Numerical Simulation of the Interaction between Longitudinal Vortices and an Oblique Shock Wave

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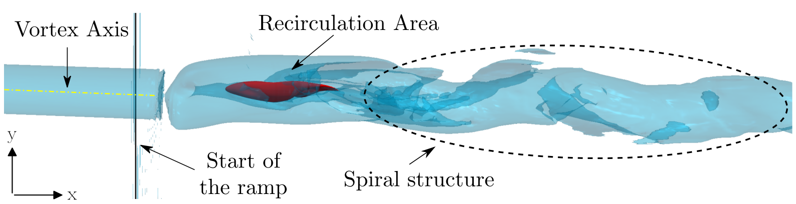
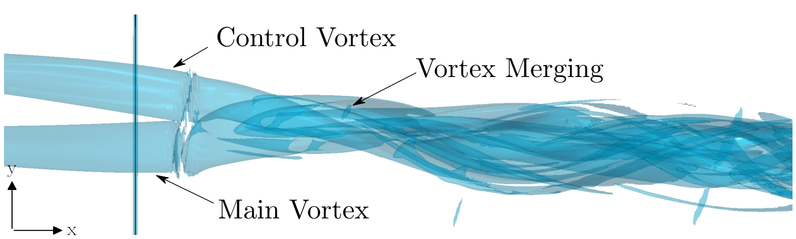
The topic of this work is the numerical investigation of the interaction between longitudinal vortices and an oblique shock. These vortex-shock interactions can occur for example on delta wings at transonic speeds, where they can lead to shock-induced vortex breakdown. As vortex breakdown can strongly affect the stability and control characteristics of an aircraft, it is crucial to correctly predict its occurrence.

The numerical simulations are performed using the DLR TAU code. Similar to previous studies on this topic[1][2], the vortices are introduced into the simulation domain by modifying the inlet boundary conditions, whereas the oblique shock is generated by a ramp in supersonic flow. Two different aspects are investigated: in the first part of the study, the interaction of a single longitudinal vortex with an oblique shock is investigated. Here, the influence of the axial velocity deficit δ and the dimensionless circulation Γ of the vortex on the stability with regard to shock-induced vortex breakdown is analyzed. In the second part of the study, the influence of the distance and the sense of rotation of a second, so-called control vortex, on the stability of the main vortex is investigated. In comparison with existing work in the literature, a broader range of axial velocity deficits is considered. The investigation of the simultaneous vortex-vortex and vortex-shock interaction has also not been conclusively covered in the existing literature. Additionally, an improved criterion to predict shock-induced vortex breakdown is formulated based on the current results.

Two exemplary results are presented in Figure 1, where the vortical structures are visualized using a blue isosurface of the Q criterion. Additionally, areas of reversed flow, that indicate vortex breakdown, are visualized using a red isosurface of the axial velocity, $v_x = -0.1\ m/s$. For a single vortex, shock-induced vortex breakdown occurs once a critical value of δ for a fixed value of Γ, or vice versa, is reached. As can be seen in Figure 1a, this results in the formation of an area of reversed flow in the vortex core and a characteristic spiral structure downstream of the recirculation area. However, by adding a second, co-rotating vortex, it is possible to achieve a stabilizing effect on the main vortex and thereby suppress vortex breakdown, compare Figure 1b.



(a) Interaction of single longitudinal vortex with an oblique shock



(b) Simultaneous interaction of two longitudinal vortices with an oblique shock

Figure 1: Comparison of the vortical structures resulting from the interaction of one or two longitudinal vortices with an oblique shock for constant parameters δ and Γ of the main vortex

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[1]Thomer et al., *Computational Fluid and Solid Mechanics* (2003).

[2]Magri and Kalkhoran, *Computers & Fluids* **86** (2013).