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Automated particle mass-flow control system for high-temperature falling particle receivers

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Introduction and Approach

Background

Falling particle receivers (FPR) employing sand-like particles are being pursued to enable increased working-fluid temperatures (>700 C) and higher cycle efficiencies for central receiver power plants.

Problem Statement

Transient irradiance on the particles causes variable heating rates. Methods are required to control the particle mass flow rate to maintain a desired particle outlet temperature with varying irradiance.

Approach

- **A slide gate was designed to adjust the particle flow rate to maintain a constant particle outlet temperature. The new mass flow rate balances the energy equation $Q = \dot{m} c_p \Delta T$.**
- **The slide gate's position is automatically adjusted using a proportional response where the change in the gate's position Δx is:**

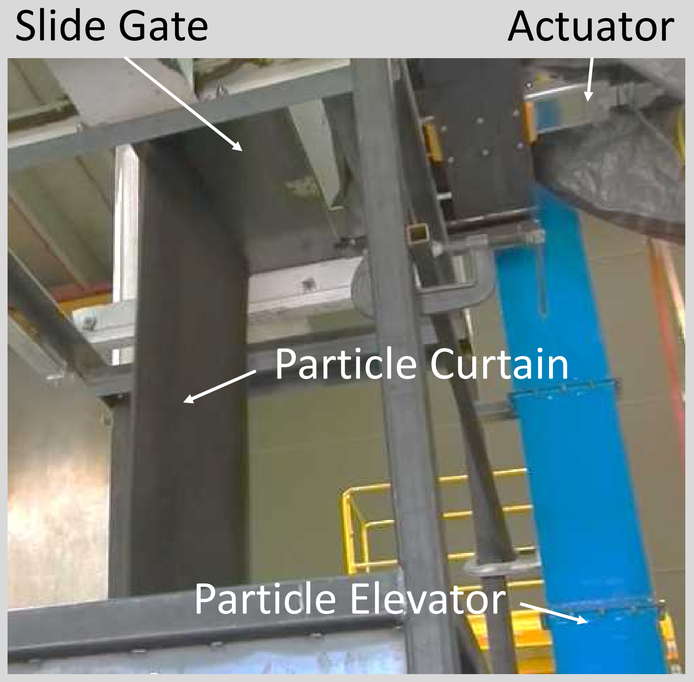
$$\Delta x = \beta\left(T_{setpoint} - T_{particle}\right)$$

$$where:$$

$$\beta = Proportional\ constant\ \left(\frac{mm}{°C}\right)$$

$$T_{setpoint} = Desired\ particle\ outlet\ temp\ (°C)$$

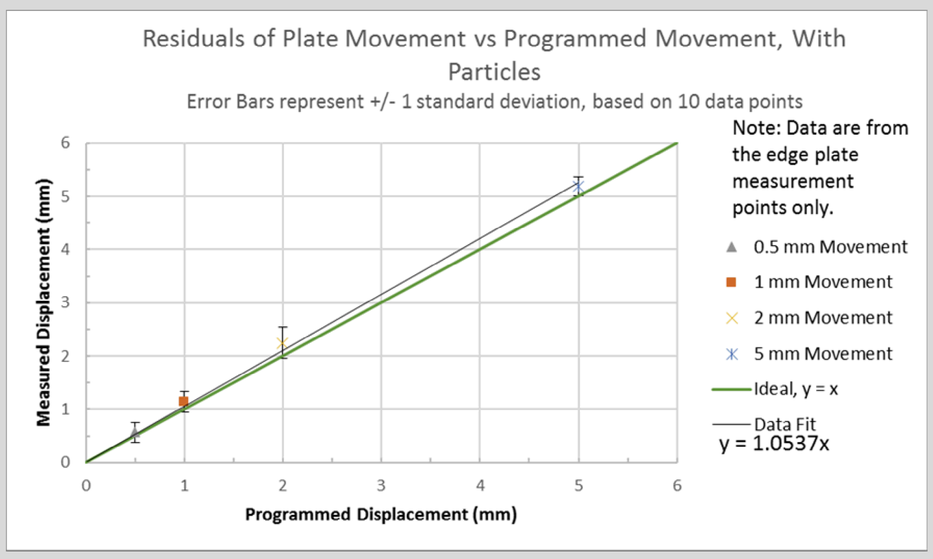
$$T_{particle} = Actual\ particle\ outlet\ temp\ (°C)$$



