Optimization Of The Cylindrical CO_2 Desorption Reactor

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Abstract

Microwave heating for CO_2 desorption provides fast, low-temperature desorption, lowering energy requirements in carbon capture. According to studies, microwaves generate selective heating, dramatically increasing desorption rates compared to traditional approaches. This new technique shows potential for effective post-combustion carbon capture procedures [1-3].
A simulation study was constructed using the COMSOL Multiphysics program to investigate, simulate, and improve the heating process. A parametric sweep was performed for the case where the waveguide was positioned at the center of the microwave cavity to study the effect of the microwave cavity dimensions (inner diameter, outer diameter, and height) on the power absorbed using the RF module. Then, based on the parametric sweep, the dimensions of the microwave cavity were optimized using the RF and optimization modules to maximize the power absorbed by the sorbent material for two cases. In Case One, the waveguide is positioned in the middle of the cavity, and in Case Two, the waveguide is positioned in the top end of the cavity. Then, the heat transfer and RF modules were used to investigate the effect of the waveguide position on the temperature and electrical field intensity distributions within the sorbent.
The dimensions of the microwave cavity considerably influence its resonance frequency, coupling efficiency, mode distribution, and field uniformity, which will determine how much power the sorbent bed absorbs. The optimal microwave cavity and reactor dimensions reduce reflection, maximize the electrical field inside the sorbent material, and assure resonance with the operating frequency, maximizing the power absorbed by the sorbent material and the microwave input power utilization. Using the optimal dimensions can result in absorbing more than 98% of the microwave power input, which results in a more efficient desorption system. The power absorbed in case one, which is positioning the waveguide at the middle height of the cavity, absorbed 1.6% more power than case two and had a more uniform electrical and temperature distribution. A design with a waveguide placed at the middle is suitable for a fluidized bed reactor where the sorbent will be moving along the length of the reactor.
The simulation results revealed a significant improvement in the power absorbed by the sorbent bed. As a result, this would help improve the microwave desorption energy utilization efficiency in the carbon capture process.

Reference

1. Ellison, C., et al., “Comparison of microwave and conventional heating for CO2 desorption from zeolite 13X”, International Journal of Greenhouse Gas Control, 107(103311), 2021.
2. Gomez-Rueda, et al., “Rapid temperature swing adsorption using microwave regeneration for carbon capture”, Chemical Engineering Journal (Lausanne, Switzerland: 1996), 446(137345), 2022.
3. Lim, T. H., et al., “Microwave-based CO2 desorption for enhanced direct air capture: experimental validation and techno-economic perspectives”, Environmental Research Letters, 19(3), 034002, 2024.

