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Hydrodynamics and heat transfer analyses of novel free falling particle receiver

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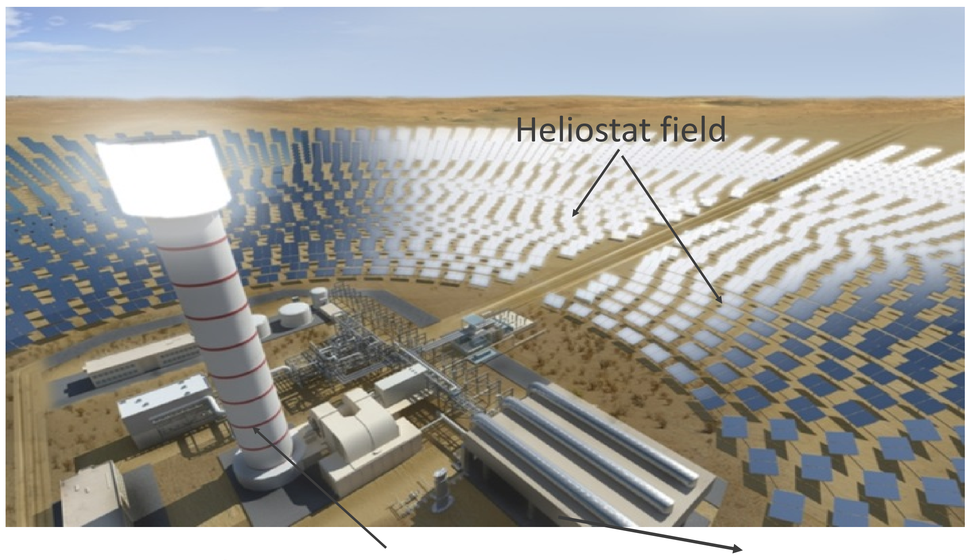
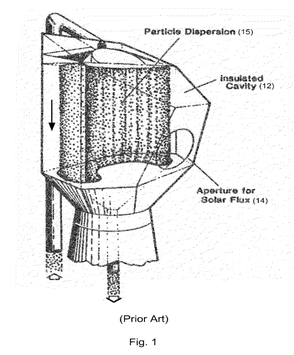
Solid particle receivers are drawing increased attention from the concentrated solar thermal community due to their capability to reach very high operating temperatures (~1000 °C) and receive high solar heat flux (~ 1MWm^{-2}). In conjunction with particle thermal storage, the CSP plants can operate with higher thermal efficiency and generate dispatchable electricity. As one of the front runner for ASTRI full-scale CSP plant, novel designs of particle receiver is being analysed for thermal performance. It is expected that the new design will materialise the predicted receiver thermal efficiency of 90%.

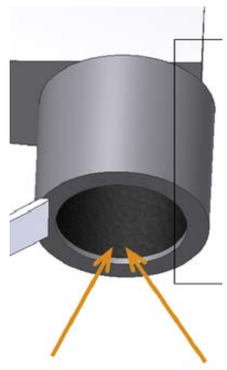
High temperature particle receivers



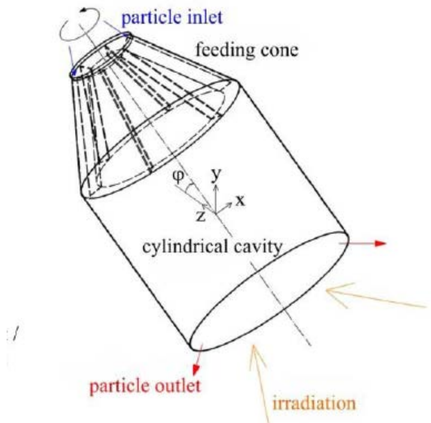
Concentrated Solar Power plant (Central tower system)



