

Additively Manufactured Intensified Device for Enhanced Carbon Capture

primary project goals

Oak Ridge National Laboratory (ORNL) is developing intensified devices combining multiple thermodynamic operations for improved efficiency for solvent-based carbon dioxide (CO₂) capture. These additive-manufactured packing structures combine heat and mass transfer, simultaneously increasing the reactive surface area and enhancing heat exchange efficiency.

technical goals

- Utilize a computational fluid dynamics (CFD) model to realize a design and perform a parametric study on key design and operational parameters.
- Demonstrate the manufacturability of an equivalent geometry of a widely used packing structure (Mellapak 250) and intensified device design with additive manufacturing techniques.
- Validate the core-scale metrics of the additively manufactured device to compare to its commercial counterpart.
- Design and print a device-scale prototype.
- Test the device-scale prototype with a commercially available solvent and simulated flue gas to evaluate overall capture performance.

technical content

ORNL is developing intensified CO₂ capture devices, which can combine multiple thermodynamic operations into one unit. Improvements in solvent-based CO₂ capture devices are targeted through analysis of monoethanolamine (MEA) absorption and desorption of CO₂. The multi-functionality of these intensified devices is envisioned to be achieved through graded packing structures with built-in heat exchanging channels made by additive manufacturing technologies, namely 3D printing.

Conventional carbon capture systems are configured with multiple unit operations that use sequentially coupled stages for mass and heat transfer. Since solvent- and sorbent-based capture intrinsically couples mass and heat transfer at the fundamental length scales, multiple stages of single-purpose unit operations would result in larger equipment size, higher equipment costs, and potentially less than optimal operating conditional for the equipment. This project aims to use additive manufacturing technologies to develop a graded packing structure to allow for the integration of heat exchange, reaction, and potentially mass exchange in one multi-functional structure, and then to optimize the geometry to maximize the capture performance. By combining these operations in the single unit, this device would lead to intensification of the capture process.

technology maturity:

Bench-Scale, Simulated Flue Gas

project focus:

Additively Manufactured Intensified Device for Solvent-Based CO₂ Capture

participant:

Oak Ridge National Laboratory

project number:

FWP-FEAA130

predecessor projects:

N/A

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partners:

N/A

start date:

07.01.2017

percent complete:

100%

To execute this project, ONRL applied capabilities in CFD, additive manufacturing, and absorber-scale demonstration/validation experiments. The team utilized a Carbon Capture Simulation for Industry Impact (CCSI²)-developed CFD model to enable optimization of an additive-manufactured intensified carbon capture device. This computational tool was used for design realization and for a parametric study on key design and operational parameters. The target structured packing control was the commercial Mellapak 250 (shown in Figure 1). ORNL fabricated 3D-printed devices with different cell densities (Figure 2). The test packing was 8 inches in diameter and 5.57 inches tall. Cell sizes of 25.4 millimeter (mm), 12.7 mm, and 6.3 mm were printed.



Figure 1: Mellapak (commercial) structured packing.



Figure 2: Packing with different cell densities, 3D-printed at ORNL.

ORNL fabricated a second-generation intensified device (Figure 3) for use in heat and mass transfer studies. The solvent-based reactive test system, shown in Figure 4, included the 3D-printed intensified device within a column containing commercial packing elements.

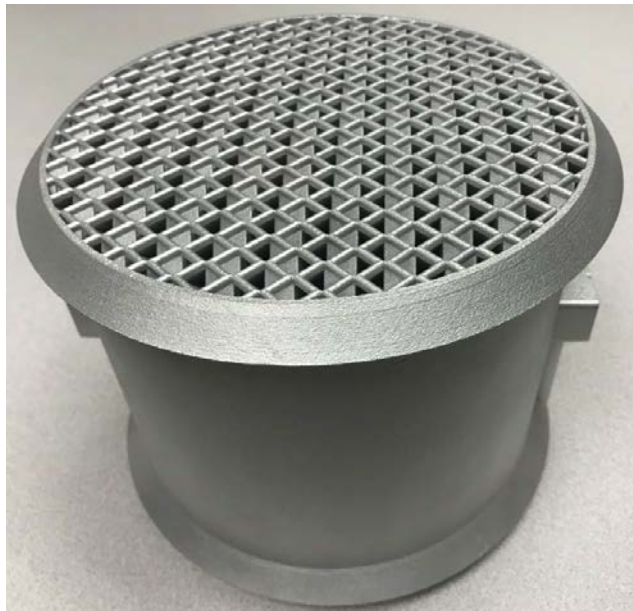


Figure 3: Second-generation intensified device.

