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Experimental study of the efficiency of the working process in the combustion chamber of the poster module of high-speed civil aircraft HEXAFLY-INT

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Abstract

The results of an experimental study of the efficiency of the working process in the combustion chamber of the stand module of a high-speed civil aircraft HEXAFLY-INT. Experimental studies were conducted at the CIAM stand within the framework of the international cooperation project HEXAFLY-INT of the 7th EU framework program. The tests were carried out with an imitation of high-altitude conditions in the flow around the bench module by a high-enthalpy flow. Pressure distributions along the engine path of the bench module are obtained in a wide range of the excess fuel ratio. The results of the evaluation of the completeness of fuel combustion in the engine chamber are presented.

I. Introduction

The HEXAFLY project developed a scale model of a high-speed civil aircraft powered by hydrogen fuel, the cruise flight of which is carried out at a speed corresponding to Mach number M = 7.5 [1-2]. The appearance of the aircraft under study is shown in Fig. 1.

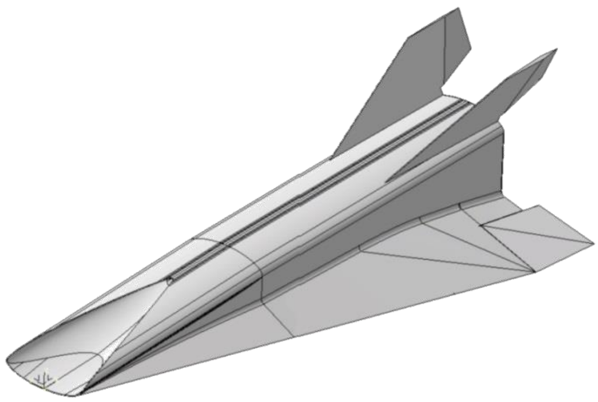

Fig. 1. The appearance of the high-speed civil aircraft model HEXAFLY-INT

In this project, the Central Institute of Aviation Motors (CIAM), Moscow, Russia, participates in the preparation, conduct and analysis of the ground tests of the stand module. The geometry of the stand module (Figure 2) differs from the original (Figure 1) in that the air-intake device of a simplified configuration is used in the stand module [3]. The module provides two fuel supply belts, one at the entrance to the inner flow path, the second - in the middle of the expanding combustion chamber.

Ground tests are conducted with modeling of high-altitude conditions, the total pressure and the total temperature of the oncoming flow correspond to the flight ones. In the HEXAFLY-INT project, 2 series of tests of different duration were conducted in order to demonstrate a positive air navigation balance (excess of engine thrust over aerodynamic resistance). In the first series of tests, the results of which are given in [4], a positive aerodynamic balance was demonstrated for the values of the excess fuel coefficient ER <0.6. The objectives of the second series of tests were

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repeated experimental confirmation of the feasibility of implementing a positive air navigation balance and expanding the range of parameters of the oncoming flow.

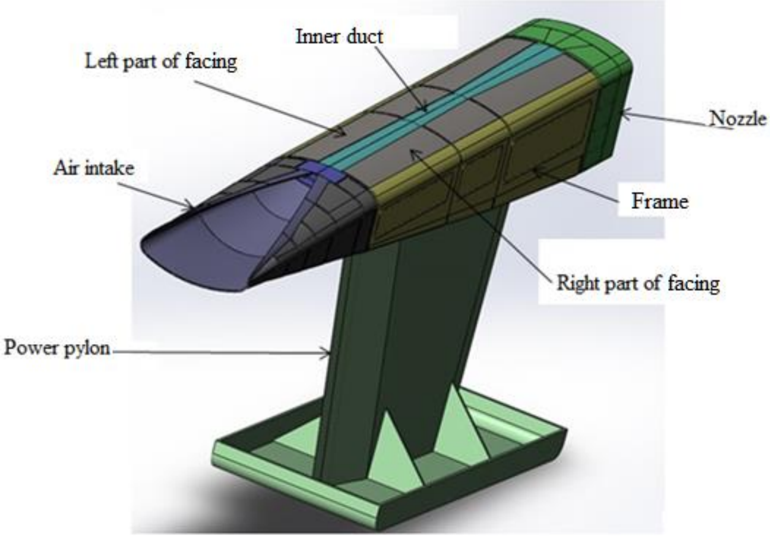

Fig. 2. Stand module of high-speed civil aircraft HEXAFLY-INT

II. Experimental studies of the bench module and analysis of the results

For experimental determination of thrust and aerodynamic resistance, the stand module was installed on the load-measuring device of the stand-the dynamometer platform (Fig. 3). The module was also equipped with static pressure sensors for analyzing the working process inside the module's flow path.

