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PRELIMINARY MEASUREMENTS OF PARTICLE MASS FLOW RATE AND CURTAIN OPACITY IN A FALLING PARTICLE SOLAR RECEIVER

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Preliminary experimental measurements of particle mass flow rate and curtain opacity was obtained in a lab-scale falling particle solar receiver under isothermal conditions utilizing a combination of strain gauges, backlighting and controlled imaging. The aim of these experiments was to provide high quality data under well characterized conditions to improve current understanding of particle-based solar receivers, and to assist in the development of accurate, detailed, computational models. These improvements will in turn potentially increase the up-take of particle-based solar receivers through improved thermal performance and a reduction in operational costs. In particular, this study aims to investigate the effect of hopper geometry and particle size on the particle mass flow rate and curtain opacity in a simplified falling particle receiver.

The experiment consisted of particles falling under their own weight into a quiescent environment from a hopper with a rectangular orifice, as shown in Figure 1. The width of the hopper, *w*, was varied from 40 to 100mm, while the gap size, *g* was varied from 2 to 6mm. The hopper half angle, *α*, was fixed at α = 80º. This angle was sufficiently large such that the flow was in the “mass flow” regime (Ketterhagen, et al., 2009). The hopper was 3D printed out of Polylactic Acid (PLA). The particles were Silicon Carbide with diameters ranging from 68 to 504µm. The mass flow rate was measured via strain gauges while a high speed camera was used to take images of the particle flow from both the front and the side of the curtain. Measurements were conducted both near the hopper exit (0<=y<=200mm), and further downstream (800<=y<=900mm). In all cases, the hopper was filled to the same height, *h*, which was set at h = 140mm. The backlight consisted of a direct-current powered LED array panel, which provided a constant and near-uniform light intensity, which varied across time by less than 0.7%. Opacity, O, was then calculated by subtracting the images taken with particles from the images taken without particles.