Figures used in the abstract

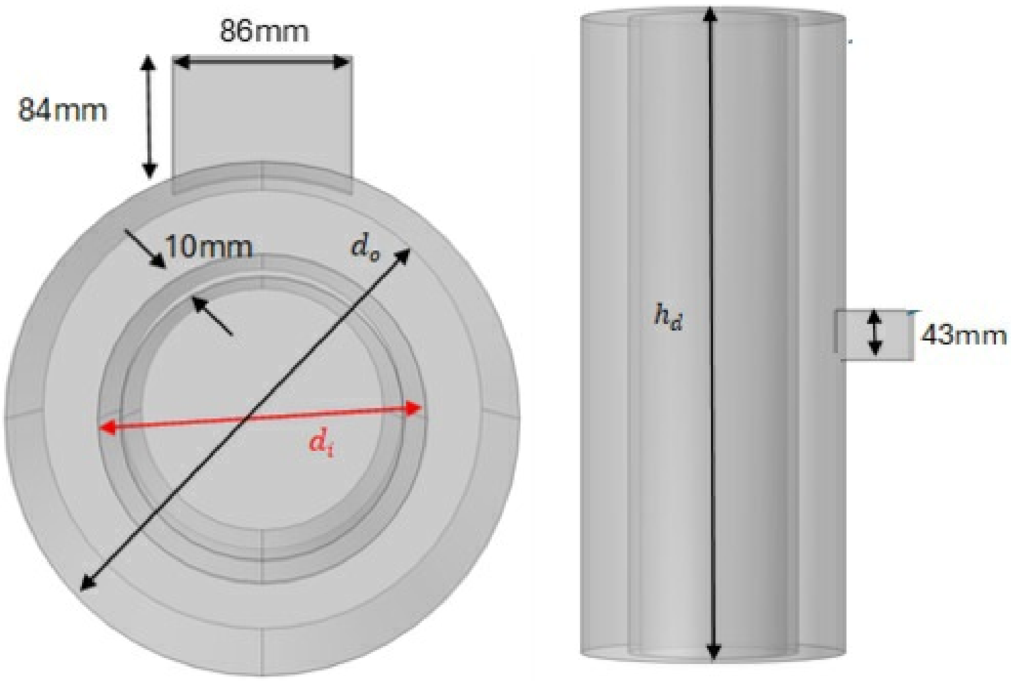

Figure 1 : The geometry of the model

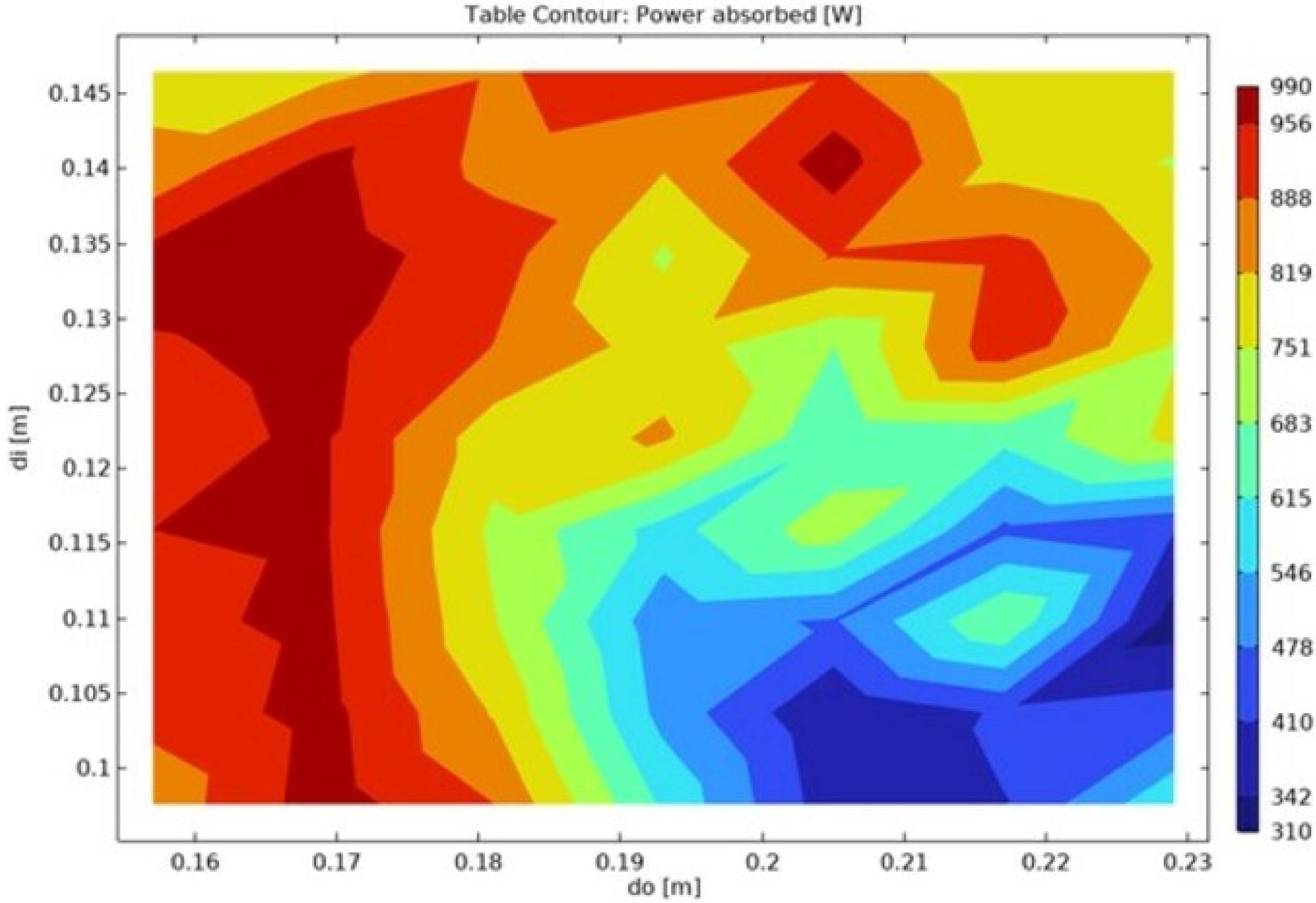

Figure 2 : The effect of the inner and