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PERSPECTIVE OF SMALL GAS TURBINE ENGINES DEVELOPMENT

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Abstract

It should be realized breakthrough improvement of perspective small gas turbines performance in comparison with current engines due to wide introduction of a complex of new technologies (composite materials; electric-drive units with supply by high-speed built-in generator; unconventional type bearings not demanding oil cooling) with reference to three base various size cores. On basis of these cores the perspective small gas turbines family can be created.

1 Small gas turbine engines

Small gas turbine engines (turboshafts, turbo-props, turbofans) are widely applied in power plants for flying vehicles of various purpose.
The class of civil small gas turbine engines includes the following types of engines:

- turboshaft engines with take-off power 300…10000 shp for light, medium and heavy helicopters;
- turboprop engines with take-off power 450…6000 shp for commuter, transport, agricultural, training and general aviation aircrafts;
- turbofan engines with take-off thrust 4.5…50 kN for regional, business, personal and training aircrafts.

2 Development priorities and goals

Directions of small turbine engines development are defined by the basic priorities at their creation. Such priorities are:

- Increase of economic efficiency of engines application on the flying vehicle (depreciation of purchase and service cost, fuel saving, life time increase);
- A safety of flights (increase of engine reliability, design simplification, effective engine condition diagnostics, increase of external impact resistance, engine control perfection, application of the increased OEI modes in a two-engine power plants);
- Ecological noise and emission requirements satisfaction with the significant margin, which is taking into account the tendency to requirements rising in the further prospect;
- The unified application, an opportunity of the further engine growth, using a base core for development family of engines of various purposes.

In perspective small gas turbine engines should be realized breakthrough improvement of specific parameters and operational characteristics in comparison with current engines:

- fuel efficiency increase on 15…20 %;
- specific weight redaction on 25…30 %;
- 3…4 times increase of reliability and life time;
- 2…3 times increase of engine "availability" (reduction of engine price and operation cost).

3 Features of small gas turbine engines

Tendencies of development small gas turbine engines have a number of the features connected to the factor of small dimension and less favorable conditions of operation in comparison with the large-size engines.

For example, helicopter engines are characterized by heavy conditions of operation: a short flight cycle, big share of heavy modes; a dust content of air, non-uniformity of a stream on engine inlet, the raised probability of hit in the engine of extraneous subjects, basing on the non-equipped landing grounds at absence of the attendants of high qualification, operation by mainly individual or small corporate users.

The listed features of helicopter engines define the basic tendencies of their development: simplification of design, reduction of stage number and numbers of details; application of the centrifugal type compressor; application of the turbine with not cooled rotor blades.

Application of the centrifugal compressor gives the following advantages:

- possibility to reach necessary surge margin without the use of variable geometry or surge bleed;
- reducing engine complexity, parts count, weight and manufacturing costs;
- increase of engine reliability;
- improved tolerance to foreign object damage and sand erosion;
- high tolerance to inlet distortion;
- low compressor moment of inertia, enabling rapid engine acceleration.

Application of not cooled turbine considerably reduces cost of the engine and raises its capacity for work in conditions with a high dust content of ambient air.

4 Perspective technologies

In perspective small gas turbine engines should be realized breakthrough improvement of specific parameters and operational characteristics in comparison with existing engines due to wide introduction in developed engines of a complex of new technologies on elements, units and systems:

- wide complex application of perspective composite materials of the various types, providing, in particular, radical (on 200…300 K) rise in gas temperature in engines with not cooled hot part;
- elimination of engine mechanical gearbox and transition to use electric-drive units with supply by high-speed built-in starter/generator;
- Application in the engine unconventional type bearings (nonmetallic composites bearings, air/gas foil bearings, electromagnetic bearings), not demanding oil cooling, elimination of engine oil system.

