Abstract for 5th EUCASS Conference
Munich, 1-5 July 2013

Technical Topic: Flight Physics

Subtopics:
1. Development of control technologies and control methodologies applied to aeronautical and aerospace flows
2. Unsteady aerodynamics
3. Flow instability

Aerostrakes suppressing asymmetric lee-vortices on a slender body at high angles of attack

Oliver Wysocki, Christian Schnepf, Erich Schülein

German Aerospace Center Göttingen
Institute for Aerodynamics and Flow Technology
Department High Speed Configurations
Bunsenstraße 10, 37073 Göttingen

Name:	Oliver Wysocki	Erich Schülein	Christian Schnepf
Phone:	+49 551/709-2353	+49 551/709-2803	+49 551/709-2317
Fax:	+49 551/709-2811	+49 551/709-2811	+49 551/709-2811
eMail:	oliver.wysocki@dlr.de	erich.schuelein@dlr.de	christian.schnepf@dlr.de

For many decades, researchers have investigated the problem of asymmetric vortices occurring on slender bodies at high angles of attack (α). These asymmetric vortices behave like a convective flow instability and lead to unwanted side forces and yawing moments, often referred to as “Phantom Yaw” in literature. These additional aerodynamic loads can be as high as to be of a concern for the whole aircraft or missile. Furthermore, the aerodynamic control surfaces (fins/rudders) lose effectiveness at these high α. Due to that, many countermeasures have been studied as e.g. strakes being a passive method. But there are also active methods like e.g. DFEs (Deployable Flow Effectors) which are not only used to reduce the phantom yaw. By controlling the asymmetric vortices, specific side forces and yawing moments were induced in order to control the body motion at high α. But a real control is quite difficult because of the nonlinearity of this effect and it’s sensitivity to small changes.

Nonetheless, most of these studies were done only under static conditions. Since slender bodies like missiles reach this high angle of attack regime only during rapid maneuvers, the influence of the body movement is not taken into account. Only a few experiments were performed with a moving model, most of them with low free stream velocities and/or pitching rates.

Therefore, a flow control device called “aerostrakes” was tested experimentally under both static and dynamic conditions and at transonic Mach numbers. Aerostrakes are two symmetrically arranged longitudinal jets forcing a fixed separation and therefore acting similar to usual solid strakes but with the possibility of turning them on and off. Due to the reduced model size, the pitching rate of the real body had to be increased according to the model scale.

The model was a generic missile with a length of L = 720mm and a diameter of D = 36mm resulting in a fineness ratio of L/D = 20 and a model scale of about 1:3. It had four wings and four fins in the rear part of the model arranged in an X-configuration. The acting total forces and moments (= sum of aerodynamic and inertial loads) were measured by the help of a 6-component strain gauge balance located inside the model. This balance was fixed to a sting

which was mounted to the so-called Maneuver Simulator. The latter is a hydraulically driven test rig converting the linear movement of a hydraulic cylinder into a pitching motion of the model. This type of pitching maneuver is a simplified one since the model is rotating around a point behind the model and not around its center of gravity (CG). Due to the high angular accelerations and the high aerodynamic loads, a rotation around the CG was not realizable. With the Maneuver Simulator, the aerostrakes were tested under static conditions (one measurement for each angle of attack) and dynamic conditions (pitching with actuation frequencies between f = 0.05 Hz and f = 5 Hz and variations in the angle of attack between α = 0° and 45°. Different flow conditions were evaluated with most of the test results obtained at $M = 0.8$ and $Re_D \approx 420000$.
Figure 1 shows the aerostrake model configuration used for the tests. The air supply used to run the aerostrakes is realized by a CO_2-Cartridge in combination with a rapid reaction valve. The CO_2 exiting the valve is channelized and divided into two separate flows indicated by the blue arrows in Fig. 1. By construction, these flows shall be symmetrical. They leave the model via two slots with the dimensions 50mm x 0.5mm (length x height) (Item 1 in Fig. 1).

The flow field outside of the slot nozzles is shown by a Schlieren image (Fig. 2) obtained with the surrounding air at rest. As can be seen, the flow field is directing slightly forward with a small asymmetry occurring.

Nonetheless, the results shown in Fig. 3 and Fig. 4 prove that the aerostrakes work quite well with a better performance for the static case. Here, at a fixed angle of attack of α = 40°, the side force coefficient c_y is reduced by about 80% and the yawing moment coefficient c_n by about 50%. In the dynamic case (Fig. 4), the valve was opened for several seconds until the CO_2-Cartridge was empty. The reduction rates are 30% for c_y and 40% for c_n respectively. Furthermore, it can be seen that the reduction rates are not stable and increase within 3 cycles although the pressure at the pressure sensor (Kulite, item 2 in Fig. 1) is quite stable.

