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Master's Thesis

Experimental investigation of the delay of step-induced transition by means of suction

Experimentelle Untersuchung der Verschiebung von stufeninduzierter Transition mittels Absaugung

prepared by

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Abstract

In the scope of this master thesis, a systematic experimental investigation of the delay of step-induced transition by means of suction was carried out. In the practical application of laminar airfoils, structural joints like steps and gaps prove challenging, often reducing the laminar flow region and thus causing an increase in overall drag as compared to design. This work examines the effect of suction at such structural joints on laminar-turbulent transition. Experiments were conducted in the Cryogenic Ludwieg-Tube Goettingen at high chord Reynolds numbers (up to $16 \cdot 10^6$), free stream Mach numbers ranging from 0.35 to 0.77 and various stream-wise pressure gradients, which are relevant for commercial aircraft. Transition was detected by means of temperature-sensitive paint on the upper surface of the 2D wind-tunnel model used for this investigation. The surface of interest (upper side) is essentially flat over large parts of the chord, enabling decoupling and systematic study of parameters. In the absence of suction, it was found that the step and gap applied to the wind-tunnel model caused transition to occur at a more upstream location compared to the case without surface imperfection. Suction through the gap, however, driven passively by a pressure difference between upper and lower side of the model induced by the outer flow, caused a delay in transition, which occurred even downstream of the location detected for the smooth model configuration (i.e. without step and gap) at the same flow conditions. Suction therefore was observed to overcompensate the adverse effect of combination of forward-facing step and gap on boundary-layer transition. For high suction rates, it is likely that initially amplified disturbances are completely or almost completely dampened. This means that no change in transition is observed above a certain suction rate. Only at low suction rates the determined transition location moves upstream, but still remains downstream of the transition location detected for the smooth configuration in most cases.
The results presented in this work prove that suction through a gap is a powerful tool to delay laminar-turbulent transition in the presence of surface imperfections for a range of flow conditions relevant for practical applications.