Practical aspect of the free-to-tumble technique for dynamic characterization of reentry vehicle

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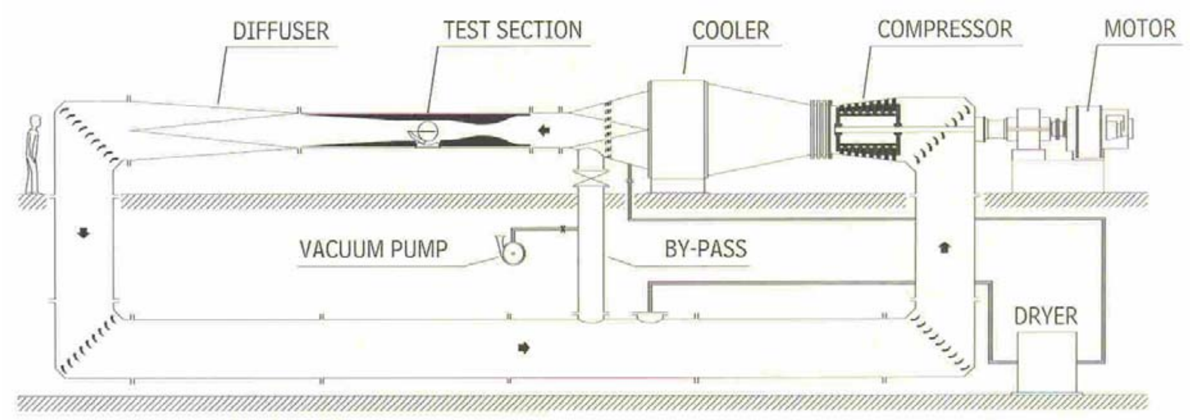
I. Introduction

Entry capsules provide an attractive option for planetary exploration missions. Designed to survive during early phases of the atmospheric entry and re-entry, these vehicles often become dynamically unstable at low attitudes. Stability of a vehicle refers to its movement or its tendency to return to an equilibrium state. It consists of two aspects: static stability and dynamics stability. Forces and moments are examined to determine if they are in the direction to force the body back to its equilibrium flight conditions. Dynamic stability encompasses the unsteady behavior of a vehicle responding to time dependent aerodynamic forces and moments produced by the vehicle's motion. The purpose of the work reported was to determine the stability characteristics and aerodynamic damping for capsules. We were using Free-to-tumble method for determine the stability characteristics. Aerodynamic stability characteristics are investigated in subsonic and supersonic flow regime. The measurements reported here are carried out in the VKI-S1 wind tunnel. The methods are described and discussed. Then, results from free to tumble are presented and the methods to extract damping coefficient from data are discussed.

II. The VKI-S1 wind tunnel



The VKI-S1 wind tunnel is a continuous closed circuit super/trans/sub-sonic wind tunnel of the Ackeret type and driven by a 615 kW axial flow compressor. Two 40 cm x 36 cm test sections are available. A transonic test section with adjustable slotted wall is used for the Mach number from 0.3 to 0.95. The maximum Mach number available depends of the Reynolds number. For supersonic testing, a contoured nozzle is design for Mach 2. A typical unit Reynolds number is 4 x 10^6/m.

The typical flow conditions are presented in detail in Table 1:

Mach	*P (Pa)*	*T (K)*	U_∞ *(m/s)*	q_∞ *(Pa)*	*Re (10^6/m)*
0.50	22050.0	286.0	168.8	3828.6	2.518
0.70	18893.0	279.7	234.9	6491.6	3.124
0.88	16184.0	276.3	293.3	8774.4	3.415
2.09	1727.5	162.6	535.2	5302.9	1.787

Table 1: typical flow conditions

III. Models

Different shapes of reentry vehicle were tested in this facility, the APOLLO, the CTV and the more recent EXPERT model. The typical size of model is 50 mm in diameter. The models can be made out of metal (steel or aluminum), Plexiglas or from resin. The material used for the fabrication defined the mass and the inertia of the model. For the lighter model, foam covered by resin was used in combination with a transversal rod made of carbon fiber. This solution was the better one in term of inertia but still need to be improved for similitude purpose or for testing with forced oscillation technique. In order to reach lower inertia, the last improvement was to use the fabrication by stereo-lithography which allow to produce hollow model with a light resin. The thickness of the wall is reduced to 1.5 mm. The model material is the DSM Somos NanoForm 15120 nanocomposite resin, which has a density of only 1.38 g/cm^3 when hardened. The light density of the model (compared to past models investigated at the VKI, using mostly Plexiglas or metals) keeps the moment of inertia down. This is important because it allows the models to oscillate at higher forced frequencies while reducing inertial damping forces. This technique gives also a better precision for the external shape and the location of the axe of rotation compared to the previous method of fabrication.