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A.M. SHOJAEI, V.S. CHIGRIN

National Aerospace University «Kharkiv Aviation Institute», Ukraine

DEVELOPMENT CONCEPT OF JET ENGINES FOR THE UNMANNED AERIAL VEHICLES

Based on published open sources, analyzed the problems solved by unmanned aerial vehicles (UAVs) and applied them to the types of gas turbine engines. Designing engine for the UAV can perform «from scratch» in designing a special engine for a specific aircraft. However, a more appropriate use of the gas generator is tested practice of modular development of gas turbine engines, upgrading them to solve specific problems. For supersonic UAV with a range of 500 km is reasonable to use a simplified and light turbojet, relatively inexpensive, although with worse performance characteristics compared with turbofan engines. The distinctive design features of these engines are a low number of compressor stages, single-stage turbine, double-bearing, single-shaft rotor, the simplified system starter, system lubrication and fuel. As objective function in designing for turbojet engines with short lifetime for the UAV is advisable to use at least economic cost to design, manufacture and operation of the engine at the given parameters of thrust and specific fuel consumption. An example of the design characteristics of the single-shaft turbojet calculation, developed for the UAV-based gas generator series turbofan training aircraft.

Key words: *Unmanned aerial vehicles (UAV), gas-turbine engines, turbojet, module Turbo-engine, supersonic UAV.*

Introduction

Since 1980s abroad are actively carried out extensive work to develop unmanned aerial vehicles (UAVs), the new generation, designed to perform various tasks in the interests of the armed forces. Currently, the development and mass production firms engaged in UAV many countries. The greatest success in this area has been made by the United States, Israel, France, Germany and Canada. Other counties are working actively toward unmanned aerial vehicles: Sweden, Japan, China, India, Iran, Australia, Poland, Bulgaria, Czech Republic, South Korea, South Africa, Brazil and others. According to reports, at the beginning of the XXI century in the armed forces of many countries were more than 120 types of UAV. Unmanned aerial vehicle-A kind of flying machine, which is administered by the pilot not on board. There are the following UAV: autonomously based on preprogrammed flight plans (uncontrollable), automatic complex dynamic automation systems, remotely piloted aircraft. By functionality can be divided into the UAV Target and decoy (simulation), and Reconnaissance UAV designed to simulate real conditions in enemy aircraft and air weapons, including cruise missiles, to work out ways and means of their destruction or training of personnel, as well as misinformation of enemy air defenses. Reconnaissance unmanned systems are used to provide battlefield intelligence, gather information and transmit it in real-time to data link connecting the aircraft operator, even with the autonomous functioning of the aircraft.

In recent years abroad to work out the unmanned combat aerial vehicles (UCAV), capable of carrying various weapons to destroy the ground, surface and air targets.

Currently, UAVs are considered as a promising component of aerospace monitoring sites that are critical for safe operation of the fuel and energy complex. Given the specificity of propulsion for the short resource UAVs and UAV disposable, cost of engines, their development should be minimized, but it must be considered and a comparison of costs and the UAV performed its function, which justifies the relatively high cost propulsion system for unmanned aircraft for special purposes. Especially to the initial periods design, this can replace physical experiments and advanced testing facilities conducting full-scale mathematical modeling.

1. Raising of task

The gas turbine engines for UAVs occupy a fairly large part of the military aircraft engines (Fig. 1).
One characteristic of the modern approach to the design of jet engine is an integrated (system), the solution of design problems. Systematic approach to design means considering the engine as part of a complex that includes a power plant and airframe of the aircraft. In Fig. 2 shows the basic requirements that distinguish engines for military and civil purposes.

