T625 GOKBEY HELICOPTER INTAKE ICING WIND TUNNEL TEST CAMPAIGN

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Abstract

The T-625 GÖKBEY is multi-role utility helicopter designed by Turkish Aerospace. Compliance demonstration for the helicopter air induction system icing requirements defined in CS-29 are accomplished with icing wind tunnel test campaign. In this paper, the wind tunnel test models, test conditions, test procedures, visualized test results and the data gathering process from the Aerodynamic Interface Plane (AIP) of the engine are introduced.

1. NOTATION

Acronyms:

AIP	Aerodynamic Interface Plane
CMI	Continuous Maximum Icing
FOD	Foreign Object Debris
IM	Intermittent Maximum
IMI	Intermittent Maximum Icing
IWT	Icing Wind Tunnel
LWC	Liquid Water Content
MVD	Median Volumetric Diameter
N/A	Not Applicable
OAT	Operating Air Temperature
RTA	Rail Tec Arsenal
SAT	Static Air Temperature

2. INTRODUCTION

T-625 GÖKBEY, designed by Turkish Aerospace, is a twin engine rotary wing light class utility helicopter. It is powered by 2 x LHTEC CTS800-4AT turboshaft engines, which includes inertial particle separator and inlet anti-icing system. The helicopter is designed and built in order to comply according to CS 29 specifications for up to 20,000 ft altitude. The helicopter air induction system shall be able to operate under the continuous and intermittent icing conditions defined in CS 29 Appendix C. Although engine air induction system is designed for up to 20,000 ft altitude, the other cold weather operation systems, such as rotor ice protection, windshield etc., are designed for up to 10,000 ft altitude for full-icing. Air induction system icing wind tunnel survey, which is the subject of this document, is accomplished in order to obtain clearance for inadvertent entry conditions.

The T625 GÖKBEY Helicopter air induction system is designed to provide:

- Correct quantity and quality of air to the compressor,
- Foreign Object Debris (FOD) protection,
- Icing protection.

The air induction system consists of three components, which are plenum, external mesh screen and the internal mesh screen. The by-pass gap, which is shown in Figure 1, is designed to provide necessary air to the engine in case of clogging of mesh screen by ice. The internal mesh is presented in Figure 2. It's main purpose is to provide additional protection for snow conditions, where accumulated snow may results with ice accretion in the plenum. In that condition, this ice formations may shed and sucked by engine. The internal grid

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prevents this undesirable condition. The mesh size of the internal grid is chosen according to engine integrated inertial particle separator specifications. Although the grids came with performance penalties mentioned in Ref [4], the engine power loss is not in critical level and engine stability limits provided by engine manufacturer are not exceeded.

Therefore, the helicopter is supposed to be able to operate under icing conditions defined in CS-29 Appendix C [1].

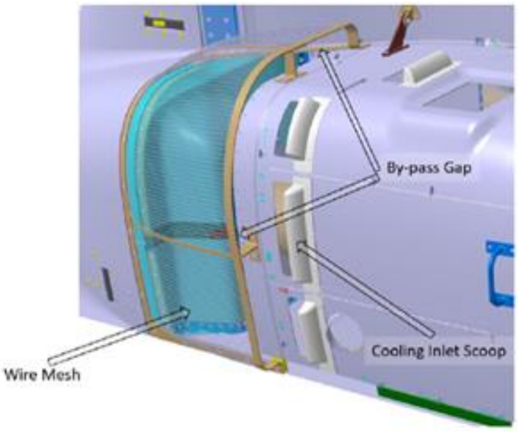

Figure 1: External/Primary Mesh Screen and By-pass Gap

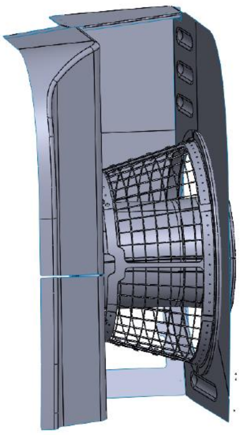

Figure 2 Internal/Secondary Mesh Screen

The icing tunnel test are performed at Rail Tec Arsenal (RTA) Icing Wind Tunnel with Aerotex GmbH. The compliance will be shown for the following requirements [1]:

