Ground Testing of a Propellant Storage and Transfer System

Lucas E. Tijerina, Hissar Aguilar, Yatri Wehmeyer
Department of Mechanical Engineering

Motivation
- Current launch vehicles have limited payload capacity mostly because they have to overcome Earth’s gravitational pull.
- An on-orbit propellant storage and transfer system would increase space mission capabilities dramatically:
  - Extended lifetime for satellites
  - Increased spacecraft range
  - Heavier effective payload
- Current technologies do not allow for such a system to be feasibly built or even functional. Some challenges:
  - Managing fluid sloshing in microgravity
  - Efficient transfer line engagement systems
  - Long term cryogenic propellant storage

Objectives
- Demonstrate the concept of rotational settling in microgravity as means to perform a propellant transfer.
- Identify and study relevant parameters in order to assess the rotational stability of the system.
- Increase the technology readiness level of on-orbit refueling systems through testing in ground laboratory.
- Build and deploy the experiment as payload for a suborbital flight for extended microgravity time.
- Achieve successful flight demonstrations to secure our position for orbital testing.

Methodology
- To fulfill such ambitious goals the research focus was initially directed towards literature review, design conceptualization and feasibility analysis.
- In preparation for the integration of the payload assembly, multiple designs were explored, see Figures 4 and 5.
- The experiment will be carried out in the following fashion:
  1. Supply tank is filled with water to 100% capacity
  2. Step motor will drive the assembly to a desired RPM in order to achieve fluid settling
  3. Motor will disengage and pumps will enable the fluid transfer.
  4. Data is collected from multi-axis load cell during the 3 minute window.

Simulation & Results
- The computer simulation consists on using Simscapes, an extension of MATLAB’s Simulink than focuses on mechanical systems, to model the rotation of rigid body seen in Figure 3.
- Variable mass cylinders with the density of water where placed in each of the tanks to simulate an instantaneous mass transfer and effectively determine the torque requirements of the motor and the maximum allowed RPM the loadcell can handle.

Conclusions
- To prevent the load cell from experiencing loads that might damage it we propose to lower the rotation speed of the system.
- Computer simulations must be improved by considering the effects of fluid dynamics, however this preliminary study is well suited to determine component requirements.
- From the feasibility analysis of our propellant storage and transfer system experiment we have concluded significant modifications have to be made to our current design in order to comply with the flight provider requirements.

Further Research
- Implement CFD modeling to describe the transient behavior of the experiment and predict the effects of sloshing to the system’s stability. This in turn would allow us to compare with the experiment results.
- Cryogenics management system. This involves active thermal control and insulation to keep the fluids from attaining their low boiling temperatures and generating undesirable vapors.
- Microgravity testing for extended time through suborbital flight providers such as Virgin Galactic, Blue Origin or UP Aerospace

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