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Crucial Parameters of Gas Generator on Tip-jet Helicopter

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Abstract

The paper defines the minimum number of parameters which are sufficient for monitoring and controlling the gas generator operation in an innovative design of a tip-jet helicopter propulsion system. Firstly, the gas generator is tested separately on its test stand installation with several selected measuring and controlling parameters. Some ideas for implementing sensors for measuring certain parameters are presented in the paper. Then, a few parameters are selected as sufficient for controlling the tip-jet helicopter and experimentally verified on a helicopter hovering test as the minimum required parameters.

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Keywords: gas generator; acquistion system; tip-jet helicopter; propulsion system; experimental testing.

1. Introduction

During the development of an innovative design of a tip-jet helicopter [1,2] there was a problem to connect the signal and supply lines through the slip ring device, because the lines connect the acquisition system, which is stationary, to the gas generator, which rotates together with the rotor head and blades of helicopter. Based on this, a need for minimum signal lines that will be enough for gas generator monitoring and controlling occurs. These parameters are selected from an independently experimental testing of the gas generator on its own test stand installation with the acquisition system described in the following chapter. That chapter also shows how we managed

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to measure pressure of high temperature combustion products with conventional pressure transducer, and it additionally presents other sensors with their application. The required minimum parameters which are enough for a satisfying operation of the gas generator in the specific tip-jet helicopter propulsion system [3] are shown at the end of the paper.

Our tip-jet concept implies a propulsion system which consists of a gas generator which produces hot combustion products which are transmitted through flexible pipes and channels inside blades to their tips. These tips are specially designed to accelerate the flow, like a nozzle does, and to direct the flow in tangential direction in order to create momentum which rotates the entire propulsion system. Based on this rotation, the blades with their airflow cross-section create an aerodynamic lifting force which is used to drive and control the helicopter. This propulsion system is shown in the following Figure 1, together with the gas-generator position in the system.

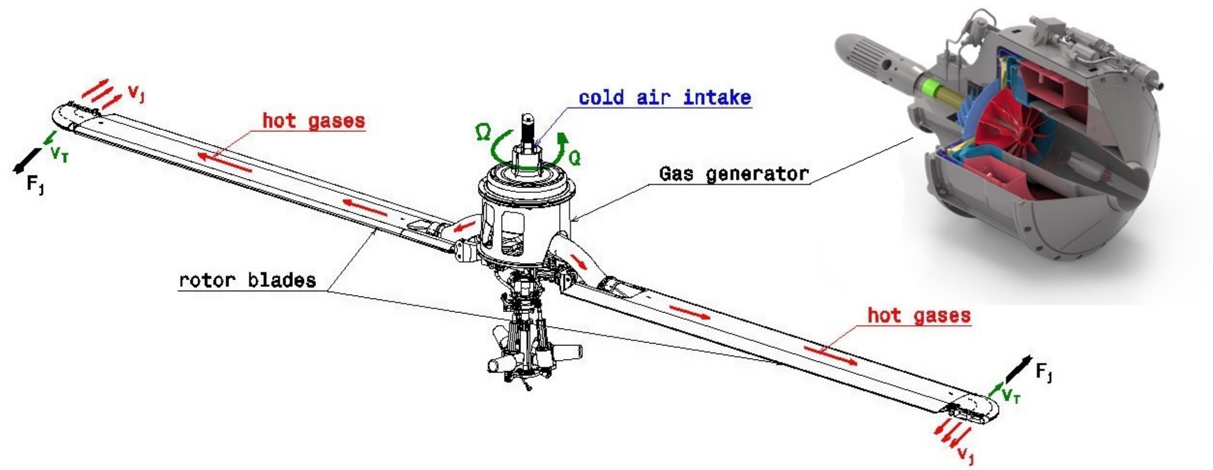

Fig. 1. Tip –jet propulsion system concept together with Phoenix-100 gas generator.