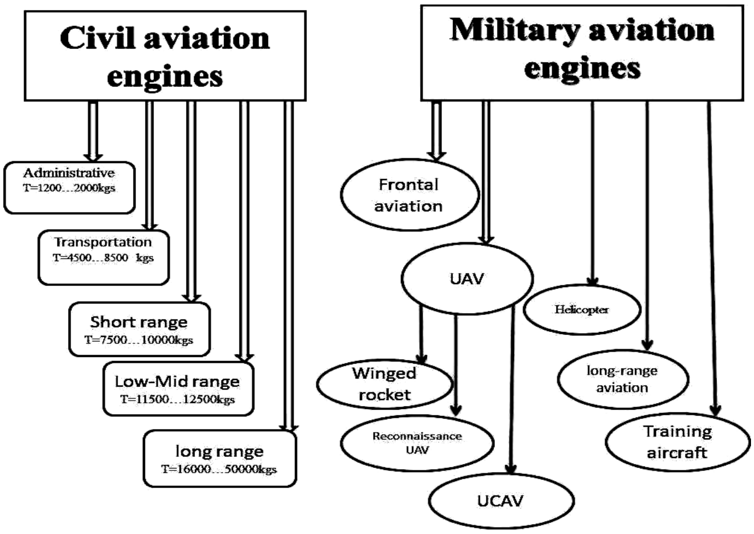

Fig. 1. The usage of gas turbine engines in aircraft

According to foreign experts [1], for unmanned aerial vehicles with a range of 500 km are advisable to use a simplified lightweight turbojet, relatively inexpensive, although with poorer performance characteristics when compared with bypass engines (turbofan jet engine).

Civil aviation	Military aviation
➪ Low consumption fuel	➪ HIGH thrust
➪ ELIGIBILITY FOR ECOLOGY	➪ High resistance to effects
	➪ Incomprehensible
➪ Low mass	
➪ High reliability	
➪ Maintainability	
➪ Low costs life cycle	

Fig. 2. Modern requirements, applicable to the jet engines

The distinctive design features of these engines are a small number of compressor stages (for example, on a tactical version of the rocket «Tomahawk» with J402-CA-400 engine compressor has two stages – centrifugal and axial), single-stage turbine, double-bearing and single-shaft rotor, simplified launch systems, lubrication and fuel supply. As an objective function in designing short lifetime jet engine for the UAV, it is advisable to use least economic cost to design, manufacture and operation of the engine at the given parameters of thrust and specific fuel consumption.

2. Decision of the put task

The determining factor for selecting the type of propulsion and thermodynamic parameters of the engine cycle, according to [2], in the design stage of technical proposals is a system that is a UAV with its terms and conditions. Consider the approach to the selection of the main parameters of the thermodynamic cycle in case the engine for unmanned aircraft takeoff weight of 5000 kg, with a controllable air intake, which is the main mode of cruise flight at an altitude of 25000 ... 40000 ft, (9….12 km) and K = 8 at a cruise speed to M = 2, the airborne speed V = = 240 km/h [3]. The main requirement in this case is the provision of required level of thrust jet engine at cruising flight.

As a first approximation demanded thrust power at cruising jet engine for the sample must be at least 6,1 kN, takeoff thrust during takeoff distance 800 m – 14 kN.

The temperature of stagnation at the flight altitude of 10 km in jet engine is $T_H^* = 223$ K.

The inlet gas temperature at the turbine T_G^* is usually determined by the achieved level of technology or other specific limitations.

In this case the amount is reasonable to limit values from 1250 ... 1275 K based on the requirements of without cooling blades and nozzle apparatus disk turbine (to reduce the cost of the engine). And optimum pressure in cycle

$$CPR_{c\ optimal} = \sqrt{\left(\frac{T_G^*}{T_H^*}\right)^{\frac{k}{k-1}}} = \sqrt{\left(\frac{1250}{223}\right)^{3,5}} = 20,4 .$$

With optimal value of $\pi_{C\ opt}$ can be calculated the optimum pressure ratio of compressor:

$$CPR_{optimal} = \frac{\pi_{opt}}{\sigma_{inlet}\left(1+\frac{k-1}{2}M_H^2\right)^{\frac{k}{k-1}}} = 2,7 ,$$

where σ_{inlet} = 0, 97 – coefficient of restitution to the adjustable air intake.

As well known [4], compressor pressure ratio economical (CPRc econ) does not coincide with CPRc optimal. CPR econ, at which the engine has a specific fuel consumption minimum (SFC min) most economical, is significantly higher than CPR optimal, at which the engine has a maximum specific thrust. Therefore, for further calculations, we accept CPR = 5.

The results of calculating thermodynamic turbojet performed by the method [5] on the maximum take-off conditions are presented in Table 1.

