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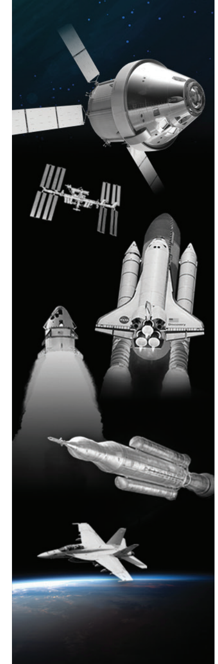

NESC tech bulletin

Experimental and Computational Study of Cavitation in Hydrogen Peroxide

Cavitation in liquid propulsion systems can lead to performance degradation and hardware failures. The NESC sponsored an investigation to measure and model cavitation in pressurized hydrogen peroxide flow. The experimentally measured and computationally predicted cavitation lengths were compared as a function of cavitation number. The measured and predicted data exhibited close agreement over the range of pressures and temperatures studied, and no calibration of the cavitation model coefficients was needed.

Background

Cavitation is a flow phenomenon that can occur in a liquid system when the local pressure drops below the vapor pressure. In propulsion systems, cavitation can then lead to performance degradation and hardware failures. In order to design robust propulsion systems, a thorough understanding of cavitation is necessary. There is little cavitation data in the available literature for hydrogen peroxide (H_2O_2), so an NESC-sponsored investigation was undertaken to determine the cavitation characteristics of 90% H_2O_2 at several pressures and temperatures. The results of the experiments, which were performed at Purdue University, were compared with simulations using the Loci-CHEM [1] computational fluid dynamics (CFD) code and the cavitation model developed by Merkle et al. [2].

Test Configuration

This test campaign targeted H_2O_2 flowing through a test article with upstream pressures of up to 2.75 MPa. The test section contained polycarbonate windows, Viton O-rings for compatibility with the H_2O_2, and simple sharp-edged inserts to form a rectangular channel test section (see Figure 1). T-type thermocouples (±1° C) were used for temperature measurements and 3.45 MPa UNIK-5000 series pressure transducers (±1.38 kPa) were used to minimize analog data uncertainties. The temperature and pressure measurements were taken immediately upstream and downstream of the test article to get the most representative measurements. The pressure drops through the test article inlet and outlet were calculated to be insignificant as compared to the pressure drop in the test section, affirming that the pressure transducer locations were adequate. A control valve on the downstream side of the test section was used to vary the downstream pressure and the mass flow rate. A high-speed camera (5 kHz frame rate) was used to record the cavitation in the test section and the instantaneous cavitation length was synchronized with the pressure and mass flow measurements.

Results

Tests were run for upstream pressures of 1.37 and 2.75 MPa at H_2O_2 temperatures ranging from 5° to 40° C. Figure 1 shows a sample of the cavitating flow in the test section. In Figure 1, the flow moves from top to bottom in the video frame, and cavitation appears as the darker regions in the channel. The experimentally measured and computationally predicted cavitation lengths were compared as a function of cavitation number. The cavitation number is defined by:

$$K = \frac{P_1 - P_{vap}}{P_1 - P_2}$$

where K is the cavitation number, P_1 is the inlet pressure, P_2 is exit pressure and P_{vap} is the vapor pressure of H_2O_2. The measured and predicted cavitation lengths exhibited close agreement over the range of pressures and temperatures studied, and no calibration of the cavitation model coefficients was needed.

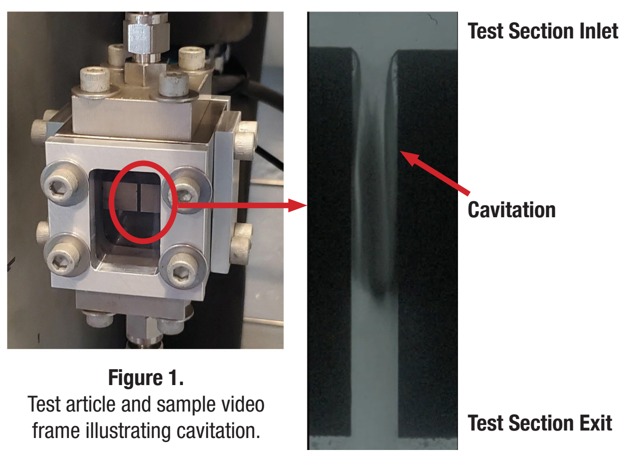

Figure 1.
Test article and sample video frame illustrating cavitation.

References

1. Westra, D.; Lin, J.; West, J.; and Tucker, K.: "Use, Assessment, and Improvement of the Loci-CHEM CFD Code for Simulation of Combustion in a Single Element GO2/GH2 Injector and Chamber," NASA Thermal & Fluids Analysis Workshop (TFAWS), Goddard Space Flight Center, August 7-11, 2006.
2. Merkle, C. L.; Feng, J. Z.; Buelow, P. E. O.: "Computational Modeling of the Dynamics of Sheet Cavitation", Proceedings of the 3rd International Symposium on Cavitation, Grenoble, France, 1998, pp. 307-311.