The gas generator is experimentally tested with a conventional nozzle (as a turbo jet engine) instead of a distributor, whose function is to divide the flow of combustion products into two lines for two blades. The engine nozzle has an equivalent influence as the distributor, flexible pipes, blades and their tips. Generator testing with only the distributor will not provide equal generator behavior and thermo-mechanical loads when it is installed in the entire propulsion system. This is the reason why we used the nozzle which will simulate real behavior of the gas generator in exploitation conditions.

2. Acquisition system for independent gas-generator testing

The acquisition system [4] for engine testing consists of the following sensors: flow meter, accelerometer, two thermocouple probes, two pressure transducers, inductive sensor and load cell (Fig.2).

The flow meter device is installed on the fuel pump and it is used to measure the mass flow rate of fuel for ignition main fuel supply system. It is a part of engine monitoring and control system.

The accelerometer, placed near the bearing, is used to monitor the engine behavior during tests, also it can determine resonant areas or some damage appearance.

Two thermocouple probes, OMEGA K-type thermo couple CH+ AL-, are installed. One reads the temperature of the more loaded bearing. The other one measures the temperature of operating fluid, mixture of combustion products, placed on the nozzle near its exit section (Fig.2).

The pressure transducer measures maximum static pressure in the gas-generator, in the area behind the diffuser and before the combustion chamber entrance. Therefore, it gives the information of compressor pressure ratio during testing. The sensor that is used is OMEGA PX602-150GV with the following characteristics: span 150 psig, accuracy 1%, input voltage 5-10Vdc, output signal 10mV/V, maximum pressure 300 psig, etc. (Fig.2). The same sensor is used for measuring the total pressure on the nozzle exit. As the gas temperature is around 700°C there is a pipe system from copper pipes installed between the pitot pressure tube and transducer, in order to cool down the combustion products mixture to an appropriate level, so as not to damage the sensor (Fig.3).

