T-625 GÖKBEY Fire Extinguishing System Performance Survey

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Abstract

The T625 GÖKBEY is a twin engine, light class, rotary wing, and multi-role utility helicopter. The rotorcraft certification altitude is up to 20000 feet. The rotorcraft is equipped with fire extinguisher system which is used to eliminate existing fire occurred within the engine cowling zone. The working principle of the system is based on providing quick discharge of pressurized extinguishing agent into the fire zone in case of a fire. Fire extinguishing system survey is accomplished to demonstrate performance of the system. In this paper, preparation phase, including simulations performed to determine flight conditions and measurement locations, test procedures, measurement techniques and test results is introduced.

1. NOTATION

Acronyms:

CFD	Computational Fluid Dynamics
ISA	International Standard Atmosphere
MPOG	Minimum Pitch on the Ground
Ng	Gas Generator Speed
NP	Power Turbine Speed
OAT	Outside Air Temperature
OEI	One Engine Inoperative
RoD	Rate of Descent
VMD	Minimum Descent Speed
VH	Maximum Design Speed
VH_{OEI}	Maximum Design Speed at OEI
VY	Best Rate of Climb Speed

2. INTRODUCTION

T625 GÖKBEY Helicopter Program, launched in 2013, is developed and designed by Turkish Aerospace. T625 GÖKBEY is a dual-engine helicopter weighing around 6 tons, which can be used for performing various types of mission profiles for civilian operators as shown in Figure 1 and described in Ref. 1 & Ref. 2.

The main function of T625 GÖKBEY Fire Protection System is to monitor and terminate any existing fire to ensure the safety of the crew and passengers and provide the safe recovery of the helicopter. The fundamental system design requirements basically come from this safety based approach.

Figure 1: T625 GÖKBEY Helicopter

The extinguishing system consists of extinguishing agent storage bottle, discharge line and distribution component which is used to increase agent homogeneity within the region. The extinguishing agent spread all over the engine cowling region with the aid of cooling inlet airflow and swept to the outside from the ejector.

Success criteria for the fire extinguishing system is that the extinguishing agent distribution within the engine cowling region shall be higher than 6% in terms of volume in any location for at least 0.5 seconds according to MIL-E-22285. To provide an acceptable means of compliance, ground and flight tests are performed to investigate system performance. To eliminate excessive workload, critical conditions are determined prior to testing.

3. TEST DEFINITION

3.1. Test Conditions

The procedure for activating the fire extinguishing system follows the steps below:

- Safe One-Engine-Inoperative (OEI) Flight Establish
- Engine (which fire conditions exhibit) to the IDLE
- Identification of Fire
- Engine (which fire conditions exhibit) to the OFF
- Actuation of the extinguishing system.

Although the actuation of the system is occurred after the engine shutdown process, the inertia of the engine rotating components will continue to produce air flow through the engine. In order to determine the exhaust flow rate, which provides additional cooling air flow, gas generator speed (Ng) versus exhaust flow rate is calculated by interpolation as presented in Figure 2.

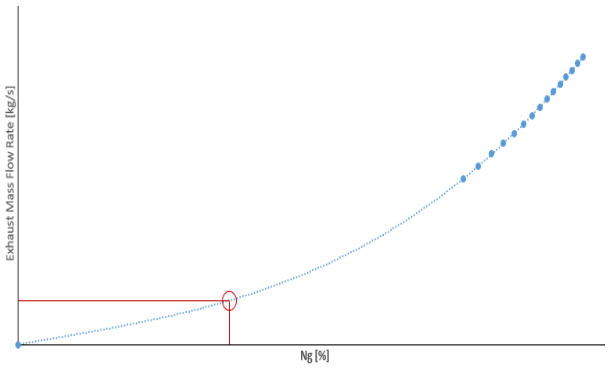


Figure 2: Ng versus exhaust flow rate at

The Ng value during extinguishing process for simulations is predicted with respect to average pilot reaction time to follow fire extinguishing procedure and Ng deceleration as given in Figure 3.

