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High-Temperature Particle Flow Testing In Parallel Plates for Particle-to-Supercritical CO_2 Heat Exchanger Applications

Concentrating Solar Technologies, Sandia National Laboratories

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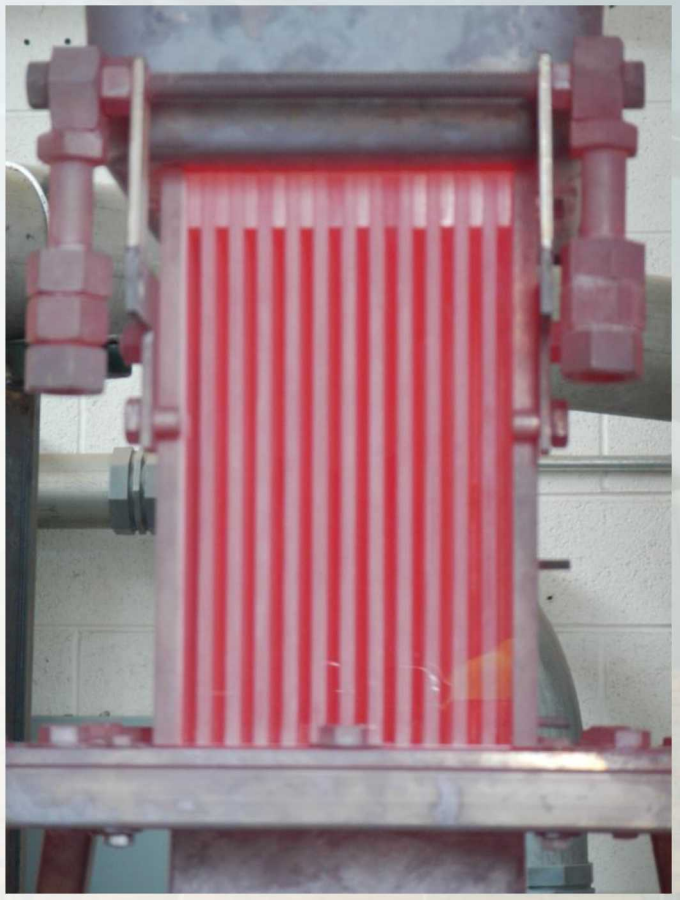
Overview

- Introduction
- Motivation
- Objectives
- Experimental Design
- Experimental Testing
- Results
- Conclusion