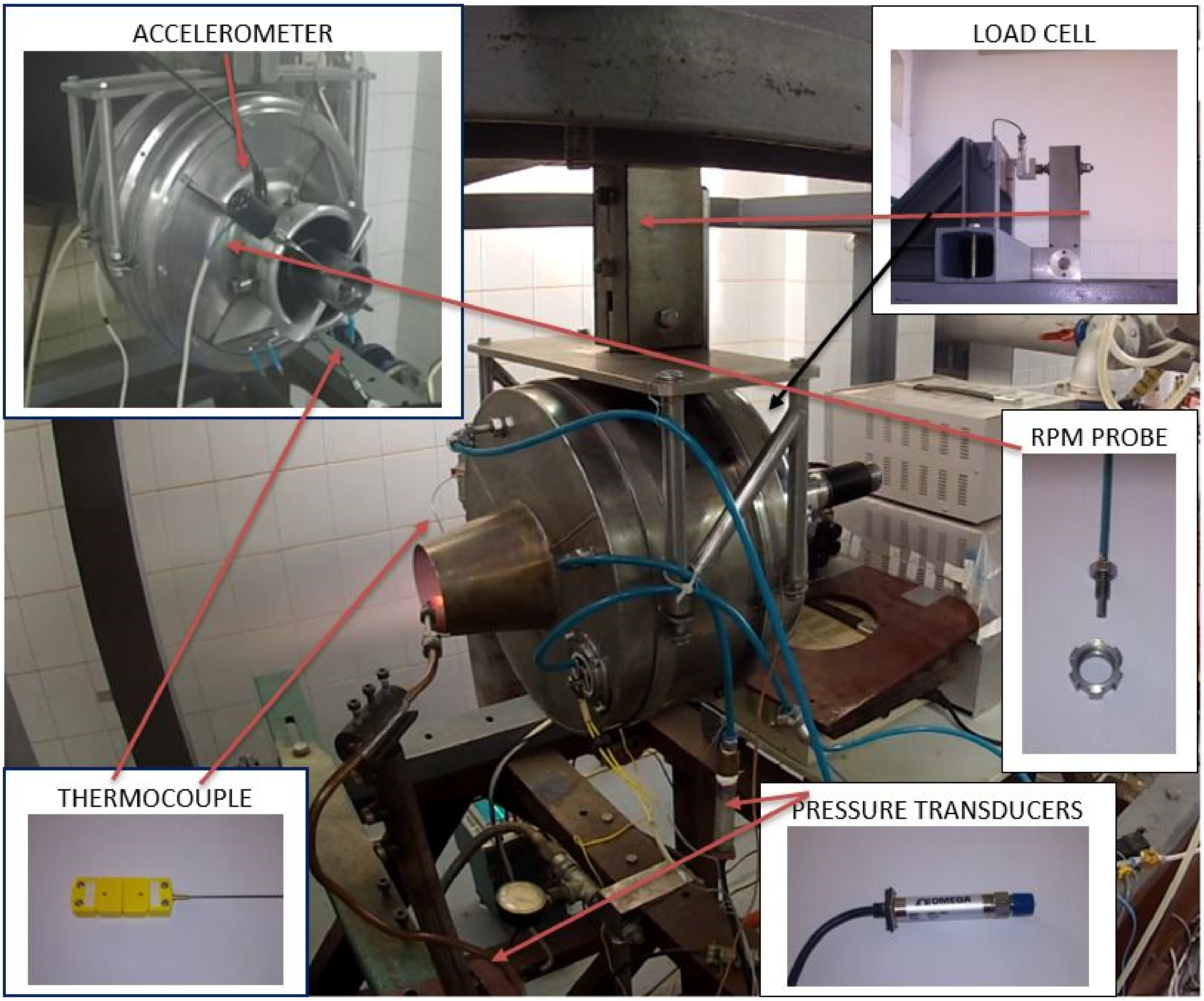

Fig. 2. Acquisition system for engine testing and monitoring.

For determining the engine, the rpm inductive sensor DW-AD-405-04-290 is used. Its characteristics are: diameter of stainless housing 4mm, operating distance of 0.8mm, supply voltage 5-30Vdc, output current $\leqslant 1/\geqslant 2.2$ A, switching frequency $\leqslant$10000Hz, ambient temperature range -25 - +70°C, etc. The measuring is done over the toothed bush located between the bearings on the shaft with the previously explained probe (Fig.2).

OMEGA S shaped load cell LC111-250 is used to measure engine thrust during testing together with appropriate level system installed on the test bench (see Fig.4). It has the following characteristics: range 0-250 lb., output current 3mV/V, supply voltage 10Vdc, with linear errors ±0.03%, repeatability 0.01%, hysteresis ±0.02 of the full range, operating temperature from -40 to 93°C etc.

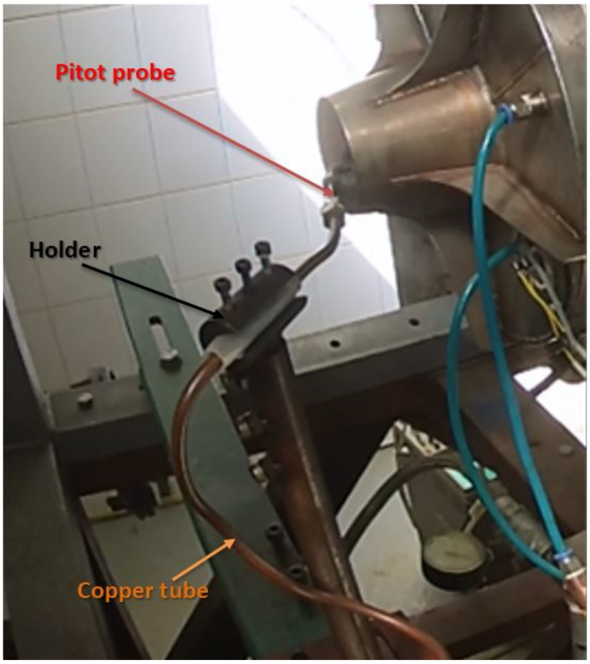

Fig. 3. Pitot probe with corresponding copper tube (just a part of it) mounted on test stand with holder.