5 Base cores

According to developed in CIAM concept of perspective small gas turbine engines, development of "critical" technologies for this class of engines is carried out with reference to three base cores of various dimension:

- "small" core with one-stage centrifugal compressor;
- "small" core with two-stage centrifugal compressor;
- "medium" core with axial-centrifugal compressor.

The cross section of base "small" core with two-stage centrifugal compressor and with built-in starter/generator is shown in fig. 1.

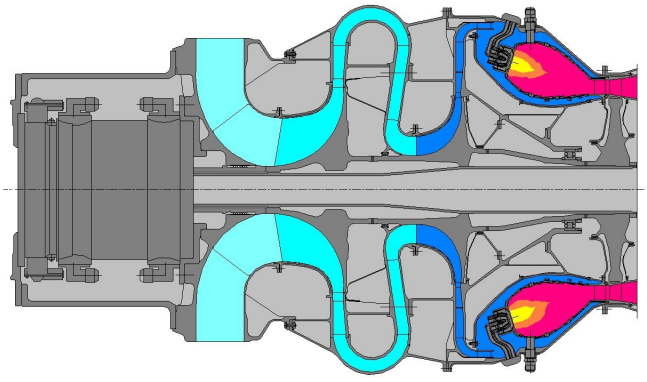

Fig. 1. Base "small" core with two-stage centrifugal compressor

On the basis of these base cores the family of perspective small gas turbine engines can be created.

6 Researches objects

As the basic object for development of perspective technologies in CIAM it is chosen base "small" core with the two-stage centrifugal compressor on the basis of which can be created perspective helicopter engine the most claimed class of power 2000…4000 shp.

Design and experimental researches are carried out in CIAM for the following units, elements and systems of perspective small turbine engines:

- one-stage centrifugal compressor with design pressure ratio PR = 12;
- two-stage centrifugal compressor with design pressure ratio PR = 16 (3D-model of compressor rotor is shown in fig. 2);

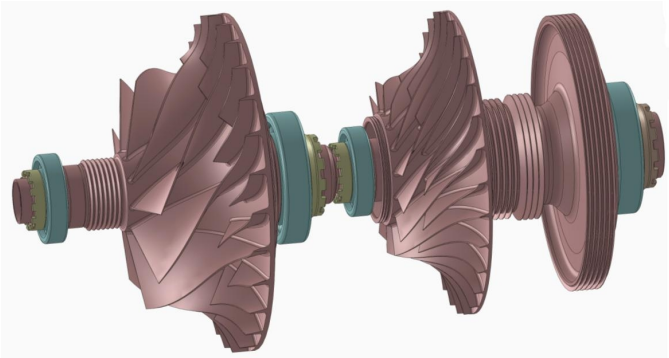

Fig. 2. Experimental rotor of two-stage centrifugal compressor

- first stage wheel of the centrifugal compressor from a polymeric composite material;
- case details of a cold part of the engine from carbon-filled plastic composite materials;
- composite inlet particle separator with an anti-erosion covering;
- not cooled composite combustion flame tube with exit gas temperature T4 > 1700 K;
- not cooled composite turbine nozzle;
- the bimetallic "blisk" turbine wheel;
- highly effective new type seals ("brush", "finger");
- composite power turbine shaft;
- ceramic composite bearings without oil cooling;
- foil bearings (experimental foil bearing is shown in fig. 3);

Fig. 3. Experimental foil bearing ∅90 mm

- advance full-authority digital multi-channel control system without hydro-mechanical back up;
- "smart" sensors with the wireless interface;
- units electric drive system with supply by high-speed built-in starter/generator;
- the advanced precision diagnostics system of the engine technical condition with functions of removed access.

7 Conclusions

For guaranteeing of new generation small gas turbine engines competitiveness should be achieved breakthrough improvement of their basic parameters in comparison with current engines.

For achievement of this purpose is required realization of the complex perspective technologies development program, described in the given article, on units, elements and systems of engines.

Efficiency of offered technical decisions should be shown by tests of experimental base cores and engines.

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