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Wave drag reduction due to a self aligning Aerodisk

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One of the most important aerodynamic design goals was and is the reduction of aerodynamic drag. No matter wether a flight object is flying with subsonic or supersonic speed, the drag is limiting flight speed and range. A different approach in aerodynamic design for different flow regimes arises from the different sources of drag. In supersonic flight the wave drag plays the most important role. As a result a favoured round and rather blunt nose in subsonic and transonic flight has a large drawback in supersonic flight, due to the occurring bow shock (see Fig. 1a)). Considering only aerodynamics, sharp and pointed nose are most beneficial in supersonic flight. But the available space in a cone or a wedge shaped nose is limited. Therefore it is not practicable for the integration of avionic or a seeker.

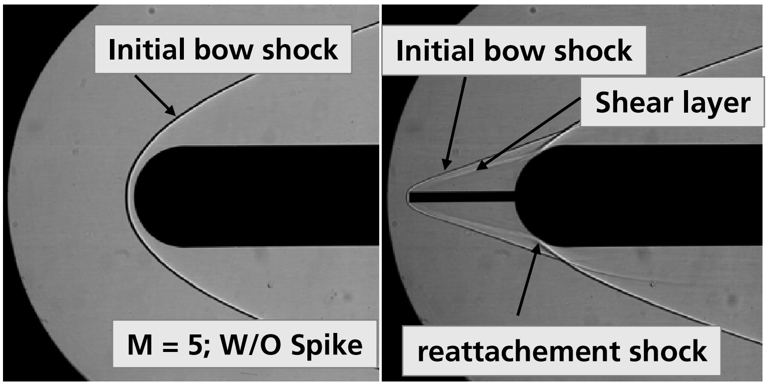
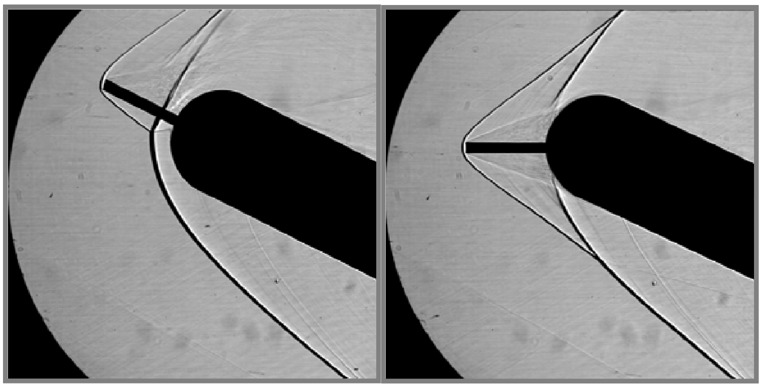


Fig. 1 Shadowgraphy of a Bow Shock and a Spike induced separation on a hemispherical model at M = 5.

A well known concept of reducing the wave drag while keeping a blunt nose in supersonic flight is the Aerospike concept (see Fig.1 b)).

A thin rod mounted on the tip of a blunt body is the simplest design of an Aerospike and the beneficial effect on the drag is investigated since decades. Slight variations of the initial design include cones, spheres or disks that are additionally mounted on the tip of the rod. In the ideal case the boundary layer on the rod separates along the whole rod surface due to the pressure rise over the initial bow shock. The separated boundary layer forms a shear layer that reattaches under a certain angle on the blunt nose (see Fig. 1 b)). As a result the outer flow is deflected and a oblique shock is formed. The shear surface itself also deflects the oncoming flow like an actual

