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Rapid prototyping for material testing and processing of particulate pharmaceuticals using 3D printing

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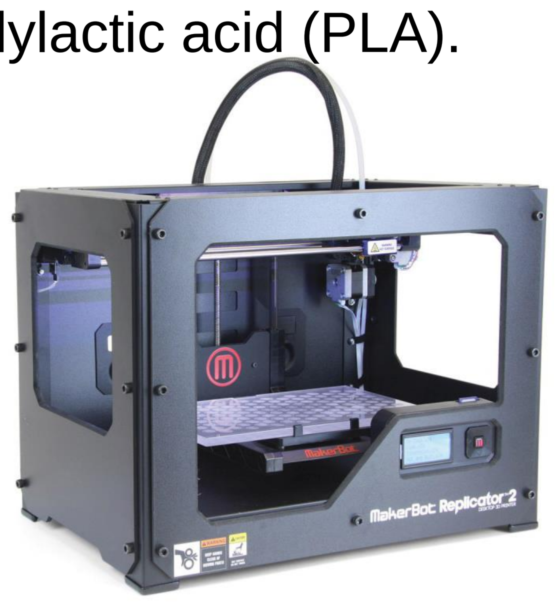
AIM

The aim of this study was to assess the possibility of predicting powder behaviour in 3D printed geometries. Powder flow through different funnel geometries was predicted and experimentally assessed to verify the validity of the predictions in the 3D printed geometries.

MATERIAL AND METHODS

Two powders were used: spray dried mannitol (Pearlitol SD100, d50=36±3 µm) and spray dried lactose (FlowLac 100 SD, d50= 38±1µm). A ring shear tester (RST-Xs) was used to analyse the flowability of the powders and the wall friction against stainless steel and a 3D printed wall plate. A 3D printer (Makerbot Replicator 2), based on fused deposition modelling, was used to print the geometries from polylactic acid (PLA).



CONCLUSION

It was possible to predict the powder flow in the 3D printed geometries, using equations for predicting powder flow in steel silos/funnels. The experiments proved that the predictions were also applicable for 3D printed geometries.

RESULTS

PART I: Powder characterisation and hopper design

Table 1: Summary of powder properties of Mannitol, analysed with a ring shear tester

Powder Properties	flow function coefficient (ffc – a.u.)	Bulk density (g/cm³)	Effective angle of internal friction (°)
Lactose	9.4 ± 0.3	0.64 ± 0.06	33.2 ±0.1
Mannitol	12.7 ± 0.3	0.47 ± 0.00	36.9 ± 0.2