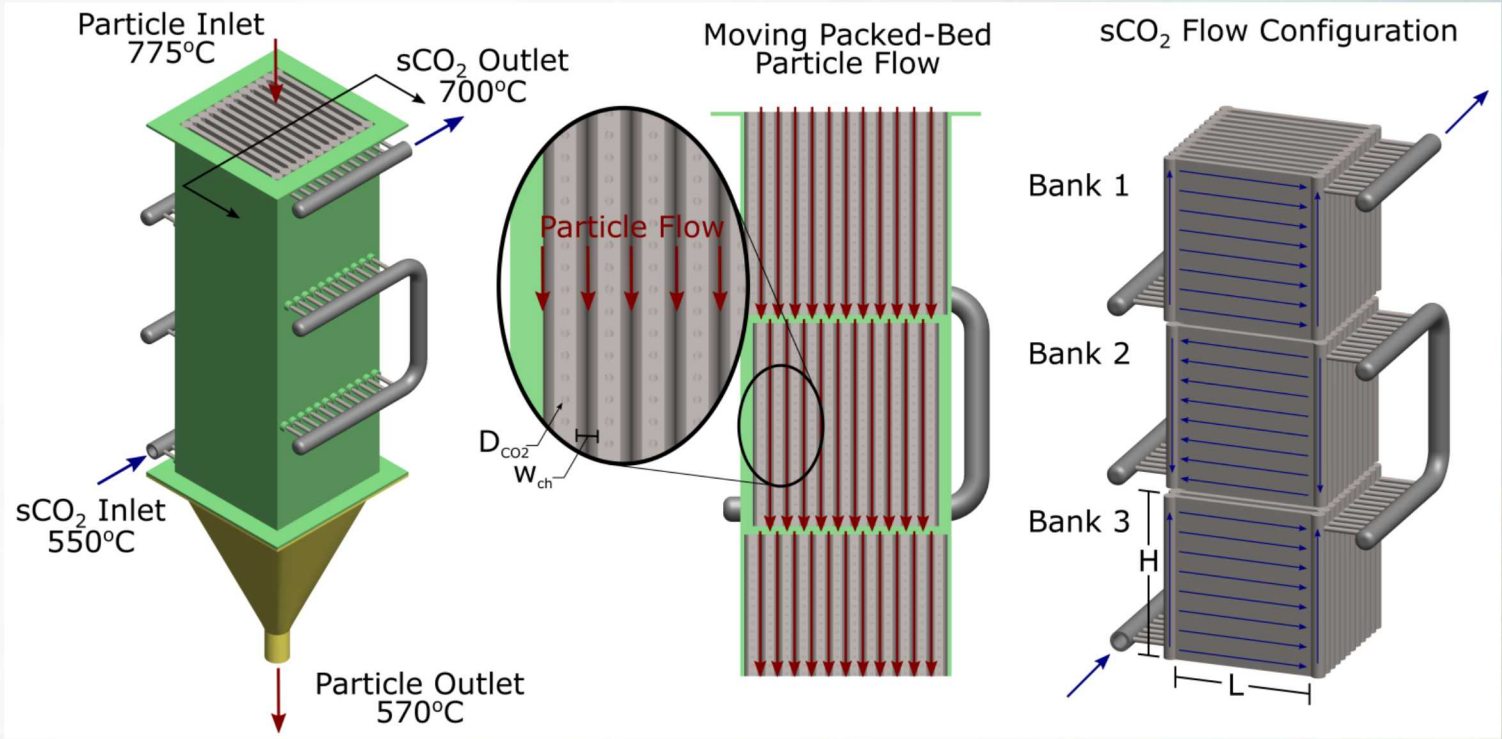
Introduction

- Moving packed bed heat exchanger
- Ceramic based particles
- sCO_2 power cycle integration
- Parallel plate test block
- Flow visualization, quartz window
- High temperature testing, 650 °C
- 4 different channel spacings