Fig. 3. Stand module HEXAFLY-INT on the dynamometer platform of the high stand

Table 1 shows the test results.

Table 1. Test results

№	Total pressure P*, bar	Total temperature T*, K	Mass flow of fuel, gramm/s	ER	Fuel supply, %	Intake start	Stabil working process	Thrust, N
1	64	2310	16/14	1,72	53/47	+	+	65
2	64	2310	12/16	1,61	43/57	+	+	65
3	65	2310	12,5/6	1,05	68/32	+	+	-100
4	49	2310	12/5	1,25	70/30	+	+	-140

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The data in Table 1 are obtained for the operating modes of the fire heater p * = 49-64 bar and T * = 2310 K, which simulates the flight at a speed corresponding to the Mach number M = 7.5. During the test, the excess fuel ratio ER and the percentage of fuel supply to the first and second belts were varied. As can be seen from Table 1, a positive air navigation balance was demonstrated at ER = 1.61 - 1.72. In work [5] it was shown that the limiting fuel consumption through the first belt of fuel supply G = 18 g / s. When this value is increased, the VZU is knocked out.

Let us analyze in detail the launch of No. 1 (Table 1), in which a positive air navigation balance was recorded. In Fig. 4 shows the dependence of the force acting on the bench module integrated with the power pylon and the pressure in the firing heater.

According to the oscillogram of the aerodynamic drag in Fig. 4 at the 10th second, the resistance drops sharply, which corresponds to the start of the intake. At the time t = 13.5 s, fuel is supplied, which is accompanied by an increase in thrust to a value of 65 N.

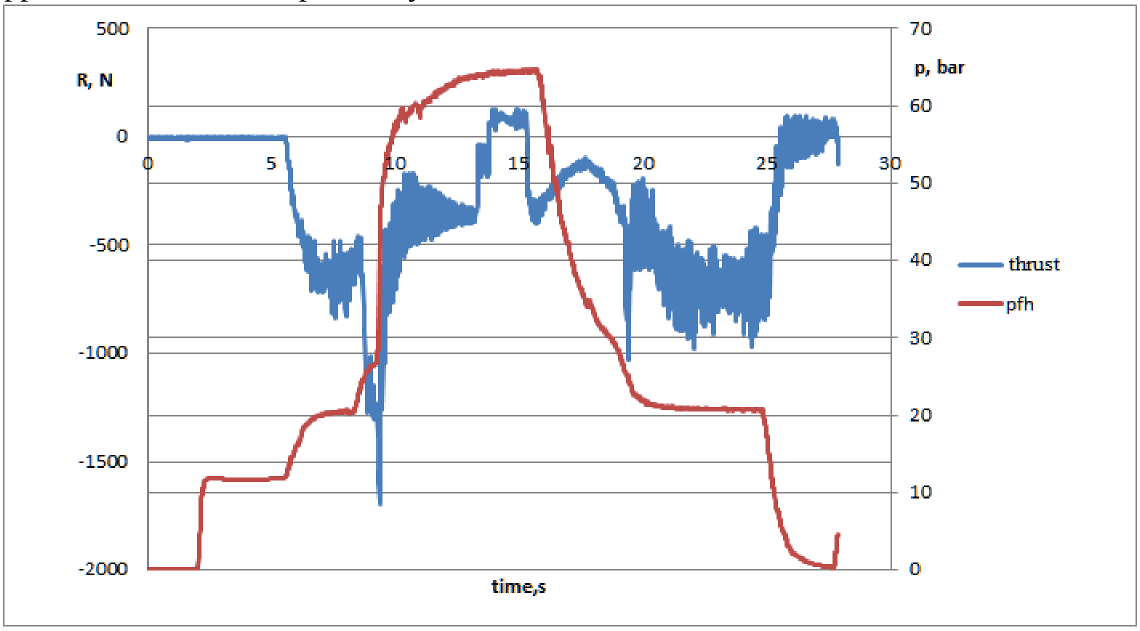

Fig. 4. The value of the total force acting on the apparatus as a function of time

The operating time of the power plant (≈2 s) was determined by the fuel delivery time, which in turn was limited by the permissible temperature of the material of the edge of the intake and the walls of the combustion chamber. In Fig. 5 shows the thermal state of these elements of the bench module, fixed by a thermal imager.

