Reynolds number and surface roughness effects on damping derivatives of the Exomars capsule

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Dynamic stability has been one of the major critical issues of entry flights with capsule configurations. Several studies showed the shortcomings of the CFD simulation but also discrepancies between different measurement techniques [1], [2], [3] and [4]. The aerodynamic behavior of the EXOMARS capsule during its entry into the Martian atmosphere is a very important parameter for the success of the mission. In particular the dynamic stability of such configurations in transonic and supersonic flight regimes is critical. The prediction of the dynamic stability using both experimental and CFD tools is quite challenging and requires reliable data on the static stability behavior of the vehicle. Therefore dynamic stability tests have been carried out in the DLR Trisonic Windtunnel Cologne on capsule models with smooth and rough surfaces in a Mach number range of 1.8 to 3.5 at different Reynolds numbers and .

The tests results for the Reynolds Number Re = 0.6Mio show, that for Mach numbers below 2.2 the capsule is dynamically unstable, for 2.2 and above 2.5 the capsule is stable (Figure 1). The runs with cross-flexure 2 by Re = 0.6Mio show the same trends as results gained with cross-flexure 3 during the test campaign by Re = 1Mio, but the capsule behavior by Re = 0.6Mio became more stable. The experiments show the transition concerning the dynamic stability at a Mach number of 2.1.

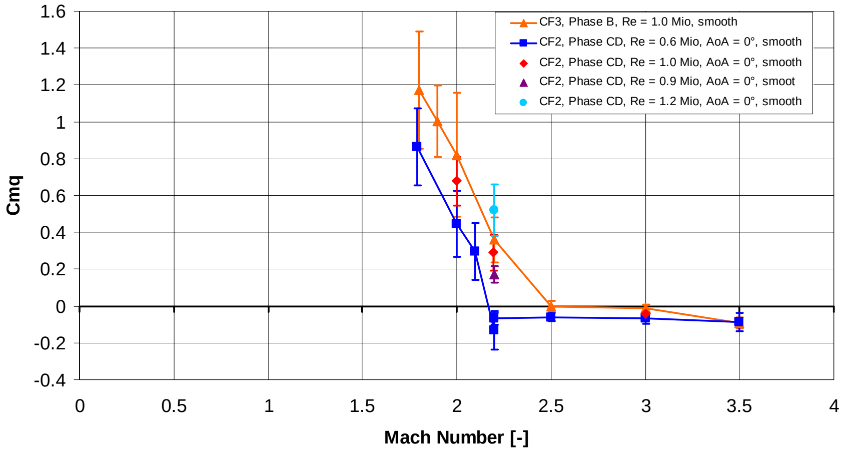

Figure 1: Pitch damping coefficient derivative for different Reynolds numbers.

In order to check the influence of the surface roughness on the on the dynamic stability behavior, the model surface was coated with roughness elements of 80 µm. For boundary layer tripping a defined surface roughness was applied to the capsule. With rough surface the capsule becomes a little bit more stable (but still unstable) below Mach 2.5. But it becomes much more unstable (and becomes unstable) above Mach 2.5 (Figure 2).

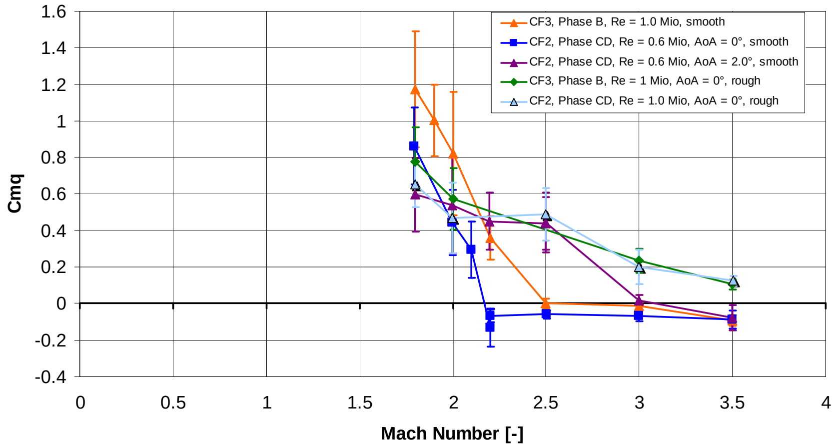

Figure 2: Pitch damping coefficient derivative for different surfaces and Reynolds numbers.

In order to analyze the wake flow, which dominates the dynamic stability behavior of the capsule, Schlieren pictures of different test configurations have been compared and the wake flow size has been determined.

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