., Davies, C., Biggs, M.J., Zivkovic, V. (2016) 'Granular dynamics of cohesive powders in a rotating drum as revealed by speckle visibility spectroscopy and synchronous measurement of forces due to avalanching', *Chemical Engineering Science*, 146, pp. 1-9.

Acknowledgments

I would like to acknowledge Newcastle university for funding this research project.