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Jet CAT P80 Thermal Analyses and Performance Assessment Using Different Fuels Types

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Abstract: The micro gas turbine propulsion systems represent a good choice for the unmanned aerial vehicles (UAVs). The present work monitors the engine parameters, correlating them with other important engine instrumentation data. The aim of this research was to study the operation of the Jet CAT using various types of fuels under various operating conditions: normal acceleration and sudden acceleration. The measured parameters were monitored under different conditions: (A) Engine operation at two different ambient temperatures – outdoor at 0ºC and inside at 19ºC; and (B) Using 4 fuel types: kerosene, diesel fuel, kerosene with 5% gasoline and kerosene with 10% gasoline. The relevance of this work is given by the fact that a detailed analysis is performed for the idle regime. The paper will present the detailed test plan used and the most relevant charts with the obtained results for: start time, force, temperature before turbine, fuel flow, depending on micro turbo engine speed.

Keywords: Jet CAT P80, fuel, performance, testing, thermal analysis

1. Introduction

Throughout worldwide, there is a clear tendency to use UAVs in various emergency situations, border monitoring, rescue, surveillance, etc, stimulating the demand for UAVs in the commercial sector [1]. The UAVs are designed by taking into account the operational range, the flight speed and endurance to determine the fuel load to be carried out. In order to obtain small fuel consumption and maximum performance, it is needed to equip the UAV with an efficient propulsion system. The UAV performance is dependent on the mass of the power plant and its specific fuel consumption since these can have a very significant effect on the reduction in size or increase in range of the UAV. One of the most performing propulsion systems that can be successfully used in UAV equipping are the micro turbo engines [2]. The micro turbo engine is designed to produce thrust from a high-velocity jet for direct propulsion. The main advantage of small gas turbine engines lies in the high energy density potential of the fuel-based systems [3]. Compared to other technologies, the advantage of the micro turbo engine is the multi-fuel capabilities and it becomes necessary to characterize the performances of the micro engines in different exploitation conditions. The most commonly used fuels for commercial aviation are Jet A and Jet A-1, which are produced to a standardized international specification. There are many studies

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regarding to change the fuel of engine for aviation [4, 5]. There are many studies regarding the kerosene replacement with other types of fuels, especially biofuel or biodiesel [6] or hydrogen [7]. However, the technology to produce biofuel is expensive and is not appropriate for aero-models amateurs, or drones, and that is one of the reasons for conducting our first stage research with ordinary fuel types (kerosene, commercial diesel, and mixture of kerosene with commercial gasoline). The question that arises is what type of fuel it is suitable to be used in the current state without any modifications of the engine and keeping the functioning performance within normal limits for the temperature before turbine. It is well known that the turbine is the most demanded turbo-engine organ and that's why is important to know its thermal limits. The burning temperature is influenced by the fuel type and its nature [8].

This research represents an experimental research, having at the basis multiple tests in different conditions, and it brings novelty by the big set of experimental data offered, highlighting the micro turbo engine performances (start time, force, fuel flow, micro turbo engine speed), thermal analysis (temperature before turbine) in function of commercial fuel types.

2. TEST PLAN

The tests were performed on Jet CAT P80 test bench [9] (Fig. 1(a)) which is part of turbo-machinery laboratory of Aerospace Engineering Faculty, University POLITEHNICA Bucharest.

The measured parameters were monitored under different conditions: (A) Engine operation at two different ambient temperatures – outdoor at 0°C and inside at 19°C; and (B) Using 4 fuel types: kerosene (K), diesel fuel (D), kerosene with 5% gasoline (K+5%G) and kerosene with 10% gasoline (K+10%G). The schematic view of the test plan is presented in Fig. 1(b)). As can be observed, the test 1 represents the first part of an engine start until the engine reaches the idle regime. Test 2 was conducted from idle regime until the safety-working regime at 90000 r/min. Test 2 was performed both on normal acceleration conditions and in sudden acceleration conditions. The parameters that were measured are: start time (t[s]), force (F[N]) fuel flow (Qc[l/h]), micro turbo engine speed (n[r/min]) and temperature before turbine (T3[°C]) in function of commercial fuel types.