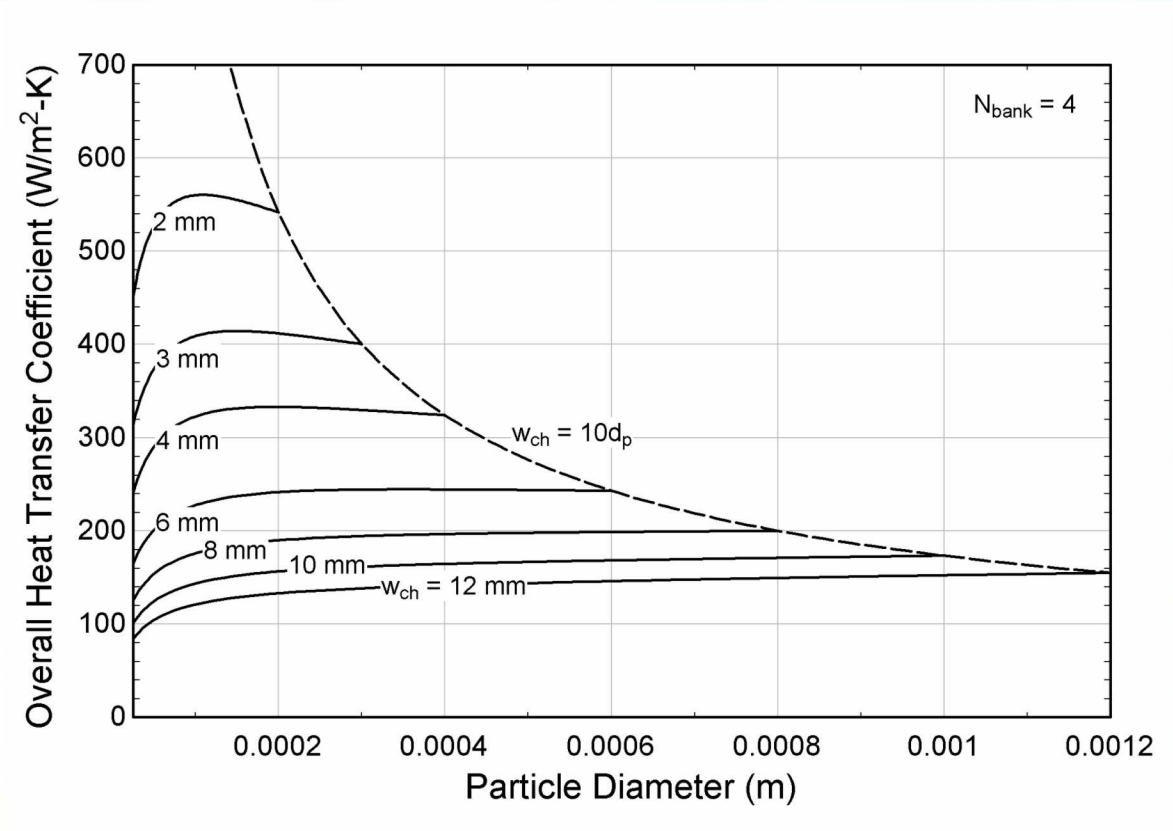


Motivation: Heat exchanger layout and geometry

Moving packed bed heat exchanger; integration with sCO_2 layout



Motivation: Heat transfer coefficient correlation



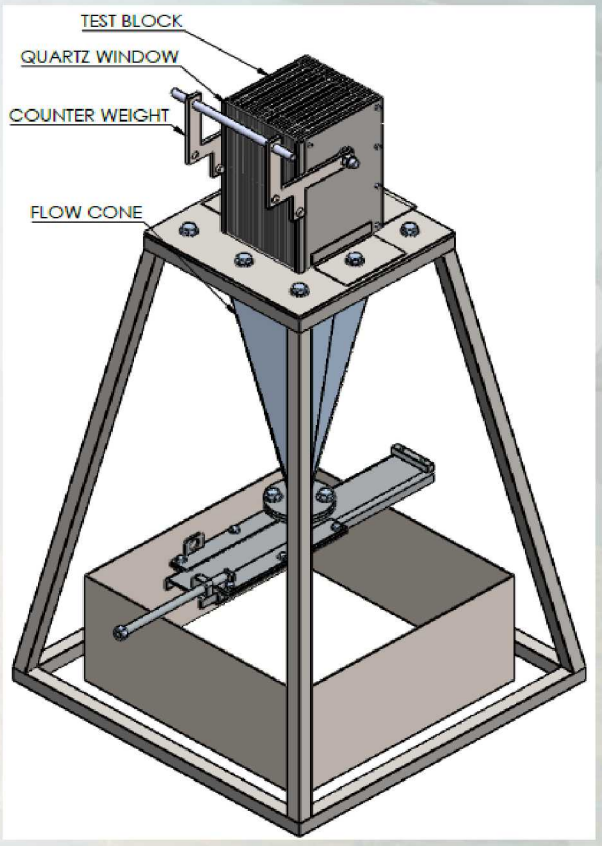
Objectives

- Measure flow distribution across channels (flow variation)
- Finding optimal channel width
- Identify particle bridging conditions
- Temperature dependence of flow in narrow channels
- Identify boundary effects

