Contribution ID: **85** Type: **Poster**

Physics Guided Deep-Learning Based Nonlinear Reduced Order Model for Aeroelastic Applications

Thursday, July 30, 2020 1:00 PM (1 hour)

This study aims to model transonic airfoil-gust interaction and the gust response on transonic aileron-buzz problems using high fidelity computational fluid dynamics (CFD) and the Long Short-Term Memory (LSTM) based deep learning approach. It first explores the rich physics associated with these interactions, which show strong flow field nonlinearities arising from the complex shock-boundary layer interactions using CFD. In the transonic regime, most linear Reduced Order Models (ROMs) fail to reconstruct the unsteady global parameters such as the lift, moment and drag coefficients and the unsteady distributive flow variables such as velocity, pressure, and skin friction coefficients on the airfoil or in the entire computational domain due to the nonlinear shock-gust interaction. As it is well known that a deep-learning framework creates several hypersurfaces to generate a nonlinear functional relationship between the gust or structural input and the unsteady flow variables as an output an algorithm is proposed to overcome the limitations of linear ROMs. This algorithm consists of two integral steps, namely a dimensionality reduction where the Discrete Empirical Interpolation Method (DEIM) based linear data compression approach is applied and the reduced state is trained using the LSTM based Recurrent Neural Network (RNN) for the reconstruction of unsteady flow variables. Current study further modifies the loss function inside the LSTM network using the residual from the Navier Stokes equation and propose a Physics guided LSTM network. The present work shows its potential for predicting transonic airfoil gust response and the aileron buzz problem demonstrating several orders of computational benefit as compared to high fidelity CFD.

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Session Classification: Posters 3