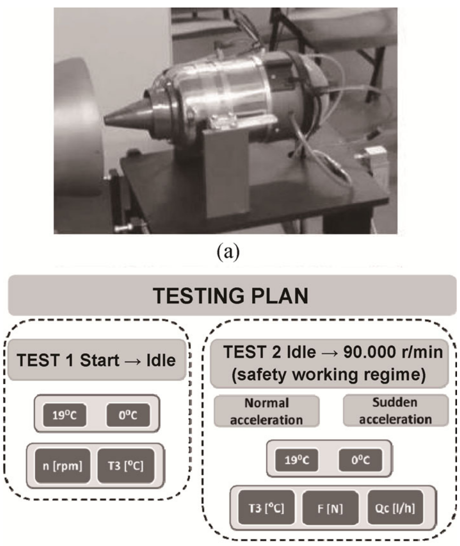

Fig. 1 Jet CAT P80-test bench(a) and Testing Plan (b)

3. Results

Below are presented the results obtained according to the test plan. The work is offering 9 figures for both tests.

Test 1 results for speed variation and temperature in front of the turbine (T3) variation depending on starting time are presented below.

Regarding the starting time, which is a micro turbo engine automat sequence, can be observed that this is different for the 4 fuel types at both ambient temperatures. At 19°C can be observed that when gasoline mixture is used the ignition time is longer than when the other fuel types are used (Fig. 2(a)). Regarding the T3 variation during the starting sequence, it is noticed that the temperatures for all fuel types do not differ from the reference case, when kerosene is used. Only at 19°C (Fig.3(b)) shows the fact that diesel fuel is developing a higher temperature than the other type of fuels.

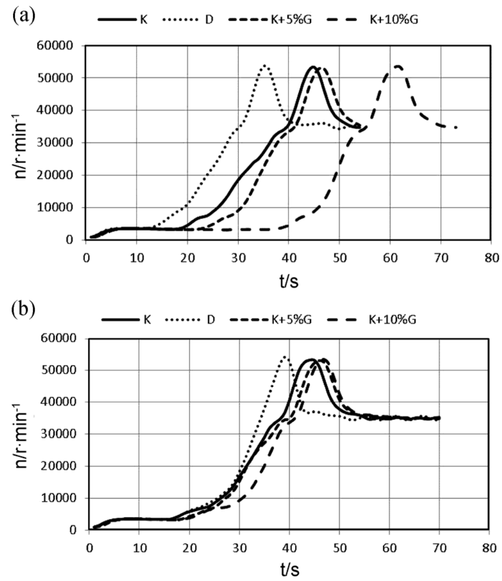

Fig. 2 Engine speed variation in function of starting time in test 1, at 19°C (a) and at 0°C (b)

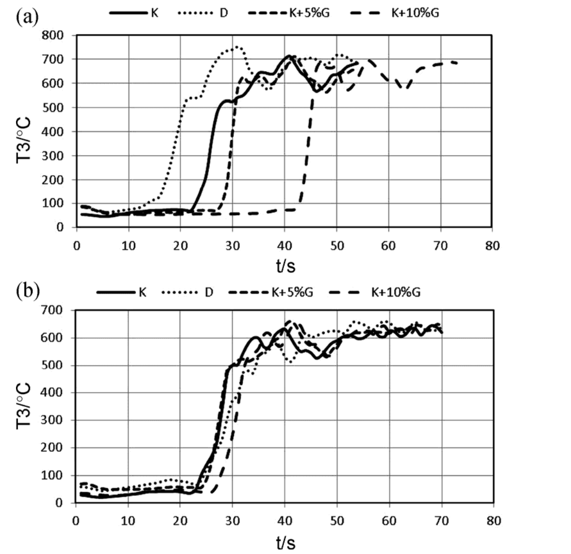

Fig. 3 T3 variation in function of starting time in test 1, at 19°C (a) and at 0°C (b)

Test 2 present the T3, force and fuel flow variation for both ambient temperatures and both for normal and sudden acceleration.