- CS 29.1093 (b)
  - (1) It must be shown that each turbine engine and its air inlet system can operate throughout the flight power range of the engine (include idling):
    - (i) Without accumulating ice on engine or inlet system components that would adversely affect engine operation or cause a serious loss of power under the icing conditions specified in Appendix C; and
  - (2) Each turbine engine must idle for 30 minutes on the ground, with the air bleed available for engine icing protection at its critical condition, without adverse effect, in an atmosphere that is at a temperature between -9°C and –1°C (between 15°F and 30°F) and has a liquid water content not less than 0.3 grams per cubic meter in the form of drops having a mean effective diameter not less than 20 microns, followed by momentary operation at take-off power or thrust. During the 30 minutes of idle operation, the engine may be run up periodically to a moderate power or thrust setting in a manner acceptable to the Agency.

While the primary objective of the test runs is to determine the combinations of icing conditions which give maximum blockage of the inlet mesh and to record the mesh blockage, the second objective of the test is to record aerodynamic parameters at the Aerodynamic Interface Plane (AIP) for development purposes.

The initial scope of the test campaign is to obtain inadvertent entry clearance for air induction system; furthermore, the most critical test conditions are examined considering the full icing clearance test cycle.

3. TEST DEFINITION

3.1. Test Facility

The test campaign is conducted at large Icing Wind Tunnel (IWT) of the Rail Tec Arsenal (RTA). The effective test section area equals to 2.9m x 1.7m x 3m (w x h x l) and the maximum tunnel speed is 80 m/s, which can be obtained at empty conditions. The test section is illustrated in Figure 3.

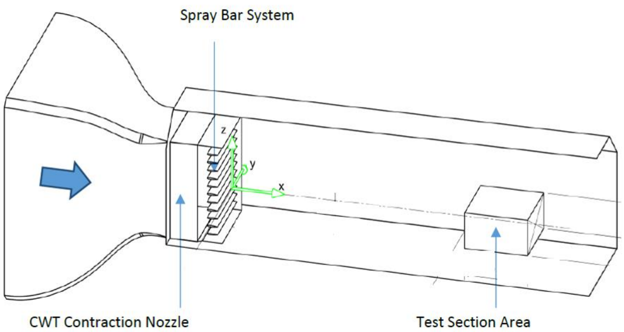

Figure 3: The RTA test section [3]

Engine intake mass flow is simulated by the mass flow system integrated into tunnel, where the mass flow rates are obtained from the engine performance program.

The test facility was calibrated before the test campaign for LWC, MVD, airspeed and their uniformity for the test section area shown in Figure 3. [3]

3.2. Test Conditions

The test points for Continuous Maximum (CM) and Intermittent Maximum (IM) icing conditions are obtained by sweep procedure as presented in Figure 4 & 5.

- Sweep 1: Choose an MVD value and sweep for temperature.
- Sweep 2: Choose the most severe temperature at step 1 and sweep for MVD.
- Sweep 3: Choose the most severe condition at step 2 and sweep for air speed.

The most severe conditions were chosen according to the ice accumulation on the secondary grid.

