

Improvement of an Altitude Test Facility Capability in Glaciated Icing Conditions at DGA Aero-engine Testing

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ABSTRACT

The A06 test facility designed for combustor testing in altitude has been modified to be converted in an icing facility for probe testing. The objective was to be able to simulate ice crystals conditions at high altitude, high Mach number and low temperature. This facility has been upgraded in several steps extending the median size of the ice crystals produced and the ice water content range. The aero-thermal and icing capabilities have been assessed during commissioning tests. Finally, in order to prepare the calibration of the facility, some measurement techniques for cloud characterization have been selected or developed, especially for cloud uniformity measurement.

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INTRODUCTION

Ice crystals have been identified as a threat for airplane affecting engines and probes [1]. To understand and reproduce these phenomena, experimental tools have been developed.

Prior to this interest for glaciated icing conditions, some icing wind tunnels had the capability to produce ice crystals with median size of about one millimeter as defined in the CS requirements. These facilities were limited to ground level altitude. As ice crystal icing is associated to high altitude condition and engine compressor environment, it was useful to develop facilities able to simulate variable pressure.

Only two facilities could produce ice crystals conditions in altitude: RaTF at NRC [4] and PSL at NASA [5]. The first facility is able to perform test on small component or specific set-up like compressor cascade and the second one is able to test engines of medium sizes. Such capabilities were missing in Europe.

In 2010, DGA Aero-engine Testing decided to develop this kind of capability in order to perform tests on probes. The center has a long experience in icing testing on probes, airfoils and engines in various facilities [2]. The objective was to select a small test facility able to

simulate low temperature and high altitude. A test facility, named A06, has been identified as the best candidate and has been upgraded to be able to simulate high Mach number and to generate ice crystals.

With the future integration of glaciated icing conditions and mixed phase in a new appendix of the requirements, means of compliance are needed for certification. At the same time, however, the representativeness of such conditions in facilities has to be improved to reproduce ice crystals with relevant properties like size, shapes and density as close as possible to natural ice crystals.

In 2012, the European project High Altitude Ice Crystals (HAIC) started [3]. One of its objectives aims to improve some facilities in order to get acceptable means of compliance and useful experimental tools for the understanding of icing from glaciated and mixed phase conditions. As partner of this project, DGA Aero-engine Testing is involved in the upgrading of its A06 test facility.

FACILITY DESCRIPTION

Among the set of facilities available at DGA Aero-engine Testing, A06 is a small test facility designed for combustor testing in altitude and at low temperature. The tests performed are relight, flame out and stability limits of combustors. A new configuration has been proposed for icing. The overall facility scheme is described in Figure 1. It is a open circuit configuration.

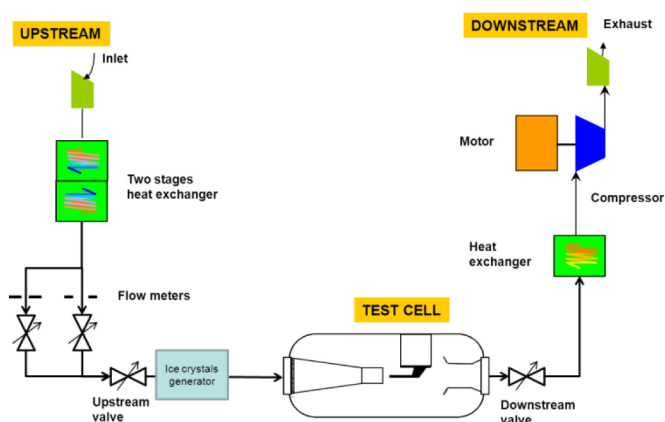


Figure 1. Overall facility scheme

A new cooling machinery with a two stages heat exchanger able to cool the airflow down to -48°C in total temperature and to adjust the humidity has been implemented. The maximum temperature difference between the dew/frost point and the air temperature is 24°C allowing a humidity range from around 50 % to 100 % within a part of the total temperature operating range.

Two branches equipped with flowmeters allow working on two air flow rate ranges, below and above 1 kg/s, with good accuracy.

The ice generator is installed between the upstream valve and the test cell.

A small scale altitude test cell used for engineering research has been adapted because its interfaces are compatible with the pipe diameters of the facility. This test cell is 2 meters in length and 0.5 meter in diameter (Figure 2).



Figure 2. View of A06 facility in icing configuration

A converging nozzle has been designed and manufactured to be able to reproduce high Mach number up to 0.9. Due to the limitation of the exhaust compressor mass flow rate, the exit diameter of this nozzle is 100 millimeters.

The air flow is blown out by an exhaust compressor able to work down to 15 kPa without pressure losses. Its maximum standard mass air flow rate is of 4.2 kg/s.

IMPROVEMENTS OF ICE CRYSTALS GENERATION SYSTEM

There are two basic methods to produce ice crystals. One consists in shaving or grinding ice blocks. This method is used in ground level test facilities because it requires to store ice blocks and to feed the grinding machine regularly. The second method uses pneumatic atomizers with high atomization pressure ratio to freeze out the droplets produced. This system can operate continuously but the median size of the ice crystals is small (< 100 microns). The main drawback is that the time for complete freezing of the droplets must be shorter than the residence time between the spray bars and the test section, leading to some restrictions in the achievable maximum median size and maximum static temperature. In addition, another possible issue is the built-up of ice accretion if partially frozen or super-cooled droplets impinging on the facility walls.

In a first step, the technical solution selected has been the freeze out technique.

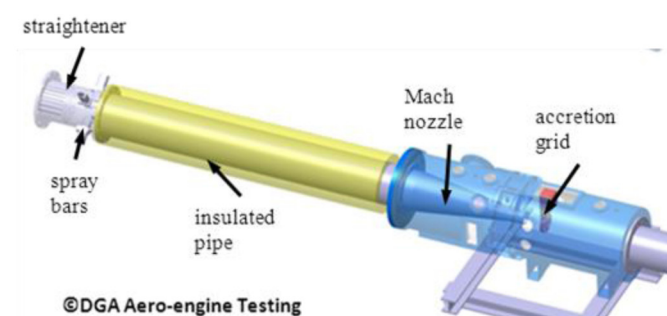


Figure 3. Initial icing test configuration

A straightener and a screen were installed upstream the ice crystal generator to get a good flow quality.

The spray grid is composed of four spray bars with one pneumatic atomizer each (Figure 4). Radial position can be adjusted to avoid ice accretion on the pipe or optimize cloud uniformity. It is also possible to use only one atomizer placed on the centerline if low ice water content is required or if there is some ice deposit accreted on the pipe wall with four atomizers (Figure 5).

Ice crystal generation is controlled by the air atomization pressure and temperature.

The distance between the ice crystal generator and the test section has been maximized to increase as far as possible the residence time for a complete freezing of the droplets (Figure 3).

Second step was the improvement of the ice crystal generator device to increase the sizes of the ice crystals produced.