30th Congress of the International Council
of the Aeronautical Sciences
DCC, Daejeon, Korea ; September 25-30, 2016

DEVELOPMENT OF TECHNOLOGY ADVANCE FOR FUTURE PROPULSION SYSTEMS OF HAUL AIRCRAFT

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Keywords: *technology advance, advanced turbofan, key technologies*

Abstract

The paper discusses results of development of technology advance providing competitiveness of aviation engines. The task is priority of Russian Federation State Programme "Development of aviation industry for 2013-2025".

Technology advance developed by CIAM in close cooperation with industrial companies initiated the implementation of modern methodology of aviation engine, which is based on leading fine-tuning new engineering decisions and technologies with validation of their efficiency in full-scale conditions at testing of experimental engine components, cores and engine demonstrators.

1 Introduction

Continuous increase of requirements for engines of new and derivative commercial aeroplanes resulted in the aircraft engines became unique objects of mechanical engineering with respect of the level of engine working cycle parameters, the level of thermal and mechanical loads, applied constructional materials, noise and emission reduction techniques, etc.

World practice shoes that achievement of such unique properties is accompanied by prolongation of development time of next generation engine in one and a half or two times in comparison with other components of new aeroplane.

In that conditions engine designers have only one way to involve in new aeroplane development in time. It is technology advance for future engines based on the prediction of engine progress for advanced commercial aeroplanes, for new materials and technologies, with development of new technological decisions on mock-up, engine component and core test models, and finally on engine demonstrators.

Such precedence rules fully corresponds to methodology of compound technical objects developed in US in the end of the eighties and based on 9 Technology Readiness Levels (TRL): starting from fundamental researches (TRL 1) up to technology demonstrator (in our case up to engine demonstrator, TRL 6) and certified product (TRL 9).

2 Development of engine technology advance in Russia in 1999 – 2011

In Russia targeted activities on novel engine technology advance for commercial aeroplanes started in 1999 in respect to new generation engine for aeroplanes with passenger capacity of 130 – 170 pax and design range up to 5000 km.

Specifications for preliminary development of basic turbofan of next generation for commercial aeroplane (as the object of technology advance for novel engines of civil aviation) defined requirements to fuel and environmental efficiencies, safety and life time of engine main parts and components, operating manufacturability, and etc. were first document developed jointly by Russian research institutes CIAM (Central Institute of Aviation Motors) and TsAGI (Central Aerohydrodynamic Institute).

Based on the mentioned specification the design of preliminary concepts of baseline turbofans with fan driven through gearbox and direct driven fan (titled as "TRDD-2005A" and "TRDD-2005C") as well as design of main engine components and systems were realized by CIAM in 2000 - 2002 jointly with Russian (JSC Aviadvigatel Perm, UEC Kuznetsov Samara) and Ukraine (SE Ivchenko-Progress, JSC Motor Sich Zaporozhye) engine manufacturers. Herewith common core of the engines was considered as base for development of engine family of next generation with range of thrust of 7-20 tons.

Civil engine trends analysis and development forecast showed that in that moment all leading engine manufacturers developed new engine cores (Table 1) with single stage high pressure turbine (HPT) as the base for design in 2003 – 2008 new and derivative serial engines in considered range of thrust.

Table 1. Leading manufacturers projects

OEM	**Project**	**Number of core stages**	**CPR**	**HPT PR**
GE, US	Tech 56	6 + 1	14.7	4.55
PW, US	PW 6000	5 + 1	~ 10	~ 4
SNECMA, France	DEM 21	6 + 1	10 - 11	3.8 – 4.0
MTU, Germany	HPC 12	6 + 1	~ 12	–

At that moment at technology advance development for next generation turbofan it was recognized expedient to accept high design parameters of the low-stage high-loaded core: compressor pressure ratio (CPR) ~ 14 in six stages of High Pressure Compressor (HPC) and High Pressure Turbine (HPT) pressure ratio PR = 4,6 - 5,0 in one-stage HPT. It was made taking into account that increase of the design value of CPR at keeping core stage number provides following:

- possibility of realization of the two spool gearless engine with high OPR value at small number of Low Pressure Compressor (LPC) stages and smaller diameter and weight of Low Pressure Turbine (LPT);
- reduction of requirements of cooling of the HPT rotor wheel and first stage of LPT nozzle vane;
- best conditions for matching of flow channel of HPT and LPT, shortening (up to removal) of the transitional channel in the turbine, possibility of effective application of contrarotation of rotors;
- improvement of turbofan transient performance due to decrease of the moment of inertia of a low pressure rotor;
- increase of gasdynamic stability of LPC due to decrease of aerodynamic loading on its blade row;
- extension of thrust range of turbofan engine family based on the common core (by 20 % of max thrust in comparison with CPR = 11).

