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DEVELOPMENT OF A CFD METHODOLOGY FOR TESTING COMBUSTION INSTABILITIES OF A SHEAR-COAXIAL GAS-GAS ROCKET INJECTOR USING AN ATMOSPHERIC BURNER

Abstract

A single-injector, atmospheric chamber experiment with a full-scale, shear-coaxial, gaseous-oxygen/gaseous-methane rocket injector was modeled using the computational fluid dynamics (CFD) package, Loci-CHEM. At the University of Alabama in Huntsville, an experimental procedure based on a Russian methodology was developed for exciting various combustion instability modes in a rocket thrust chamber using an injector in this setup. Like this experimental methodology, a similar computational methodology should allow a great variety of scaling studies to be conducted between experimental setups using a single, full-scale injector in a small test chamber and multi-injector arrangements in full-scale thrust chambers. With this methodology and system scaling understood, potential combustion instability problems can be identified on the component level early in the development process of new engine systems. This would be a great advantage in the early stages of development since building multiple full-scale engines for testing various injectors in various configurations may prove prohibitive. This also applies to attempting to run many full-scale CFD models since the length scales needed to adequately capture turbulent mixing of propellants are so much smaller than the thrust chamber, itself which controls the overall acoustics in the problem. This length scale problem requires large amounts of computational resources to handle. Since combustion instability involves the coupling of several phenomena, initial benchmarking for the Loci-CHEM code was conducted for the acoustics, finite-rate chemistry, and turbulent mixing of species in the flow field of the injector and test chamber. A single-equation Arrhenius model for methane-oxygen combustion was implemented and tested. For the shear-coaxial injector modeled in this study, pressure-frequency and instability mode data were available from recent experimental studies using the same methodology. The overall computational methodology is described, comparisons between the computational results and the experimental data are shown, and best practices are recommended.