Yu. Shoshin, F. Sirenko

BASIC TECHNICAL DATA OF UKRAINIAN, SOVIET AND RUSSIAN CRUISE ENGINES OF AIRCRAFT

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MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
National Aerospace University
“Kharkiv Aviation Institute”

Yu. Shoshin, F. Sirenko

BASIC TECHNICAL DATA OF UKRAINIAN, SOVIET AND RUSSIAN CRUISE ENGINES OF AIRCRAFT

Tutorial

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Наведено основні технічні дані й короткі відомості про конструктивні особливості авіаційних газотурбінних двигунів різних типів і поколінь, що створені у дев'яти дослідно-конструкторських бюро. Вказано літаки і вертольоти, де застосовувались і застосовуються ці двигуни.

Для студентів під час виконання лабораторних робіт з конструкції авіаційних газотурбінних двигунів, а також при виконанні курсових і дипломних проектів з газотурбінних двигунів.

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This tutorial comprises technical data and brief information about structural features of different aircraft gas turbine engines that belong to different generations. Tutorial also gives information about aircraft and helicopters that are powered by these engines.

This tutorial will be useful for laboratory activities and course projects that concern aircraft gas turbine engines.

Ref.: 11 names

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INTRODUCTION

This learners' guide contains basic technical data and brief information about more than fifty gas-turbine engines (GTE), and airplanes and helicopters, powered by these engines.

This guide is divided into nine chapters. Each chapter is devoted to definite engine design bureau of the USSR, Ukraine and Russia.

Learners` guide contains basic technical data of serial cruise GTEs for aircraft. All information presented here is for public use. It was collected from engine technical descriptions, aviation handbooks, fact sheets for aviation shows, magazines, etc.

Given information may help students during laboratory activities on studying design features of more than twenty aircraft engines of different types and generations, which are presented in studying rooms of aircraft engines and power plants chair.

Learners' guide will be useful for an analysis of basic parameters and structures evolution. This guide will be useful for course projects (prototype choosing and making estimation of designed engine perfectness).

CONVENTION

$\mathbf{P}$	–	thrust;
$\mathbf{C_{sp}}$	–	specific fuel consumption of TJE and TFE;
$\mathbf{N}$	–	power;
$\mathbf{C_{sp\,eqv}}$	–	specific fuel consumption of TPE and PFE;
$\mathbf{C_{sp\,N}}$	–	specific fuel consumption of TShE;
$\mathbf{T_G}$	–	turbine inlet temperature;
$\mathbf{G_{air}}$	–	total airflow;
$\mathbf{V_{fl}}$	–	flight speed of aircraft or helicopter;
$\mathbf{H_{fl}}$	–	flight altitude of aircraft or helicopter;
$\mathbf{L_{fl}}$	–	flight distance;
$\mathbf{M_{takeoff}}$	–	takeoff mass of aircraft or helicopter;
$\mathbf{M_{payload}}$	–	payload mass.

INDEXES

takeoff	–	takeoff;
cr	–	cruise;
a	–	afterburning;
eqv	–	equivalent;
eff	–	efficient;
max	–	maximum.

ABBREVIATIONS

RDB	–	research and design bureau;
IGV	–	inlet guide vane;
LPC, LPT	–	low pressure compressor (turbine);
IPC, IPT	–	intermediate pressure compressor (turbine);
HPC, HPT	–	high pressure compressor (turbine);
FT	–	fan turbine;
ISA	–	international standard atmosphere (at altitude $\mathbf{H=0}$, air temperature is $\mathbf{T_{amb}=288{,}15K}$, pressure is $\mathbf{P_{amb}=101325Pa}$, air density $\rho=\mathbf{1{,}2250}\frac{\mathbf{kg}}{\mathbf{m^3}}$, sonic velocity $\mathbf{a=340{,}29}\frac{\mathbf{m}}{\mathbf{s}}$).

1 AIRCRAFT GAS-TURBINE ENGINES

Zaporozhskoye engineering design bureau (ZEDB) “Progress” n.a. academician A. G. Ivchenko

Design bureau No 478 was founded on May 5th, 1945 according to the order No 193 of Aviation engineering public commissioner development bureau. DB No 478 was the name of the enterprise.

Chief designers:

Hero of Socialist Labour, academician	A. G. Ivchenko (1945-1968 years);
Hero of Socialist Labour, academician	V. A. Lotarev (1968-1988 years);
Hero of Ukraine, Ukrainian academy of science corresponding member	F. M. Muravchenko (1988-2010 years);
Academician of Engineering Academy of Ukraine	I. F. Kravchenko (from 2010 year).