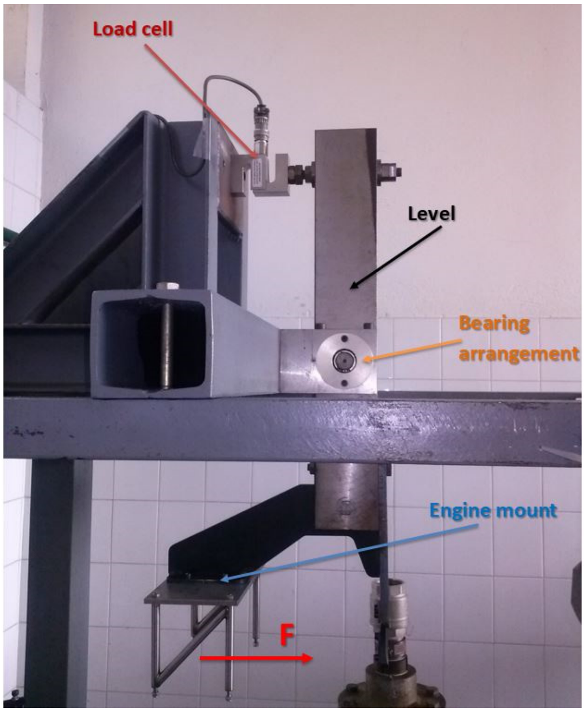

Fig. 4. Level mechanism with S-shaped load cell for measuring the thrust force of turbo jet engine.

The following Fig. 5 presents a diagram with measured values of these basic generator parameters on 55,000 rpm during testing, while the values of ambient pressure and temperature were measured independently.

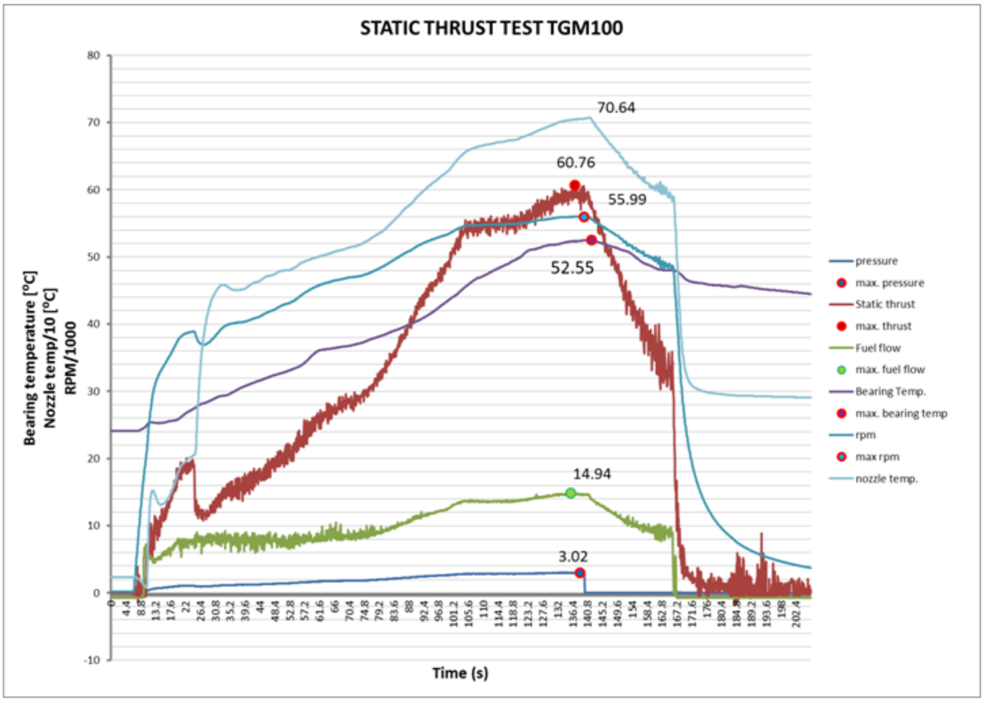

Fig. 5. Static test results for Phoenix-100 gas-generator tested in turbo jet variant of application.

