

On Reducing the Model Form Uncertainty in CFD Simulations

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Turbulent flow simulations are among the most challenging problems in computational fluid dynamics (CFD). Results of such simulations reflect uncertainties originating from various sources. It is highly desirable that contributions from at least identified sources of uncertainty would be eliminated or reduced. The model form uncertainty resulting from the deficiency of a turbulence model to correctly describe the flow physics is the most significant and least understood source of uncertainty in CFD simulations. The classical approach to reduce its contribution is to implement high-fidelity/high-order turbulence models. Compared to the second-order RANS, LES, and combined RANS/LES models, high-order statistical closures have received little attention mostly due to their mathematical complexity. Yet, such closures provide deeper insight into flow physics. Therefore, high-order statistical closures can be more effective and computationally cheaper alternative to LES in flows with complex physics. When simple models are required, reducing high-order statistical models to engineering needs can also be more fruitful than introducing ad-hoc corrections in the existing engineering models to compensate for their shortcomings. Possibilities to overcome complexities associated with the high-order statistical approach will be considered. Practicality of this approach will be discussed and demonstrated in flows of aerodynamic interest such as free shear flows, boundary layer, and separated flows. An emerging computational technique, multimodel approach, in which the model uncertainty is reduced by combining the results of simulations based on several turbulence models, will also be introduced.