1.1 Turboprop engine AI-20A

TPE AI-20A is a single-shaft engine with controllable-pitch propeller. Gearbox of propeller drive is designed under the loop planetary-differential scheme.

Compressor – axial, nine stage.
Combustion chamber – annular.
Turbine – axial, three stage, reactive.
Serial production started in 1958.

Technical features

Takeoff mode ($\mathbf{H = 0\ m}$, $\mathbf{V_{fl} = 0 \frac{km}{h}}$, ISA):

Equivalent power	**2940 kW (4000 hp);**
Specific fuel consumption	$\mathbf{0{,}353 \frac{kg}{kW \cdot h}} \left(\mathbf{0{,}259 \frac{kg}{hp \cdot h}} \right)$;
Pressure ratio	**7,32;**
Turbine inlet temperature	**1080 K;**
Total air consumption	$\mathbf{20{,}9 \frac{kg}{s}}$.

Cruise mode ($\mathbf{H = 8000\ m}$, $\mathbf{V_{fl} = 630 \frac{km}{h}}$):

Equivalent power	**1680 kW (2300 hp);**

Specific fuel consumption	$\mathbf{0{,}285\ \frac{kg}{kW \cdot h}\left(0{,}210\ \frac{kg}{hp \cdot h}\right)}$;
Overall sizes:	
length	**3096 mm;**
width	**842 mm;**
height	**1180 mm.**
Net engine mass	**1080 kg.**

Application. Four engines driven passenger airplane An-10 ($\mathbf{V_{cr} = 580\frac{km}{h}}$, $\mathbf{M_0 = 54\ tonnes}$, number of passengers – **100 peop.**); four engines driven passenger airplane Il-18 ($\mathbf{V_{cr} = 650\frac{km}{h}}$, $\mathbf{M_0 = 61{,}2\ tonnes}$, number of passengers – **75…100 peop.**).

Modifications. From 1965 – AI-20M ($\mathbf{N_{eq\ takeoff} = 3170\ kW}$, $\mathbf{C_{sp\ eq\ takeoff} = 0{,}325\frac{kg}{kW \cdot h}}$) for four engines driven cargo airplane An-12; from 1969 – AI-20DM and AI-20D ($\mathbf{N_{eq\ takeoff} = 3810\ kW}$, $\mathbf{C_{sp\ eq\ takeoff} = 0{,}320\frac{kg}{kW \cdot h}}$) for a two engines driven cargo airplanes An-8 and An-32.

1.2 Turboprop engine AI-24

TPE AI-24 is a single shaft engine with controllable-pitch propeller. Gearbox of propeller drive is designed under the loop planetary-differential scheme.

Compressor – axial, ten stage.
Combustion chamber – annular.
Turbine – axial, three stage, reactive.
Serial production started in 1962.

Technical features

Takeoff mode ($\mathbf{H = 0\ m}$, $\mathbf{V_{fl} = 0\frac{km}{h}}$, ISA):

Equivalent power	**1876 kW (2550 hp)**;
Specific fuel consumption	$\mathbf{0{,}364\ \frac{kg}{kW \cdot h}\left(0{,}267\ \frac{kg}{hp \cdot h}\right)}$;
Pressure ratio	**6,4**;
Turbine inlet temperature	**1150 K**;
Total air consumption	$\mathbf{13{,}1\frac{kg}{s}}$;

Cruise mode ($\mathbf{H = 6000\ m}$, $\mathbf{V_{fl} = 475\frac{km}{h}}$):

Equivalent power	**1105 kW (1500 hp)**;
Specific fuel consumption	$\mathbf{0{,}322\ \frac{kg}{kW \cdot h}\left(0{,}237\ \frac{kg}{hp \cdot h}\right)}$.
Overall sizes:	
length	**2346 mm**;
width	**677 mm**;
height	**1075 mm**.
Net engine mass	**600 kg**.

Application. Two engines driven passenger commuter airplane An-24 ($\mathbf{V_{cr} = 450...475\frac{km}{h}}$, $\mathbf{M_0 = 21{,}8\ tonnes}$, number of passengers – **48…52 peop.**).

Modifications.AI-24T, AI-24VT ($\mathbf{N_{eq\ takeoff} = 2074\ kW}$) for a two engines driven cargo airplane An-26 and airplane An-30.

