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# AEROTHERMAL ANALYSIS OF NOMINAL AND OFF-DESIGN FIRST STAGE SEPARATION IN A LAUNCH VEHICLE WITH RETRO-ROCKETS

**Abstract**

Modern launchers rely on multi-staging for achieving space exploration and satellite deployment since it delivers greater efficiency and flexibility. Multi-stage rockets offer several advantages over single-stage designs: among all, multiple-stage launchers are more efficient than single-stage ones because they remove the useless mass of empty fuel tanks and engines as they ascend, therefore they can achieve higher speeds and altitudes. Nevertheless, stage separation introduces additional risk into the launch mission: failures in the decoupling mechanism could lead to stages collisions as well as to higher-than-expected aerothermal loads on the launcher surface. As the separation process occurs within a high-velocity flow, computational fluid dynamics (CFD) plays a crucial role in simulating the dynamics of the separated stage. The present study focuses on a launch vehicle first/second stage separation, which is achieved using retro rockets. In detail, 3D numerical computations are performed by means of the overset technique implemented in the CFD commercial solver CFD++ [1]. The overset method is based on two 3D tetrahedral grids: the former (overset grid), which is built around the first stage, is in relative motion with respect to the second stage. In particular, the overset grid moves over a fixed tetrahedral volume mesh containing the second stage owing to the aerodynamic forces. At each time-step, the elements of background mesh which fall inside the overset grid are blanked out: by doing so, a hole is carved within the background volume mesh. Then, this cavity is filled by the overset grid in order to obtain a new computational mesh that is used by the CFD++ solver to compute the flow-field solution of the specific time-step. Both nominal and off-design separations are investigated in the proposed research: indeed, one of the aims of this research is the evaluation of the stage dynamics behaviour consequent to an abnormal functioning of the stage separation system, as an example due to decoupling mechanism failure during this phase. This research is jointly funded by Sapienza University and the Italian Space Agency-Agenzia Spaziale Italiana (ASI) as part of the research project N.2019-4-HH.0 0 CUP: F86C17000080005 carried out under a framework agreement between the Parties.