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Investigation of a two-phase vortex flow in a tank with liquid residues for its discharge under low-gravity conditions

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The falling of the boosters of expendable launch vehicles, such as the Soyuz-2, can result in fires in areas of impact, particularly in steppe and forest regions. This is due to the presence of liquid hydrogen peroxide (HP) on board the boosters, which is used in a catalytic gas generator to power the turbopumps that supply fuel components in liquid propellant rocket engines. When a booster crashes to the ground due to structural failure, oxygen and kerosene from damaged fuel tanks, as well as HP, can be released and undergo high-temperature decomposition, potentially leading to a fire.

This problem also applies to orbital stages of launch vehicles and spacecraft that have completed their mission. To prevent explosions and an increase in space debris, it is crucial to follow guidelines [1] and safely release any remaining liquid fuel residues into space through a process called passivation.

The traditional method of purging tanks with gas and releasing liquid residues of HP into space during passive flight of the booster faces the challenge of effectively ejecting the liquid residues from the tank through the drainage hole in low gravity conditions. Previous attempts to solve this problem using methods such as [2, 3] have proven ineffective as they require a high gas velocity to effectively disperse and remove liquid droplets through the drainage hole.

The proposed solution in the article addresses the issue of purging tanks in low gravity conditions by introducing acoustic energy in the form of a modulated gas flow, creating a vortex gas-dynamic pattern in the tank. This method utilizes the decreased surface tension of the liquid caused by acoustic action, which makes it easier to disperse the liquid into droplets of the desired size. Additionally, the vortex effect of the gas-dynamic flow pattern in the tank further enhances this process.

In order to address this issue, several steps must be taken, such as determining the necessary gas flow rate supplied to the tank using Hartmann acoustic generators, determining the parameters and power of the acoustic impact, determining the number of injection points for the gas into the tank, analyzing the particle dispersion within the formed vortex pattern in the tank, and simulating the flow of the gas-liquid mixture out of the tank. Initial evaluations indicate that this problem can be solved.

References

[1] IADC Space Debris Mitigation Guidelines/ IADC-02-01 Revision 2/ Mar 2020
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