1.3 Turbofan engine AI-25

TFE AI-25 is a two shaft engine without primary and secondary flows mixing.

Compressor is axial, eleven stage, two spool, consisting of a three stage low pressure compressor (LPC) and an eight stage high pressure compressor (HPC).

Combustion chamber is annular.

Turbine is axial, three stage, reactive, consisting of an one stage high pressure turbine (HPT) and a two stage low pressure turbine (LPT).

Serial production started in 1967.

Technical features

Takeoff mode ($\mathbf{H = 0\ m}$, $\mathbf{V_{fl} = 0\frac{km}{h}}$, ISA):

Thrust	**14,7 kN (1500 kgf)**;
Specific fuel consumption	$\mathbf{0{,}0581\frac{kg}{N \cdot h}\left(0{,}57\ \frac{kg}{kgf \cdot h}\right)}$;
Total pressure ratio	**8,0**;
Bypass ratio	**2,2**;
Turbine inlet temperature	**1145 K**;
Total air consumption	$\mathbf{44{,}8\ \frac{kg}{s}}$.

Cruise mode ($\mathbf{H = 6000\,m}$, $\mathbf{V_{fl} = 550\frac{km}{h}}$):

Thrust	**4,43 kN (452 kgf)**;
Specific fuel consumption	$\mathbf{0{,}081\frac{kg}{N \cdot h}\left(0{,}795\,\frac{kg}{kgf \cdot h}\right)}$.
Overall sizes:	
length	**1993 mm**;
width	**820 mm**;
height	**896 mm**.
Net engine mass	**348 kg**.

Application. Three engines driven commuter Yak-40 ($\mathbf{V_{cr} = 550\frac{km}{h}}$, $\mathbf{M_0 = 16{,}1\,tonnes}$, number of passengers – **24…32 peop.**).

1.4 Turbofan engine AI-25TL

TFE AI-25TL is a two shaft engine with primary and secondary flows mixing. AI-25 was the prototype for this engine. Comparing to prototype, AI-25TL has bigger pressure ratio of compressor (number of HPC stages was increased to nine) and higher TIT (HPT blades are cooled).

Serial production started in 1972.

Technical features

Takeoff mode ($\mathbf{H = 0\,m}$, $\mathbf{V_{fl} = 0\frac{km}{h}}$, ISA):

Thrust	**16,9 kN (1720 kgf)**;
Specific fuel consumption	$\mathbf{0{,}061\frac{kg}{N \cdot h}\left(0{,}60\,\frac{kg}{kgf \cdot h}\right)}$;
Total pressure ratio	**9,5**;
Bypass ratio	**2,0**;
Turbine inlet temperature	$\mathbf{1230\,K\left(TIT_{max} = 1310K\right)}$;
Total air consumption	$\mathbf{46{,}8\,\frac{kg}{s}}$.

Cruise mode ($\mathbf{H = 6000\,m}$, $\mathbf{V_{fl} = 550\frac{km}{h}}$):

Thrust	**5,04 kN (515 kgf)**;
Specific fuel consumption	$\mathbf{0{,}082\,\frac{kg}{N \cdot h}\left(0{,}807\,\frac{kg}{kgf \cdot h}\right)}$.

Overall sizes:

length	**3358 mm**;
width	**985 mm**;
height	**958 mm**.
Net engine mass	**400 kg**.

Application. One engine driven trainer L-39, which was manufactured in Czechoslovakia.

1.5 Turbofan engine DV-2

TFE DV-2 is a two shaft engine with primary and secondary flows mixing. AI-25 was the prototype for this engine. Modular designing concept is implemented for this engine.

Compressor is axial, two spool, consisting of an one stage fan (low pressure compressor) with two boosters and a seven stage high pressure compressor.

Combustion chamber is annular.

Turbine is axial, three stage reactive, has an one stage high pressure turbine and a two stage low pressure turbine (fan turbine).

Serial production started in 1991 by ZVL “Povjagske Strojarne” (ChSSR, Slovakia).

Technical features

Takeoff mode ($\mathbf{H = 0\,m}$, $\mathbf{V_{fl} = 0\,\frac{km}{h}}$, ISA):

Thrust	**21,56 kN (2200 kgf)**;
Specific fuel consumption	$\mathbf{0{,}0607\,\frac{kg}{N \cdot h}\left(0{,}595\,\frac{kg}{kgf \cdot h}\right)}$;
Total pressure ratio	**16,9**;
Bypass ratio	**1,46**;
Turbine inlet temperature	**1400 K**;
Total air consumption	$\mathbf{49{,}8\,\frac{kg}{s}}$.