Fig.1 represents engine architectures for TRDD-2005A and TRDD-2005C with designation of new elements and components which became base of «Technology advance development Programme providing development of new generation turbofan for commercial aeroplanes of civil aviation” (further called as technology advance Programme).

It should be noted that due to higher CPR of high speed HPC of geared turbofan (TRRDD- 2005A) entry temperature in unified HPC is higher than one in TRDD-2005C. That is why at maximum engine rating the HPC of Turbofan 2005A operate with lower speed and CPR, but with higher HPT PR (at same turbine entry temperature). On the contrary HPC of “TDDD-2005C” operates at maximum parameters.

Since 2004 in the scope of the Federal State Programme «Development of civil aviation technics in RF for 2002-2010 and time period up to 2015» production (with participation of industry companies) and experimental investigations of elements and components providing of development of new engine (Fig. 2) were started.

Then technology advance, developed by CIAM in close collaboration with industry companies in 2002 – 2008 in the scope of the mentioned state Programme was starting point of implementation of recent methodology for development of aircraft engine, based on advance development new technical decisions and technologies with their efficiency confirmation under real conditions during testing of experimental engine components, cores and engine demonstrators.

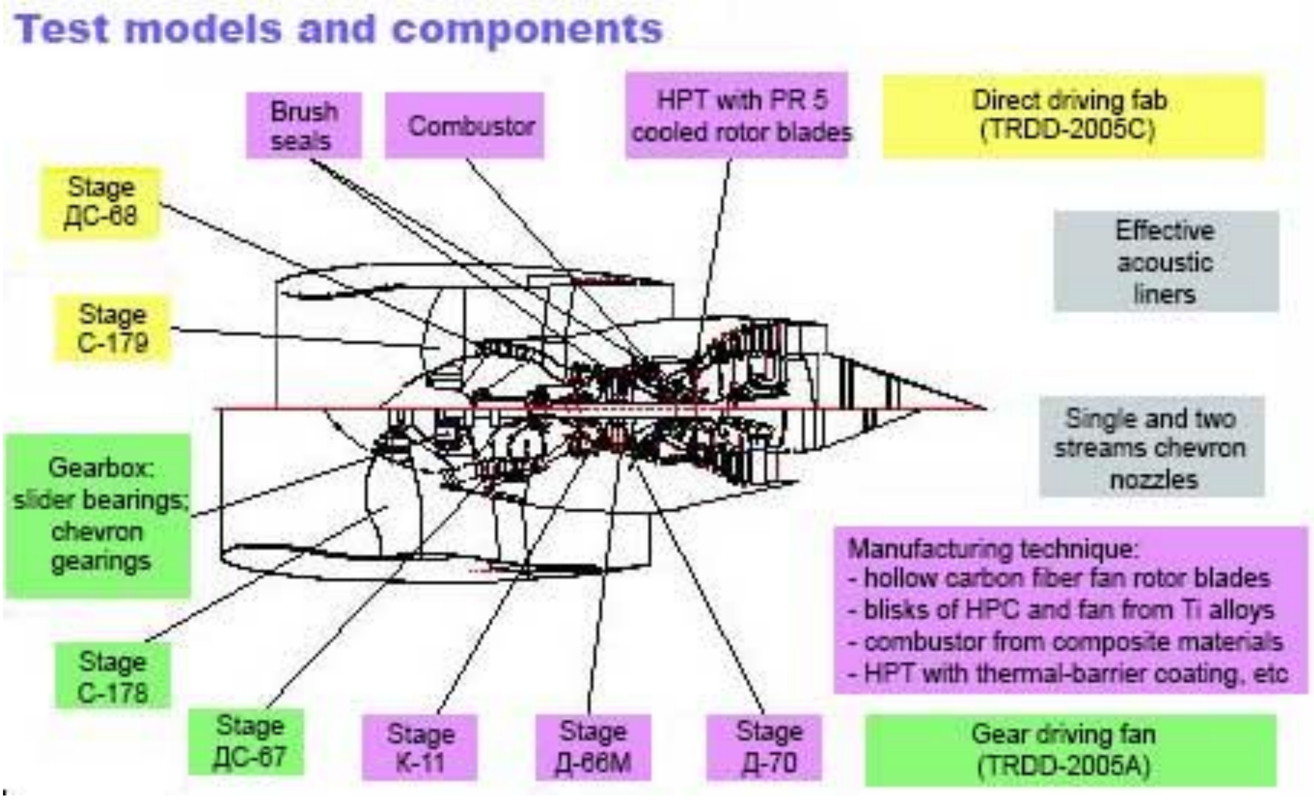


Fig. 1. Architectures of TRDD-2005A and TRDD-2005C as the development objects for technology advance

