Implementation of Sub-Cooling of Cryogenic Propellants by Injection of Non-condensing Gas to the Generalized Fluid Systems Simulation Program (GFSSP)

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ABSTRACT

Cryogenic propellants are readily heated when used. This poses a problem for rocket engine efficiency and effective boot-strapping of the engine, as seen in the “hot” LOX (Liquid Oxygen) problem on the S-1 stage of the Saturn vehicle. In order to remedy this issue, cryogenic fluids were found to be sub-cooled by injection of a warm non-condensing gas. Experimental results show that the mechanism behind the sub-cooling is evaporative cooling. It has been shown that a sub-cooled temperature difference of $\Delta t \approx 13^\circ F$ below saturation temperature [1]. The phenomenon of sub-cooling of cryogenic propellants by a non-condensing gas is not readily available with the General Fluid System Simulation Program (GFSSP) [2]. GFSSP is a thermal-fluid program used to analyze a wide variety of systems that are directly impacted by thermodynamics. In order to model this phenomenon, additional capabilities had to be added to GFSSP in the form of a FORTRAN coded sub-routine to calculate the temperature of the sub-cooled fluid. Once this was accomplished, the sub-routine was implemented to a GFSSP model that was created to replicate an experiment that was conducted to validate the GFSSP results.

METHODS

- Analyze GFSSP mixing capabilities and compare with steady-state energy equation formulations
- Create static LOX tank model with GFSSP
- Implement He Injector to the model
- Compare results to Vaniman experimental results
- Implement subroutine to model to calculate new fluid temperatures
- Create FORTRAN subroutine to add new physics to the model

ANALYSIS AND RESULTS

• It was found that normal modeling procedures with GFSSP could not be utilized and therefore an unconventional tank model was created.
• GFSSP mixture options were analyzed and determination of which calculation package produced most accurate results.
• A new derivation of the energy equation of mixing of fluids was created to simulate evaporative cooling.

REFERENCES


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