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Bypass transition in boundary layers subject to strong pressure gradient and curvature effects. (English) Zbl 07173490

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Summary: This paper aims at characterizing the bypass transition in boundary layers subject to strong pressure gradient and curvature effects. A series of highly resolved large-eddy simulations of a high-pressure turbine vane are performed, and the primary focus is on the effects of free-stream turbulence (FST) states on transition mechanisms. The turbulent fluctuations that have convected from the inlet first interact with the blunt blade leading edge, forming vortical structures wrapping around the blade. For cases with relatively low-level FST, streamwise streaks are observed in the suction-side boundary layer, and the instabilities of the streaks cause the breakdown to turbulence. Moreover, the varicose mode of streak instability is predominant in the adverse pressure gradient region, while the sinuous mode is more common in the (weak) favourable pressure gradient region. On the other hand, for cases with higher levels of FST, the leading-edge structures are more irregularly distributed and no obvious streak instability is observed. Accordingly, the transition onset occurs much earlier, through the breakdown caused by interactions between vortical structures. Comparing between different cases, it is the competing effect between the FST intensity and the stabilizing pressure gradient that decides the path to transition and also the transition onset, whereas the integral length scale of FST affects the scales of the streamwise streaks in the boundary layer. Furthermore, while the streaks in the low-level FST cases are mainly induced by leading-edge vortical structures, the corresponding fluctuations show a stage of algebraic growth despite the weak favourable pressure gradient and curvature.

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76 Fluid mechanics

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