A "Green Cold-Gas" Propulsion System for Cubesats
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Background – Cubesat Maneuvering
• Current Cubesat maneuvering techniques are mainly passive, with little to no ability to change orbits.
• Basic attitude control primarily using Earth’s magnetic field or gravity.
• Very low torque, long time-constant stability (hours), and low accuracy.
• Near-term flights with momentum wheels. Need momentum dumping.
• Available technologies
  • Magnets, Magnetorquers, Momentum wheels (needs dump), Conventional thrusters (solid, fluid thrusters), Gravity gradient, Drag, Electric Thrusters (ion, plasma,...).
  • A push in research to determine a high efficiency, green propellant that is less harmful to the environment
• This work is developing a "green" cold gas thruster system capable of producing thrust in the uN to mN range to be used for small satellites

Cold Gas Thruster and Propellant
• Cold Gas thruster: commonly used in satellites since the 1960’s due to their relatively low complexity, efficiency, and low cost/power consumption.
• List of limitations for cold gas thrusters used on cubesats:
  • Scaling down to the picosatellite size
  • Secondary payload status restrictions
  • Regulations for non-toxic emissions
  • Significant benefits of using cold gas thrusters in space:
    • Dynamic orbital maneuvers
    • Low budget, mass, volume
    • Minimal moving parts
    • Relatively inexpensive fabrication costs
  • System Design
    • Nanochannel array separates liquid and vapor phases of propellant
    • Relies on vapor pressure of the fluid to generate thrust
    • Propellant: a pressurized gas, as toxic exhaust
• Based on the mission criteria, a water based solution with propylene glycol was investigated.
• Propylene glycol is commonly known as modern day anti-freeze but has a multitude of applications
  • Biomedical food additive
  • Bio-fuels
  • Pharmaceutical solvent
• Minimizes freezing in two ways:
  • Freezing point depression − hydrogen bond disruption minimizing chance for nucleation
  • Less solid ice means less overall expansion at higher concentrations of PG

Propellant Characterization
• Experiments were conducted in a vacuum chamber that maintained a milliTorr pressure to simulate space conditions
• Various trials were conducted to determine properties of vapor phase aqueous propylene glycol by varying:
  • Temperature – controlled with a bang-bang thermostat
  • Capillary tube diameter – order of hundreds of micrometers
  • Solution concentration – 0% PG (Water) up to 100% PG in intervals of 20% PG
• Flow in the regime tested is expected to follow Hagen-Poiseuille equation
• Necessary data was gathered that will further the research for vapor flow through nanochannels
• For pure propylene glycol (100%PG) flow was higher than expected considering the low vapor pressure indicating potential slip

Propylene Glycol Freezing
• Aqueous propylene glycol was tested in a thermally controlled chamber to measure the expansion that occurs upon transition from liquid to solid phase
• As temperature decreases the liquid compresses slightly, but sees a dramatic increase in volume once crystallization of the water occurs (~9% for water)
• Notably, the expansion during freezing decreased linearly with respect to increase in the concentration of propylene glycol in the aqueous solution

Thrust Generated
• Vaporizing a propellant via nanochannels to vacuum was studied as a means of propulsion for small satellites
• Specific impulse (Isp) - measure of propellant efficiency
  \[ Isp = \frac{\Delta m}{m_{in} \cdot g} \]
  • Using Aqueous PG Isp and nanochannel array dimensions the theoretical thrust was calculated
• Thrust is tuned by adjusted the nanochannel dimensions or the propellant material properties

References

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ARCSAT-1 & ARKSAT-2
ARCSAT-1
• LEO-to-Earth atmospheric composition measurements
• CubSat deorbit using Solid State Inflation Balloon
ARKSAT-2
• In space demonstration of an agile, low-cost, non-toxic, biocompatible, and non-pressurized micro-propulsion system

Images:
[Image 1-31x2188 to 815x2515]
[Image 3-31x2188 to 815x2515]