NASA SBIR/STTR Technologies

T1.02-9827 - Prediction of Strutural Response and Fluid-Induced Vibration in Turbomachinery

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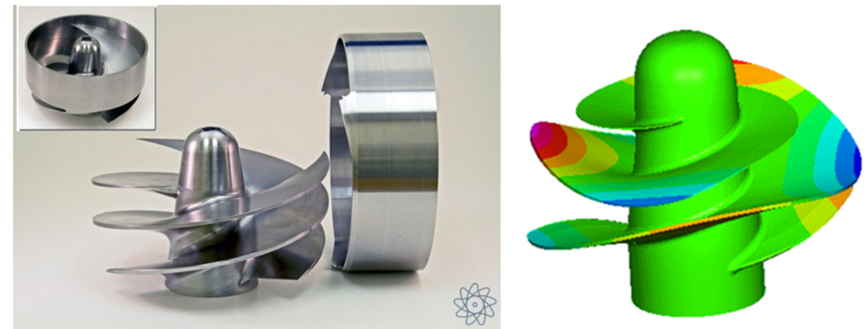
Identification and Significance of Innovation

Advanced turbomachinery components play a critical role in launch vehicle and spacecraft liquid rocket propulsion systems. To achieve desired efficiencies, extremely tight tolerances are often imposed which set up strong interactions that influence the aerodynamics and the structural performance of blades. These transient interactions can deform blades and significantly impact the vibrational and acoustic characteristics of the engine, greatly reduce the efficiency, and even lead to engine failure. Current production design tools for turbomachinery do not account for the coupled fluid-structure interaction (FSI) associated with these phenomena. This STTR effort will develop and deliver a multidisciplinary turbomachinery design tool to account for FSI and enable more accurate modeling of systems and subscale demonstrators. CFDRC will supplement the NASA massively parallel Loci framework with highly accurate and efficient integrated FSI capabilities to enable better understanding of critical turbomachinery problems in liquid rocket propulsion systems that defy conventional predictions.

Estimated TRL at beginning and end of contract: (Begin: 3 End: 5)



Fluid-Structure Interaction Predictions of Damage in Inducer Blades for Liquid Rocket Propulsion System

Technical Objectives and Work Plan

The overall technical objective of this project is to develop an integrated, comprehensive, tightly-coupled physics-based, multidisciplinary simulation tool for prediction of structural response and fluid-induced vibration in turbomachinery components for liquid rocket propulsion systems. The developed tool will couple existing codes written in the massively parallel NASA production Loci framework (Loci/CHEM, Loci/STREAM, etc.), with a nonlinear large-deformation structural solver, CoBi, to solve fluid-structure interaction in turbomachinery applications from first-principles. This coupling will be integrated in the Loci computational framework, and Loci CFD solvers will drive the finite element structural solution in turbomachinery by means of direct invocation of APIs to be created for this purpose. The tool will be rigorously validated against coupled as well as decoupled problems. The specific objectives of the Phase I effort are summarized as follows: a) develop support for constrained deformations in Loci moving overset grid systems; (b) develop multidisciplinary turbomachinery coupling interface; c) verification and baseline validation of developed technology; d) demonstration of the technology for liquid rocket engine turbopump/inducer applications; and e) deliver and test software on NASA HPC systems, and assist MSFC personnel w/applications.

NASA Applications

A fully-coupled fluid-structure interaction tool has a large number of applications in the NASA launch vehicles propulsion systems including: prediction of rocket launch-induced fluctuating pressure loads and structural response; vehicle buffet during ascent; prediction of water suppression system interactions with ignition over pressure (IOP) for accurate prediction of acoustic environment; rocket nozzle side loads; fluid-induced vibration of J-2X turbine and inducer blades; and many others.

Non-NASA Applications

Aerospace engineers will be able to utilize the technology to analyze early designs and reduce dependence on expensive wind tunnel/water tunnel and flight tests. Benefits will be achieved in performance, improved structural integrity, structural life, and vehicle safety. Applications include analysis of aerospace vehicle dynamic loads, buffet, flutter, control reversal; and noise, vibrations.

Firm Contacts

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