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Multidisciplinary Design Optimization of Lifting Surfaces: State-of-the-Art and Industrial Applications

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Lifting surfaces, such as aircraft wings, hydrofoils, propeller blades, and turbine blades are critical components in many engineering systems because much of the overall performance hinges on those components. The design of lifting surfaces is challenging because simulating the physics involves nonlinear aerodynamics and fluid-structure interaction. There has been much progress in the design of lifting surfaces based on computational fluid dynamics (CFD) and its coupling to computational structural mechanics (CSM) models. Accuracy and speed are two desirable characteristics of physics modeling, but this is not enough for design optimization [1]. Hundreds of shape variables are required to enable the shape optimization of lifting surfaces [2]. Currently, gradient-based optimization algorithms combined with adjoint methods to efficiently compute the gradients of the physics models provide the most promising approach for performing lifting surface design optimization [3]. The coupled-adjoint method has emerged as a promising approach to compute the gradients of multiphysics models, including fluid-structure interaction simulations. However, there are several remaining challenges for the widespread industrial application of these state-of-the-art methods. This talk will summarize the state-of-art in lifting surface design optimization approaches. Topics will include adjoint method implementation [4, 5, 6], coupled-adjoint methods and frameworks [7, 8, 9]. In addition to implementation, current theoretical challenges include considering dynamic and unsteady physics [10, 11, 12] including flutter and limit cycle oscillations [13]. There are also challenges more directly related to industrial applications, such as integration with CAD [14, 15, 16], existing commercial software [17], and considering practical design constraints [18, 19]. We will give examples from a wide variety of applications such as the design of aircraft wings [7, 20], hydrofoils [21, 22], turbomachinery [23, 24], wind turbines [25], and propellers [26, 27].

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