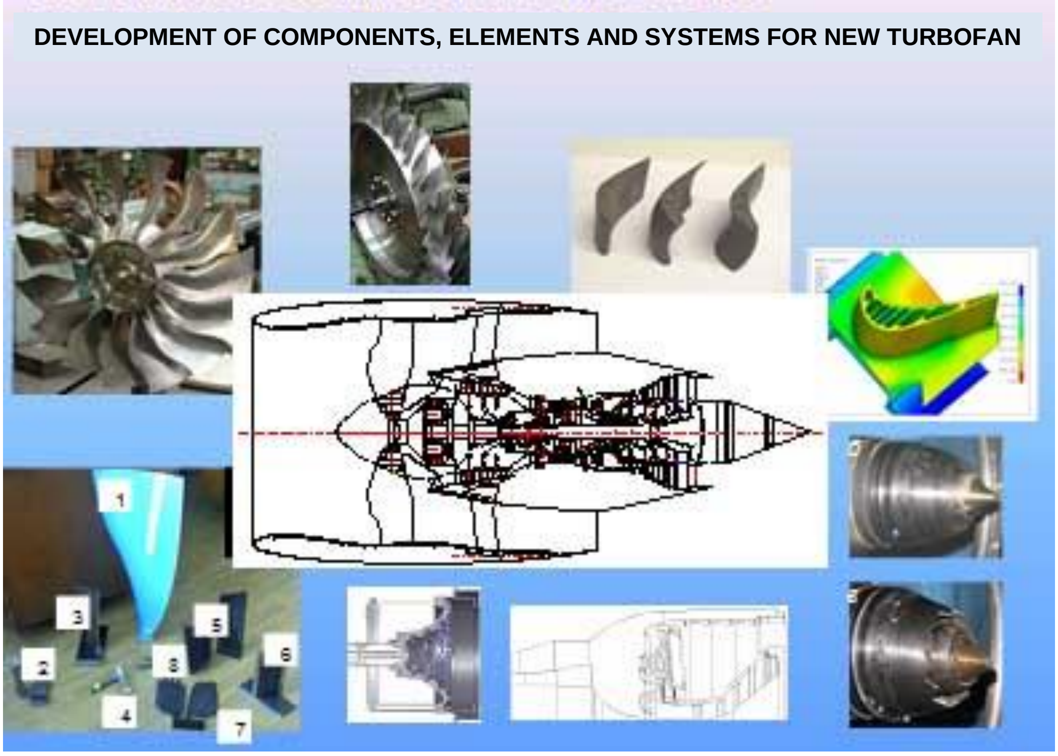
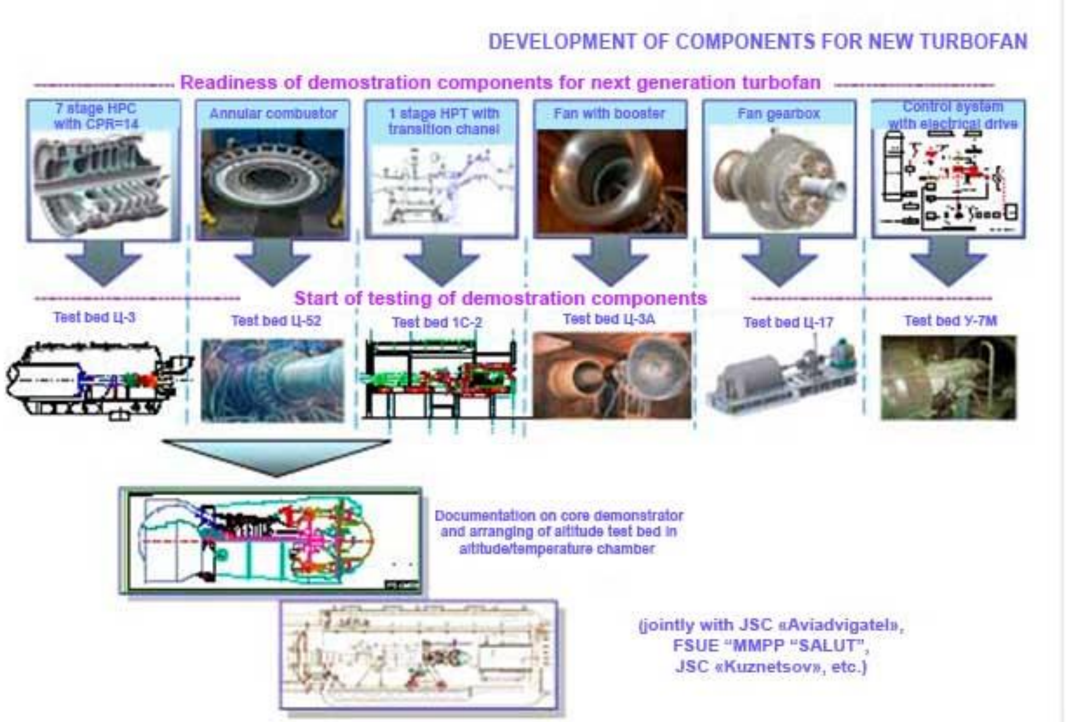


Fig. 2. Development of elements, components and systems of advanced turbofan

New results (TRL = 3 -5), obtained on models and experimental mock-up (widechord low noise fan with above rotor units, low weight fan rotor blades with hollow titanium and polymeric composites, typical high loaded HPC stages and experimental 7 stage compressor, new type of combustor head unit, superloading single stage HPT, turbine blades with long life time and high efficient cooling, active-reactive liners, chevron nozzles, reversers, and etc.) are mostly implemented in elements and engine components of core demonstrator and engine demonstrator , developed on the new generation engine PD-14 Programme for advanced Russian commercial aeroplane MS-21 (Fig. 3).