Cruise mode ($\mathbf{H = 6000\,m}$, $\mathbf{V_{fl} = 575\,\frac{km}{h}}$):

Thrust	**8,23 kN (840 kgf)**;
Specific fuel consumption	$\mathbf{0{,}0777\,\frac{kg}{N \cdot h}\left(0{,}762\,\frac{kg}{kgf \cdot h}\right)}$;
Fan diameter	**645 mm.**
Net engine mass	**450 kg**.

Application. One engine driven trainer L-39MS (then it got the name L-59), which was manufactured in Czechoslovakia.

1.6 Turbofan engine D-36

TFE D-36 is a three shaft engine without primary and secondary flows mixing and with high bypass ratio. Modular designing concept is applied in this engine.

Compressor is axial, 14 stage, three spool, has an one stage transonic fan (low pressure compressor), a six stage subsonic intermediate pressure compressor (IPC) and a seven stage high pressure compressor.

Combustion chamber is annular.

Turbine is axial, three shaft, five stage, reactive, has an one stage high pressure turbine (HPT), an one stage intermediate pressure turbine (IPT), a three stage fan turbine (FT).

Serial production started in 1977.

Technical features

Takeoff mode ($\mathbf{H = 0\ m}$, $\mathbf{V_{fl} = 0\ \frac{km}{h}}$, ISA):

Thrust	**63,7 kN (6500 kgf)**;
Specific fuel consumption	$\mathbf{0{,}0372\ \frac{kg}{N \cdot h}\left(0{,}365\ \frac{kg}{kgf \cdot h}\right)}$;
Total pressure ratio	**20,2**;
Bypass ratio	**5,6**;
Turbine inlet temperature	$\mathbf{1450\ K\ (TIT_{max} = 1510K)}$;
Total air consumption	$\mathbf{253\ \frac{kg}{s}}$.

Cruise mode ($\mathbf{H = 8000\ m}$, $\mathbf{V_{fl} = 800\ \frac{km}{h}}$):

Thrust	**15,7 kN (1600 kgf)**;
Specific fuel consumption	$\mathbf{0{,}066\ \frac{kg}{N \cdot h}\left(0{,}649\ \frac{kg}{kgf \cdot h}\right)}$.
Overall sizes:	
length	**3470 mm**;
width	**1541 mm**;
height	**1711 mm**.
Net engine mass	**1106 kg**.

Application. Three engines driven takeoff and landing airplane Yak-42 ($\mathbf{V_{cr} = 750...810\,\frac{km}{h}}$, $\mathbf{M_0 = 53{,}5\ tonnes}$, number of passengers – **104…120 peop.**); two engines driven short takeoff and landing military transport plane An-72 ($\mathbf{V_{cr} = 550...600\,\frac{km}{h}}$, $\mathbf{M_0 = 34{,}5\ tonnes}$, $\mathbf{M_{payload} = 10\ tonnes}$) and airplane An-74, which is the North modification of An-72.

1.7 Turbofan engine D-18T

TFE D-18T is a three shaft engine without primary and secondary flows mixing and with high bypass ratio. Modular designing concept is applied in this engine. Engine is equipped with thrust reversal, arranged in bypass.

Compressor is axial, 15 stage, three spool, has an one stage supersonic fan (low pressure compressor), a seven stage transonic intermediate pressure compressor (IPC) and a seven stage subsonic high pressure compressor.

Combustion chamber is annular.

Turbine is axial, three shaft, six stage, reactive, has an one stage high pressure turbine (HPT), an one stage intermediate pressure turbine (IPT), a four stage fan turbine (FT).

Thrust reversal is annular, lattice-type with flaps, which block the bypass duct during reversing.

Serial production started in 1985.

Technical features

Takeoff mode ($\mathbf{H = 0\,m}$, $\mathbf{V_{fl} = 0\,\frac{km}{h}}$, ISA):

Thrust	**230 kN (23400 kgf)**;
Specific fuel consumption	$\mathbf{0{,}0375\,\frac{kg}{N \cdot h}}\left(\mathbf{0{,}349\,\frac{kg}{kgf \cdot h}}\right)$;
Total pressure ratio	**23,8**;
Bypass ratio	**5,9**;
Turbine inlet temperature	**1600 K**;
Total air consumption	$\mathbf{760\,\frac{kg}{s}}$.