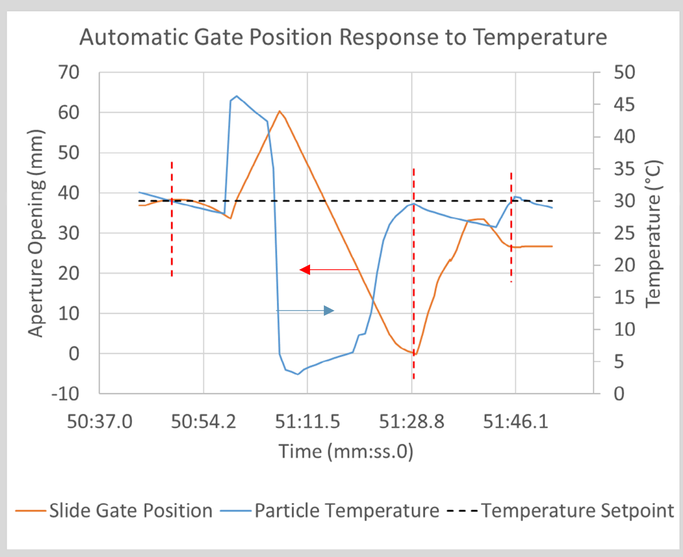
Particles falling by the slide gate. They are recirculated to the top hopper via the blue bucket elevator on the right. The electromechanical actuator can be seen in the top right.

Results and Findings

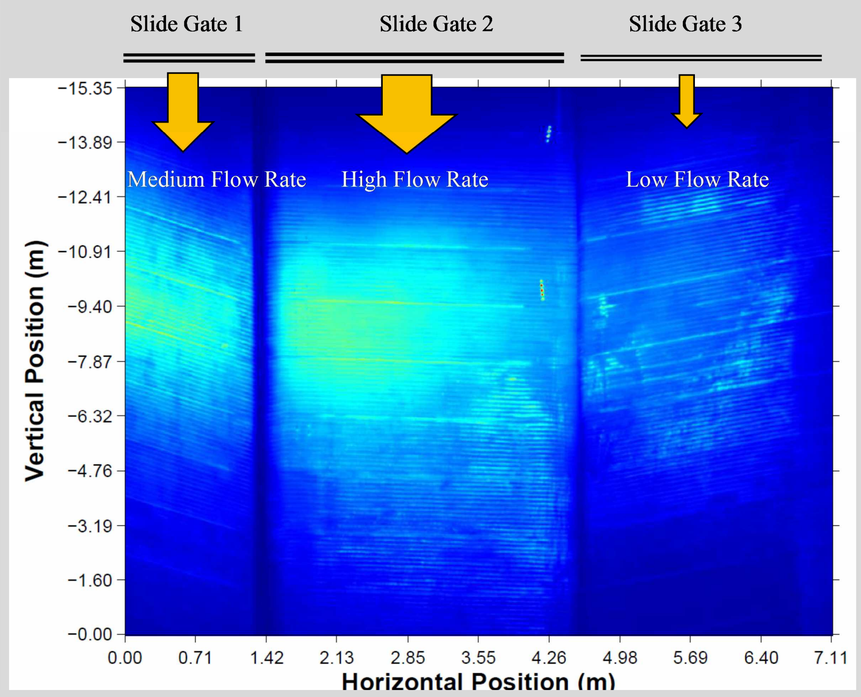
- **Movement of the slide gate can be controlled with sub-millimeter precision**
- **Movement resolution corresponds with a mass flow rate resolution of less than $1\frac{kg}{s*m}$**
- **Small error in the gate's positioning may be due to particle interaction and friction and slippage within the servo motor.**



- **The gate position can be automatically adjusted using only the particle outlet temperature and a proportional response**
- **As the particle temperature approaches the desired set point, the gate's change in position slows or stops**



- **Multiple slide gates can be used to accommodate larger scales and non-uniform irradiance within the receiver. Regions of higher concentration can have higher particle mass flow rates (and vice versa)**



Conclusions

- **Particle mass-flow control using temperature-controlled slide gates appears viable to maintain particle outlet temperatures with time-varying irradiance. Designs and components have been developed to withstand high-temperature operation.**
- **Multiple slide gates can be used for larger-scale systems and to accommodate non-uniform irradiance distributions**

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