Experimental Design

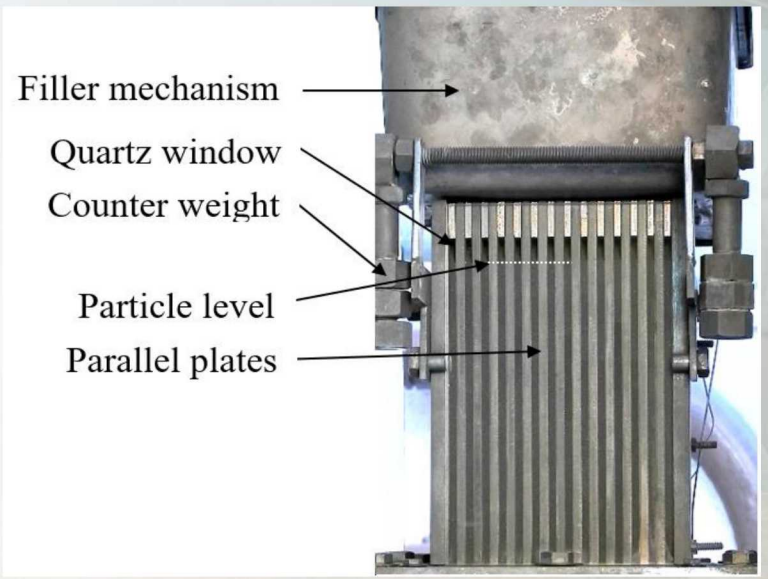
- Standard sheet metal sizes
- Interchangeable spacers
- Variable mass flow
- Modify existing test infrastructure
- High temperature filler mechanism

Standard sizes	Decimal [inch]	Decimal [mm]
1/4”	0.25	6.35
3/16”	0.1875	4.76
12 GA	0.105	2.66
1/16”	0.0625	1.58



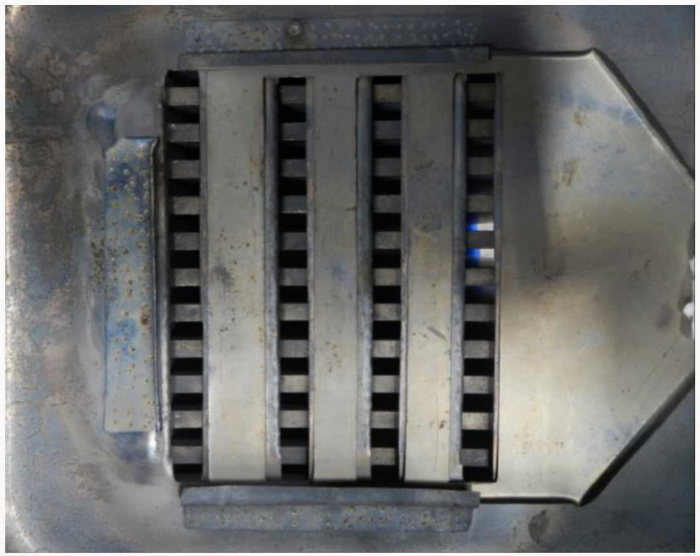
Experimental Testing

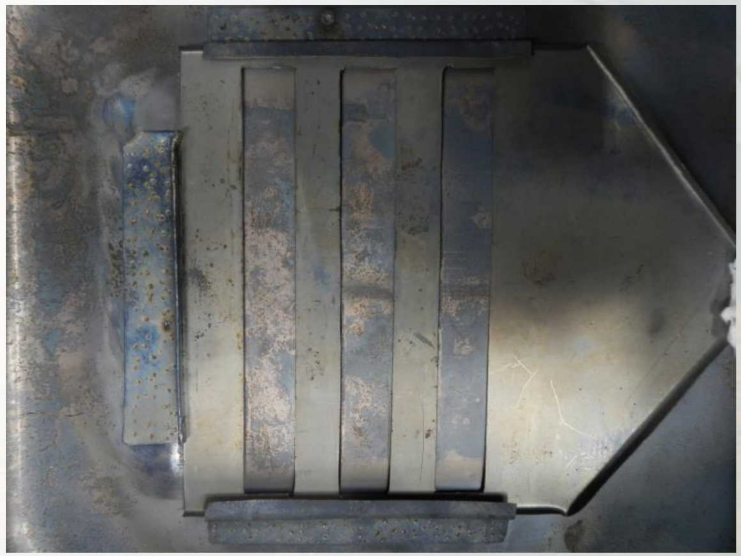
- Experiments done at 650 °C and 25 °C for comparison
- Heat up the test block (15 h)
- Fill test block at high temperature
- Record video of flow test
- Measure mass flow
- Calculate flow variation
- $Flow\ \text{variation}\ (\%) = \frac{V_{max} - V_{min}}{V_{max}} \times 100$



