Full System Modeling and Validation of the Carbon Dioxide Removal Assembly

R. F. Coker[1], J. Knox[1]

[1]NASA Marshall Space Flight Center, Huntsville, AL, USA

Abstract

Introduction: Developments intended to improve system efficiency and reliability for water and carbon dioxide separation systems to be used on crewed vehicles combine sub-scale systems testing and multiphysics simulation. This paper describes the development of COMSOL Multphysics® simulations in support of the Atmosphere Revitalization Recovery and Environmental Monitoring (ARREM) project within NASA's Advanced Exploration Systems (AES) program. Specifically, we model a variety of cylindrical breakthrough experiments to explore our predictive capability.

Use of COMSOL Multiphysics: The transport of a concentrated species, water or carbon dioxide, in a carrier gas, nitrogen, was modeled as free and porous media flow through a bed of silica gel pellets. The adsorption rates and pellet loading were determined from solving a distributed ODE based on Toth isotherms. The resulting heat transfer in the porous media and the solid housing was modeled with the respective physics nodes. However, this use of COMSOL interfaces in 2D has proven unsuccessful, so we have developed our own 1D PDEs which represent the same physics and solved those in the COMSOL simulation.

Results: Using COMSOL software to solve our PDEs that model the bulk desiccant process has resulted in a favorable match to temperature and concentration data for a range of inlet dew points, initial conditions, and flow rates. For example, Figures 1 and 2 show experiment and simulation comparisons for the gas temperature and water vapor pressure, respectively. Note the model uses the measured inlet dew point and temperature for time-dependent inlet boundary conditions. Further work will focus on modeling 2D and 3D flow as well as different sorbents and sorbates and expanding the model regime to determine various sensitivities. Barring unforeseen issues with those models, COMSOL simulations should be a useful tool to explore design space for ARREM water separation development.

Conclusions: The need for optimized atmosphere revitalization systems is necessitated by the aggressive new missions planned by NASA. Innovative approaches to new system development are required. This paper presents such an approach for the AES ARREM project, where testing is supplemented with modeling and simulation to reduce costs and optimize hardware designs. The application of the COMSOL model in 1D to simulate sub-scale breakthrough tests shows promise. The efforts represented here will be continued to support the design of Atmosphere Revitalization systems under the ARREM project. These modeling and simulation efforts are

expected to provide design guidance, system optimization, and troubleshooting capabilities for atmosphere revitalization systems being considered for use in future exploration vehicles.

Figures used in the abstract

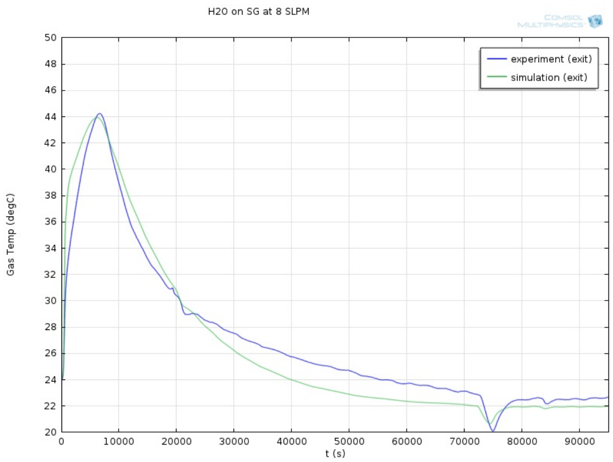

Figure 1: Experiment and simulation comparisons for the gas temperature.

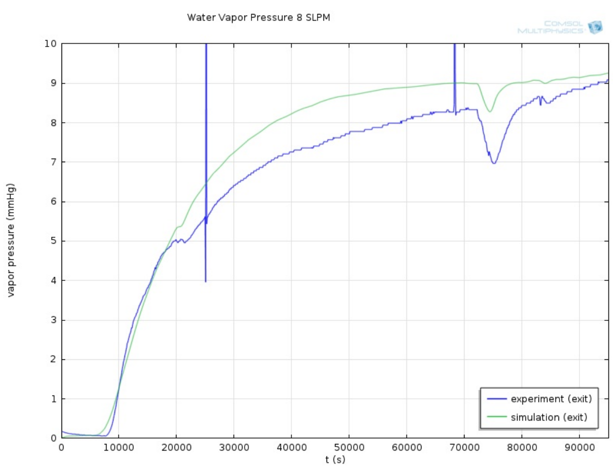

Figure 2: Experiment and simulation comparisons for the water vapor pressure.