EXPERIMENTAL VERIFICATION OF NUMERICAL SIMULATION OF THE FLOW INSIDE THE TIP-JET HELICOPTER PROPULSION SYSTEM

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1. Introduction

This paper presents the research that determines the total pressure loss of the high speed, high temperature compressible flow of turbine exhaust gas products through the tip-jet helicopter propulsion system [1, 2]. The combustion products are transmitted from the area after the gas generator nozzle [3] to the tips of the blades with a specially designed system of channels inside the specially developed laser welded Inconel blades [4] (Fig.1). Blade tips are equipped with the nozzles for creating the maximum thrust force in tangent direction, which created the torque that drives the entire helicopter rotor [5, 6]. This force is depended on the mass flow and pressure of the operating fluid, and it governs the performance of the whole tip-jet propulsion system and helicopter.

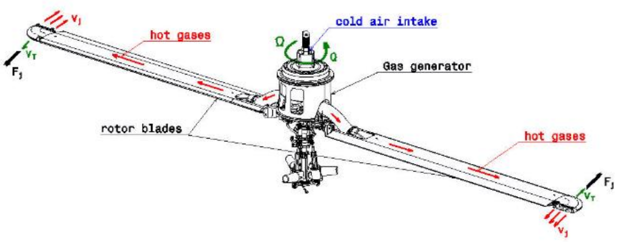

Fig. 1. Tip-jet helicopter propulsion system.

In order to increase the performance of the tip-jet propulsion system, this flow should be optimized in the sense of making the compromise that leads to a solution that minimizes the total pressure drop along the pipeline, and at the same time keeping the mass and dimensions within the acceptable limits. Therefore, a numerical mathematical 3D model has been made for this case. Results obtained from the numerical model are compared and verified with experimental results gained from a series of tests carried out in EDePro laboratory facilities.

2. Experimental measurement

The acquisition system consists of several sensors in order to determine the state and behavior of the gas generator and it is explained in detail in paper [7]. This way, the inlet parameters for the distribution channel system for the tip-jet helicopter can be concluded. Two pressure sensors are added in order to measure the pressure after the distributor, where the flow is divided into two branches for each blade (Fig. 2), and the pressure on the nozzle of one of the blades (Fig. 3). In this way, the first sensor measures the pressure drop through the distributor, and the second sensor measures the pressure drop through the blade channel and nozzle.

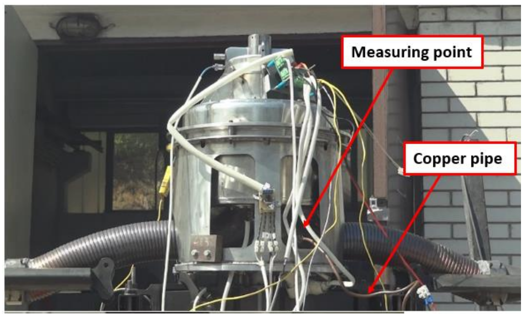

Fig. 2. Pressure sensor on the distributor.

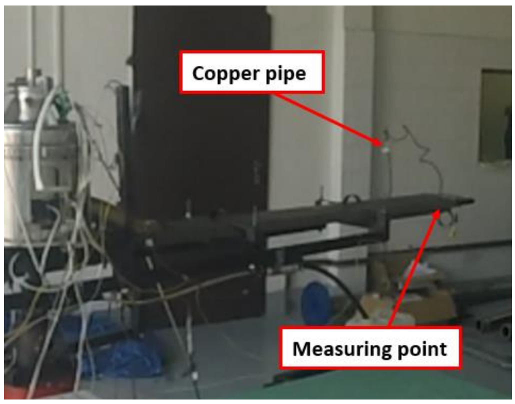

Fig. 3. Pressure probe on the nozzle.

OMEGA PX602-150GV pressure sensors are used for measuring and they have the following characteristics: accuracy 1%, span 150 psig, maximum pressure 300 psig, input voltage 5-10Vdc, etc. The temperature of the combustion products that are transmitted through the propulsion system is around 650°C. Therefore, a special pipe system from copper pipes is installed between the measuring point and the pressure sensor, in order to cool down the combustion products mixture to an appropriate level that will not damage the sensor. A similar solution used for measuring the total pressure on gas generator nozzle, is explained in paper [8]. The measured values during the static test for defining the thrust force on the blades nozzles are shown in the diagram in the following Fig. 4.

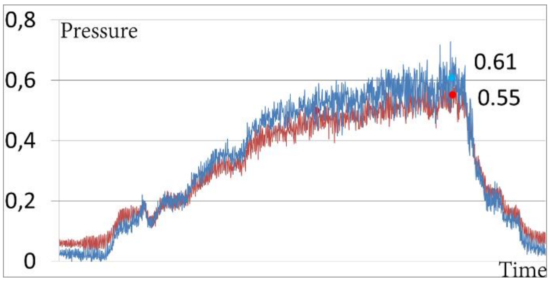

Fig. 4. Overpressure on the distributor (red) and on the blade nozzle (blue).

3. Numerical model

The Darsie equation was used for the calculations.

$$\Delta p = \rho Y_g = \lambda\left(\frac{\delta}{D}, Re\right)\frac{l}{D}\frac{\rho v^2}{2}$$

So were the equations for the hydraulic local resistance for every critical cross section.

$$\Delta p = \rho \zeta v^2/2$$

The coefficient ζ was taken from a specific table. The Mach number was calculated from the following equation.

$$\frac{p_0}{p} = \left(1 + \frac{\kappa - 1}{2} M^2\right)$$

Numerically calculated values for pressure and Mach number were taken and verified during the experiment.

4. Conclusions

The experiment and numerical simulations show that there is a significant pressure drop through the channel system inside the tip-jet propulsion system. This directly influences the losses in the entire system. But it can be concluded that the efficiency can be increased by elongation of the blades, i.e. with an increase in the rotor diameter, the pressure losses are greater but the force arm is bigger, so the torque is larger and it can overcome greater resistance. This is the reason why tip-jet helicopters have the larger rotor diameter compared to the conventional helicopters.

Acknowledgements

The authors wish to acknowledge and thank the company EDePro – Engine Design and Production in Belgrade for support and for encouragement in the project realization.

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