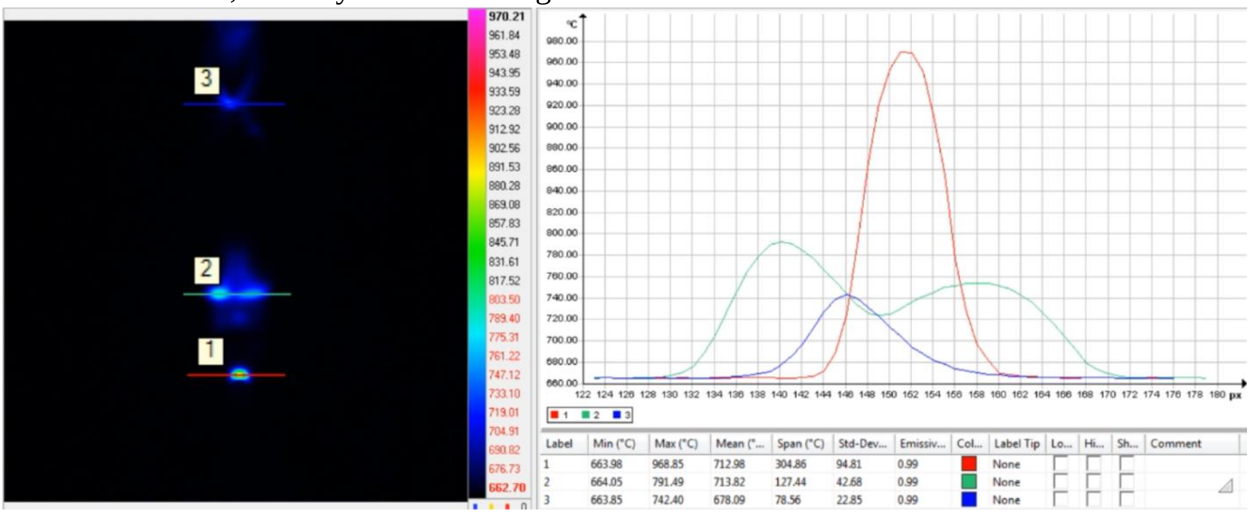

Fig. 5. Thermal state of the heat-stressed elements of the stand module design HEXAFLY-INT

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In Fig. 6 shows the distribution of pressure along the length of the flow path at a time corresponding to the combustion process in the combustion chamber. By the length of the closed flow path, 15 pressure gauge belts were installed, three sensors in each belt (left, right, and center, as shown in the diagram). According to these distributions, one can see a local increase in the static pressure in the weakly expanding combustion chamber between the second section of the fuel pylons and the entrance to the expanding nozzle part, which indicates the heat release in this part of the flow path. Also, according to the graphs, it is possible to make an assumption about a local low-speed zone in the central part of the entrance to the combustion chamber, just behind the intake throat.

In the starts, where positive thrust was not demonstrated, but there was a steady burning in the CS pressure distribution and the character of the thrust sensor readings look similar. It should be noted that in general the test module demonstrates a positive air navigation balance at sufficiently high fuel surplus ratios (ER> 1.58). With smaller ER, the thrust is zero, or <0. To increase the flight range of the aircraft with the engine of the presented concept, it is necessary to move to substantially lower ER [5].