Free falling receiver



Face down recirculation receiver



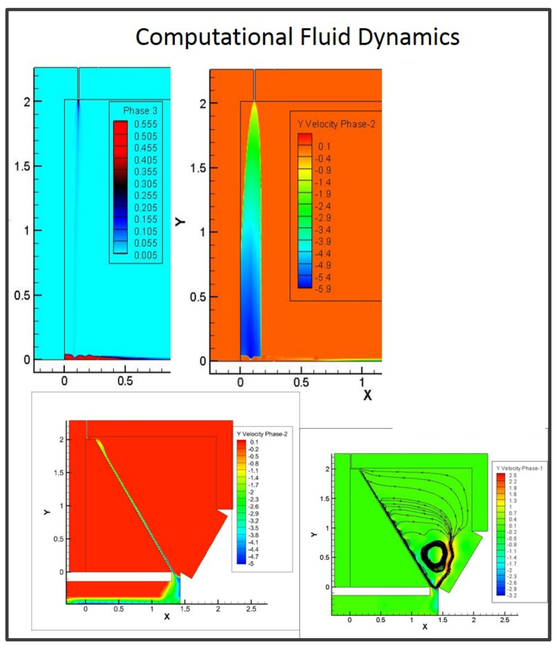
Centrifugal receiver

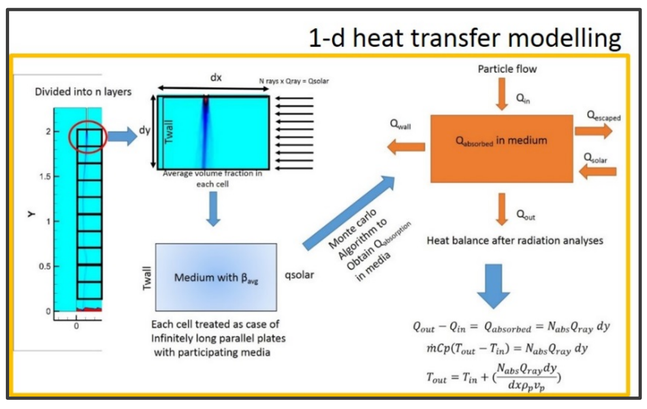
Solid particle receivers

- Can reach high temperatures (~1000°C)
- Cheap particles/safe
- Can receive high heat flux (> 1 MWm^{-2})

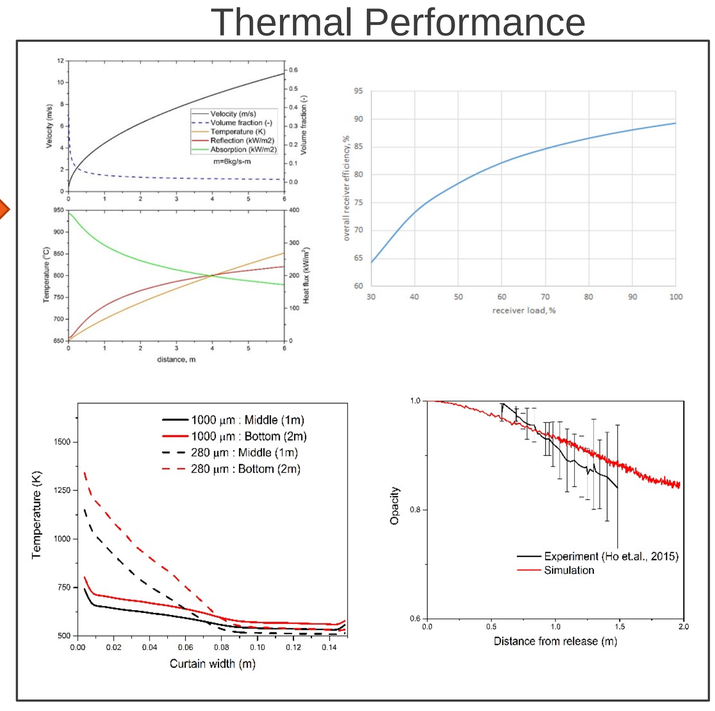
- On-sun tests of particle receivers have given thermal efficiency of only 60%.
- Susceptible to very high reflective losses.

Design Improvements to improve thermal performance





Methodology



Results

- Novel design of free falling particle receivers from rigorous CFD and heat transfer analysis.
- In detail hydrodynamic and radiation characteristics analysis of the particle curtain in free falling particle receiver.
- Simple free falling particle receiver is expected to underperform due to
  - High transmission loss at part-loads especially for larger particles (~1000 µm).
  - Finer particles offer better absorptance of solar radiation but suffer from uneven heating across the particle curtain.
- Improved designs proposed to improve performance due to:
  - Increased residence time of particles
  - Homogenous heat transfer to particle curtain

Future work

- Detailed investigation on radiation characteristics of particle curtain and its dependence on particle size and mass-flowrate.
- Proof of concept experimental setup for the novel particle receiver

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