Numerical Prediction of Heat Transfer Coefficients during Xenon Tank Fill in Microgravity

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Topic Area: Fluids

NASA's Gateway will serve as an orbital outpost to enable sustained human lunar exploration and facilitate access to destinations beyond the Moon. To maintain sustainable deep space missions, on-orbit propellant transfer and refueling must be realized. One of Gateway's critical components, the Power and Propulsion Element (PPE), will use solar electric propulsion to perform attitude control maneuvers and orbit transfers. Xenon will be used as the propellant for the PPE and stored in a composite overwrapped pressure vessel (COPV). During the propellant refueling process, xenon will compress causing the fluid and tank walls to warm. There is concern that the bond between the tank liner and composite may degrade at elevated temperatures, along with the possibility of the tank exceeding design pressure. While on-orbit testing is being proposed, numerical models are being used to predict the thermal response and reduce risk during a refueling operation in microgravity where natural convection is diminished. Accurate numerical models may be used to inform decisions for follow-on testing, or design and operation of refueling architectures. Challenges of modeling xenon tank fill in microgravity include non-ideal gas behavior, operating near the fluid's critical point, and lack of experimental flight data. This study presents a computational fluid dynamics (CFD) model with conjugate heat transfer that is used to predict averaged heat transfer coefficients during tank filling. At the anticipated injection flow rates, the CFD results showed that forced convection dominates in microgravity. Initial results from a multi-node Thermal Desktop model that assumed a purely conducting fluid (Nu=1) over-predicted the CFD fluid temperature and pressure, while a similar model allowing for natural convection under-predicted. The heat transfer coefficients predicted by CFD were implemented into the multi-node model, and the COPV thermal response from the two computational approaches were compared with good agreement.