outer diameter of the microwave cavity on the power absorbed.

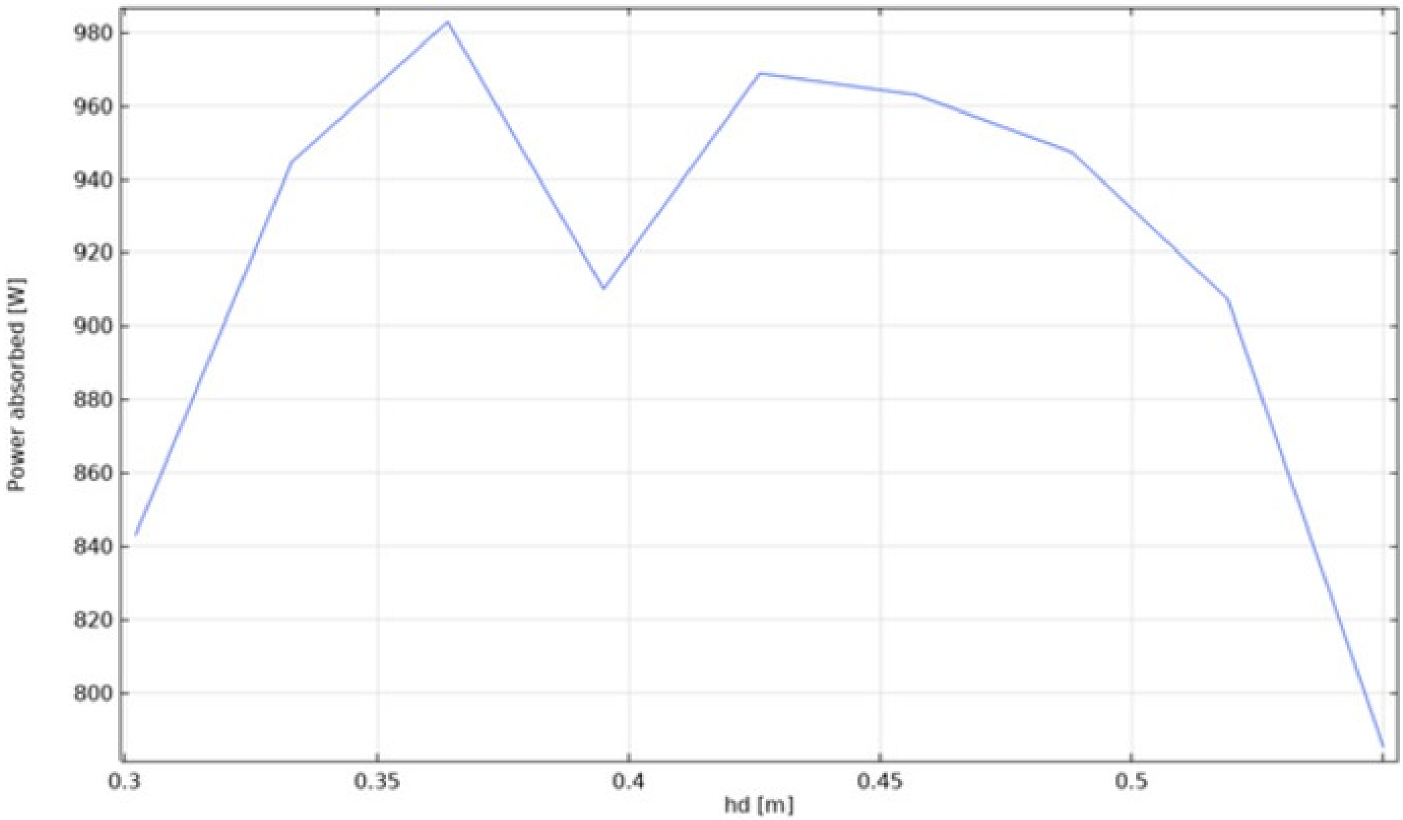

Figure 3 : The effect of the height of the microwave cavity on the power absorbed.

