Design and Development of a Particle Flow Control Mechanism for Particle-Based CSP System Applications*

***Patent Pending**

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1. Introduction

Within particle-based Concentrated Solar Power Systems (CSP), particles are the heat transfer medium, and therefore, the heat transfer effectiveness of these systems is reliant on their ability to effectively control particle mass flow rate. The vast majority of approaches for particle flow control in high temperature CSP is based on a slide-gate approach where a gate is linearly actuated across a tear-drop shaped opening. The slide-gate mechanism has a sensitivity of 0.354 g/s-mm, which is defined as the mass flow rate over the position of the gate [1]. In the present work, we have designed and tested a new particle flow control mechanism with the potential for faster response times and different sensitivities than a slide gate approach enabling more control of particle flow.

2. Particle Flow Control

2.1. New Devices

A new device with two different configurations is designed and compared to the current state-of-art mechanism, the slide gate. The principal idea behind the new device is based off a chuck mechanism in a drill. In the new device described here, a similar slide gate actuator movement is considered to be applied to the moving components. However, this movement is horizontal in the slide gate mechanism whereas in the new device it is vertical. The vertical movement of the actuator changes the nozzle cross section area at the bottom opening of the new device, thereby altering the particle mass flow rate (patent-pending). The two configurations assessed in this work are called “Configuration 1” and “Configuration 2.” The primary differences between the two designs are due to the jaw geometry and jaw angle. Configuration 1’s jaw geometry overlaps the two adjacent jaws to create a nearly square device outlet at a jaw angle is 61.5°. On the other hand, Configuration 2 does not have an overlapping jaw geometry, which produces a cross-shaped device outlet, and is at a jaw angle of 57°. Additionally, Configuration 2’s device outlet is about twice the size of Configuration 1’s.

2.2. Experimental Apparatus and Testing Methods

The experimental apparatus consists of a device clamp, device stand, collection area, and a particle feeder. The devices are tested at room temperature by pouring a measured mass of HSP40/70 ceramic particles (0.5kg to 3kg), into the particle feeder that flows directly into the inlet of the device. The time that the particles take to exit the device is measured through video processing at the outlet of the device.

2.3. Results

Three different settings of the jaws are tested to determine the longest transient period in particle flow development: fully open setting, as well as the 4mm, and 7mm jaw extensions known as settings 1 and 2, respectively. Figure 1 displays that the fully open position has the largest transient period of about 2 seconds before the mass flow rate (slope of the data) becomes constant and setting 2 has the shortest period of less than 1 second. Based on this data, all subsequent experiments were carried out for more than 2 seconds.

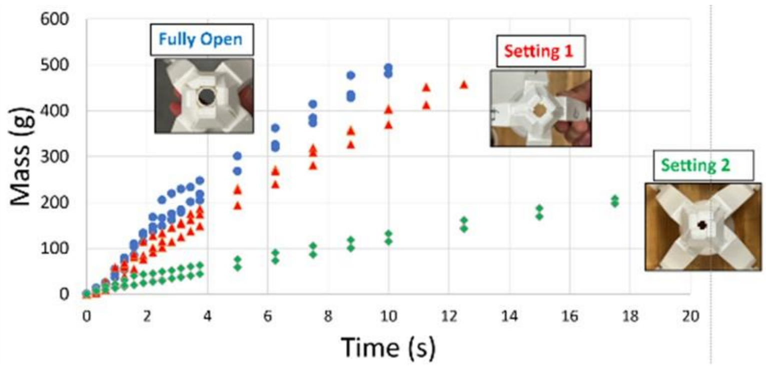

Fig. 1: Steady state flow testing results for Fully Open (Blue), Setting 1 (Red), and Setting 2 (Green)

The slope of the lines in Figures 2 convey the sensitivity of the new design configurations. The green line shows the sensitivity of the slide-gate mechanism in the same range of movement of the new proposed design [1]. Note that the closed position is denoted by the 0 mm jaw movement. Configuration 1 has a sensitivity of 4.28 g/s-mm, which is over ten times greater than the sensitivity of the slide-gate. Similarly, Configuration 2 has a sensitivity of 17.6 g/s-mm, which is about fifty times greater than the slide-gate. Both devices demonstrate significant improvement in the response time for particle flow control.

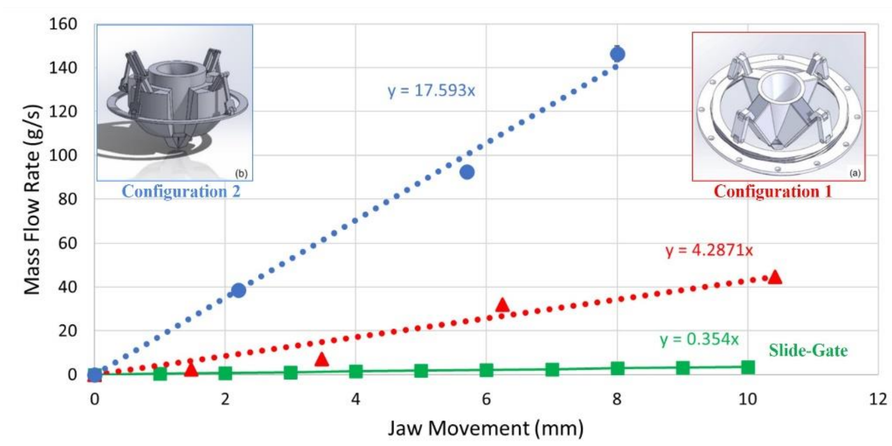

Fig. 2: Configuration 1 (Red) and 2 (Blue) sensitivities compared to the state-of-the-art Slide-Gate (Green) [1]

3. Conclusions

Configuration 1 has a sensitivity of 4.28 g/s-mm and Configuration 2's sensitivity is 17.6 g/s-mm. The higher sensitivity values are primarily due to increased change in cross-sectional area of the opening per unit vertical movement of the new control mechanism compared to the current state of the art.

4. Acknowledgements

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References

[1] Albrecht, Kevin J., and Clifford K. Ho. *High-Temperature Flow Testing and Heat Transfer for a Moving Packed-Bed Particle/SCO2 Heat Exchanger*. 2018, p. 040003, https://doi.org/10.1063/1.5067039.