DEVELOPMENT OF COMPONENTS FOR NEW TURBOFAN

Readiness of demostration components for next generation turbofan

7 stage HPC with CPR=14

Annular combustor

1 stage HPT with transition chanel

Fan with booster

Fan gearbox

Control system with electrical drive

Start of testing of demostration components

Test bed Ц-3

Test bed Ц-52

Test bed 1С-2

Test bed Ц-3А

Test bed Ц-17

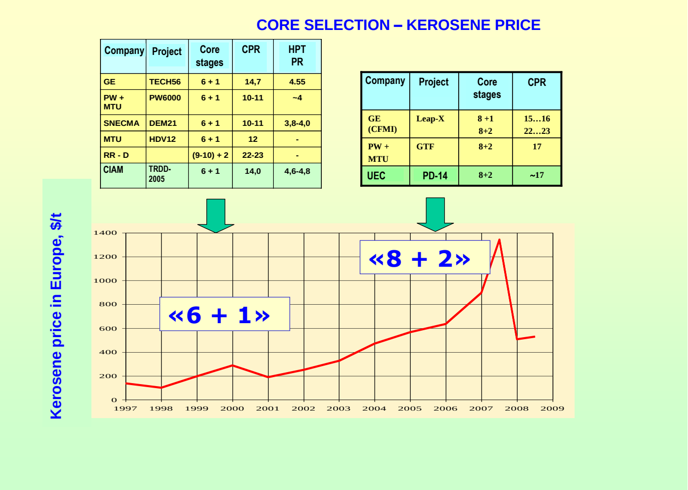
Test bed У-7М

Documentation on core demonstrator and arranging of altitude test bed in altitude/temperature chamber

(jointly with JSC «Aviadvigatel», FSUE "MMPP "SALUT", JSC «Kuznetsov», etc.)

Fig. 3. Development of technologies with TRL 4-5

Economic crisis of 2007 – 2008 corrected the directions of technology advance for novel aircraft engines (Fig.4).



CORE SELECTION – KEROSENE PRICE

Company	Project	Core stages	CPR	HPT PR
GE	TECH56	6 + 1	14,7	4.55
PW + MTU	PW6000	6 + 1	10-11	~4
SNECMA	DEM21	6 + 1	10-11	3,8-4,0
MTU	HDV12	6 + 1	12	-
RR - D		(9-10) + 2	22-23	-
CIAM	TRDD-2005	6 + 1	14,0	4,6-4,8

Company	Project	Core stages	CPR
GE (CFMI)	Leap-X	8 +1 8+2	15…16 22…23
PW + MTU	GTF	8+2	17
UEC	PD-14	8+2	~17

Fig. 4. Change of kerosene price by time.

When price of the aviation kerosene exceeds 600 USD per 1 ton all world leading engine manufacturers changed the advanced engine concepts staking on engine cores with 2-stage HPT and increased CPR. The aim of the step was improve engine fuel efficiency.

In Russia advanced engine (PD-14) with 2-stage HPT was also accepted as basic engine version.

A major contribution to development of key technologies for turbofan PD-14 was carried out in 2009 – 2011 at main role of JSC Aviadvigatel with participation of organizations of United Engine Corporation and scientific & technical support by CIAM.

Ground testing of core demonstrator of PD-14 started since 2010. Recently the engine is under certification tests.

New engine should provide fuel efficiency improvement by 12 – 15% in comparison with engines like CFM56/V2500, meeting environmental ICAO Standards with significant margins, high reliability and low direct operating cost.

Developed technology advance could be applied for development of engines with direct driven fan as well as with fan driven by gearbox, allowing to extend capabilities for design economically efficient family of new generation turbofan family based on common core with wide range of thrust of 9 -18 tons.

3 Novel directions of technology advance development

Practice shows that to develop technology advance for new generation base engine are needed at least 10-15 years, so development of technology advance on breakthrough technologies is already started to provide development of 6 generation engines (turbofan with high engine cycle parameters, open rotor, turbofan with unconventional cycles, hybrid engines and distributed propulsion systems, propulsion systems for light SSBJ and supersonic airliner and APU based on fuel cells) in 2025-2030 time period, which recently active elaborate in world aircraft engine design practice through regular forward running.