Table 1

Thermic calculation of turbojet single-shaft

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        BASIC DATA
Thrust R = 14000.0N TG=1250.0K Hu=43000.kDj/kg
Sinlet =.97 Sc = .96 ηc = .86 ηt = .89
KCIкс = .98 FIc = .98  PIc = 5.0
Goхл = 3.00%   Pн = 101300.Па  Tн = 288.K
        Without afterburning mode TG = 1250.K
Gair = 19.99 kg/c    PIc = 5.0
Pуд = 700.4  Cуд = .10805 R = 14000.0
ПИt = 1.95    ПИc = 2.38
Pc = 491305. PG = 471653. Pt = 241257.3
Tc = 483.5   Tt =1090.6  Cc = 686.0
     Hc = 196794.    Ht = 198770.7
C1a = 210. m/c Dk1 = .381 m  Dвт1 = .133 m
Dcp = .286 m  ДЛИНА РЛ = .124 m
a1 =327.9 m/c  W1k = 442.6 m/c U1k = 389.6 m/c
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The indexes in table 1: H_U *– calorific value of the fuel;* S_{inlet} *– coefficient of restitution in regulated air intake;* η_c *and* η_t *– Compressor efficiency and Turbine efficiency;* S_c *– Pressure recovery distortion in the combustion chamber; KCIc – the completeness of combustion ratio; FIc the coefficient rate of the nozzle;* π_C^* *– pressure ratio of compressor; Goхл – selection of air cooling, and the needs of the aircraft;* G_{air} *– Engine air flow; Pуд –specific thrust , Cуд – specific fuel consumption; Pc, PG, Pt, Tc, TG, Tt – Pressure and temperature behind compressor and turbine; Cc – velocity of the gas from jet nozzle.*

The calculation of the altitude – velocity has shown that the designed engine with the program adjustment $n_{ТКпр.}$ = const and all conditions controlled nozzle when flying at an altitude of 10,000 m and M = 2 provides traction 10,8 kN, which is somewhat higher required thrust. If using an unregulated supersonic nozzle in the same conditions provides traction 7 kN, which is close to the necessary value. This significantly simplifies the design of the nozzle and the engine control system, reduced weight and cost of power plant, significantly reduced the specific fuel consumption (from 0,1418 kg / N·h to 0,1308 kg/N·h). Fuel consumption per hour during the flight of the UAV to cruising in this case is 916 kg/h. The low temperature at the compressor inlet at takeoff and cruise modes (T_{inlet}^* not more than 500 K) and at the outlet of the compressor (T_{outlet}^* not more than 600 K) can be used in the compressor design cheap martials (steel) or, if the goal is to reduce the mass of the propulsion system alloys titanium. Contemporary methodology for creating advanced gas turbine engines of all engine building companies based on the advanced development of scientific and technological potential for key technologies, sites, systems, basic gas generators.It is advisable to use this methodology to reduce time and reduce the cost of engine development for UAVs. For example, on unmanned reconnaissance and target Tupolev TU-143, «REYS» turbojet TR3-117 is based on a gas generator turbo shaft engine TV3-117 used and well proven in the Mi-8, Mi-17, Mi-24, Mi-28, Ka-27, Ka-50 and others. On UAVs developed in Russia «Skat» take-off mass 10000 kg plan to install the RD-5000B thrust 49,5 kN, established on the basis of two engines RD-93 (modified RD-33 turbofan aircraft MIG-29) [6]. For the turbojet, discussed in the example, you can use a gas generator series Turbofan Engine RT.172-26 «Adur» MK.101 development Rolls-Royce, Turbomeca [7] (air flow through the first stage – 20,8 kg/s, $\pi_C^* = 4$, T_G^* = 1490 K) gas generator or series design turbofan ZMKB «Progress» DW-2 training and combat aircraft L39MS/L-59 [8] (air flow through the first stage – 20,24 kg/s, π_C^* = 6 C, T_G^* = 1352 K). Both engines have a modular design that greatly simplifies the design process based on the series turbojet gas generator.It is possible to use gas generators with the same parameters of some other series engines.When using a gas generator engine DW-2 and a small decrease in cycle parameters to simplify the design and provide a resource(π_{HP}^* = 5,5, T_G^* = 1275 K), engine provides a thrust at takeoff 14,23 kN, when flying at cruising – 7,07 kN, whichsatisfies the above example.