Cruise mode ($\mathbf{H = 11000\,m}$, $\mathbf{V_{fl} = 800\,\frac{km}{h}}$):

Thrust	**47,6 kN (4860 kgf)**;

Specific fuel consumption $\mathbf{0{,}0582\ \frac{kg}{N \cdot h}\left(0{,}57\ \frac{kg}{kgf \cdot h}\right)}$.

Overall sizes:
- length **5400 mm**;
- width **2792 mm**;
- height **2937 mm**.

Net engine mass **4100 kg**.

Application. Four engines driven wide-body cargo airplane An-124 ($\mathbf{M_0 = 405\ tonnes}$, $\mathbf{M_{payload} = 150\ tonnes}$) and six engines driven airplane An-225 ($\mathbf{M_0 = 600\ tonnes}$, $\mathbf{M_{payload} = 250\ tonnes}$).

1.8 Turbofan engine D-436T1

TFE D-436T1 is a three shaft engine without primary and secondary flows mixing and with thrust reversal. Modular designing concept is applied in this engine. D-36 was the prototype for this engine.

Compressor is axial, 14 stage, three spool, has an one stage supersonic fan (low pressure compressor) with an one booster, a six stage transonic intermediate pressure compressor (IPC) and a seven stage subsonic high pressure compressor.

Combustion chamber is annular.

Turbine is axial, three shaft, five stage, reactive, has an one stage high pressure turbine (HPT), an one stage intermediate pressure turbine (IPT), a three stage fan turbine (FT).

Thrust reversal is annular, lattice-type with flaps, which block the bypass duct during reversing.

Flight tests were finished in 1995.

Technical features

Takeoff mode ($\mathbf{H = 0\ m}$, $\mathbf{V_{fl} = 0\ \frac{km}{h}}$, ISA):

Thrust **74,2 kN (7570 kgf)**;

Specific fuel consumption $\mathbf{0{,}038\ \frac{kg}{N \cdot h}\left(0{,}37\ \frac{kg}{kgf \cdot h}\right)}$;

Total pressure ratio **22,7**;

Bypass ratio **4,91**;

Turbine inlet temperature **1483 K**;

Total air consumption $\mathbf{254\ \frac{kg}{s}}$.

Cruise mode ($\mathbf{H = 11000\,m}$, $\mathbf{V_{fl} = 800\frac{km}{h}}$):

Thrust	**14,7 kN (1500 kgf)**;
Specific fuel consumption	$\mathbf{0{,}062\,\frac{kg}{N \cdot h}\left(0{,}608\,\frac{kg}{kgf \cdot h}\right)}$.
Overall sizes:	
length	**3829 mm**;
width	**1810 mm**;
height	**1911 mm**.
Net engine mass	**1450 kg**.

Application. Two engines driven takeoff and landing airplane Tu-334-10 ($\mathbf{M_0 = 46{,}1\,tonnes}$, number of passengers – **102 peop.**). Primary flight was on February 8, 1999.

Modifiations. D-436TP to power amphibian Be-200 (number of engines – **2**, $\mathbf{M_0 = 36\,tonnes}$, number of passengers – **64 peop.**), D-436T2 (forced by $\mathbf{T_G^*}$ increasing to $\mathbf{1520\,K}$) to power Tu-334-200 ($\mathbf{P_{takeoff} = 80{,}3\ kN}$, number of passengers – **126 peop.**)

1.9 Turboshaft engine D-136

TShE D-136 is a three shaft engine with free turbine. Modular designing concept is applied in this engine. This engine is the most powerful turboshaft engine, which uses D - 36 as a prototype.

Compressor is axial, 13 stage, two spool, has a six stage low pressure compressor and a seven stage high pressure compressor.

Combustion chamber is annular.

Turbine is axial, three shaft, four stage, reactive, has one stage high pressure turbine (HPT), a two stage free turbine.

Serial manufacturing started in 1982.

Technical features

Takeoff mode ($\mathbf{H = 0\,m}$, $\mathbf{V_{fl} = 0\frac{km}{h}}$, ISA):

Power	**8380 kW (11400 hp)**;
Specific fuel consumption	$\mathbf{0{,}269\,\frac{kg}{kW \cdot h}\left(0{,}198\,\frac{kg}{hp \cdot h}\right)}$;
Pressure ratio	**18,3**;
Turbine inlet temperature	**1478 K**;
Total air consumption	$\mathbf{36\,\frac{kg}{s}}$.