3.1 Turbofan with high engine cycle parameters

Analysis results with respect to impact of changes of main engine cycle parameters of advanced turbofan and their core size, defined by corrected air flow at the compressor exit $W_{corr\ core}$, showed that advanced turbofan with takeoff thrust 6…18 tons could be presented by two spool geared engines with bypass ratio BPR = 15-18, OPR= 55-60 (taking into account environmental and structure restrictions), takeoff turbine entry temperature up to 1900K (without margins for engine development, production and operation) and low size core with $W_{corr\ core}$ ~0,5…1,5 kg/s (Fig. 5).

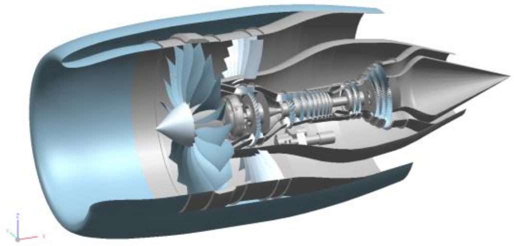


Fig. 5. Turbofan with high engine cycle parameters.

Decrease of core size reflects both increase of engine cycle parameters/BPR and increase of technological problems to develop high efficiency turbomashines. Reaching targeted level of component efficiencies, including minimization of air flow for hot part cooling jointly with higher engine cycle parameters are major approach to reduce specific fuel consumption on cruise conditions (M=0,8, flight level FL = 11 km) by ~15% in comparison with 5 generation turbofan.

Effective way of gas temperature decrease for turbofan with high BPR 10…12 is variation of external exhaust nozzle. E.g. using two-position external variable nozzle for turbofan with BPR=12.5 and Fan Pressure Ratio FPR = 1.35 cruise SFC could be reduced by ~1.3 %, gas temperature by ~11 K at cruise conditions and by ~15 K at takeoff; required variation of exit area of external nozzle is ~11 %. Reduction of tip speed at takeoff is equal to ~2.5 %, and reduction of external jet velocity is equal to ~3.8 % resulting on turbofan noise reduction.

Variation of guide vanes of LPC of geared turbofan allows decrease of takeoff gas temperature (keeping fan surge margin equal to 20%) for considered turbofan amounts 5 – 8 K. The benefit could be increased in case of specific LPC design.

3.2 Open rotor

Results of parametric analysis of advanced open rotor with two spool core and geared pushed propfan driven by turbine (Fig. 6) showed that the open rotor with considered size (takeoff thrust of 8600 kgf), cooling HPT and core components efficiencies taking into account core low size, have following optimal engine cycle parameters: gas temperature of 1450 K and OPR of 42.

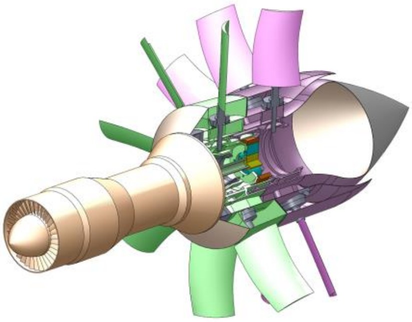


Fig. 6. Open rotor.

Diameter of forward row of open rotor is equal to 2.4 m.

To define open rotor parameters at al operating ratings of propulsion system mathematical model of two-row open rotor was developed based on the method of aerodynamic parameters calculation according to impulse theory of air propellers (theory of Sabyanin-Yuriev).

It was shown that propulsive efficiency of 2 row open rotor for operating ratings at the same torsion torques applied for both blade rows (MF=MR), is higher by ~3−6 % than one for single row open rotor due to utilization of tangential part of exhaust velocity of forward row by rear blade row.

In spite of high fuel efficiency of aeroplanes with open rotor, main problem of the engine is community noise. Such propulsion system could not provide for aeroplane of 2025 required competitive margins with respect to existing and future noise requirements.

Nevertheless probably when new now noise configurations of aeroplane of 2025, as well as improvements of numerical simulation will be applied on practice, the problem will be decided., Therefore during development of advanced aeroplanes it is very reasonable to pay proper attention not only to conventional engine architectures but also to open rotor.

Investigations showed that utilization of rear rotor blades with low height allows significantly reduce open rotor noise at takeoff. Benefit from the configuration at flyover certification point is less significant.

3.3 Turbofan with unconventional engine cycle

Parametric investigations of engine with unconventional cycles are carried out (Fig. 7). It was showed that heat regeneration combined with intercooling provides improvement of specific fuel consumption.

Herewith intercooling between turbine stages is more effective than regeneration after LPT. Optimal location of air cooler in core channel corresponds to condition when PR of LPC = 0,1…0,3• PR HPC. Optimal location of regenerator is in the “mid” of turbine.