The presented acquisition system proved to be useful for determining, monitoring and controlling the gas-generator operation and behavior. With a few presented sensors and their output results, we later managed to numerically simulate the flow in the gas generator with Computation Fluid Dynamic software.

3. Required parameters of gas generator acquisition system for helicopter application

We selected three parameters from the described acquisition system to monitor and control the gas generator during helicopter flight. These are the rpm indicator, fuel flow meter signal and more loaded bearing temperature. The rpm sensor is unavoidable because it shows directly the momentary gas generator operation regime, which directly governs the throttle. The generator is self-sustaining during operation, but the operating regime is controlled with the amount of fuel per unit of time. So the fuel flow is used to control the gas generator and with it the entire tip-jet helicopter propulsion system. This parameter is the main one for controlling the power of the helicopter, while the rpm indicator is practically feedback of the system. The bearing temperature is chosen as the parameter which indicates the state of the bearing system which has the lowest exploitation life. The sudden increase in bearing temperature value, without the changes in operation regime, is probably the best indicator of the beginning of the failure process in the bearings. By placing the thermocouple probe on more loaded bearing, we monitor the life state of the bearing system and the entire gas generator. These three signals are transmitted from the helicopter fuselage to the gas generator on the top of the rotating propulsion system using the slip ring device. The supply lines for starter-generator electric motor of the gas generator are also transmitted through the slip ring along with the required three signals. The rpm indicator for the rotating speed of the entire propulsion system of the tip-jet helicopter is placed on the fuselage.

4. Conclusion

Several helicopter hovering tests were done with the described measuring system [5], see Fig.5. The three explained parameters: rpm, fuel flow and bearing temperature indicator, were sufficient for monitoring and controlling the gas generator and the entire propulsion system during the hovering tests. These successful hoverings are probably the best proof that the three chosen signals are the required minimum for tip-jet helicopter flight.

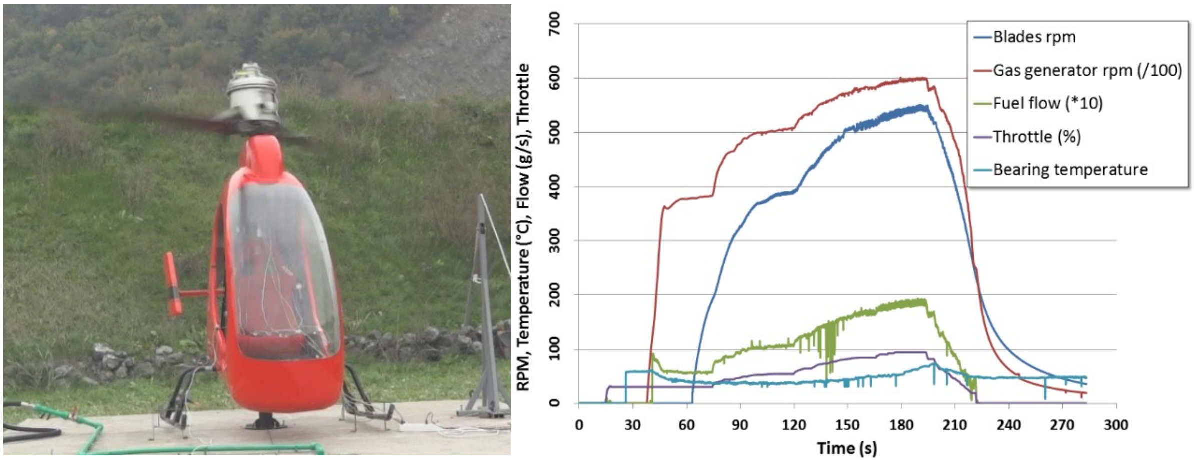

Fig. 6. Tip-jet helicopter hovering test.

The paper also presents two verified ideas, one for thrust force measuring, with an appropriate level system and sensor as in the Fig.4, and the other for the solution for measuring the total pressure of hot combustion products with a simple conventional pressure transducer.

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