Experimental studies on the "Phantom Yaw Effect" at maneuvering slender bodies

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Abstract:

Asymmetric vortices can occur unexpectedly on slender bodies at high angles of attack. These vortices separating from the nose or/and shoulder region induce a side force and also a corresponding yawing moment often referred to as "phantom yaw".

In the last decades, there have been many experimental and also numerical studies on this phenomenon. The aim was to understand this effect and to find the influencing parameters. There have also been investigations on using the asymmetric vortices for control purposes in addition to the fins. Despite this, another target of research has been the suppression of the vortex inducing side forces and yawing moments in order to increase the stability of e.g. a missile in a maneuver.

Most of the wind tunnel tests have been done without model motion at several but fixed angles of attack. Since slender bodies as missiles achieve these high angles of attack via very rapid pitching maneuvers, the model motion is supposed to have some impact on the test results. One reason for the lack of dynamic test data at high Reynolds numbers are high inertial and aerodynamical forces acting on the test model and it's support. They result in contradicting design issues. On the one hand, the support needs to be stiff to withstand all forces and moments and on the other hand, the aerodynamic behaviour of the model shall not be changed by the support.

Nonetheless, a maneuver simulator has been built at the DLR Goettingen. By means of this device, wind tunnel tests in a transonic wind tunnel at high Mach and Reynolds numbers, pitching rates of up to $\omega = 700^{\circ}/s$ and pitching maneuvers from $\alpha = 0 \ldots 45^{\circ}$ have been done.

We compared the "phantom yaw"' emergence at a clean configuration with the ones at a configuration housing a pair of symmetric longitudinal slot nozzles which were fed by natural ventilation. The results showed a yawing moment for the clean configuration at angles of attack higher than $\alpha = 38^{\circ}$. They also showed that the jet flow through the slot nozzles successfully suppressed the yawing moment by causing a fixed separation. Differences between static and dynamic tests could be seen as well.

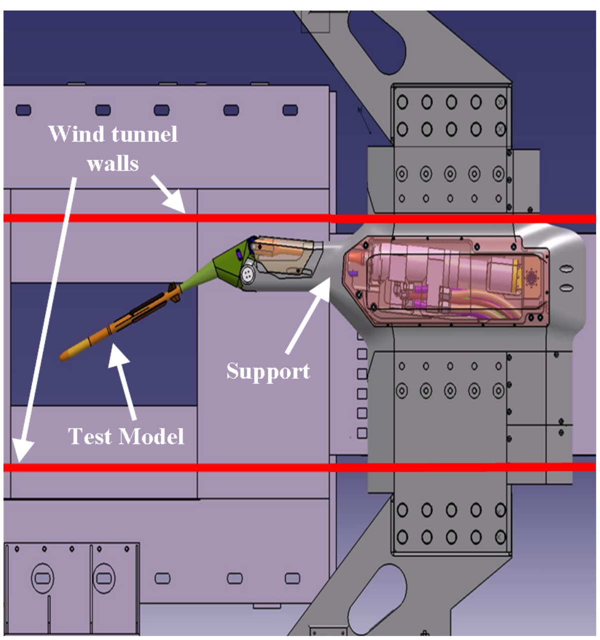

Figure 1: *The Maneuver Simulator in the TWG*

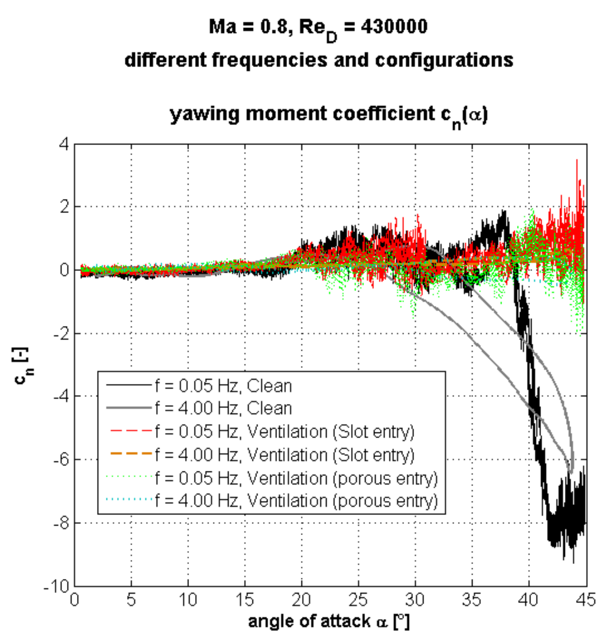

Figure 2: *Test results from TWG experiments*