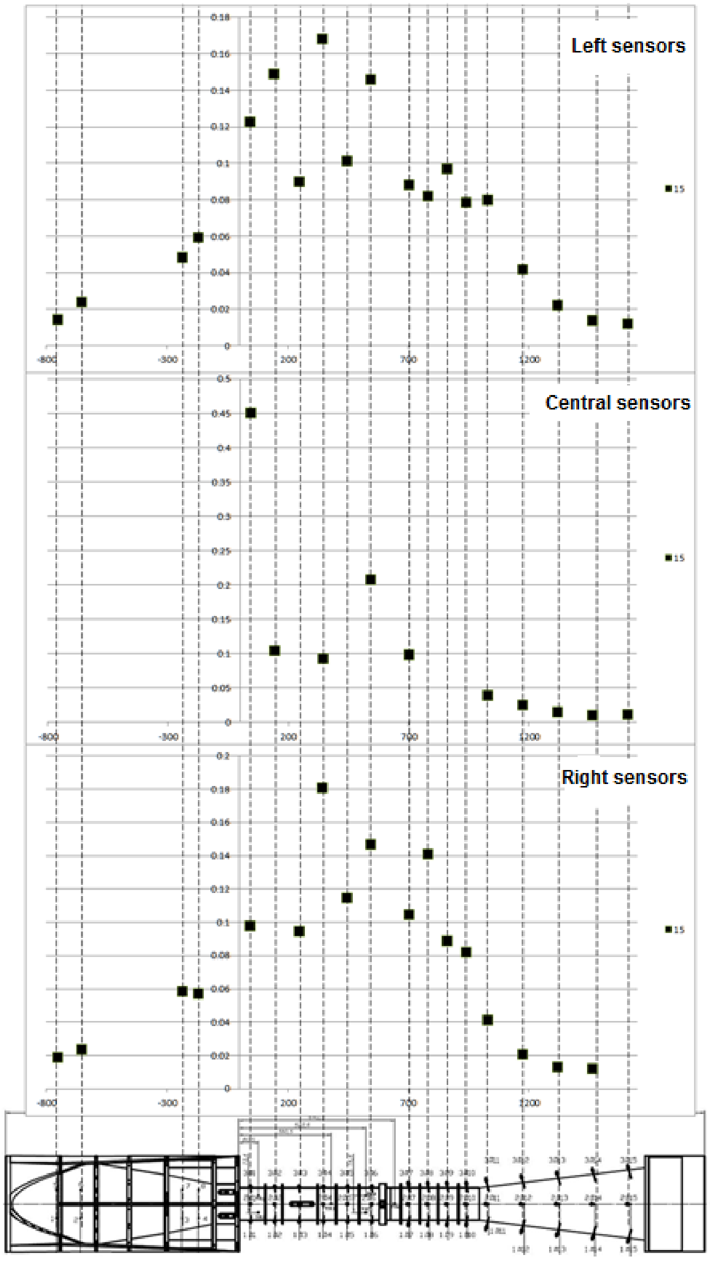

Fig. 6. Pressure distribution along the length of the flow path

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Evaluation of the efficiency of the working process in the combustion chamber was carried out by the method of determining the completeness of combustion, which is based on the readings of the thrust sensor and the distribution of pressure along the path. In Fig. 7 shows the dependence of the completeness of combustion on ER, calculated from the data of [6]. At the maximum value of ER, the combustion completeness does not exceed the value η = 0,6, and it decreases with decreasing ER.

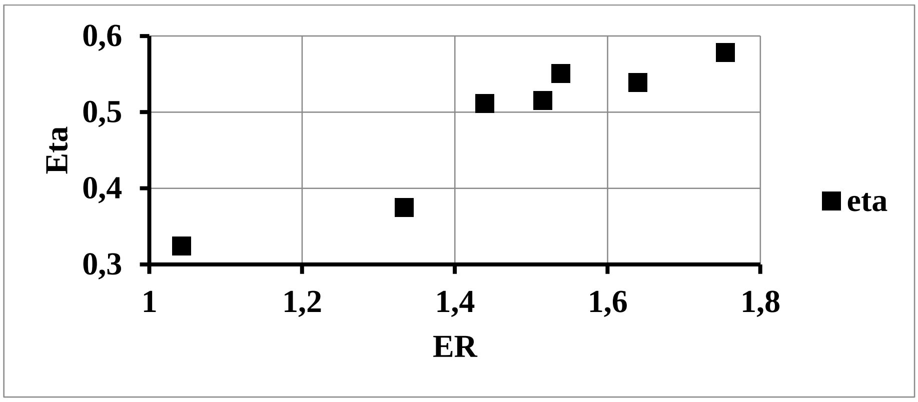

Fig. 7. The dependence of the completeness of combustion on ER

III. Conclusion

Within the framework of the international cooperation project HEXAFLY-INT in CIAM, the bench module of a high-speed civil aircraft was tested, during which a positive aeropropulsive balance was demonstrated. For the selected regimes p * ~ 49-65 bar, T * ~ 2310 K, the values of the completeness of fuel combustion in high-altitude conditions are obtained for the incident flow velocity corresponding to the Mach number M ~ 7.5, which are in the range η = 0.3-0, 6 when ER = 1 is changed to 1.8.

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