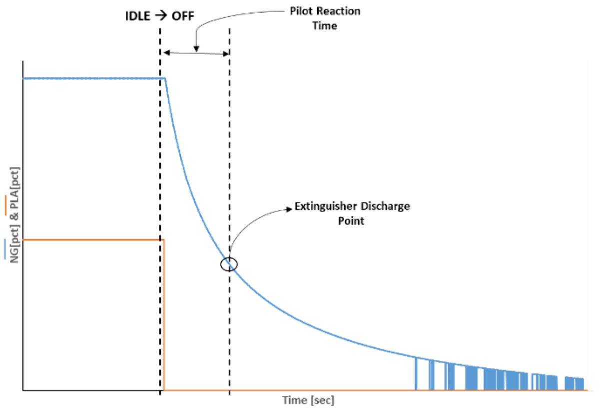


Figure 3: Extinguisher discharge point

In order to define critical airflow conditions, different cases are analyzed with CFD by considering the flight conditions provided by Ref.3. The altitude and temperature of analyzed conditions are selected to maximize density which increases the cooling air mass flow rate and to be within the altitude limits defined in Ref. 3.

The investigated flight/ground conditions are listed in Table 1.

Table 1: Analyzed flight conditions

	Altitude [ft]	Temperature [°C]	Flight Condition
C1	4500	ISA	Level Flight -VH_{OEI}
C2	4500	ISA	Low RoD -VMD
C3	4500	ISA	Mid RoD -VMD
C4	4500	ISA	Max RoD -VMD
C5	4500	ISA	Low RoD – Mid Speed
C6	4500	ISA	Mid RoD - Mid Speed
C7	4500	ISA	Max RoD - Mid Speed
C8	4500	ISA	Low RoD - VH_{OEI}
C9	4500	ISA	Mid RoD - VH_{OEI}
C10	4500	ISA	Max RoD - VH_{OEI}
C11	4500	ISA	Climb - COEI -VY
C12	4500	ISA	Climb - 2min OEI -VY
C13	2750	ISA	MPOG
C14	2750	ISA	OFF

To determine the critical airflow condition, to total mass flow rate entering the engine bay region is settled for the main objective. The results in terms of mass flow rates under the flight conditions defined in

Table 1 are plotted in Figure 4 for left and right engines.

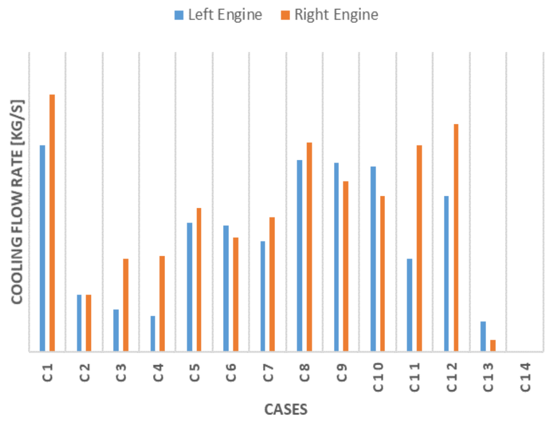


Figure 4: Obtained cooling air mass flow rates for left and right engines

Since the C14 Case represents the OFF condition, simulation is not performed and cooling air flow rate is assumed as zero. The cases are analyzed with minimum weight (practicable) in order to maximize speed and climb rate.

The maximum flight speed under descent conditions are limited with VH in order to eliminate potential risk for unattainable recovery situations.

Additionally, the effect of operating conditions such as descent rate, maximum speed, gas generator speed are also examined. The mass flow variation with respect to flight speed at constant descent rate is illustrated in Figure 5.