Overall sizes:

length	**3964 mm**;
width	**1670 mm**;
height	**1160 mm**.
Net engine mass	**1050 kg**.

Application. Two engines driven multipurpose helicopter Mi-26T ($\mathbf{V_{max} = 295\frac{km}{h}}$, $\mathbf{M_0 = 49{,}6\ tonnes}$, $\mathbf{M_{payload} = 20\ tonnes}$ or **80 peop.**).

1.10 Propfan engine D-27

PFE D-27 is a propfan engine of the new generation with two multi-bladed, coaxial, contra rotating, low-noise, sabre-shaped propellers (propfans).Modular designing concept is applied in this engine. Engine is designed by a three shaft scheme.

Compressor is two spool, has a five stage axial low pressure compressor (first and second stages are supersonic) and an axial-centrifugal high pressure compressor (first and second stages are axial and last is centrifugal).

Combustion chamber is annular.

Turbine is axial, six stage, reactive, has an one stage high pressure turbine with monocrystal blades and a four stage power turbine, which drives two contra rotating propfans through shafting and differential gearbox.

Flight testing was finished in 2000.

Technical features

Takeoff mode ($\mathbf{H = 0\ m}$, $\mathbf{V_{fl} = 0\frac{km}{h}}$, ISA):

Equivalent power	**10290 kW (14000 hp)**;
Specific fuel consumption	$\mathbf{0{,}231\frac{kg}{kW \cdot h}\left(0{,}170\ \frac{kg}{hp \cdot h}\right)}$;
Pressure ratio	**22,9**;
Turbine inlet temperature	**1640 K**;
Total air consumption	$\mathbf{27{,}4\ \frac{kg}{s}}$.

Cruise mode ($\mathbf{H = 11000\ m}$, $\mathbf{V_{fl} = 750\frac{km}{h}}$):

Equivalent power	**4960 kW (6750 hp)**;
Specific fuel consumption	$\mathbf{0{,}177\ \frac{kg}{kW \cdot h}\left(0{,}130\ \frac{kg}{hp \cdot h}\right)}$.

Overall sizes:

length	**4198 mm**;
width	**1260 mm**;
height	**1370 mm**.
Propfan diameter	**4500 mm.**
Net engine mass (without propfan)	**1650 kg**.

Application. Four engines driven military cargo airplane An-70 ($\mathbf{V_{max} = 750\frac{km}{h}}$, $\mathbf{M_0 = 130\ tonnes}$, $\mathbf{M_{payload} = 30\ tonnes}$).

1.11 Turboprop engine TV3-117VMA-SBM1

TPE TV3-117VMA-SBM1 was designed in cooperation with public enterprise “Motor Sich” and SPE “Plant n.a. V. Y. Klimov” (Saint-Petersburg) having been used TV3-117VMA as a prototype. New shafting and gearboxes to transport power from free turbine to propeller were added. They ensured necessary engine power. The six blade, controllable-pitch propeller AV-140 was designed by public enterprise “Aerosila”.

Engine compressor is axial, 12 stage, an one spool, with movable inlet guide vanes and next four stages guide vanes.

Combustion chamber is annular.

Turbine is axial, two shaft, four stage, reactive, has a two stage compressor turbine and a two stage free turbine. Free turbine is linked to front gearbox through shafting and rear gearbox

Serial manufacturing started in 2000.

Technical features

Takeoff mode ($\mathbf{H = 0\ m}$, $\mathbf{V_{fl} = 0\frac{km}{h}}$, ISA):

Power on free turbine`s shaft	**1838 kW (2500 hp)**;
Specific fuel consumption	$\mathbf{0{,}280\ \frac{kg}{kW \cdot h}\left(0{,}206\ \frac{kg}{hp \cdot h}\right)}$;
Pressure ratio	**10**;
Turbine inlet temperature	$\mathbf{1226\ K\left(TIT^{*}_{max} = 1293\ K\right)}$;
Total air consumption	$\mathbf{9{,}78\ \frac{kg}{s}}$.

Cruise mode ($\mathbf{H = 6000\ m}$, $\mathbf{V_{fl} = 575\frac{km}{h}}$):

Power on free turbine`s shaft	**1287 kW (1750 hp)**;

Specific fuel consumption	$\mathbf{0{,}262\ \frac{kg}{kW \cdot h}}\left(\mathbf{0{,}193\ \frac{kg}{hp \cdot h}}\right)$.
Overall sizes:	
length	**2860 mm**;
width	**880 mm**;
height	**1210 mm**.
Net engine mass	**570 kg**.