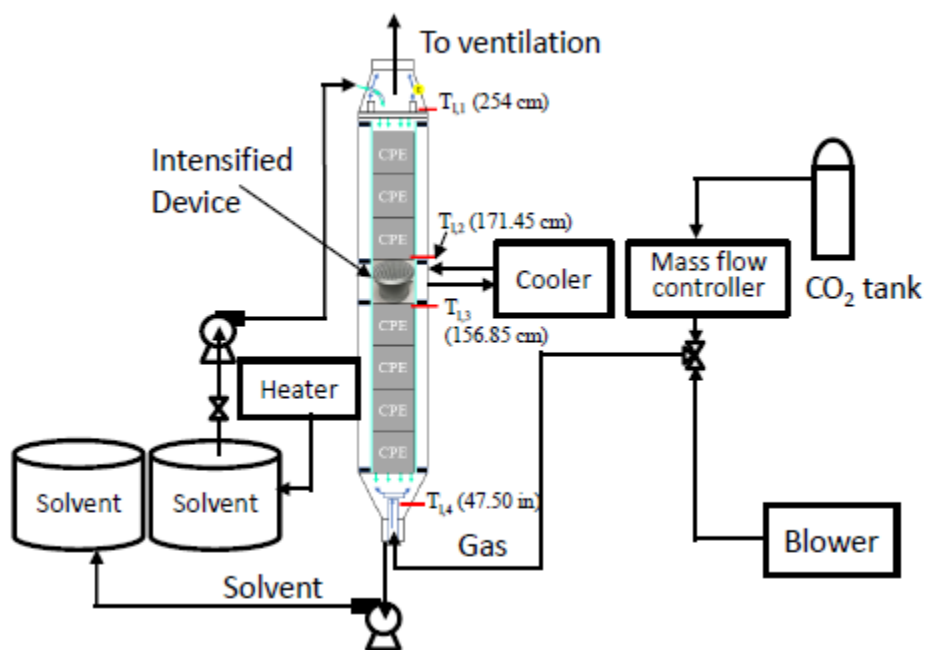


Figure 4: Reactive system test facility.

technology advantages

- Improvement of CO₂ capture efficiency by simultaneously increasing reactive surface area and enhancing heat exchange efficiency in order to maintain the forward absorption reaction in the absorber column.

R&D challenges

- Fabrication of a benchmark geometry for a conventional packing structure, interpreting the computationally derived intensified device requirements, and demonstrating the manufacturability of the intensified device design additive manufacturing techniques.

status

ORNL has successfully designed, printed, characterized, and tested a 3D-printed intensified packing device. The intensified device had hydrodynamic behavior that was not much different than that of the commercial-structured packing elements. The intensified device was capable of substantially reducing the amine solvent temperature *in situ*. Experiments showed enhanced CO₂ capture rates using the intensified device.

available reports/technical papers/presentations

Sun, X., et al. "Additively Manufactured Intensified Device for Enhanced Carbon Capture," Presented at Final Project Review Meeting, Pittsburgh, PA, November 2019. https://www.netl.doe.gov/projects/files/ORNL%20FWP-FEAA130%20final%20project%20review_110819.pdf.

Bolton, S., Kasturi, A., Palko, S., Lai, C., Love, L., Parks, J., Sun, X., and Tsouris, C., "3D Printed Structures for Optimized Carbon Capture Technology in Packed Bed Columns," Separation Science and Technology, 54, 2047-2058 (2019).

Sun, X., et al. "Additively Manufactured Intensified Device for Enhanced Carbon Capture," Presented at the 2019 NETL CO₂ Capture Technology Meeting, Pittsburgh, PA, August 2019. <https://netl.doe.gov/sites/default/files/netl-file/X-Sun-ORNL-Additively-Manufactured-Device.pdf>.

Sun, X., et al. "Additively Manufactured Intensified Device for Enhanced Carbon Capture," Presented at the 2018 NETL CO₂ Capture Technology Meeting, Pittsburgh, PA, August 2018. <https://netl.doe.gov/sites/default/files/netl-file/X-Sun-ORNL-Additive-Manufacturing-Utilization.pdf>.

Sun, X., et al. "Additively Manufactured Intensified Device for Enhanced Carbon Capture," Presented at Project Kickoff Meeting, Pittsburgh, PA, October 2017. <https://www.netl.doe.gov/projects/files/FWP-FEAA130-Kickoff-101917.pdf>.