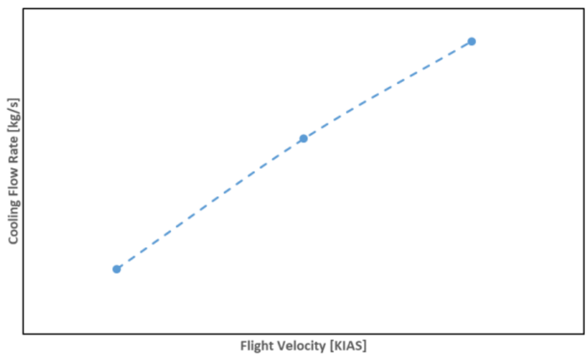


Figure 5: Mass flow rate variation with respect to flight speed at constant descent rate

The streamline distribution of the cooling flow is presented in Figure 6.

At the end of first set of CFD simulations, critical flight conditions which identify the maximum and minimum cooling air flow conditions are determined as:

- Level flight at VH_{OEI}
- Climb with 2 minute OEI power
- Descent with VH_{OEI}
- Engine OFF condition

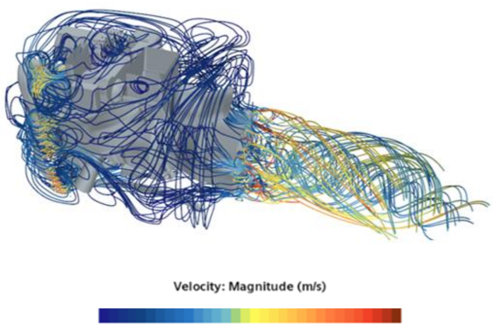


Figure 6: Streamline of cooling airflow

3.2. Instrumentation

Proper installation and location of agent sampling probes are crucial factors in conducting a meaningful test program. Existing concentration recorders use a maximum of 12 probes, requiring careful consideration in selecting areas to be sampled. This guarantees the acquisition of valuable data per set and a comprehensive program composite for evaluating overall system performance.

There are two main concepts to determine the position of the probes. These are four-ring sampling and three-ring sampling probe positioning. In this test plan, three-ring sampling positioning, illustrated in Figure 7, was chosen since this sampling is used for short nacelle configurations according to Ref. 4.

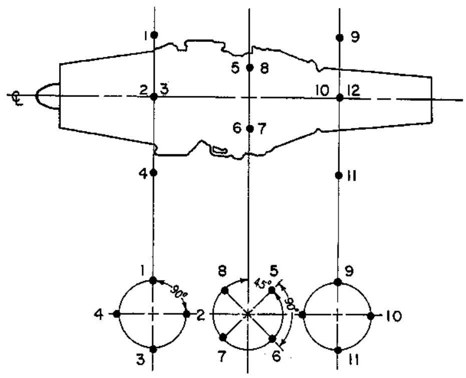
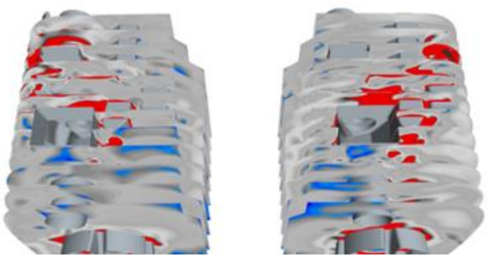
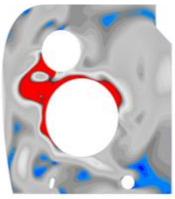


Figure 7: Typical three-ring sampling probe positioning

After the probe-positioning concept is selected, the velocity profiles obtained by CFD simulations are investigated at different planes. Since the critical flight conditions are determined, the flow distribution is investigated in these conditions in order to determine maximum and minimum localized air velocities in the designated area.



(a) All planes



(b) Single plane in detail

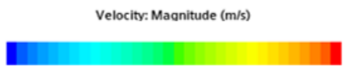


Figure 8: CFD analysis outcomes in order to determine most adverse flow region

In Figure 8, the high and low velocity regions are highlighted. Critical planes were examined one by one and risky points were chosen for the probe locations. This plan aims to align the three ring sampling probe positioning as much as possible. Moreover, it is purposed to comply with the following criteria for the location of the probes Ref. 4;

- High flow areas
- Low flow areas
- Around fire sources

The measurement system is based on optical light measurement and it includes:

- 12 optical modules
- 1 vacuum pump
- 1 manifold distributor
- 1 pressure regulator
- 1 gas distribution hose

The total length of each probe is designed as identical in order to eliminate measurement error which might be caused by relatively different distances.

