The 9th European Congress on Computational Methods in Applied Sciences and Engineering
ECCOMAS Congress 2024
3–-7 June 2024, Lisbon, Portugal

Numerical studies on the influence of steps on secondary instability mechanisms in crossflow-dominated boundary layers

B. Ambrosino[§†*], **F. Tocci**[§], **A. Theiß**[§] **and S. Hein**[§]

[§] German Aerospace Center, Institute of Aerodynamics and Flow Technology, 37073 Göttingen, Germany

[†] Universidad Politécnica de Madrid, Plaza Cardenal Cisneros 3, E-28040 Madrid, Spain

Keywords: *stability analysis, crossflow, swept wing, surface irregularities, fluid dynamics*

Surface irregularities such as steps, roughness and waviness can have a significant impact on the laminar-to-turbulent transition process over wings and tails of commercial aircraft. In this work, the effect of forward-facing steps (FFS) on subsonic crossflow-vortex-dominated boundary layers is investigated. The geometry under study is a swept-wing, which reproduces the experimental setup of Rius-Vidales et al. [1] in the Low Turbulence Tunnel (LTT) at the Delft University of Technology. The setup is characterized by the presence of a forward-facing step with different heights. Results from direct numerical simulations (DNS), conducted in previous work on this geometry, are here employed as the base flow for the instability analysis. In particular, two-dimensional linear stability theory (LST-2D) and three-dimensional parabolized stability equations (PSE-3D) are employed to study the influence of two step heights on the secondary instabilities of crossflow vortices and identify how those perturbations change compared to the case without step. Furthermore, the analysis aims to assess the instability characteristics of the flow in the region downstream of the step and to identify the unstable disturbances that are developing. In order to cope with a base flow that is periodic in the direction parallel to the leading edge and features a slow variation along the crossflow- vortex axis, the stability problem is formulated in a non-orthogonal coordinate system, following the approach proposed by Li *et al.* [2] and later employed by Groot *et al.* [3] to perform LST-2D computations on an experimentally measured crossflow-vortex-dominated flow over a forward-facing step.

Acknowledgments

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No. 955923.

REFERENCES

[1] Rius-Vidales, A.F. and Kotsonis, M., *Impact of a forward-facing step on the development of crossflow instability*, Journal of Fluid Mechanics , Vol. 924, A34.

[2] Li, Fei and Choudhari, Meelan M., *Spatially Developing Secondary Instabilities in Compressible Swept Airfoil Boundary Layers.* Theoretical and Computational Fluid Dynamics, Vol. 25, 2011, pp. 65-84.

[3] Groot, K. and Eppink, J., *Stability Analysis of the Flow over a Swept Forward-Facing Step using PIV Base Flows in a Nonorthogonal Coordinate System.* AIAA 2021-2908 Aviation Forum, 2021.