It was also shown that intercooling provides cruise SFC reduction by 1…3%, interregeneration in combination with intercooling could improve SFC by 4…7% (in comparison with engine with conventional cycle.

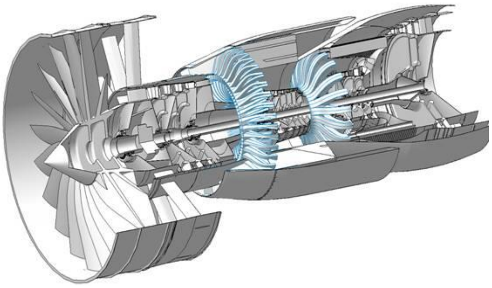


Fig.7. Turbofan with unconventional engine cycle.

It was noted, that engines with interregeneration have high combustor inlet temperature (1100…1200 K).

Total mass of insulating matrix, cases and transient channels for engine with takeoff thrust level of 9 tf is equal for air cooler with intercooling 170 kg, for engine with intercooling and interregeneration of air cooler 210 kg, regenerator – 169 kg. Specific mass of turbofan with intercooling by ~7.5%, with intercooling and interregeneration by ~18.5% are higher than specific vass of conventional cycle turbofan.

Comparative emission assessment shows that significant reduction of combustor inlet temperature for engine with intercooling (by ~125K) allows to reduce NOx emission indices at takeoff by approximately 1.8 times.

Compact heat exchanger and constructive solutions providing rational location of heat exchanger into the engine is the critical technologies.

3.4 Distributed Propulsion System

Different architectures of distributed propulsion systems (DPS) are formed in the scope of development of concept of remote core demonstrator for advanced DPS (Fig.8), in which multi fans are driven by single core (it allows to provide high BPR without increase of engine diameter and therefore meet requirement on integration of propulsion system with airframe, reduction of fuel consumption, emission and noise).

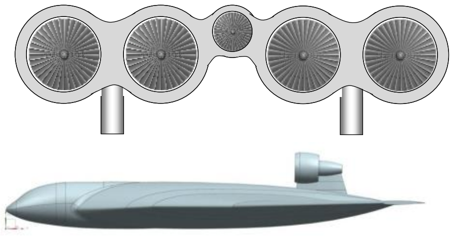


Fig.8. Distributed Propulsion System

3 main DPS architectures with fans mechanical driven by free turbine of remote core through transmission (remote shafts, bearing and gearboxes); with fans driven by individual free turbines through the gas flow extracted from remote core; with fans driven by electromotors (EM) using electric energy produced by electrogenerator, located on the same shaft as free turbine of remote core. Calculations of parameters for each DPS with FPR of 1.3, 1.4 and 1.5, which are correspond to BPR 22, 15 and 11, were performed. Cruise SFC of corresponding DPS are equal to 0.464, 0.48 and 0.495 kg fuel/kgf*h. Different architecture of DPS were used for long-haul aeroplanes of 2025–2030 time period (pax = 300, range = 10000 km). Due to contrary impact of FPR on SFC and engine mass optimal FPR value is equal to 1.4, which provides minimum of fuel efficiency of aeroplane at level 10.8 g/pax.km in case of gasdynamic and mechanical drives. It was also noted that DPS with gasdynamic drive is more complicated than DPS with mechanical drive.

DPS with electrical drive is the worst propulsion due to it is 3.2 times heavier than DPS with mechanical drive at approximately the same Specific Fuel Consumption (SFC) for all 3 DPS options. Fuel efficiency of electrical driven DPS is 34 g/(pax.km), which is even worse than one for recent aeroplanes.

3.5 Hybrid Propulsion System

Hybrid PS in which propulsor (fan of turbofan) is driven by turbine, or by electromotor or simultaneously by both depending on flight conditions are of high interest for advanced regional and small airliners.

Hybrid turbofan (HTF) with electromotor (Fig.9) driven by storage battery (SB) and by electrochemical generator based on fuel cells.

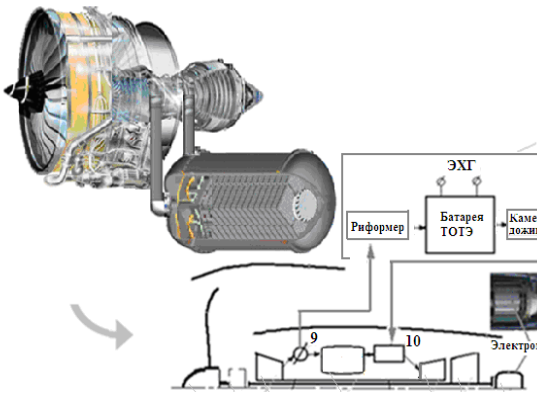


Fig.9. Hybrid Propulsion System

In first case it should be taken into account that mass and volume of SB are significantly increased together with increasing of range. Cost of transportation will depend on two parts: fuel price and electricity price in proportions required for the transportation. Contribution of each price will be defined by specific technical realization of selected optimal architecture and parameters of HTF. Simplicity and reliability could be attributed to advantageous of the HTF architecture. In the future such PS could be applied for aeroplanes operated on relatively short roots (up to ~1500–2000 km) using SB with specific mass less than 1.3 kg/kW•h and rational relationship between fuel and SB mass.