Before and after test campaign, calibration of the measurement system is achieved in three steps as follows:

- Verification of the modules internal acquisition frequency
- Exposure of the twelve modules to the calibrated gases before concentration tests
- Exposure of the twelve modules to the calibrated gases after concentration tests for stability verification.

4. PRE-TEST PHASE

Simulator run, laboratory tests and engine air restart are performed prior to conducted fire extinguishing survey in order to prepare the pilots to the tests.

These preparations involve laboratory tests, engineering simulator runs, engine restart in flight tests contribute the pilot's awareness of possible helicopter behaviors during engine shutdown and engine restart tests, as described in the following sections.

4.1. Laboratory Tests

These comprehensive laboratory tests collectively ensure that the starter generator meets stringent performance standards and can withstand the demanding operational environments of helicopter turboshaft engines, thus enhancing overall system reliability and safety. The laboratory test bench is provided in Figure 9.

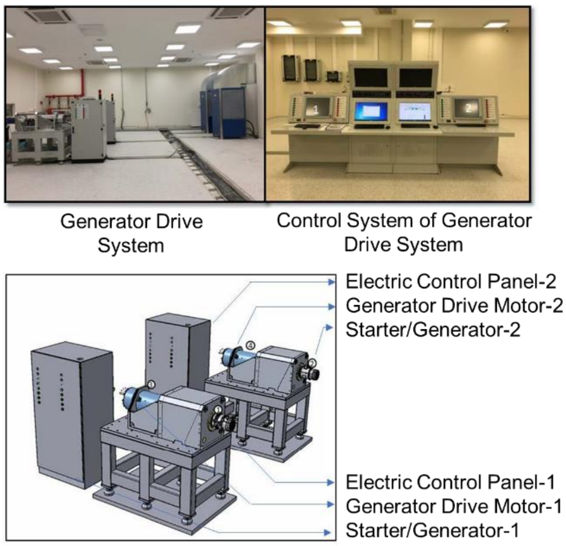


Figure 9: Laboratory Test Bench

In addition to Engine Start Laboratory Test, structural integrity of the complete system, including pipes, attachments and bottle has been performed as shown in Figure 10.

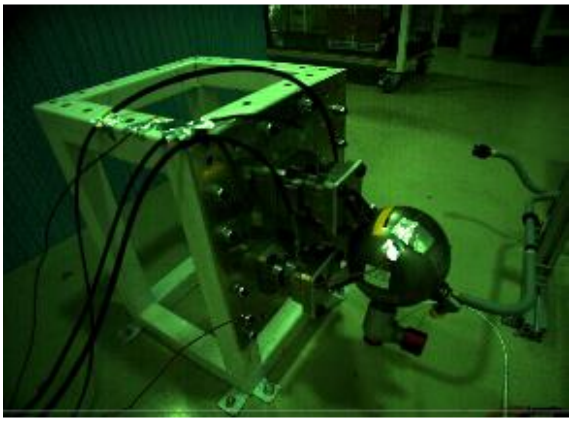


Figure 10: Structural integrity test

4.2. Engineering Simulator Run

The simulator has been actively used to enhance the pilot's awareness of possible helicopter behaviors during engine shutdown and engine restart in flight tests at different altitudes and speeds as shown in Figure 11.

Figure 11: Engineering Simulator

4.3. Engine Restart In Flight Tests

The next phase involves the meticulous planning and execution of flight tests after the successful completion of the laboratory tests and the valuable insights gained from simulator simulations. These flight tests serve as a crucial step in validating the performance of the T-625 helicopter and its engine restart capability in flight conditions.

