The Dynamics of Static Stall

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Stall on lifting surfaces is a commonly encountered, mostly undesired, condition in aviation that occurs when a critical angle of attack is exceeded. At low angles of attack $\alpha$, lift increases linearly with $\alpha$. At higher angles of attack an adverse pressure gradient builds up on the airfoil's suction side which eventually forces the flow to separate and the lift to drop. The stall process comprises a series of complex aerodynamical phenomena, including transition to turbulence, shear layer instability, vortex formation, and flow separation.

In the present study, the dynamic process of flow separation on a stationary airfoil in a uniform flow was investigated experimentally. Airfoil stall was intentionally provoked by suddenly increasing the angle of attack from slightly below to immediately beyond the static stall angle of attack $\alpha_{ss}$. During this transition the separating flow field and the airfoil’s surface pressure distribution were measured simultaneously with a high temporal resolution allowing us to investigate the chronology of events during stall development.

The sudden increase of the angle of attack within the observation period is presented in figure 1. In response to the increase of $\alpha$, the lift coefficient decreased indicating the occurrence of stall. At pre-stall, the flow is attached for the most part with a small recirculation region at the trailing edge (figure 2(a)). The post-stall flow field is characterised by a large separation region which starts near the leading edge (figure 2(b)).

During the transition of the flow from an unstalled into a stalled state, the unsteady movement of the separation point, the growth of the separated region, and surface pressure fluctuations were examined in detail. The chronology of stall development starts with an abrupt upstream movement of the separation point. Subsequently, large scale shear layer structures are formed and grow while travelling downstream. This leads to a gradual increase of the separated flow region reaching his maximum size at the end of stall development which is marked by a significant lift drop.

![Fig. 1 Exemplary evolution of the lift coefficient and angle of attack for an intentionally stalled airfoil.](image1)

![Fig. 2 Instantaneous flow fields at $\alpha = 15.06^\circ$ (a) and $\alpha = 15.49^\circ$ (b) representing pre-stall and post-stall flow states.](image2)

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