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Boundary layers over wing sections

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Abstract

The understanding of developing boundary layers over wings is an important topic from the perspective of industrial applications. An increased understanding would be consequential not only for achieving higher fuel efficiency but also in the design of aircraft control strategies. With these aims in mind, the current work aims to further the understanding of developing boundary layer over wingsections. The study is performed with two particular perspectives in mind -unsteady aerodynamic effects in a pitching airfoil and turbulent boundary layerstructure in non-equilibrium boundary layers over a stationary airfoil.The boundary layer evolution in unsteady natural laminar flow airfoils undergoing small-amplitude pitch-oscillations is investigated. For high Reynolds numbers the origins of the non-linear unsteady aerodynamic response of laminar airfoils is explained on the basis of quasi-steady assumptions. Temporal nonlinearitiesin aerodynamic forces are shown to be inherently linked to thenon-linearities of static aerodynamic force coefficients and that a simple phaselagconcept can model the observed non-linear unsteady response. On the other hand at lower Reynolds numbers, when there exists an unstable leading edgelaminar separation bubble, the unsteady response is dynamically rich and changes in boundary layer characteristics can be abrupt. Such quasi-steadyphase-lag concepts are no longer appropriate to explain the unsteady flow physics in such a case. For the case of stationary airfoils, flow statistics for flow around an airfoil at two different Reynolds numbers are compared to assess Reynolds number effects in non-equilibrium flows. Pressure gradient effects found to be stronger at low Reynolds numbers, leading to higher energy in the larger structures present in the outer part of the turbulent boundary layer.

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