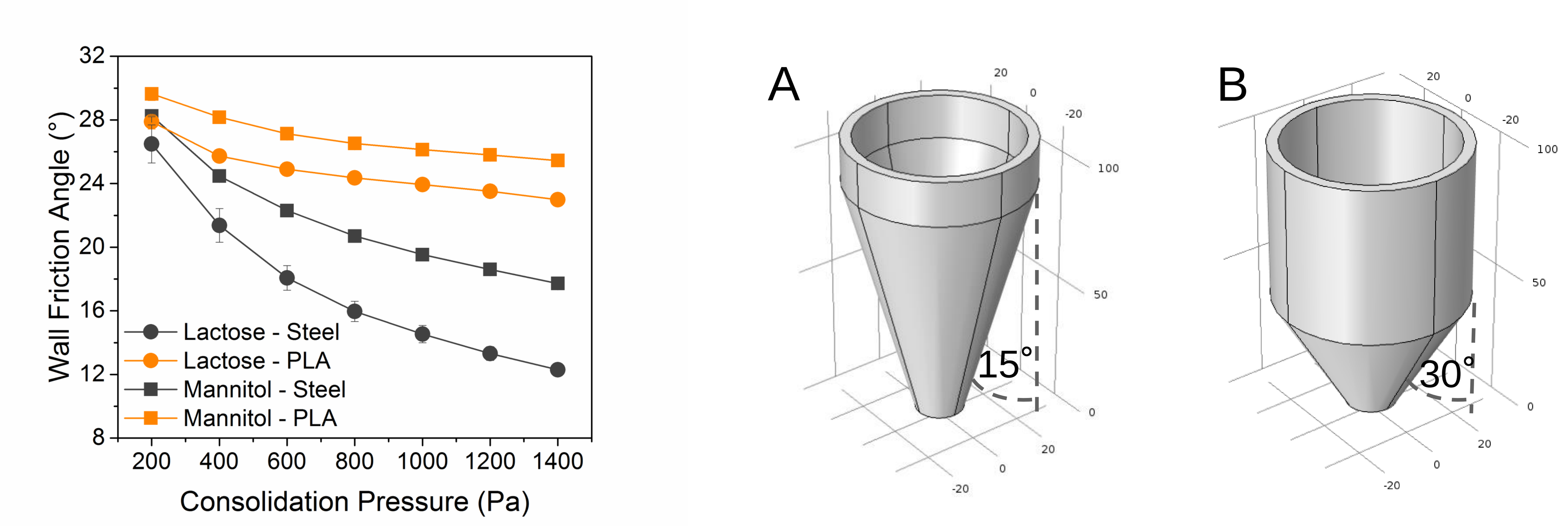


Fig.1: left: wall friction of Mannitol against PLA and stainless steel; right: design of funnel A and B

There is a clear difference in wall friction between powder - steel and powder - PLA. With lower consolidation pressures the difference decreases. Depending on the outer angle θ_c of the hopper, different flow pattern should be observable. Two funnels with different outer angles were, therefore, designed:

Funnel A: 15 ° **Funnel B**: 30°

PART II: Powder flow prediction and observation

Predictions about the powder flow, based on calculations first established by Jenike (1), were made, using the friction within the powder, as well as the friction between powder and wall material.

Table 2: Predicted powder flow pattern and experimentally observed flow pattern

Powder Flow Pattern		Funnel A	Funnel B
Lactose	predicted	mass flow/ mixed flow	funnel flow
	observed	mixed flow	funnel flow
Mannitol	predicted	mass flow/ mixed flow	funnel flow
	observed	mixed flow	funnel flow

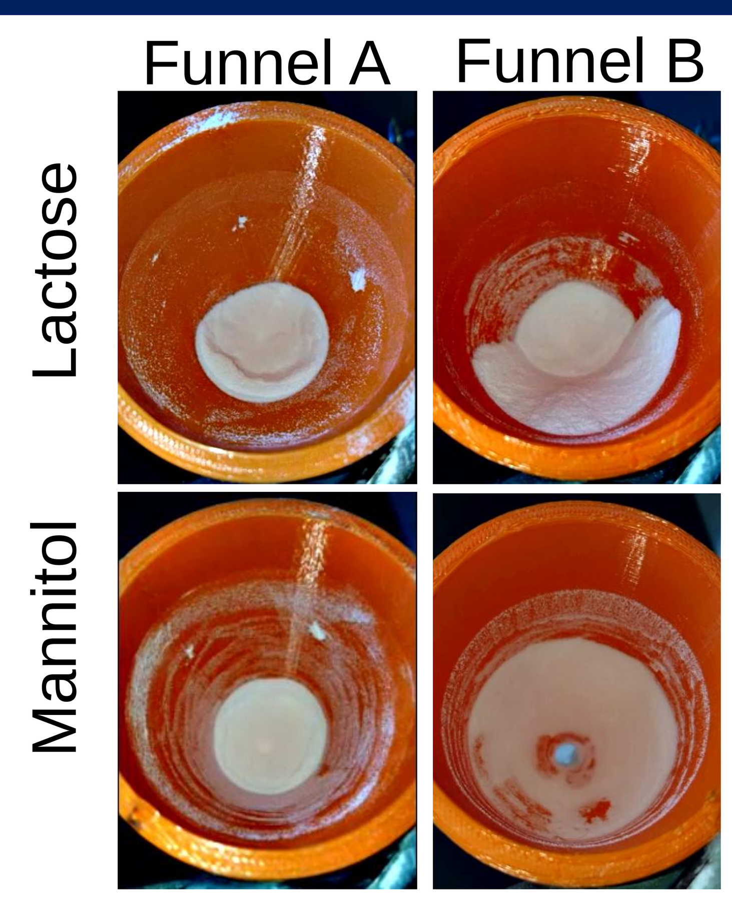


Fig.2: Picture of the observed powder flow taken from a video

FUTURE PERSPECTIVES

3D printing provides rapid and economical means for designing and creating of innovative powder handling geometries. Predictions of the powder behaviour in the 3D printed geometries gives the possibility for optimizing the design of the geometries *in-situ* prior to printing. Furthermore, interfaces for process analytical technology can easily be integrated in these designs.

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Reference
(1) Jenike A.W., 'Quantitative design of mass flow bins', Powder Technology (1967), 237-244

Information
For download of the abstract, the poster and for access to the videos please visit: *hirschberg.dk/sheffield2017*