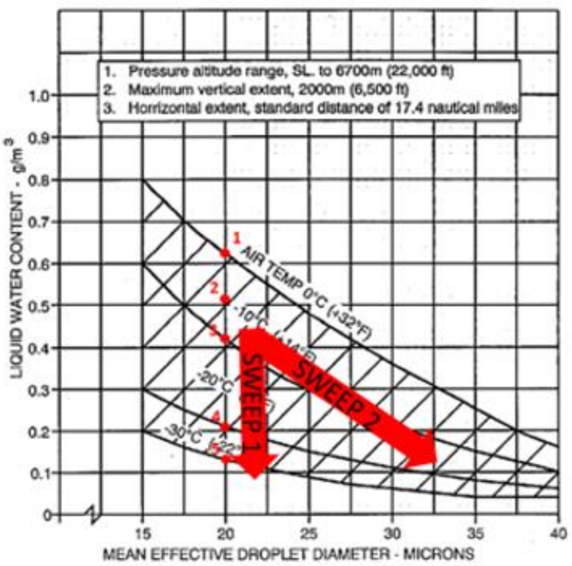

Figure 4: The sweep process for CM icing conditions

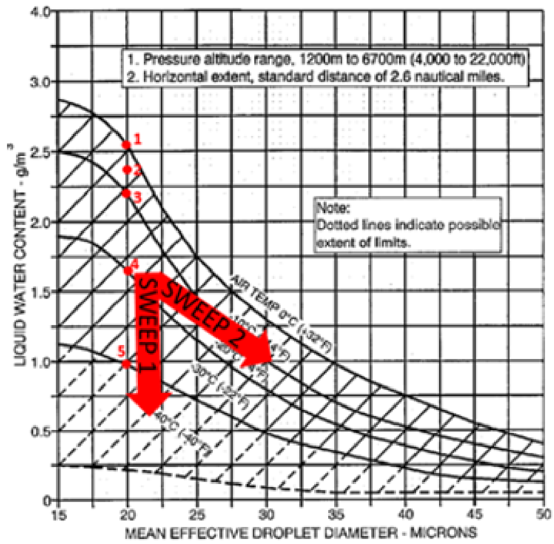

Figure 5: The sweep process for IM icing conditions

Exposure time for each cycle of continuous and intermittent clouds were calculated by the horizontal extent of the clouds [1], which are assumed as 17.4 nm for continuous maximum icing condition and 2.6 nm for intermittent maximum icing condition, divided by airspeed. Some of the test points are modified by extending the test duration due to insufficient tunnel capabilities about LWC, MVD and airspeed.

In addition, hover and ground-run tests are performed with the minimum tunnel speed. Exposure time of these tests were set as 30 minutes as declared in Ref [1]. At ground runs, the mass flow rate is modified periodically to represent idle, moderate power and take-off power at the end of the test. This procedure is given in Figure 6.

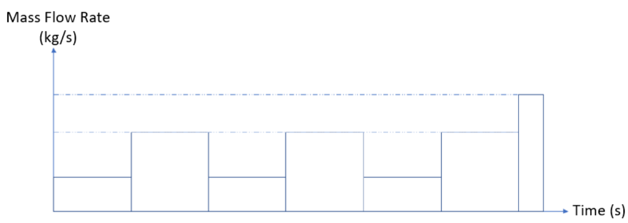

Figure 6: Ground run mass flow rate variations

Inadvertent icing test cycle, given in Figure 7, is explained as direct sequential penetration into continuous maximum and intermittent maximum icing clouds and thirty minutes hold capability in continuous maximum icing conditions [2].

Additionally, full icing condition, given in Figure 8, is represented as repeated cycles of continuous and intermittent clouds until ice accretion stabilized [2].

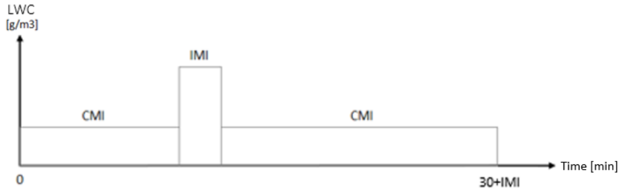

Figure 7: Icing cycle representations for inadvertent entry clearance

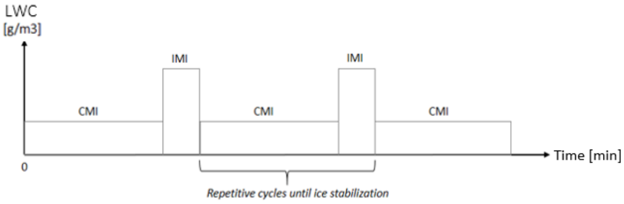

Figure 8: Icing cycle representations for full icing clearance

During this campaign, more than twenty test points were run. A simplified test matrix is presented for three cases in Table 1.

Table 1: Simplified test matrix

Maneuver	OAT [°C]	Airspeed [m/s]	MVD [µm]	CMI LWC [g/m3]	IMI LWC [g/m3]	Total Time [min]
Forward Flight	-2.5	75	20	0.59	0.82	36.19
Forward Flight	-20	60	20	0.21	1.03	43.33
Hover	-5	20	40	0.6	-	31

3.3. Test Model

The full-scale test model is used with the left half of the helicopter. The helicopter intake model is integrated with an engine internal section representative duct geometry and the internal engine flow is simulated by tunnel mass flow simulator. Some details on the fuselage are discarded since they do not affect the intake icing characteristics.