Experimental Testing : filler mechanism

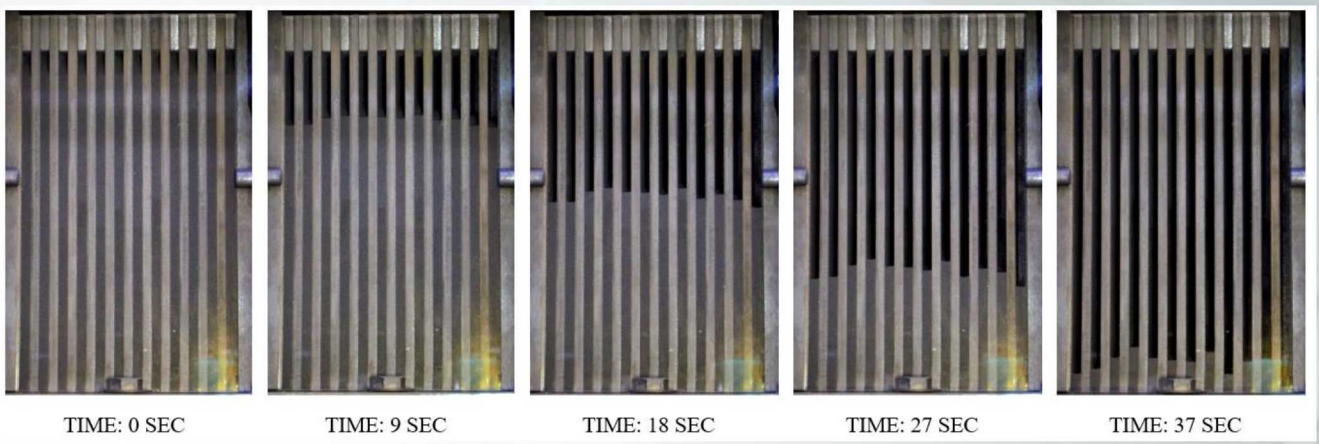
- Filler mechanism used to fill test block at high temperature
- Shown in the open and closed positions