Engine restart in flight test is performed at 4500 ft pressure altitude and VH_{OEI}. Critical parameters for starting of engine are evaluated and demonstrated in Figure 12.

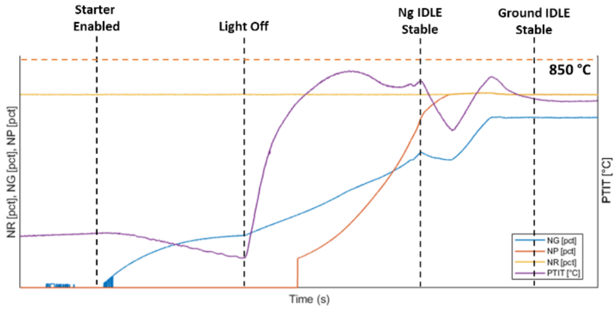


Figure 12: Engine Air-restart at 4500ft Hp, VH_{OEI}

5. RESULTS AND DISCUSSIONS

Tests were conducted under determined worst flight conditions where engine fire extinguishers are being forced to operate at their performance limits in order to show that fire extinguishing system will be successful for all conditions.

In addition to distinguishing agent parameters, helicopter flight velocity, the gas generator speed (NG) and turbine speed (NP) values of engine which the bottle was fired in each test are also collected during the tests.

The fire extinguishing system of the left and right engine compartments successfully passed all ground and flight tests for certification requirements. The minimum time of extinguishing agent concentration during testing is observed greater than 6% by volume, which is the success criteria, at each tested conditions.

The sample extinguishing agent distribution obtained from measurement probes during testing are presented in Figure 13.

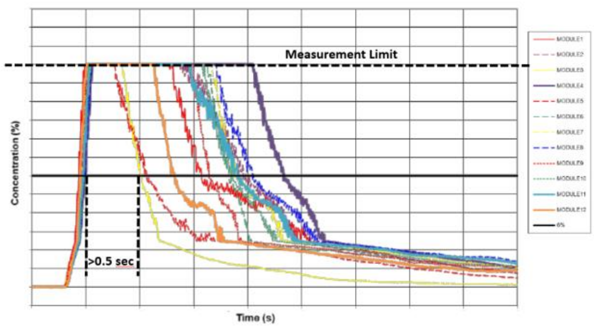


Figure 13: Extinguishing agent concentration with respect to time

It also should be noted that the ground tests are performed successfully in a very conservative manner.

Throughout the ground tests, there is no rotation in drive train and rotors and engines are in off mode. Hence, there is no exhaust flow and resulting secondary cooling flow in the engine bay. When there is no inflow at cooling inlets, induced by exhaust flow, discharged extinguishing agent can find a path to escape from cooling cut-outs.

6. CONCLUSIONS

Eight test points which include three different flight conditions and one ground condition per engine is performed during fire extinguisher performance evaluation survey.

The survey demonstrates satisfactory performance of the T625 GÖKBEY rotorcraft fire extinguisher system within the entire flight envelope when tested under the most severe flight conditions and following the most conservative procedures.

In conclusion, no specific limitation or procedure, except than the normal procedure which pilot should follow during engine fire condition, is required.

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7. REFERENCES

1. Anıl Mayda, Emre Sancar, “*Engine Installed Performance Testing Activities*”, Vertical Flight Society’s 80th Annual Forum, May 2024.
2. 2. Can Esen, H. Mert Yalçınkaya, “*Powerplant Control System Tuning Activities*”, 49th European Rotorcraft Forum, Sep 2023.
3. 3. Federal Aviation Administration (FAA), “*Criteria For Aircraft Installation And Utilization Of An Extinguishing Agent Concentration Recorder*”, FAA-DS-70-3, 1970.
4. 4. Federal Aviation Administration (FAA), “*General Guidelines for Measuring Fire-Extinguishing Agent Concentrations In Powerplant Compartments*”, AC 20-100, 1977

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