Application. Two engines driven passenger airplane for local airlines An-140 ($\mathbf{V_{cr} = 575\frac{km}{h}}$, $\mathbf{M_0 = 19{,}1 tonnes}$, number of passengers – **50 peop.**).

1.12 Turbofan engine AI-22

TFE AI-22 is two-shaft engine equipped with thrust reversal, arranged in bypass. Modular designing concept is applied in this engine.

Compressor is axial, two spool, has an one stage fan (low pressure compressor) with five boosters and a seven stage high pressure compressor.

Combustion chamber is annular.

Turbine is axial, four stage, reactive, consisting of an one stage high pressure turbine and a three stage low pressure turbine (fan turbine).

Petaloideous mixing chamber is arranged before uncontrolled jet nozzle.

The engine passed certification test in 2001 – 2002.

Technical features

Takeoff mode ($\mathbf{H = 0\,m}$, $\mathbf{V_{fl} = 0\frac{km}{h}}$, ISA):

Thrust	**36,82 kN (3755 kgf)**;
Specific fuel consumption	$\mathbf{0{,}04\ \frac{kg}{N \cdot h}}\left(\mathbf{0{,}395\ \frac{kg}{kgf \cdot h}}\right)$;
Total pressure ratio	**15,87**;
Bypass ratio	**4,77**;
Turbine inlet temperature	**1455 K**;
Total air consumption	$\mathbf{125{,}3\ \frac{kg}{s}}$.

Cruise mode ($\mathbf{H = 11000\,m}$, $\mathbf{V_{fl} = 800\frac{km}{h}}$):

Thrust	**7,6 kN (775 kgf)**;
Specific fuel consumption	$\mathbf{0{,}064\ \frac{kg}{N \cdot h}}\left(\mathbf{0{,}63\ \frac{kg}{kgf \cdot h}}\right)$.

Overall sizes:

length	**3010 mm**;
width	**1341 mm**;
height	**1549 mm**.
Net engine mass	**765 kg**.

Application. Two engines driven passenger airplane Tu-324 and Yak-48, number of passengers – to **50 peop.**

1.13 Turbofan engine AI-222-25

TFE AI-222-25 is a two shaft engine with primary and secondary flows mixing. Modular designing concept is applied in this engine.

Compressor is axial, two spool, has a two stage, heavily loaded fan (low pressure compressor) and an eight stage high pressure compressor with movable inlet guide vanes and three rows of guide vanes. Fan disks and fan blades are made bodily from titanium alloy

Combustion chamber – annular.

Turbine is axial, two stage, reactive, consists of an one stage high pressure turbine and an one stage low pressure turbine. Turbine blades are manufactured by casting with controlled crystallization.

Jet nozzle is common for both, primary and secondary flows.

The engine passed certification test in 2005-2006.

Technical features

Takeoff mode ($\mathbf{H = 0\,m}$, $\mathbf{V_{fl} = 0\,\frac{km}{h}}$, ISA):

Thrust	**24,5 kN (2500 kgf)**;
Specific fuel consumption	$\mathbf{0{,}065\,\frac{kg}{N \cdot h}\left(0{,}64\,\frac{kg}{kgf \cdot h}\right)}$;
Total pressure ratio	**15,4**;
Bypass ratio	**1,18**;
Turbine inlet temperature	**1470 K**;
Total air consumption	$\mathbf{49{,}4\,\frac{kg}{s}}$.

Cruise mode ($\mathbf{H = 11000\,m}$, $\mathbf{V_{fl} = 800\,\frac{km}{h}}$):

Thrust	**2,9 kN (300 kgf)**;
Specific fuel consumption	$\mathbf{0{,}089\,\frac{kg}{N \cdot h}\left(0{,}875\,\frac{kg}{kgf \cdot h}\right)}$.

Overall sizes:

length	**2238 mm**;
width	**860 mm**;
height	**1102 mm**.
Net engine mass	**440 kg**.

Application. An one engine driven trainer Yak-130.

1.14 Turboshaft engine AI-450

TShE AI-450 is turboshaft engine with free turbine.

Engine consists of three components:

– gas generator,

– gearbox with radiator,

– free turbine.

Compressor is centrifugal, one stage with the one side air intake.

Combustion chamber is annular, loop.

Gas generator turbine is axial, one stage, reactive.

Free turbine is axial, one stage, reactive.