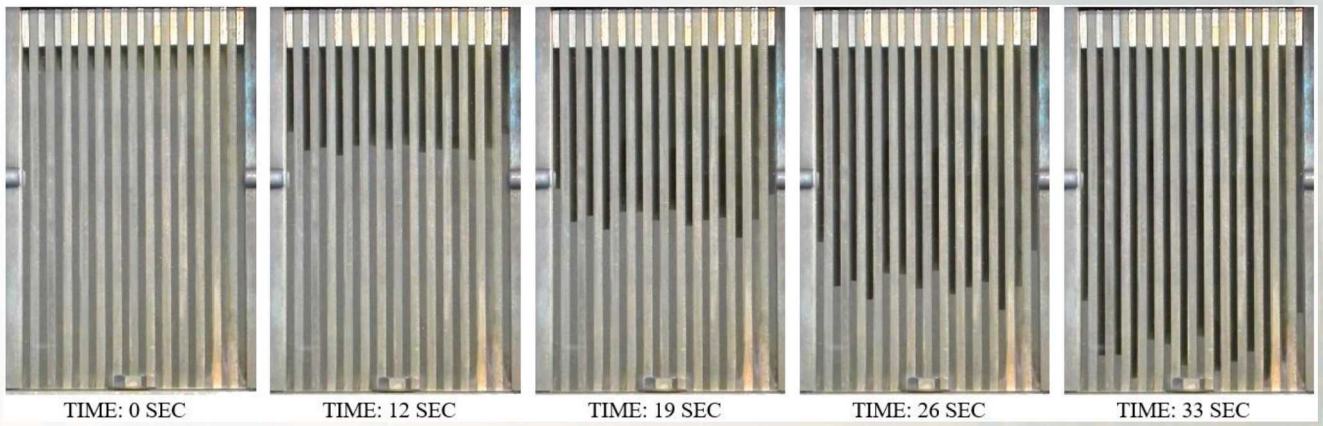


Experimental Testing : hot flow testing

- 650 °C
- 6.35 mm spacing

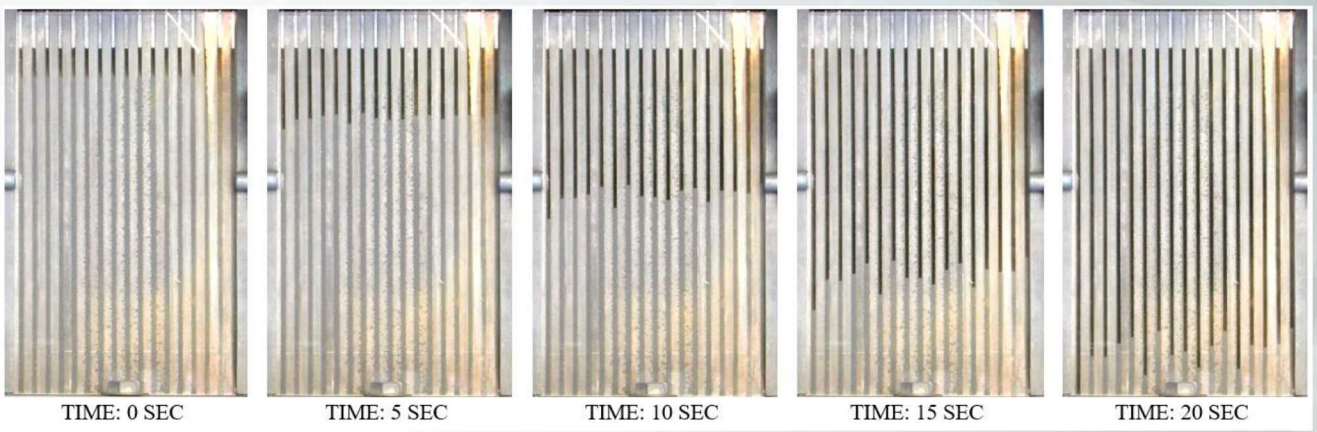


- 650 °C
- 4.76 mm spacing

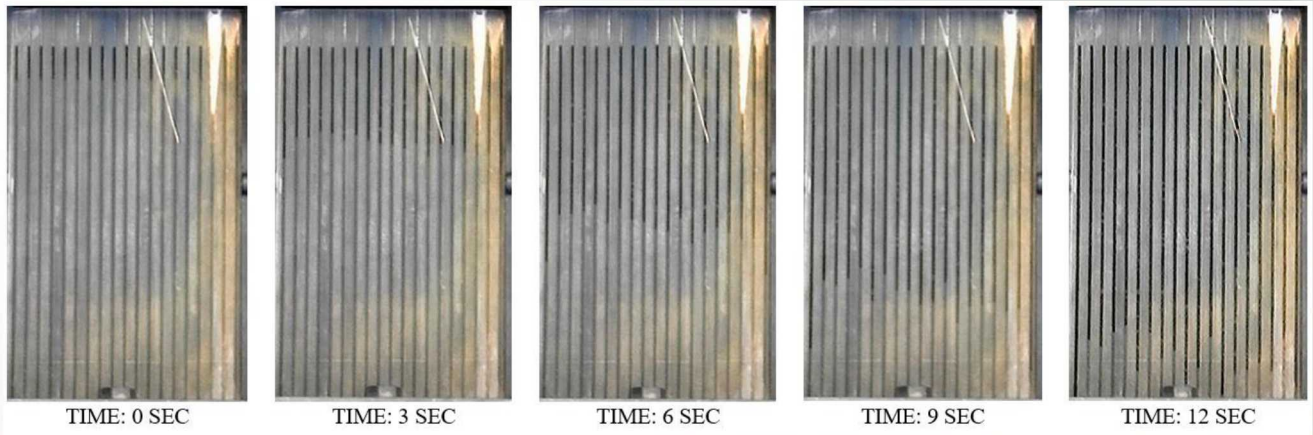


Experimental Testing : hot flow testing

- 650 °C
- 2.66 mm spacing



- 650 °C
- 1.58 mm spacing



Results: flow variation

Flow distribution results for 25 °C testing

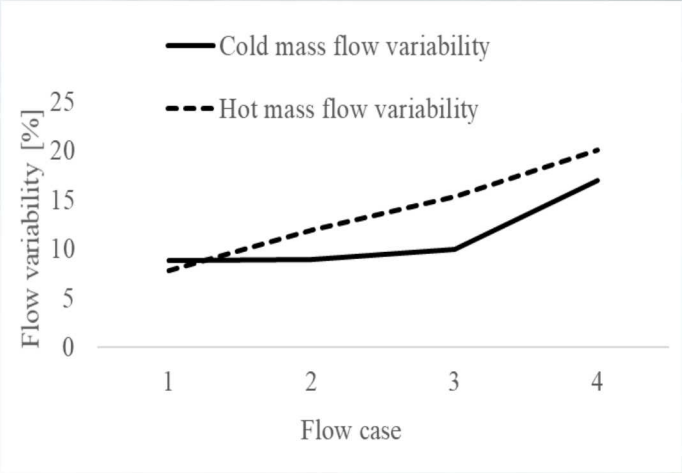
Channel Spacing	Mass Flow Variability [%]	Mass Flow [kg/s]	Flow velocity [mm/s]