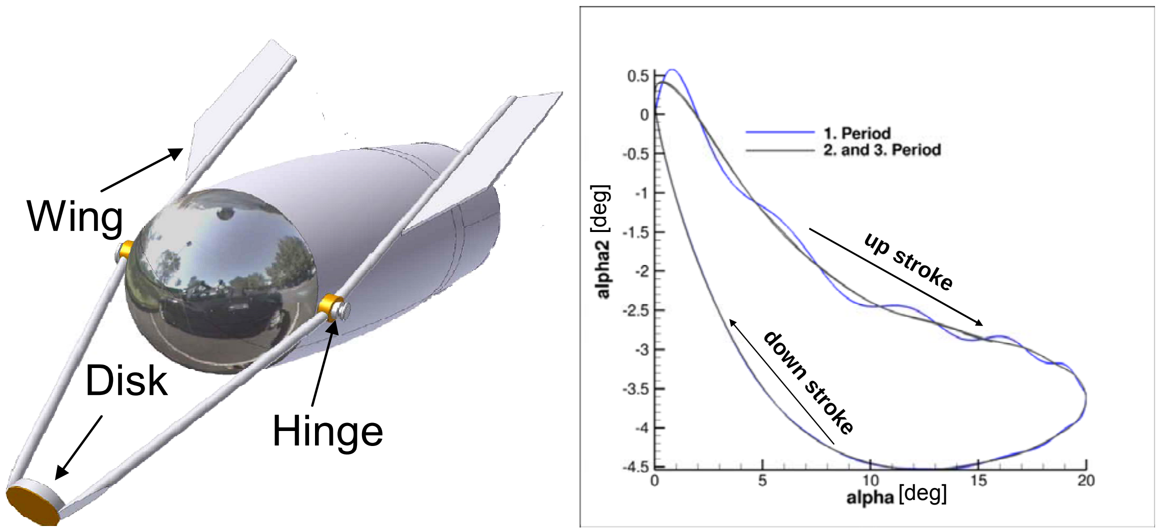
conical body would do and the initial bow shock is transformed to a weaker conical shock. The conical shock units further downstream with the reattachment shock. With this simple method a drag reduction of more than 50 percent can be achieved in comparison with a blunt body.
But this high reduction rates are only possible for very low angles of attack α. As the angle of attack is increased the effectiveness of the Aerospike decreases. A favoured shock system like in Fig. 1 b) is not achievable anymore and at angles of attack > 15°, depending on the specific case, no drag reduction can be gained due to unfavourable shock system shown in Fig 2 a)..



a) b)

Fig. 2 Shadowgraphy of a fixed and an aligned Spike at M = 2, α = 20 °.

A movable Aerospike that points always into the flow direction even though the main body has an angle of attack could sustain the beneficial effect in the region of low and high angles of attack (see Fig. 2 b)). The point where the effectiveness is close to zero is shifted to higher α. This paper deals with such an Aerospike, in fact it is just a disk that is mounted to a frame (see Fig. 3 a)). On the other end of the frame small wings are attached. The aerodynamic forces acting on the wings induce a pitching moment about the hinge and align the disk with the oncoming flow.



a) b)

Fig. 3 Sketch of a self aligned disk applied on a hemispherical model. Declination of the Spike α2 versus α (missile) for M =1.4 and a sinusoidal pitching manoeuvre with a frequency of f = 5 Hz of the missile.

The dynamics and performance of the self-aligning disk concept will be numerically investigated on a generic missile geometry and compared with available experimental data. Since the Aerodisk should be aligned with the oncoming flow due to aerodynamic forces a 6DoF flight mechanic tool is coupled with the flow solver to calculate the pitching motion parameter of the Aerodisk. A pitching motion of the disk relative to the missile is realized by the chimera technique.

In Fig 3 b) the angle of attack of the Aerodisk $\alpha 2$ is plotted vs. the angle of attack of the missile. In this test case the missile undergoes a sinusoidal pitching manoeuvre with a frequency of f = 5 Hz and angles of attack between $\alpha = 0°$ and $\alpha = 20°$ at M = 1.4. The numerical simulation yields to small declination of the disk to the oncoming flow for high angles of attack. But neglecting this small declination the self-aligning Aerodisk shows a good performance. At high angle of attack and also at high pitching rates the Aerodisk is aligned to the oncoming flow and a wave drag reduction is sustained.