FULLY COUPLED CFD-FEM ANALYSIS OF THE HYMAX GEOMETRY MODIFIED TO INDUCE FLUTTER

Tsz Yeung (Harry) Xu* and Earl Dowell

Duke University,
2080 Duke University Road, Durham, NC 27708
United States of America

ABSTRACT

Accurate predictions of dynamic structural behavior in hypersonic flows are critical in designing the next generation of high-speed flight vehicles. To maximize efficiency, future designs will need to be lightweight while capable of sustaining immense aerodynamic forces. Lighter structures inherently have less stiffness, making them more prone to crossing the aeroelastic dynamic instability boundary, or better known as the flutter boundary, as speeds increase. Complicating matters in the high-speed regime is the introduction of shocks, which can impart additional localized loads onto structures, which affect the onset of flutter.

The Hypersonic Multibody Aeroelastic eXperiment (HyMAX) by the University of New South Wales Canberra is a benchmark experiment where a cantilevered plate is subjected to Mach 5.8 flow and different shock impingements. The nominal plate thickness in the experiment is 2 mm, which results in damped oscillations of the plate. From prior work by McHugh et al.[1], the flutter point is sensitive to the non-dimensional dynamic pressure; using the flow conditions and dimensions from the HyMAX experiment, it is well away from the expected flutter boundary. To induce flutter, the plate thickness must be gradually decreased until the non-dimensional dynamic pressure approaches the flutter boundary.

In a previous study, FUN3D, a fully unstructured Navier-Stokes code developed by the NASA Langley Research Center, and its built-in linear aeroelastic modal solver was used to determine the flutter point for the HyMAX geometry when exposed to two different shock impingements and a case with no shock. A limitation of the previous study is the usage of a linear structural modal solver, which prevents accurate analysis of the plate when it undergoes large deformations during post-flutter limit cycle oscillations.

This study attempts to remedy the limitations of a linear structural modal model by coupling FUN3D with a finite element code using FUNtoFEM. This provides a good comparison between the computational flutter point derived from the linear structural modal solver and a FEM solver while also enabling the ability to capture the post-flutter limit cycle oscillation behavior with greater accuracy. This study contributes to the field by analyzing one of the primary configurations used in the AIAA Aeroelastic Prediction Workshops and builds upon prior work from McHugh et al. to identify the flutter boundary in hypersonic flows. This work will also provide insight into potential modifications of an existing hypersonic experiment to induce stronger fluid-structure coupling and expands the database of computational results of thin plates subjected to non-symmetric flows with and without shock impingement.

The final paper will include a thorough description of the mesh and solver setup used, a validation study using classical panel flutter results, results for the flutter point prediction and post-flutter behavior, comparison between results obtained using linear versus nonlinear shell elements, and a discussion comparing the results from McHugh et al., the modal results from the previous work, and the CFD-FEM results from this study.

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[1] McHugh et al., *Journal of Aircraft*, https://doi.org/10.2514/1.C035992