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Author: Mr. Marco Leonardi
University of Rome "La Sapienza", Italy, marco.leonardi@uniroma1.it

Mr. Francesco di Matteo
Italy, fra.di.matteo@gmail.com
Prof. Francesco Nasuti
University of Rome "La Sapienza", Italy, francesco.nasuti@uniroma1.it
Prof. Marcello Onofri
University of Rome "La Sapienza", Italy, marcello.onofri@uniroma1.it

THRUST CHAMBER MODELING FOR SYSTEM ANALYSIS OF LIQUID ROCKET ENGINES

Abstract

The design and engineering analysis of a Liquid Rocket Engine (LRE) inherently requires the potential to predict the behaviour of the propulsion unit at different levels of detail. The main approaches in the analysis of propulsion systems consist on one hand in focusing on a singular propulsion component and on the other hand in studying the interaction of the various components within the complete engine. The latter is a challenging topic as each of the LRE components needs to be modelled in an accurate way to correctly simulate the mutual component influence on the overall engine performance. Furthermore one should also aim for simplified sub-models assuring a reasonable computational time which is a desired feature for design iterations. EcosimPro is an object oriented simulation tool focused on the analysis of complete systems that spans different engineering fields. Thanks to the object oriented philosophy the single components can be connected to each other in order to analyse systems at different complexity levels. Propulsion systems can be investigated by the European Space Propulsion System Simulation (ESPSS) library which is embedded in the EcosimPro platform. The available system modelling tools for combustion chambers are based on an unsteady component in chemical equilibrium for the first part of the chamber including the converging section of the nozzle, while the nozzle diverging section is modelled with a quasi-stationary (or quasi-steady) component both in frozen and equilibrium conditions. The present model is improved by a new combustion chamber component. The primary goal of this research is to provide a component able to increase the overall capabilities of the tool, in both the design process and the analysis of operational conditions. The limits related to the use of a simple centred scheme, such as the one presently coded, are overcome with the implementation of an approximate Roe's Riemann solver for multispecies flows. The correct upwinding of the convective fluxes guarantees a suitable description of the wave propagation phenomena, while the non-equilibrium analysis, conducted by means of finite-rate chemistry models, leads to a more accurate flow description, particularly in the simulation of transients. In the final paper a specific LRE will be analysed. The main parameters featuring the combustion chamber will be compared with both data available in open literature and results obtained with the existing combustion chamber, testing the capabilities of the new component in reproducing adequately both steady state and transient conditions.