Mechanical Engineering Master's Defense

Toward an Uncertain Modeling of Hypersonic Aerodynamic Forces

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abstract

The focus of this investigation is on the development of a surrogate model of hypersonic aerodynamic forces on structures to reduce the computational effort involved in the determination of the structural response. The application is more precisely focused on uncertain structures. Then, following an uncertainty management strategy, the surrogate may exhibit an error with respect to Computational Fluid Dynamics (CFD) reference data as long as that error does not significantly affect the uncertainty band of the structural response. Moreover, this error will be treated as an epistemic uncertainty introduced in the model thereby generating an uncertain surrogate. Given this second step, the aerodynamic surrogate is limited to those exhibiting simple analytic forms with parameters that can be identified from CFD data.

The first phase of the investigation focuses on the selection of an appropriate form for the surrogate for the 1-dimensional flow over a flat clamped-clamped. Following piston theory, the model search started with purely local models, linear and nonlinear of the local slope. A second set of models was considered that involve also the local displacement, curvature, and integral of displacement and an improvement was observed that can be attributed to a global effect of the pressure distribution. Various ways to involve such a global effect were next investigated eventually leading to a two-level composite model based on the sum of a local component represented as a cubic polynomial of the downwash and a global component represented by an auto-regressive moving average (ARMA) model driven nonlinearly by the local downwash. This composite model is applicable to both steady pressure distributions with the downwash equal to the slope and to unsteady cases with the downwash .

The second part of the investigation focused on the introduction of the epistemic uncertainty in the aerodynamic surrogate and it was recognized that it could be achieved by randomizing the coefficients of the local and/or the auto-regressive components of the model. In fact, the combination of the two effects provided an applicable strategy.

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