Fluid-Structure Interaction Modeling of Transient Nozzle Flow

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Nozzle side forces due to fluid-structure interaction, shock transition and reacting flow effects are known to cause severe structural damage to any new rocket engine in development during testing. Although three-dimensional, transient, turbulent, chemically reacting computational fluid dynamics methodology has been demonstrated to capture major side load physics with rigid nozzles, hot-fire tests often show nozzle structure deformation during major side load events, leading to structural damages if structural strengthening measures were not taken.

The modeling picture is incomplete without the capability to address the two-way responses between the structure and fluid. The objective of this study is to develop a coupled aeroelastic modeling capability by implementing the necessary structural dynamics component into an anchored computational fluid dynamics methodology.

The computational fluid dynamics component is based on an unstructured-grid pressure-based computational fluid dynamics formulation, whereas the computational structural dynamics component is developed under the framework of modal analysis. Transient aeroelastic nozzle startup analyses at sea level were performed to demonstrate the successful simulation of nozzle wall deformation with the proposed tightly coupled algorithm, and the computed results pertinent to fluid-structure interaction presented.