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THE MARS OXYGEN ISRU EXPERIMENT: CONTROL METHODS AND STEPS TOWARDS AUTONOMOUS PROPELLANT PRODUCTION ON MARS

Abstract

The Mars Oxygen ISRU Experiment (MOXIE) demonstrated the ability of a system to produce oxygen on the surface of Mars by utilizing solid oxide electrolysis from atmospheric carbon dioxide. The current operational methodology for MOXIE requires extensive planning, atmospheric predictions, and dynamic modeling to ensure the safety of the system during brief, intermittent runs. This work builds on the mission goals of MOXIE to develop control algorithms that will lay the foundation for optimized, autonomous functionality of future systems. A control algorithm was implemented in both laboratory-based testing as well as on the MOXIE flight model to maintain a stable cathode exhaust pressure during periods of varying atmospheric density by adjusting the RPM of the inlet compressor. This addresses a key issue where the density induced exhaust pressure variations are factored into the safety margin that must be allocated to avoid damage due to carbon deposition at the cathode. This increased margin results in a reduction of the total oxygen yield. The laboratory experiments designed to test the controller induced sharp changes in both ambient pressure and cathode pressure setpoints to mimic annual cycles of the Mars atmosphere. The pressure changes were evaluated across multiple gains for the control algorithm to assess controller performance with respect to maintaining constant pressure at the stack exit as the inlet pressure varied. The laboratory experiments validated a) the controllability of the MOXIE compressor through feedback from pressure sensor 4 (P4), located upstream of the cathode VFCD, and b) that the range of control gains was sufficient to handle induced inlet density variations. The validations led to the implementation of the P4 control algorithm on the MOXIE flight model during a time of rapidly changing Mars atmospheric density. The laboratory setup achieved a maximum flow rate of 6.07 g/hr of oxygen production, and MOXIE achieved a cumulative oxygen production of 6.66 grams over a 75-minute run while employing the P4 control algorithm. The ability of an atmospheric ISRU system to adapt to ambient density variations while maintaining a desired oxygen production output is a key first step in achieving an optimal control methodology for maximum oxygen generation of future systems. This work demonstrates the ability of a system to adapt to the ambient atmospheric density changes in the Mars environment. Future work will focus on improving the control methodology of MOXIE-like systems to optimize oxygen production and enable human exploration of Mars.