Mitigating Particle Egress through the Aperture of an Open Solar Vortex Receiver

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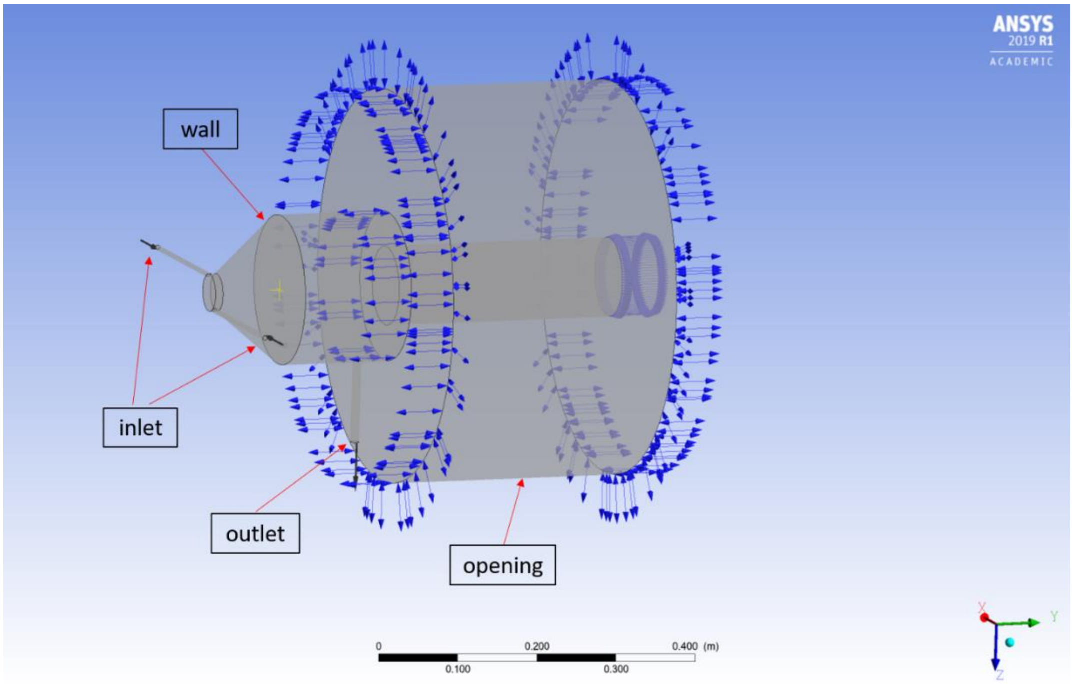
There is growing interest in the use of solid particles as a heat absorber in receivers for concentrated solar thermal (CST) systems. This is because particles, such as silicon carbide particles, are generally good radiation absorbers, due to their large specific surface area, and can be operated at high temperatures. A novel concept of solar particle receiver technology for CST applications was recently patented by the Centre for Energy Technology (CET) at the University of Adelaide, termed the Solar Expanding-Vortex Particle Receiver-Reactor (SEVR). Particle-laden flows are injected forming a vortex within the SEVR for radiation absorption. The design of the SEVR was adapted from that of its predecessor, the Solar Vortex Reactor (Trommer 2006; Z'Graggen 2008), to potentially improve performance (Chinnici et al. 2015; Chinnici et al. 2016; Chinnici et al. 2017). The SEVR is designed as an open receiver that has potential advantages over the use of a quartz window because it avoids the risks of damage and reduced thermal efficiency due to particle deposition. However, new understanding of the aerodynamic mechanisms that govern particle dynamics is needed to prevent particle egress through the aperture of an open receiver. The motivation of the paper is to address this challenge.

In this paper, a computational fluid dynamics (CFD) model of a lab-scaled open vortex-based solar particle receiver is developed as shown in Figure 1, using 'ANSYS CFX 19.3 (2019R1)'. This model was adopted and modified from a previous study on a solar vortex gasifier done by Meier, Ganz and Steinfeld (1996) and Tian, Nathan and Cao (2015). Shear Stress Transport (SST) model was employed to simulate the particle-laden flows within the cavity under isothermal conditions. The relationship between particle egress and the outlet pressure for different configurations has been investigated. The CFD simulation results presented that the outlet pressure plays an important role in influencing the flow pattern and therefore mitigating particle egress through the aperture of the SEVR. For a specified configuration, the outlet pressure changed from -200 Pa to -500 Pa can mitigate particle egress from nearly 30% to 6.33%. However, 6.33% of particle egress is still unacceptably high because such particle egress will cause pollution and reduce the energy efficiency in real applications. It was found that high Reynolds number at inlet increases particle egress through the aperture due to large inertia. High egress rates are found for Stokes number around 1 within the cylinder because such particles are distributed close to the centre of the cavity, which makes particles easier to escape through the aperture.

Figure 1. Boundary conditions of the SEVR in CFX Pre.



References

Chinnici, A, Arjomandi, M, Tian, ZF, Lu, Z & Nathan, GJ 2015, 'A Novel Solar Expanding-Vortex Particle Reactor: Influence of Vortex Structure on Particle Residence Times and Trajectories', *Solar Energy*, vol. 122, pp. 58-75.

Chinnici, A, Arjomandi, M, Tian, ZF & Nathan, GJ 2016, 'A Novel Solar Expanding-Vortex Particle Reactor: Experimental and Numerical Investigation of the Iso-thermal Flow Field and Particle Deposition', *Solar Energy*, vol. 133, pp. 451-464.

Chinnici, A, Xue, Y, Lau, TCW, Arjomandi, M & Nathan, GJ 2017, 'Experimental and numerical investigation of the flow characteristics within a Solar Expanding-Vortex Particle Receiver-Reactor', *Solar Energy*, vol. 141, pp. 25-37.

Meier, A, Ganz, J & Steinfeld, A 1996, 'Modeling of a novel high-temperature solar chemical reactor', *Chemical engineering science*, vol. 51, no. 11, 1996/06/01/, pp. 3181-3186.

Tian, ZF, Nathan, GJ & Cao, Y 2015, 'Numerical modelling of flows in a solar–enhanced vortex gasifier: Part 1, comparison of turbulence models', *Progress in Computational Fluid Dynamics, an International Journal*, vol. 15, no. 2, pp. 114-122.

Trommer, D 2006, 'Thermodynamic and kinetic analyses of the solar thermal gasification of petroleum coke', ETH Zurich.

Z'Graggen, A 2008, 'Solar Gasification of Carbonaceous Materials: Reactor Design, Modeling, and Experimentation', ETH Zurich.