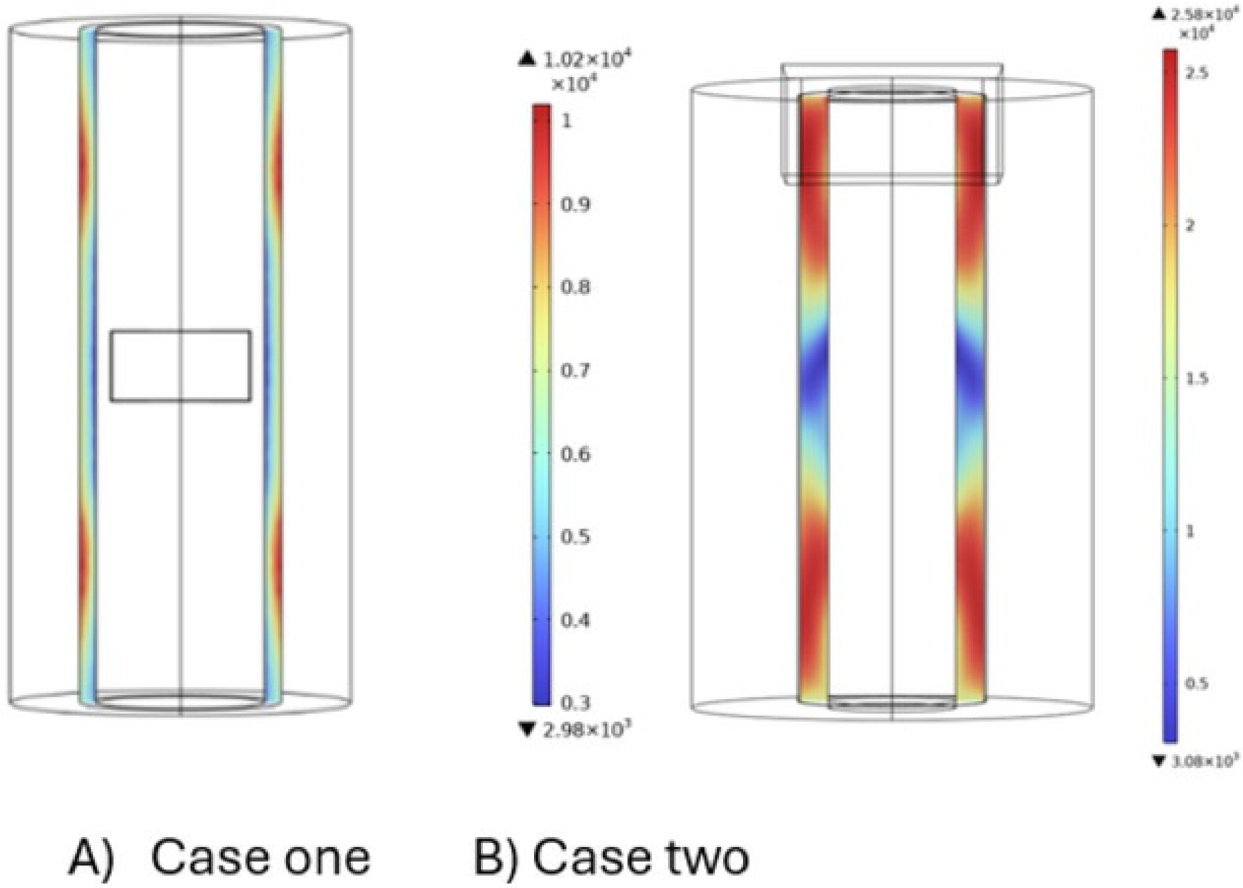

Figure 4 : Electrical filed distribution at plane x=0 for case 1) waveguide placed at the middle and case 2) waveguide placed at the end top.