Experimental and Computational Validation of a Novel Particle Flow Control Valve for CSP Systems*

*Patent Pending

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1. Introduction

Particle-based Concentrated Solar Power (CSP) systems most often utilize the state-of-the-art slide gate mechanism for particle flow control. The slide-gate was found to have a sensitivity of 0.354 g/s-mm, a measure of mass flow rate over actuation position [1]. Particle-based CSP developers have noted that the slide gate is conducive to particle lodging, leaking, and difficulty actuating under particle pressure as well as differential expansion of the gate from thermal cycling. The goal of this work is to design, develop and test a novel particle flow control device that can operate without any hindrance from these shortcomings.

2. Particle Flow Control Device

2.1. Room Temperature Experimental Apparatus

After multiple iterations using 3D printed prototypes [2], a new particle flow control mechanism was built from aluminium, and subsequently tested at room temperature, shown in Figure 1. The device mechanism functions by rotating an outer driving ring, which in-turn moves an inner modulating ring vertically up and down. This modulating ring subsequently raises (or lowers) the connected jaws with it, thus providing a change in the nozzle opening as needed. A stepper motor is used to rotate the outer driving ring, while the inner funnel body is kept fixed.

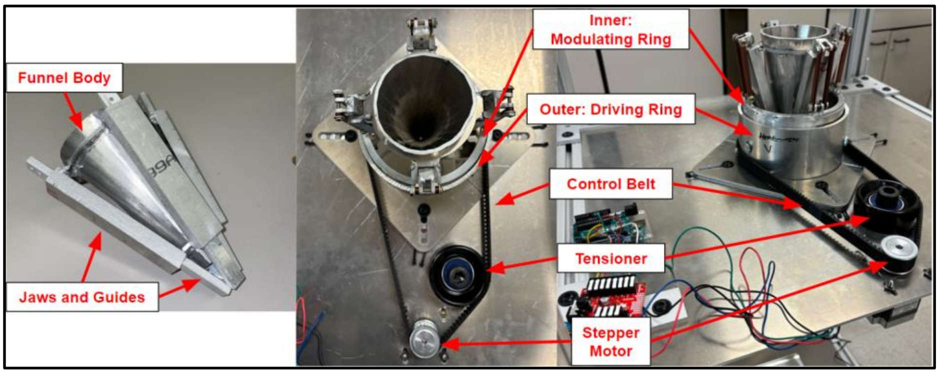

Figure 1 - Aluminum Particle Flow Control Device

Experiments were conducted by opening the valve when filled with a known mass of HSP 40/70 particles to the desired flow setting (jaw position) using the motor actuator, allowing the particles to fall into a collecting bin resting on a mass scale. The mass flow rate at each flow setting was calculated by measuring the time taken for the particles to transfer into the collecting bin. The experiments were repeated 4 times for each jaw opening position to test for repeatability and a maximum standard deviation of 1.82% was calculated. Most importantly, no particle leakage or blockage were observed in any of the tests performed thus far at room temperature. The valve design is currently being tested for operation at higher temperatures.

2.2. Room Temperature Simulation

Particle flow simulations were conducted to validate the room temperature results. The SolidWorks model of the device at each flow setting was imported into Ansys Rocky 2022, a particle simulation software. HSP 40/70 particle properties were modelled within Rocky, albeit at a lower Young’s modulus to reduce simulation time [3]. Before the initialization of the simulation, equivalent of 500 g of particles was loaded into the funnel body. The simulations ended when the results achieved a steady-state mass flow rate value. The room temperature data is compared to the simulation data in Figure 2.

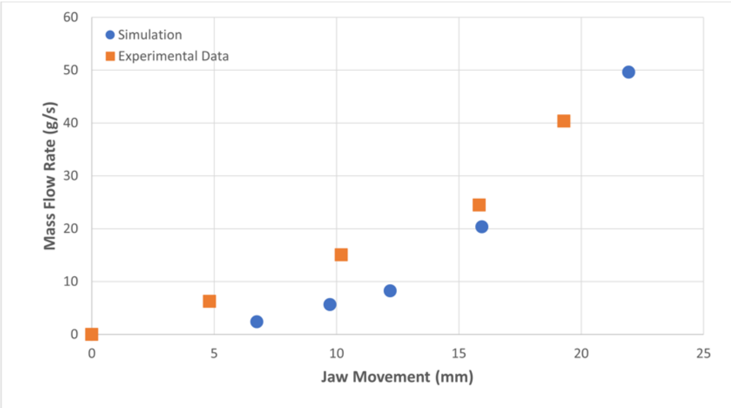

Figure 2 - Room Temperature Experimental Data Compared to Simulation Data

3. Conclusions

The room temperature particle flow control device has demonstrated its ability to control mass flow rate, minimizing particle leakage and lodging, while maintaining ease of operability. The room temperature simulations verified the experimental data and validated the use of these simulations to accurately predict particle flow control of other alternative designs and high-temperature CSP conditions.

4. Acknowledgements

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