Aerospace Europe Conference 2023
Joint 10th EUCASS – 9th CEAS Conference

Abstract #XXX
Preferred Topics: CFDMPS
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Type: Oral
Status of corresponding author: Student

Title

Setup of a numerical methodology for the study of active-pressurization of cryogenic tanks

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Abstract

In this paper, a numerical methodology to study the active-pressurization phenomenon inside cryogenic tanks is developed. This task is carried out comparing the numerical predictions obtained with several models with the experimental results of a ground-based active-pressurization experiment, inside a liquid nitrogen (N_2) tank [1]. In this experiment, the tank was pressurized with gaseous N_2, having a much higher temperature than that of the fluid initially present in the tank, and was injected from a radial diffuser.

The study of the active-pressurization phenomenon has received a significant interest over the years, due to the need to minimize the pressurant gas requirements, for reasons of system weight savings in the aerospace applications. Previous experimental and numerical studies, in the literature, have revealed the influence of the following factors on the pressurant gas requirements: the inlet gas temperature, the injector design, the interfacial heat and mass transfer, the tank wall and geometry, the pressurant gas species, and the pressurization speed.

Here, a numerical setup is proposed, which is suitable to describe the main thermo-fluid-dynamics phenomena characterizing the active-pressurization phenomenon. This setup allows to accurately represent both the pressure rise rate during gas injection and the pressure drop occurring at the end of gas injection. The tank is modeled as 2D axisymmetric, and the solution of the conduction through the tank wall is coupled to the solution inside the fluid by means of a conjugate heat transfer model. Thermal stratification developing in the ullage and in the wall in contact with the ullage after 30 seconds of active-pressurization can be seen in Fig. 1. The two-phase fluid interface is tracked using the Volume of fluid (VOF) method, and the phase transition is calculated with the Lee model. Temperature varying thermophysical properties are considered for the fluid and wall regions, given the wide temperature range. Finally, the comparison of laminar and turbulent results shows that the introduction of a turbulence model is necessary to describe with higher fidelity the pressure decay occurring at the end of gas injection.

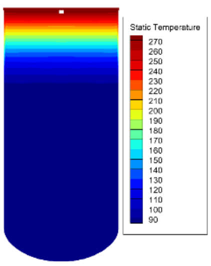

Fig. 1 Temperature contour at 30 seconds for the validation test case from [1].

References

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