The test model orientation is changed with respect to flight conditions as presented in Figure 9 & 10. In order to include rotor downwash effect within the tunnel, the tests points for hover and ground runs are accomplished by adjusting flow angles (by changing the model orientation) to represent the rotor downwash effects at minimum tunnel speed.

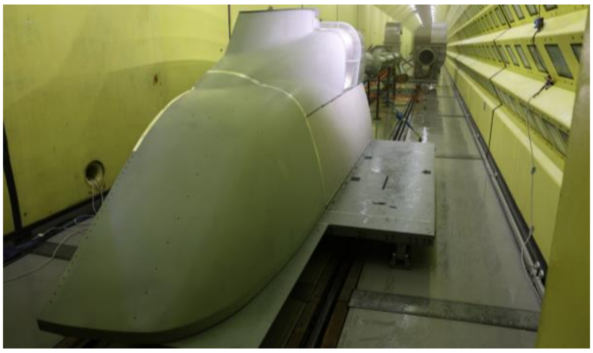

Figure 9: Test model orientation for forward flight

Figure 10: Test model orientation for hover /ground runs

3.4. Data Collection

The test model is equipped with rakes at AIP, shown in Figure 11, in order to evaluate variation of pressure data under the exposure of icing conditions. The rakes are equipped with heater in order to avoid ice formation around the rake, particularly around the pressure measurement probes. Ten rakes are used to measure pressure recovery, swirl, and pressure distortion at the AIP. Each rake consists of four 5-hole probes.

The results of this document do not include any pressure measurement since the collected data is not used in the induction system certification. It is collected to validate CFD models and to investigate the timely variation of the pressure recovery, swirl and distortion caused by the ice accretion on the induction system.

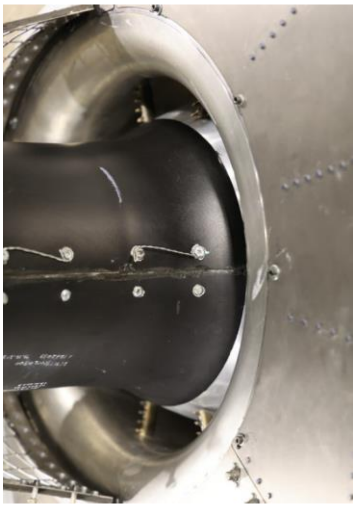

Figure 11: Pressure rakes at AIP

A control system is used to power the heaters for the pressure rakes. The control system is capable to control each rake heaters individually. The functionality of the control system and the rake heaters are tested in a small-scale IWT at the FH Joanneum technical university in Graz, Austria before rake integration of the actual test model.

Each rake also includes a thermocouple to check the rake and heater temperature. These temperature values were used to switch power on and off when user-defined temperature values are reached. A photograph of the control computer setup and the power supplies in the control room is shown in Figure 12.

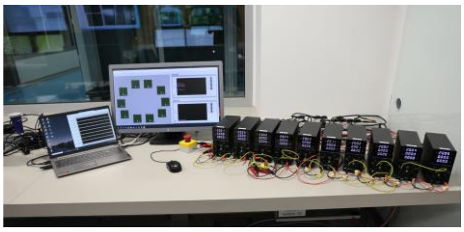

Figure 12: Heater control power supplies and control system setup

10 seconds data collection is achieved for every two minutes time period. For the rest, the purge mode of the pressure scanners is activated. This method is applied when the icing cloud is active to prevent the water particles to move inside the pressure tubes and affect the pressure measurements.

4. RESULTS & DISCUSSION

More than twenty points are tested in the icing wind tunnel at different environmental and cloud conditions with different helicopter configurations. Results of some tests are presented below. The visualized test results, which identify the amount of blockage on the wire-mesh grids are systematically photographed for each test points. For the critical test points, the ice shapes are scanned by 3-D laser scanner to use them in the future before the full-icing flight tests.

The ice accumulation on the grids at -2.5°C and -20°C outside air temperature (OAT), forward flight condition is illustrated in Figure 13 & 14, respectively.

Figure 13: Ice accumulation on grids at -2.5°C

Figure 14: Ice accumulation on grids at -20°C

Glaze and rime ice can be identified easily from the opacity of the ice shapes. At both cases, curved front part of the external mesh is partially blocked. However, there are enough clean surface to supply required air to the engine.