Using of conventional jet fuel for fuel cell battery (FCB) could be attributed to advantageous of second HTF architecture. In comparison with first architecture HTF, complication of the scheme due to additional components such as reformer, FCB, afterburner, which operation is mostly depend on the mode of whole PS, is its disadvantageous. Also control system of the PS and integration of energy system with PS and whole PS with airframe could be also more complicated.

General problems of technical implementation of considered HTF are connected with significant decreasing of gasdynamic stability of the booster at power supply for low pressure shaft from external source (in the case from electromotor). To resolve the problem initial oversizing of booster stages by pressure ratio or non-usage of booster for HTF are needed..

Essential analysis of possible HTF architectures should be next step of the activities. Based in the results of analysis the HTF circuit solutions as well as their rational parameters, control schedules and control principles should be selected. Finding of optimal parameters of the system “aeroplane+PS” with HTF is following step. Main ways of the finding are following:

– improvement of specific parameters of SB, EM, FCB;

– reduction of required power of electrical systems, which could be provided by aircraft takeoff weight, flight range decrease, aerodynamic efficiency improvement, flight speed reduction, and etc.

– optimal matching of operating modes of gas turbine and electrical parts of HTF.

List of key technologies is defined for development of ground demonstrator of advanced HTF:

– development of turbomashinery with high gasdynamic stability at wide operating rotational speeds;

– development of variable electric drives with specific mass lower than 0.1–0.3 kg/kW;

– development of fuel cells with specific mass lower than 1.0 kg/kW, and SB with specific mass of 1.0 kg/kW*h;

– creation of high integrated heat-resistant electronic pattern base including load patterns ($\lambda = 10^{-8} \ldots 10^{-10}$ 1/h, $t \geq 125$ °C);

– development of with specific power up to 350 kJ/m^3;

– development of switching facilities for voltage of 270…540 V;

– development of magnetic bearings, and etc.

3.6 Propulsion System for supersonic civil transport

Engines with parameters, materials and technologies implemented in 2016-2017 (recent engine), by 2020 (near future engine) and by 2025-2935 (far future engine) are considered in the scope of updating of technical concept of high efficiency low noise PS for advanced supersonic business jet (SSBJ).

In first case engine based on the scaled core of PD-14 turbofan (scaling factor is 86.6% by diameter and 75% by corrected air flow) at full fixed engine cycle parameters and gasdynamic efficiencies of its components could be considered. Cruise engine parameters at FL of 15 km and M=1.8 , inlet pressure recovery 0.92 are following: Turbine Entry Temperature TET = 1794K, OPR = 27.8, BPR = 2.78, installed SFC = 1.02 kg fuel/kgf*h at engine thrust of 1450 kgf.

The development of turbofan with wide variable exhaust system (variable nozzle and mixer) with BPR 2.5…3.5 (depending on intake and nozzle efficiencies and cruise/takeoff thrusts ratio) is predicted for near future time (up to 2020).

The development of variable cycle engines (VCE, Fig. 10) including engine architecture with adaptive fan, high cycle parameters(TET ~1900…2100K, OPR~40…50, T3max ~1100…1150K, ΔSFC_{cruise} = -5…6%) as well as new engine components and cycles (intercooling, constant volume combustor, etc.)

are probably predicted for far future (2025…2035).

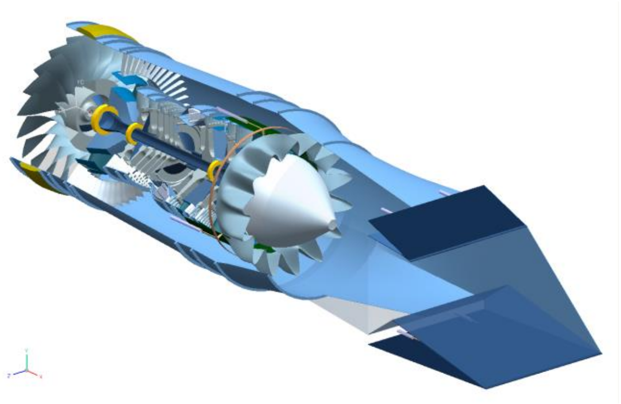


Fig 10. Variable cycle engine.

4 Key technologies

Key technologies are defined for fullsized development. Assessment of risks of development were carried out for different engine architectures. Proposals on priority activities aimed at key technologies development and enclosing development of VCE mathematical models, design of new type of engine components, numerical and experimental activities on key components and materials, as well as design and test investigations of demonstrator model are defined for technology advance Programme.