Conclusions

1. The determining factor for selecting the type of UAV propulsion and thermodynamic parameters of the engine cycle is a system that is a UAV with its conditions of use and power plant.
2. As an objective function in designing short life-time jet engine for the UAV, it is advisable to use least economic cost to design, manufacture and operation of the engine at the given parameters of thrust and specific fuel consumption.
3. For supersonic UAV with a range of 500 km is advisable to use a simplified light turbojet, developed on the basis of mass-produced gas generator turbine engines.

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Рецензент: д-р техн. наук, ст. научн. сотрудник В.В. Логинов, Харьковский университет Воздушных Сил им. Ивана Кожедуба, Украина.

КОНЦЕПЦІЯ РОЗРОБКИ ГТД ДЛЯ БЕЗПІЛОТНОГО ЛІТАЛЬНОГО АПАРАТУ

А.М. Шоджаі, В.С. Чигрин

По матеріалах відкритих видань проаналізовано завдання, що вирішуються безпілотними літальними апаратами (БПЛА) і вживані для них типи газотурбінних двигунів. Розробку двигуна для БПЛА можна виконувати «з нуля», проектуючи спеціальний двигун для конкретного літального апарату. Проте доцільнішим є використання газогенераторів перевірених практикою розробок модульних ГТД, модернізуючи їх для вирішення конкретних завдань. Для надзвукових БПЛА з дальністю польоту до 500 км доцільно використовувати спрощені легкі ТРД, порівняно недорогі, хоча і з гіршими технічними характеристиками в порівнянні з ТРДД. Відмітними конструктивними особливостями таких двигунів є компресор з малим числом ступенів, одноступінчата турбіна, двоопорний одновальний ротор, спрощені системи запуску, мастильна і паливопостачання. Як цільову функцію при проектуванні малоресурсних ГТД для БПЛА доцільно використовувати мінімум економічних витрат на проектування, виробництво і експлуатацію двигуна при заданих параметрах тяги і питомої витрати палива. Наведений приклад проектувального розрахунку характеристик одновального ТРД, що розробляється для БПЛА на базі газогенератора серійного ТРДД учбово-тренувального літака.

Ключові слова: безпілотний літальний апарат, турбореактивний двигун, газогенератор, модульний ГТД.

КОНЦЕПЦИЯ РАЗРАБОТКИ ГТД ДЛЯ БЕСПИЛОТНОГО ЛЕТАТЕЛЬНОГО АППАРАТА

А.М. Шоджаи, В.С. Чигрин

По материалам открытой печати проанализированы задачи, решаемые беспилотными летательными аппаратами (БПЛА) и применяемые для них типы газотурбинных двигателей. Разработку двигателя для БПЛА можно выполнять «с нуля», проектируя специальный двигатель для конкретного летательного аппарата. Однако более целесообразным является использование газогенераторов проверенных практикой разработок модульных ГТД, модернизируя их для решения конкретных задач. Для сверхзвуковых БПЛА с дальностью полета до 500 км целесообразно использовать упрощенные легкие ТРД, сравнительно недорогие, хотя и с худшими техническими характеристиками по сравнению с ТРДД. Отличительными конструктивными особенностями таких двигателей являются компрессор с малым числом ступеней, одноступенчатая турбина, двухопорный одновальный ротор, упрощенные системы запуска, смазки и топливопитания. В качестве целевой функции при проектировании короткоресурсных ГТД для БПЛА целесообразно использовать минимум экономических затрат на проектирование, производство и эксплуатацию двигателя при заданных параметрах тяги и удельного расхода топлива. Приведен пример проектировочного расчета характеристик одновального ТРД, разрабатываемого для БПЛА на базе газогенератора серийного ТРДД учебно-тренировочного самолета.

Ключевые слова: беспилотный летательный аппарат, турбореактивный двигатель, газогенератор, модульный ГТД.

Шоджаи Амир Мохаммад – студент каф. конструкции авиационных двигателей Национального аэрокосмического университета им. Н.Е. Жуковского «ХАИ», Харьков, Украина, e-mail: ashojaei577@gmail.com.

Чигрин Валентин Семенович – канд. техн. наук, доцент, доцент каф. конструкции авиационных двигателей Национального аэрокосмического университета им. Н.Е. Жуковского «ХАИ», Харьков, Украина, e-mail: chigrin_vs@rambler.ru.