A Hybrid Magneto-active Propellant Management Device for Active Slosh Damping in Spacecraft

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Introduction

- Fuel slosh has been one of the key problems faced by liquid propellant spacecraft. Fuel slosh can adversely affect a spacecraft's stability, cause nutation, and affect fuel consumption as well as the trajectory change especially during change in attitude of the craft or during the stage separation.

"This research deals with the innovation and use of a hybrid magneto-active membrane, used as a Magneto-active Propellant Management Device (MAPMD)"

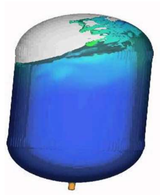

Figure 1. *Sloshing of Liquid Oxygen in a Fuel Tank. Source : Flow Science, Inc.*

- This helps in the active control of the free surface effect and in reducing fuel slosh.
- The viability of merging existing diaphragm membrane with a magneto-active inlay allows us to control the membrane during in-flight conditions.

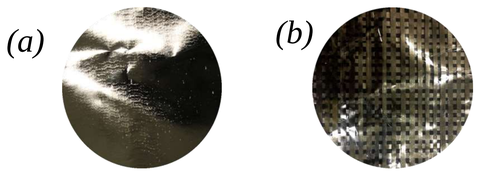

Figure 2. *(a) MAPMD Sheet (b) MAPMD Mesh*

Experiment

- All the tests are conducted using slosh test bed at ERAU which utilizes a spherical tank having 8" diameter. The magnetic field is generated by using a combination of electromagnet and permanent magnets.

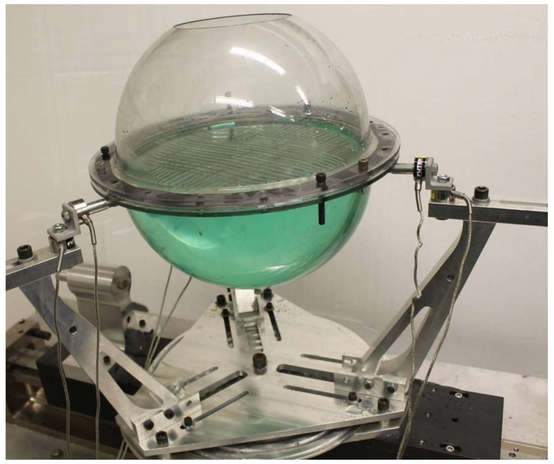

Figure 3. *Experimental Fuel Slosh Test bed at Embry-Riddle Aeronautical University.*

- A magneto active matrix is built out of Metglas, a thin metal alloy ribbon, because it has very high magnetic permeability and very low core loss.
- This matrix is used as an embedded layer within the polymer membrane used for the conventional propellant management devices.
- Two models, one as a plain sheet and another with the described matrix are tested for efficiency.
- The results are plotted on Matlab and analyzed after parameter estimation.

Results

- The experiment is conducted in three phases. The first phase is the free slosh characterization wherein the baseline sloshing values are taken. In the second phase the slosh test is conducted with the inactive MAPMDs. In the third phase, the magnetic field is applied and active MAPMDs are used.

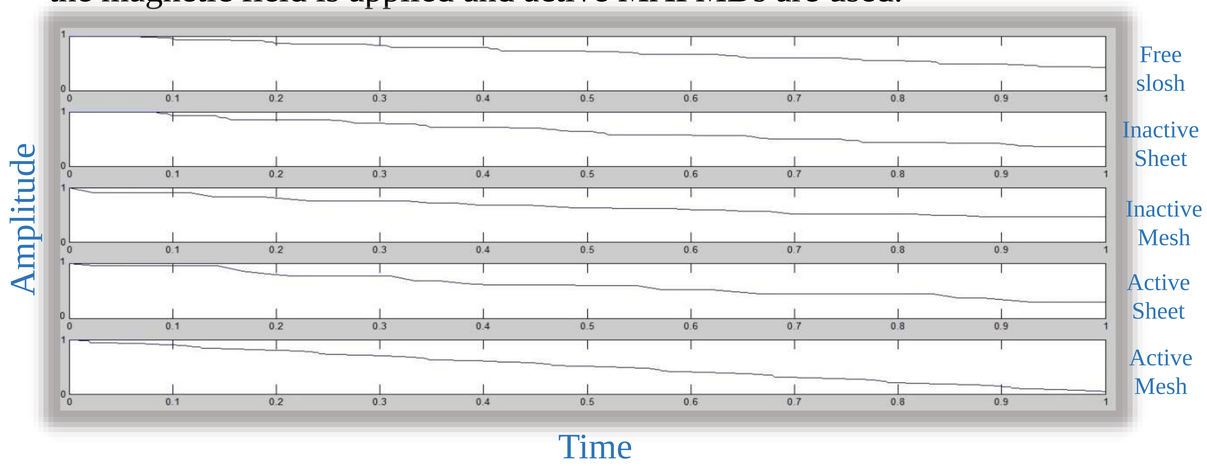

Figure 4. *Damped Remnant Slosh Amplitude for High Slosh Condition*

- The above graph shows the normalized slosh amplitude characterization for various conditions. It can be seen that the slosh amplitude decreased dramatically with the use of an active MAPMD device. It is seen that the MAPMD mesh displays better results in terms of damping due to the increased flexibility and the ability to absorb energy on a much better scale. The slightly stiffer MAPMD sheet though not as effective as the mesh still displayed appreciable damping characteristics.

Conclusion

The experiment discusses a novel method of slosh damping using MAPMDs or magneto active propellant management devices which can be actively controlled. They were developed as a hybrid between conventional propellant management devices and magneto active materials.

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