Regarding the normal acceleration sequence, in both 0°C and 19°C, T3 is in normal limits and the values monitored are much closer to the kerosene (Fig. 4). It is noticeable that on sudden accelerations, which are dangerous due to the T3 increase, from the four fuel types, the diesel fuel is the most unsafe (Fig. 5).

Concerning the Jet CAT P80 force, for both normal and sudden acceleration, we can conclude that using diesel fuel and the kerosene mixture with gasoline fuel we obtain a greater or appropriate force values than using simple kerosene fuel (Figs. 6 and 7).

Analyzing the fuel consumption for all test cases we can conclude that the values monitored for diesel fuel are the lowest (Figs. 8 and 9).

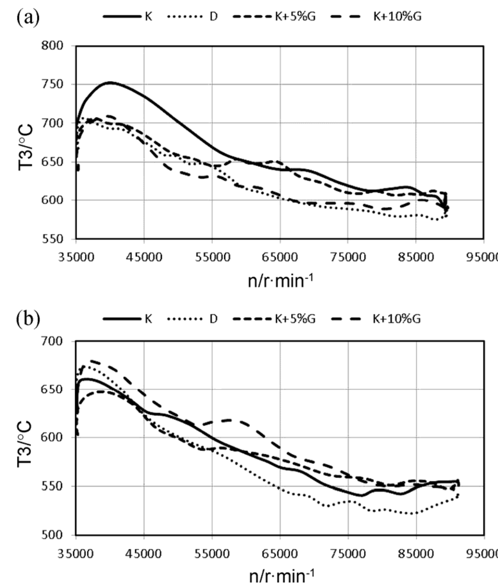

Fig. 4 T3 variation in function of engine speed in test 2, at normal acceleration and 19°C (a) and at 0°C (b)

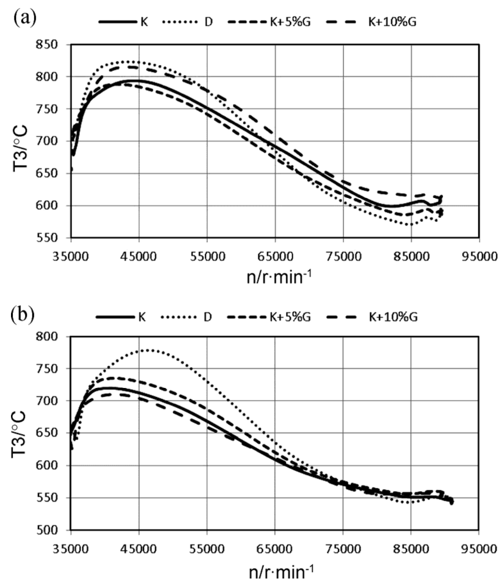

Fig. 5 T3 variation in function of engine speed in test 2, at sudden acceleration and 19°C (a) and at 0°C (b)

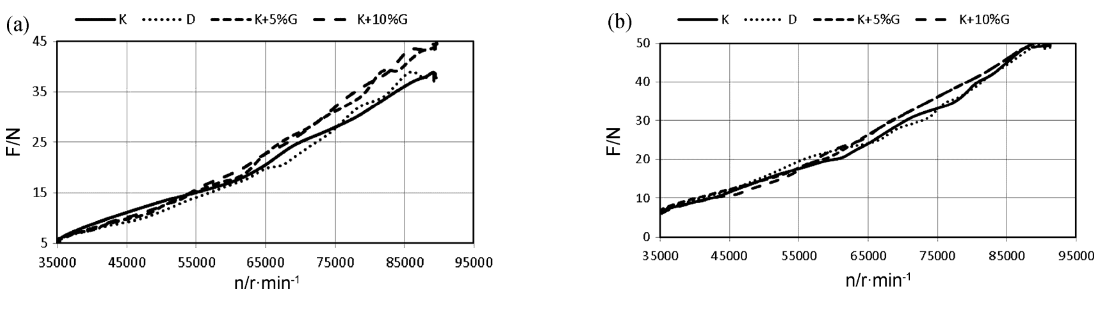

Fig. 6 F variation in function of engine speed in test 2, at normal acceleration and 19°C (a) and at 0°C (b)