List of key technologies to create full size and small size ground APU demonstrators on fuel cell and to generate draft specification on design ground hybrid APU with power of ~10 kW are formed based on the performed complex analysis

Following technologies which designing will provide the base to create new generation of high efficient aviation APU based on the fuel cell for future aeroplanes have to be concerned:

− development of high efficient solid-oxide fuel microcells (microSOFC) and their packages with current terminals and connectors providing acceptable weight-dimensional performances for aviation applicability;

− development plasma converter of aviation kerosene for onboard power units with high productivity (on synthesis gas), providing capability to operate APU based on the fuel cell using conventional hydrocarbon fuel (without using of hydrogen);

− development of membrane catalytic systems for hydrogen separation from synthesis gas with high productivity based on the metals of group 5 (V, Nb, T), allowing to reduce of consumption precious metals by tenth times, significantly decrease of volume, mass and cost of membrane system;

− development of mobile multicapillary storages for storage of compressed hydrogen providing the performances exceeding of existing and predicted for near future SB including storages for liquid and cryogenic hydrogen;

− development of polymer electrolyte fuel cell (PEFC) for power units with world level of specific power of 0,8…1,0 kW/kg based on technology bipolar plates for fuel cell from composite materials;

− development of numerical control system of APU based on fuel cell integrated with control system of “electrical aircraft” and provided control of operation of all power unit blocks during all flight segments including emergency cases;

− development electrical actuators with high specific performance for rational replacement of various aircraft energy customers (mechanical, hydraulic, pneumatic) by electric drives;

− implementation of measures providing preparation of complex hydrogen infrastructure including production systems, hydrogen storage, autonomous fuelling stations for initial phase of operation of test aircraft APU based on the fuel cell of first generation.

Each of the mentioned technologies provides certain function or obtaining of certain quality of new type of APU for advanced aeroplanes.

5 Conclusions

Conducted comparative analysis of efficiency of considered engines and PS under fuel efficiency criteria (fuel consumption per pax and 1 km) for advanced regional aeroplanes and airliners is shown following:

– next generation aeroplanes with advanced PS based on the turbofan of 2025 level allow significantly reducing fuel consumption and reach fuel efficiency of transportation around 12.5–13.0 g/pax.km for and around 9.0–9.5 g/pax.km for short-medium-haul aeroplanes and around 12–13 g/pax.km for long-haul aeroplanes;

– most preferable for regional aeroplanes is PS based on the 2 open rotor providing fuel efficiency on the level by 11 g/pax.km (at $M_{cr} = 0.76$), in spite of high engine mass and small decrease of aerodynamic efficiency in comparison with regional aeroplanes with conventional turbofan. Aeroplane with conventional turbofan will provide fuel efficiency (at $M_{cr} = 0.78$) around 12.5 g/pax.km, which is by ~12% worse than regional jet with turbofan;

– it is not recognized definitely benefit of one of the considered architectures for short-medium-haul aeroplanes due to absolute difference in their fuel efficiencies are not higher than 0.40 g/pax.km, which is very close to accuracy of predicted engine and aircraft input parameters. Fuel consumptions of aircraft with open rotor at design flight speed (M_{cr} = 0.80) is close to one of aircraft with turbofan;

– Using of any PS from considered PS (turbofan, turbofan with unconventional cycle and DPS) for long-haul aeroplanes provides high level of fuel efficiency, but maximal effect is connected with using of DPS (11.5g/pax.km);

– conducted analysis of fuel efficiency estimations for aeroplanes of 2025 and 2035 with turbofan and HTF showed that both HTF architectures provide aircraft fuel efficiency benefit in comparison with aircraft with turbofan of same time period. It was established that improvements of airframe efficiency only during move from 2025 to 2035 aircraft allow to decrease required cruise thrust by 12-13% and to improve fuel efficiency by 10-11% for regional and short-medium-haul aeroplanes. Aeroplanes with HTF are better than aeroplanes with turbofan by 7–8% and 2–3% for regional jets and short-medium-haul aeroplanes accordingly.

Results of generalization and analysis of key technologies for advance engine and PS taking into account technical risks are shown that minimal critical risks of creation of advanced aircraft has turbofan, then open rotor and turbofan with unconventional cycles. All these PS have low risks indicator. Aircraft with DPS (mostly due to maximal integration of PS into the aircraft configuration) has high risks level, and aircraft with HTF has extreme high risks.

Analysis of status of the activities on technology advance development for engines of 2025-2030 time period shown that recently conducted scientific researches on selection of technological solutions, development and labor investigations of new breakthrough technologies in order to approve their efficiency have yet on initial phases corresponding to TRL 2-4 [1,2].
Development of technology advance providing competency of advanced civil engines is prior goal of State Programme of RF “Development of aviation industry for 2013-2025”.

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