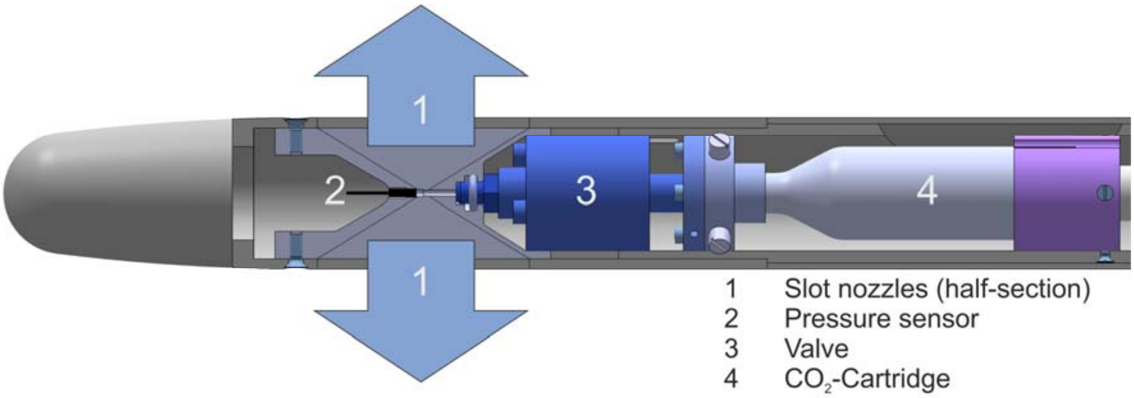

Fig. 1: Model with symmetrical slot nozzles (CAD-model)