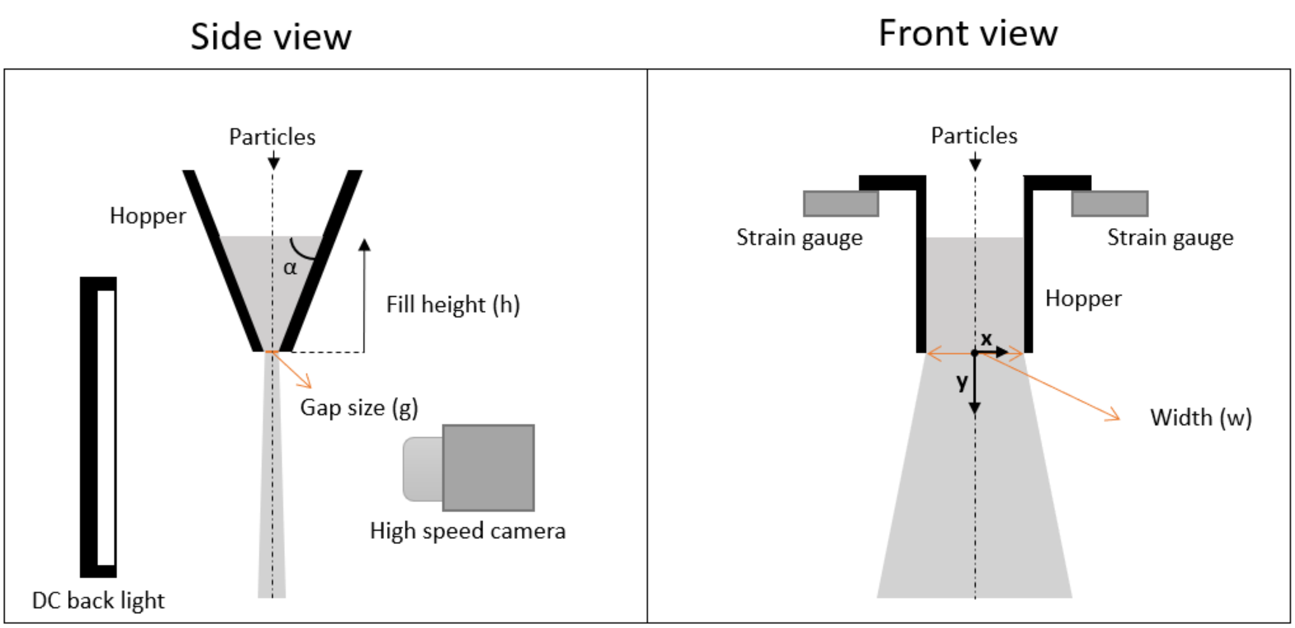

Figure 1: A schematic of the side and front view of the experimental setup

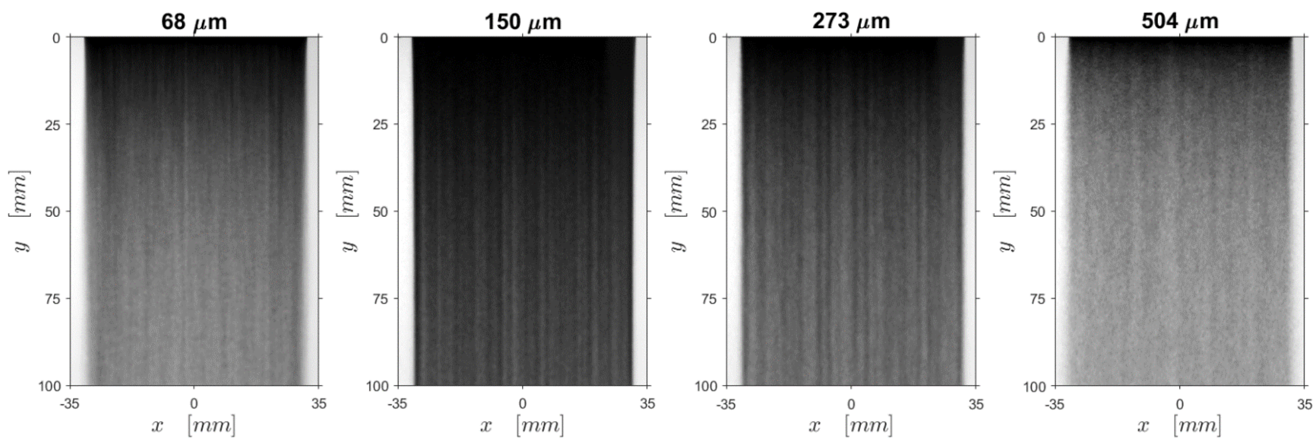

Figure 2. Time averaged images from the front of the particle curtain for 4 different particle sizes. The particle flow is from top to bottom.

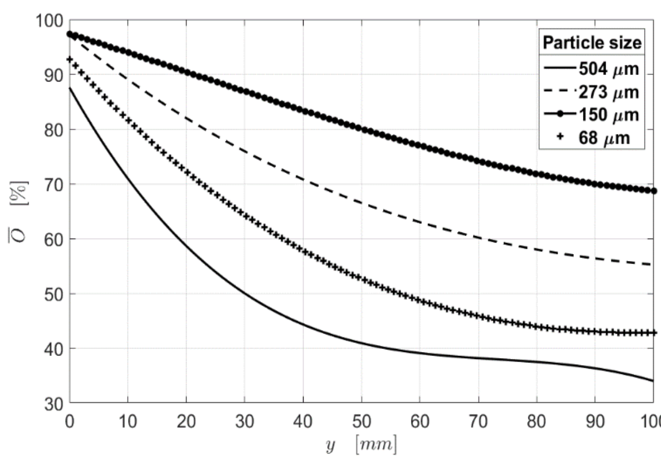

Figure 3. Time averaged opacity, $\bar{O}$, versus drop height, y

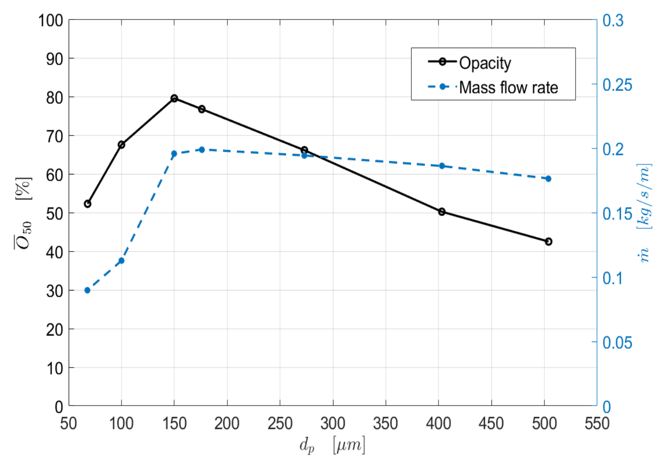

Figure 4. Averaged opacity and mass flow rate versus particle size for y = 0-100mm

Figure 2 shows time averaged images of the particle curtain in the range $0 \le y \le 100$mm for 5 different particle sizes. As can be seen, the opacity at the hopper exit (y=0) is similar for all particle sizes, however, for larger drop heights the opacity changes significantly depending on the particle size. This trend is more explicitly presented in Figure 3, which shows the relation between the time averaged opacity, $\bar{O}$, and the drop height for different particle sizes. In general, the opacity increases for smaller particles, however, $\bar{O}$ is lower for d_p=68μm than 150μm. This is because the mass flow rate for the former is significantly lower than the latter, which is probably due to the increased particle-particle and particle-wall friction as the particle surface area per volume increases (i.e., as the diameter decreases).

In Figure 4 the time averaged opacity at a drop height of 50 mm, $\bar{O}_{50}$, and particle mass flow rate, $\dot{m}$, is plotted for different particle sizes (d_p). As can been seen, there is a local maximum of mass flow rate and opacity that occurs at d_p≈150 μm. Taken together, the results show that both the particle mass flow rate, and opacity, are strongly influenced by particle size, and that curtain opacity also varies significantly with drop height.

References

[1] Ketterhagen, W., Curtis, J., Wassgren, C. & Hancock, B., 2009. Predicting the flow mode from hoppers using the discrete element method. *Powder Technology,* Volume 195, pp.1-10.