In addition to the forward flight cases, some hover and ground-run cases are performed. A result of a hover case is presented in Figure 15.

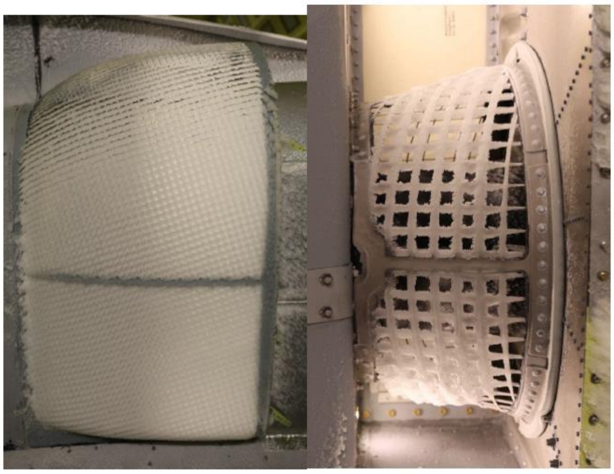

Figure 15: Ice accumulation on grids at -5°C at hover

Although side face of the primary grid is almost clogged completely, top face of the primary grid was clear. Some amount of ice accreted on the secondary grid and the gap on the grid is reduced. The system was still capable to suck required amount of air, since the secondary grid area is designed conservatively for icing purposes.

At all test runs, the ice accumulated at primary grid and no significant ice accretion is observed at secondary grid. Therefore, the required engine airflow for satisfactory operation is provided by the air induction system.

The parameters of cloud and mass flow simulator were stable during the test. A simple example of the parameters during test phase is given in Figure 16.

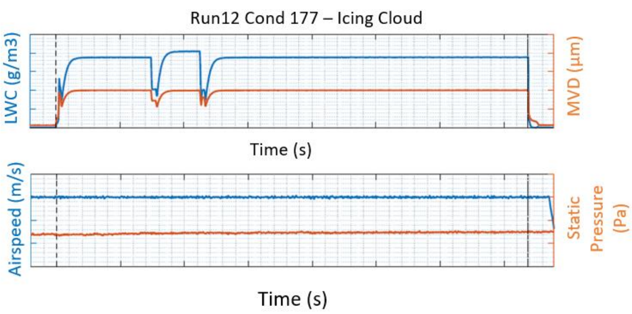

Figure 16: Stability of test parameters

Mass flow rate stability is used for compliance to prove the engine air suction capability is not affected by the ice accretion on the grids.

It is important to note that, test durations are extended to cover the LWC and MVD stabilization times in all cases.

5. CONCLUSIONS

Air induction system of the T625 Gökbey Helicopter is investigated in detail according to CS-29 1093 & AC-29 1093. In total, more than twenty tests are performed and it is clearly seen that the secondary mesh has provided the required engine inlet flow rate. The external and internal grids prevented the formation of big ice chunks in the plenum. Although the ice accretion is occurred as a thin film layer in the plenum, it does not adversely affect the aerodynamics characteristics of the induction system significantly. Therefore, it can be concluded that the plenum and grids are designed effectively. Induction system icing tunnel test is accomplished successfully.

Test results show compliance for CS 29.1093 b.1.i and CS 29.1093 b.2 subjects for inadvertent entry. In addition, tests give confidence about induction system performance before full icing flight test campaign.

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6. ACKNOWLEDGMENTS

Turkish Aerospace would like to thank to Richard Moser and Wolfgang Breitfuß for their supports and efforts during the icing wind tunnel test campaign.

7. REFERENCES

1. European Aviation Safety Agency “CS 29 Amendment 3, Certification Specifications for Large Rotorcraft”, 2012

2. Federal Aviation Administration “AC 29-2C, Certification of Transport Category Rotorcraft”, 2016

3. “General Information and Guide for Customers, Climatic / Icing Wind Tunnel Vienna”, RTA, 2023

4. Daldal, A.B., Sancar, E., Mayda, A., Okatan, L., Cakiroglu, T., Bayat, A., Ezertas, A. A.,, The Vertical Flight Society’s 80th Annual Forum & Technology Display. “Engine Installed Performance Testing Activities”. Montreal, Canada, 2024