System Identification for Coupled Fluid-Structures: "Aerodynamics is Aeroelasticity Minus Structure" – Theory, Numerical and Experimental Applications

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A novel system identification that constructs a coupled fluid-structure system with a reduced set of state variables is presented. Unlike all of the existing methods where aerodynamics is treated separately from structure, the new method works directly on time history data of the coupled aeroelastic system measured in a realistic flow condition. Assuming that the structural model is known a priori either from an analysis or a test, it is possible to identify the underlying aerodynamic system from the sampled time histories. Two of the key operations herein are linear transformations between the structural and aeroelastic states and subtraction of the structural states from the coupled states. Hence, the method is given the nickname "Aerodynamics is Aeroelasticity Minus Structure (AAEMS)". Once the aerodynamic system is known an aeroelastic reduced-order model suitable for Constant Mach, Varying Density conditions can be constructed in discrete-time, state-space format by coupling the structural and aerodynamic models. For demonstration, the method is applied to NASA AGARD wing modeled by an in-house Euler code developed at Temasek Lab. of National University of Singapore. An experimental application to a three-dimensional lifting surface is also presented, where a rigid wing specimen was fabricated and tested at Seoul National University in a low speed, subsonic wind tunnel with two motion sensors for plunging and pitching. It is demonstrated that the proposed method is attractive from the perspective of structural engineers who do not have extensive training in aerodynamics and CFD. It is fast, efficient in generating reduced-order aeroelastic models with a minimum amount of effort and time with much convenience. Above all, the method is deeply rooted in the notion that no physical system in the real world is purely aerodynamic or structural and as such one has to take into account the inevitable coupling effects during system identification and modeling.