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DYNAMIC-STRUCTURAL MODELING AND TRAJECTORY ANALYSIS OF A HYPERSONIC ACCELERATOR VEHICLE UNDER EFFECT OF SKEWED THRUST GENERATED BY THE SCRAMJET ENGINE 14-X S

Abstract

During the development of hypersonic related technologies is usual the use of suborbital rockets to provide the ideal test conditions for such technologies. For instance, some suborbital rockets as VS-30/Orion, VSB-30 and VS-40 supported some hypersonic technological development programs as SHEFEX, HIFiRE, and ScramSpace. Nowadays, the Brazilian Institute for Advanced Studies (IEAv) is conducting the hypersonic vehicle project named 14-X, which part of its roadmap consist in to validate, in actual flight conditions, a scramjet engine which development is achieving the flight-testing phase in 2020. The hypersonic accelerator vehicle (HAV), defined to support this flight-testing, uses the basic configuration of the well-known bi-stage suborbital rocket VSB-30, already used in hypersonic experiments. The current experiment consists in connecting the scramjet engine (14-X S) on top of the rocket's second stage, accelerate it up to Mach 7 at 30km altitude and ignites the scramjet engine for some seconds. During its operation time, the scramjet engine remains attached to the rocket's second stage. The design of the 14-X S assembles two scramjet chambers in a plane symmetry. In this frame, the aim of this paper is to perform a dynamic-structural analysis, as well as the impact on the HAV's trajectory during the scramjet operation period. The analysis will cover the impact of the scramjet operation in the elastic behavior of the vehicle, also assuming the effects of one critical failure mode (one engine off). The complete HAV plus 14-X S dynamic modelling will take into account the translational, rotational and flexible dynamic equations, from which it is possible to obtain a fully non-linear system of equations of motion, where the roles of the macro dynamics (translational and rotational flight mechanics) and the micro dynamics (elastic vibrations) can be clearly observed. The modal superposition technique is applied to represent the elastic displacement, whereas the Galeerkin approach is used for micro dynamics effects. The results of this work will present the vehicle's behavior in a framework of flight safety and flight dynamics response.