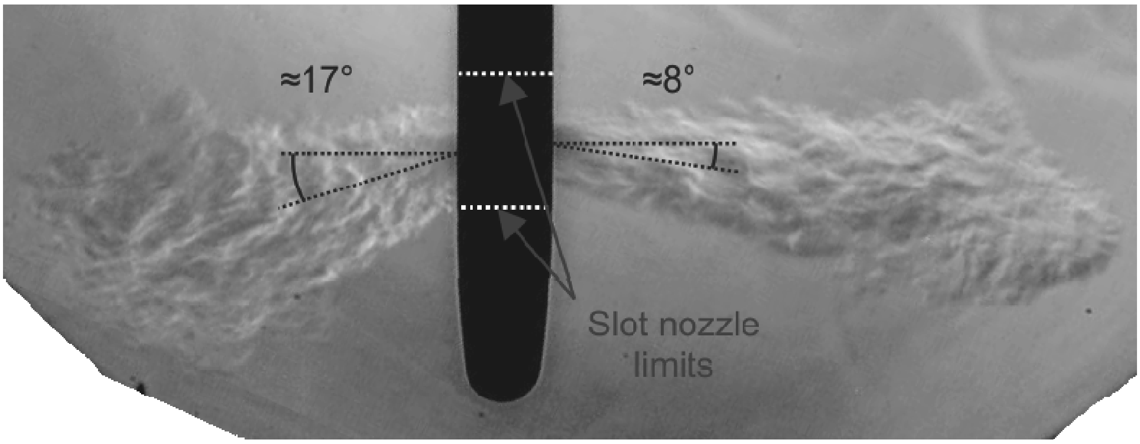

Fig. 2: Schlieren image of the flow out of the slot nozzles

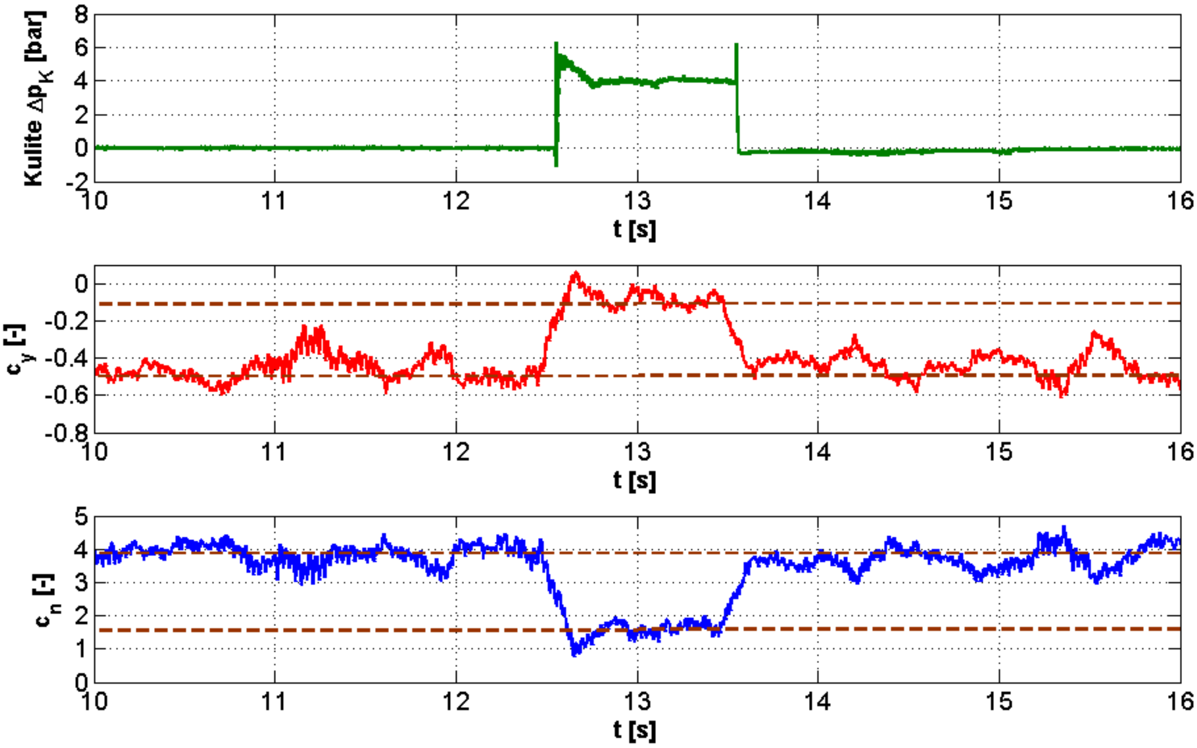

Fig. 3: Influence of aerostrakes on c_y and c_n under static conditions
($\alpha = 40°$, $M = 0.8$, $Re_D = 0.42$ Mio)

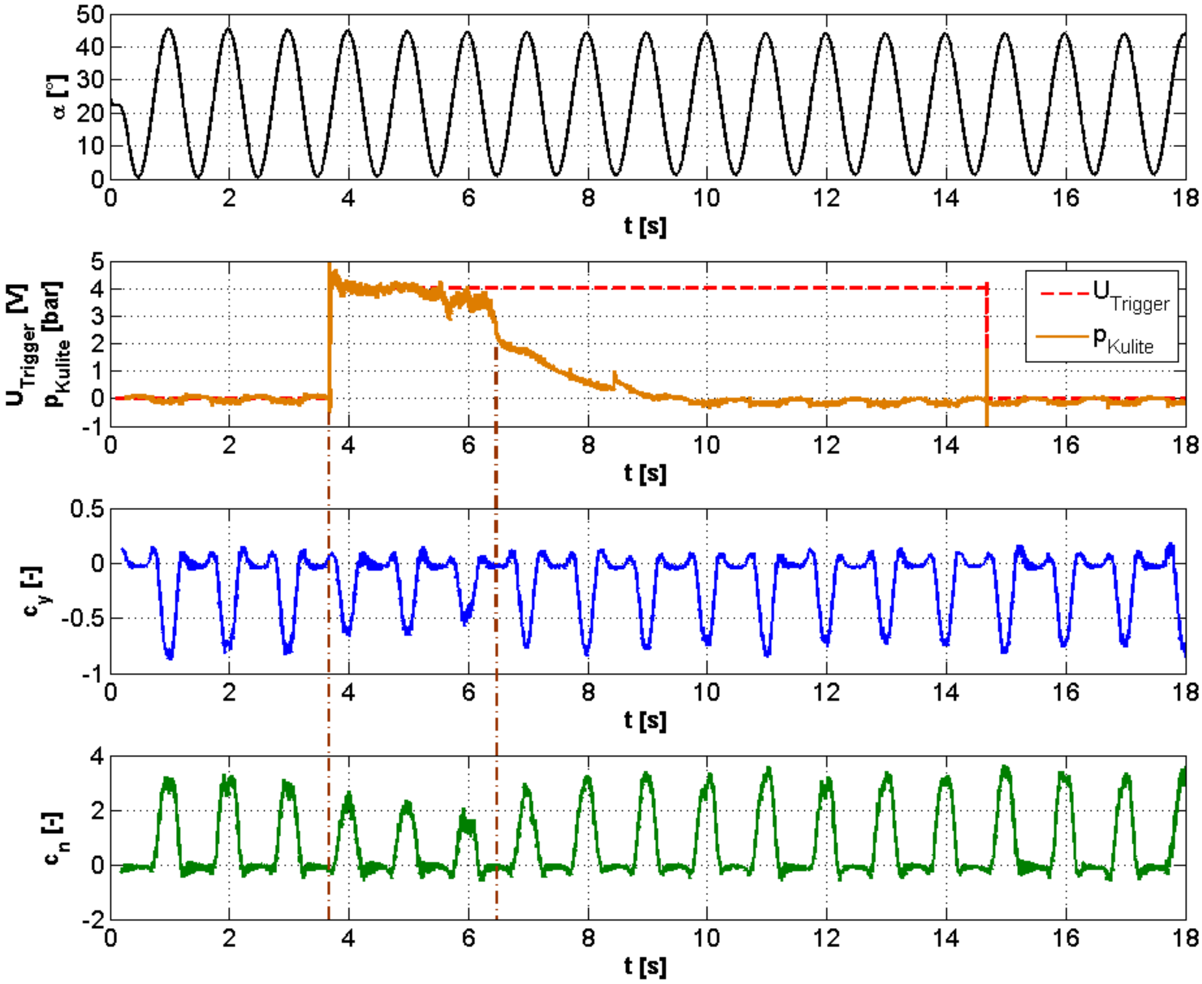

Fig. 4: Influence of aerostrakes on c_y and c_n under dynamic conditions

(f = 1 Hz, M = 0.8, Re_D = 0.42 Mio)