1/4”	5.69	0.146	6.14
3/16”	8.95	0.147	6.77
12 GA	16.4	0.148	10.8
1/16”	18.53	0.150	18.57

Flow distribution results for 650 °C testing

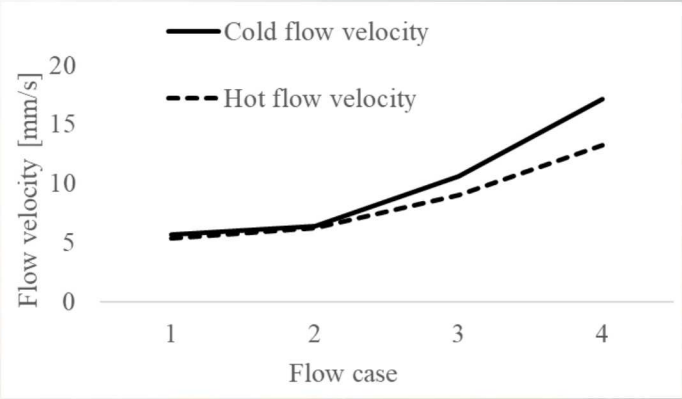
Channel Spacing	Mass Flow Variability [%]	Mass Flow [kg/s]	Flow velocity [mm/s]
1/4”	7.75	0.146	5.3
3/16”	11.94	0.147	6.2
12 GA	15.32	0.146	9
1/16”	20.08	0.149	13.2

Results: flow variation

- Flow variation comparison
- Case 1 to 4; 6.35 mm to 1.58 mm
- Slower flow at high temperature
- High temperature cause more flow resistance

