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Enhanced Analytical Modelling of Shock Wave-Boundary Layer Interaction around NACA 64A204 Airfoil: CFD Approach

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Abstract

This research paper presents an analytical modeling study investigating the interaction between shock waves and laminar boundary layers on the NACA 64A204 airfoil. The primary objective is to validate a previously established asymptotical analytic model for supersonic viscous laminar steady flow around a thin airfoil, employing an improved analytical/statistical model based on numerical simulation approaches. The numerical simulations were conducted using Ansys Fluent 2022 R2, yielding precise numerical results of the local Mach number distribution along the airfoil's extrados. Through a comprehensive comparison between the analytical and numerical results, an enhanced analytical model was developed, resulting in the validation of the model with an average relative error of approximately 12% inside the boundary layer and 2.3% outside the boundary layer within an 80% chord-length range. This research significantly contributes to the understanding of shock wave-laminar boundary layer interaction on critical supersonic airfoils, thereby advancing the field of high-speed vehicle development. The findings offer valuable insights into the intricate aerodynamic phenomena associated with such interactions, facilitating improved design and analysis of supersonic airfoil systems. Moreover, this research makes notable contributions to the domain of transportation engineering by advancing fundamental knowledge and refining analytical models, ultimately leading to the development of more precise predictive tools for aerodynamic analysis and design optimization. These advancements have the potential to promote the efficient and sustainable progress of high-speed aircrafts, fostering innovation within the transportation field.

Keywords: Analytical Modeling, Shock Waves- Boundary Layer Interaction, Supersonic airfoils, High-speed aircrafts, Aerodynamic analysis and design optimization