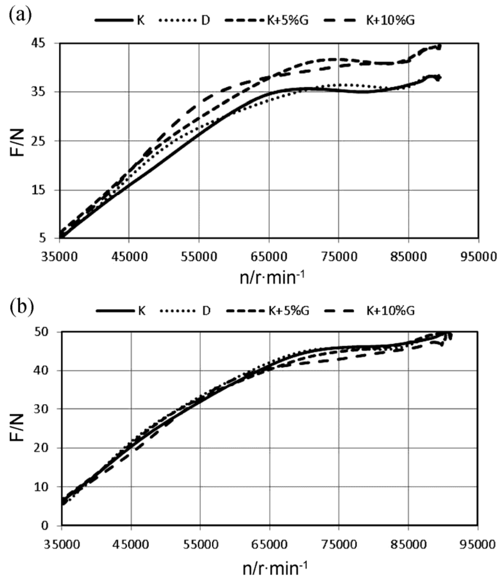

Fig. 7 F variation in function of engine speed in test 2, at sudden acceleration and 19°C (a) and at 0°C (b)

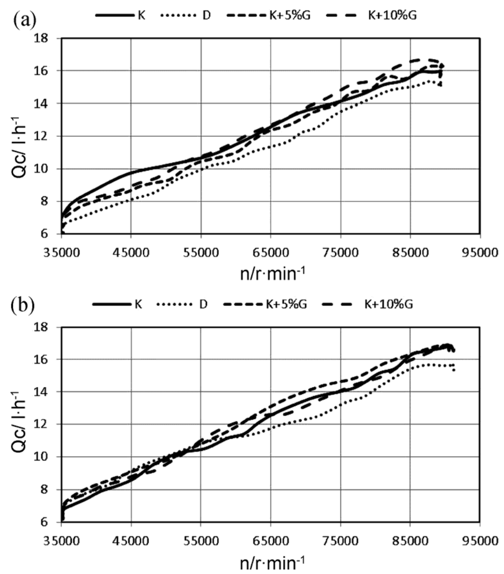

Fig. 8 Qc variation in function of engine speed in test 2, at normal acceleration and 19°C (a) and at 0°C (b)

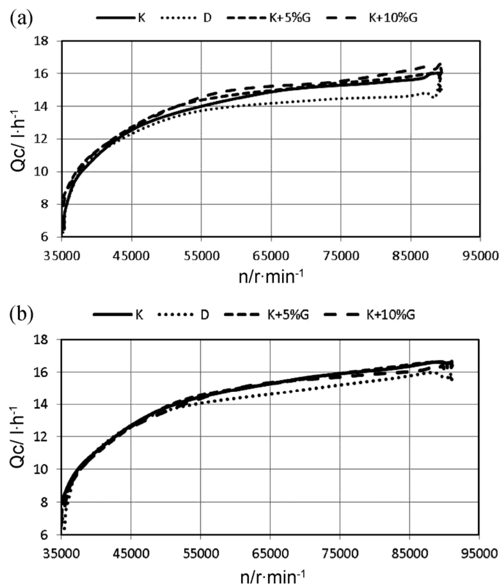

Fig. 9 Qc variation in function of engine speed in test 2, at sudden acceleration and 19°C (a) and at 0°C (b)

4. Conclusions

First, analyzing the temperature in front of the turbine, we can conclude that the Jet Cat P80 can operate safely from the gas-dynamic point of view, with the four types of fuel, under both temperatures and normal and sudden acceleration conditions. Concerning the T3, we can conclude from Fig. 3 the fact that the diesel fuel T3 is the highest, giving us a better engine force and the lowest starting time, and still not put the engine in danger. In addition, the temperature before turbine, the most vital functioning parameter what was monitored, which can put the engine in failure, has not exceeded the safety engine operational limit, both in normal and in sudden acceleration (Figs. 4 and 5). Regarding the normal acceleration sequence, in both 0°C and 19°C, T3 is within normal limits and the values monitored are much closer to the kerosene (Figs. 7 and 10). We can conclude that Jet Cat P80 can operate without any constructive changes within safety limits and can be exploited in normal and low ambient temperature conditions, both in normal and in sudden acceleration.

The results obtained are the basis for future research involving the use of several types of fuel, including bio fuels.

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