Spring 6-5-2019

Omni-gravity Hydroponics System for Spacecraft

Tara M. Prevo
Portland State University

Let us know how access to this document benefits you.
Follow this and additional works at: https://pdxscholar.library.pdx.edu/mcecs_mentoring
Part of the Computer and Systems Architecture Commons, and the Digital Communications and Networking Commons

Citation Details
https://pdxscholar.library.pdx.edu/mcecs_mentoring/37

This Poster is brought to you for free and open access. It has been accepted for inclusion in Undergraduate Research & Mentoring Program by an authorized administrator of PDXScholar. For more information, please contact pdxscholar@pdx.edu.
Omni-gravity Hydroponics System for Spacecraft

Tara M. Prevo, Dryden Drop Tower

Experiments & Results

To determine the long duration operational limits of the Plant Water Management Hydroponics for space operations, a scaled 1-g channel was designed to mimic full-scale performance in microgravity that could be tested terrestrially. Designed by Rihana Mungin, the Formlabs V4 SLA 1-g test cells were 3D printed at Portland State University. Each cell was tapped, fitted with lure lock connectors, and sealed with Teflon tape. Figure 1 shows the 1-g test cell schematic with a detailed view of the superhydrophobic textured surface coated with CYTONIX WIX-2100™. By minimizing the Bond number Bo and performing experiments horizontally, the effects of gravity are minimized, surface tension phenomena dominates, and 'low-gravity' conditions are simulated, where

\[ Bo = \frac{\Delta p g l^2}{\sigma} < 1 \]

\[ \rho, fluid
density \]

\[ L, characteristic
dimension \]

A tube harness was constructed to closely model the hardware for the upcoming Plant Water Management hydroponics technical demonstration on the International Space Station. The fill procedure ensured that no bubbles were introduced prior to operation. The harness included modular adapters for a peristaltic pump to drive flow rates between 0 and 0.33 mL/s. Model plants were saturated prior to insertion into the channels to ensure fill levels were not distorted.

At lower fills, the downstream liquid profile approached bubble ingestion on the outlet as flow rates increased, shown in Figures 2A and 2B. At higher fills, embolisms form as shown in Figure 2C, indicating a trend toward instability. In some configurations, mass ejections occurred as inertial forces overcame capillary forces, shown in Figure 2D, which corresponds to Weber numbers

\[ We = \frac{\rho v^2 L}{\sigma} > 3 \]

\[ v, fluid
delocity \]

In the 1-g test cell demonstrations, new stability regimes were identified. This phenomenon is independent of the effects of gravity, and therefore must be taken into consideration as an upper limit to operation in space. As plants are introduced to the system, the roots disrupt the flow even further, causing droplet ejections at lower flow rates. These regimes will provide the foundation for experiment crew procedures and safety protocols. The first flight demonstrations will launch aboard Space X-18 in July 2019.

Future Work & Acknowledgements

- Further data collection and analysis will be conducted for 1g tests with simulated plants with both tap and string root models.
- Drop tower experiments with the full-scale hydroponic test cell, shown in Figure 3, will be performed in the coming weeks to confirm the terrestrial long-duration test results. Simulated plants will be scaled up to check operational limits in disrupted flow.
- Once stable operating limits are confirmed, further control of oxygen intake and delivery to plant roots will be investigated. Plant needs vary, which requires the system to self-regulate to keep a constant supply of nutrients, water, and gases available to the plant roots.
- Flight demonstrations aboard ISS are scheduled for 2019 which will provide first confirmation of models developed herein.

I wish to thank Rihana Mungin and Mark Weislogel, Rawand Rasheed, Sam Mohler, Jesse Goodman, Caleb Turner, Logan Torres, and Dan Ringle for their assistance and support during experiment definition, development, and data collection efforts. The research team at Dryden Drop Tower Laboratory exemplifies the vision and passion that NASA and Portland State University both value.

I also wish to thank Christof Teuscher and the Undergrad Research and Mentoring Program for providing this opportunity.


Data Summary

Several key limits of operation were identified and are plotted above as a function of fill percentage and flow rate with a detailed view of corresponding log{graphic} stable regimes on the right. Higher fills can withstand more flow, however as plants are introduced and the flow is disrupted, stable operational limits decrease dramatically. Embolism formation, as shown in Figure 2C, could produce either stable or unstable free surfaces as they vary in size. It is important to note that while testing with plant models, some embolisms may have ejected droplets that were reabsorbed due to collision with the model stem or foliage.

Figure 1: 3D Printed 1.55 mL 1-g test cell, designed with textured superhydrophobic surface [1]

Figure 2: 1 g test cells during (A) Bubble ingestion [1], (B) Re-stabilization and coalescence [1], (C) Semi-stable liquid embolism, (D) Mass ejections

Figure 3: Drop tower test apparatus

- After curing the system with syringe reservoirs (1), an HD camera (2) will take video of the test cell liquid profile (3) as flow is driven by the peristaltic pump (4) and backed by a light panel (5). The flow rate is controlled by a voltage regulating circuit (6). Batteries not pictured.