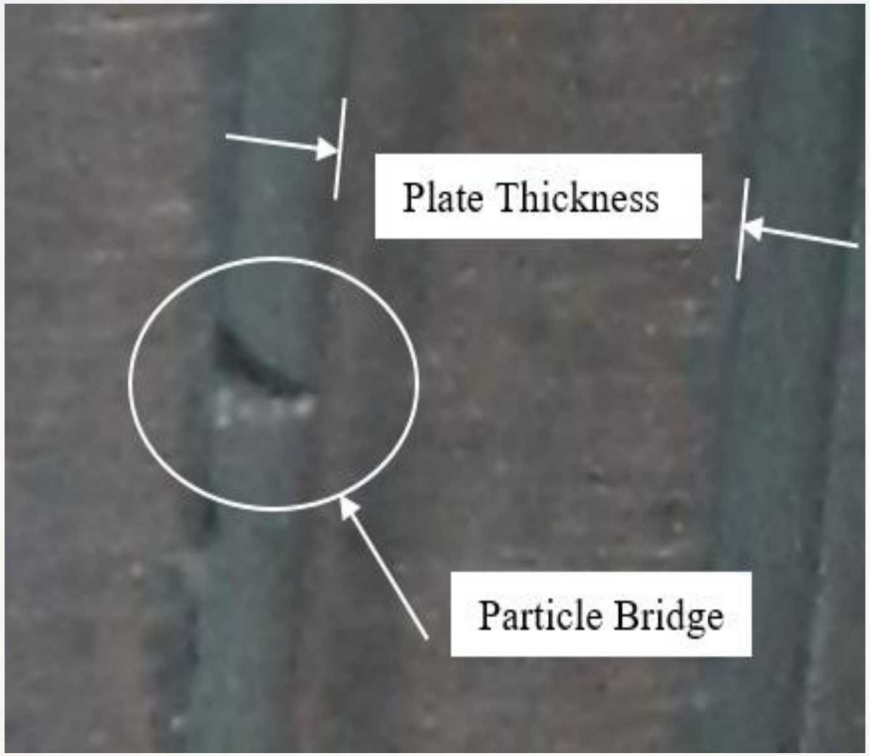


Mass flow variation

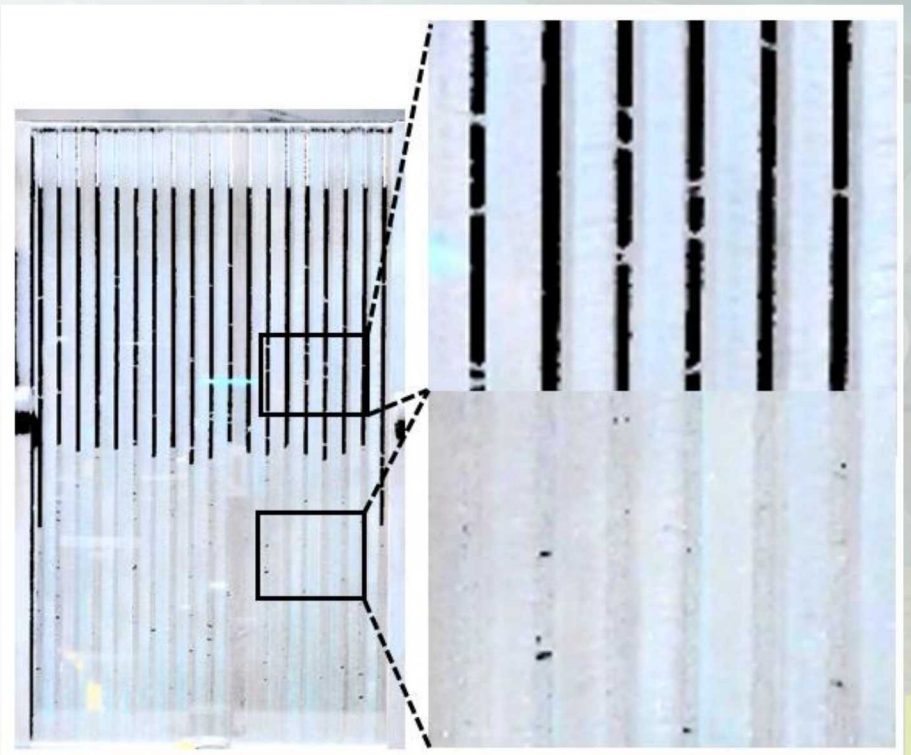


Flow velocity variation

Results: bridging



Photograph of particle bridge: 1.58 mm channel



Voids and bridges forming on quartz window surface

Conclusion

- Lessons learnt; high temperature filler mechanism needed
- Temperature dependence of flow distribution
- 15% flow variation at chosen channel size of 2.66 mm
- 12 GA = 0.105 inch (2.66 mm) was the best channel size
- Particle bridging is not an issue if channel is more than 5 times a particle diameter.
- Boundary effects of the experimental setup were identified and disregarded in the calculation

Acknowledgements

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