Modeling of Atmosphere Revitalization

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Abstract

All spacecraft systems must be minimized with respect to mass, power, and volume. Here, we focus on current efforts to improve system efficiency and reliability for water separation systems to be used on crewed vehicles. These development efforts combine sub-scale systems testing and multi-physics simulations to evaluate candidate approaches. The best performing options will then be implemented in full-scale integrated atmosphere revitalization tests. This paper describes the initial development of COMSOL simulations in support of the Atmosphere Revitalization Recovery and Environmental Monitoring (ARREM) project within NASA's Advanced Exploration Systems (AES) program. The transport of a dilute species, water, in a carrier gas, nitrogen, was modeled as free and porous media flow through a 4-cell bed of sorbent pellets, with pressure boundary conditions. The sorption rates and pellet loading were determined from solving a distributed ODE. The resulting heat transfer in the porous media and the solid housing was modeled with the respective physics nodes. A wall-distance calculation was required to determine the local packing density of the pellets. Boundary conditions (inflow/outflow and wet/dry air) were switched after every half-cycle of the desiccant bed. Figure 1 illustrates the geometry modeled, with the 4 blue domains being the cells, with any two non-adjacent beds flowing in or out with wet or dry air at any time. The first out-of-the-box attempt at using COMSOL Multiphysics to model the reversing-flow bulk desiccant process has resulted in a favorable match to data, at least in temperatures. Concentration is not matched as well, but this could be due to a number of reasons, from how the data was acquired (compared to the simulation) to variability in physical parameters (e.g. the sensitivity of the results to the axial dispersion coefficient, used isotropically in the dilute species transport equation, has not been investigated). Further work will focus on modeling a thermally linked bed, which uses an aluminum housing, as well as larger-scale, higher flow rate experiments to determine various sensitivities. Barring unforeseen issues with those models, COMSOL should be a useful tool to explore design space for ARREM water separation development. 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 initial application of the COMSOL model in 3D to simulate a cyclic bulk-desiccant sub-scale test 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.
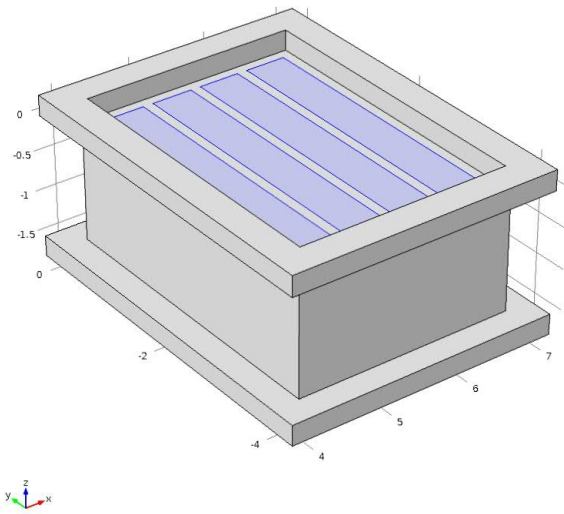
Figures used in the abstract

Figure 1: Geometry of the desiccant bed (units are in inches).