Nozzle has central body and provides gases withdrawal to the atmosphere.

Gearbox R-450 is a two stage with helical cylindrical gears, has ratio equal to 6,5.

Technical features

Takeoff mode ($\mathbf{H = 0\ m}$, $\mathbf{V_{fl} = 0 \frac{km}{h}}$, ISA):

Power	**342 kW (465 hp)**;
Specific fuel consumption	$\mathbf{0{,}353 \frac{kg}{kW \cdot h}} \left(\mathbf{0{,}260 \frac{kg}{hp \cdot h}} \right)$;
Pressure ratio	**7,33**;
Turbine inlet temperature	**1420 K**;
Total air consumption	$\mathbf{1{,}72 \frac{kg}{s}}$;
Overall sizes:	
length	**965 mm**;
width	**554 mm**;
height	**635 mm**.
Net engine mass	**103 kg**.

Application. Two engines driven different purpose helicopters Ka-226, Ka-228, Ka-215, Ka-115 ($\mathbf{M_{payload} = 1{,}5...4\ tonnes}$).

2 AIRCRAFT GAS-TURBINE ENGINES

Moscow scientific-production enterprise (SPE) “Saturn” n.a. A. M. Lyulka

Scientific-production enterprise was founded in 1946 and was known as State experimental enterprise №165 (Ministry of aviation of the USSR).

Chief designers:

Hero of Socialist Labour, academician	A. M. Lyulka (1946 – 1984 years);
PhD, professor	V. I. Chepkin (from 1984).

2.1 Turbojet engine TR-1

TJE TR-1 is the first soviet turbojet, a single shaft engine.
Compressor is axial, eight stage. Rotor of compressor is drum type.
Combustion chamber is annular.
Turbine is axial, one stage, reactive.
Jet nozzle is uncontrolled with central body.
The engine passed certification tests in 1947.

Technical features

Takeoff mode ($\mathbf{H = 0\ m}$, $\mathbf{V_{fl} = 0\ \frac{km}{h}}$, ISA):

Thrust	**13,33 kN (1360 kgf)**;
Specific fuel consumption	$\mathbf{0{,}132\ \frac{kg}{N \cdot h}}\left(\mathbf{1{,}29\ \frac{kg}{kgf \cdot h}}\right)$;
Total pressure ratio	**3,16**;
Turbine inlet temperature	**1050 K**;
Total air consumption	$\mathbf{31{,}5\ \frac{kg}{s}}$;
Overall sizes:	
length	**3860 mm**;
engine diameter	**856 mm**.
Net engine mass	**856 kg**.

Application. Four engines driven bomber Il-22 ($\mathbf{V_{max} = 718\ \frac{km}{h}}$, $\mathbf{M_0 = 24\ tonnes}$, $\mathbf{M_{payload} = 2\ tonnes}$); two engines driven fighter Su-11 ($\mathbf{V_{max} = 940\ \frac{km}{h}}$, $\mathbf{M_0 = 6{,}35\ tonnes}$).

2.2 Turbojet engine AL-5

TJE AL-5 is a single shaft engine.
Compressor is axial, seven stage.
Combustion chamber is annular.
Turbine is axial, one stage, reactive.
Jet nozzle is uncontrolled with central body.
The engine passed flight tests in 1949-1952.

Technical features

Takeoff mode ($\mathbf{H = 0\ m}$, $\mathbf{V_{fl} = 0\ \frac{km}{h}}$, ISA):

Thrust	**49 kN (5000 kgf)**;
Specific fuel consumption	$\mathbf{0{,}097\ \frac{kg}{N \cdot h}\left(0{,}95\ \frac{kg}{kgf \cdot h}\right)}$;
Total pressure ratio	**4,5**;
Turbine inlet temperature	**1100 K**;
Total air consumption	$\mathbf{95\ \frac{kg}{s}}$;
Overall sizes:	
length	**4300 mm**;
engine diameter	**1200 mm**.
Net engine mass	**1170 kg**.

Application. Two engines driven bomber Il-46 ($\mathbf{V_{max} = 718\ \frac{km}{h}}$, $\mathbf{M_0 = 24\ tonnes}$, $\mathbf{M_{payload} = 2\ tonnes}$); two engines driven fighter Su-11 ($\mathbf{V_{max} = 1190\ \frac{km}{h}}$, $\mathbf{M_0 = 9{,}3\ tonnes}$)

2.3 Afterburning turbojet engine AL-7F-1

ATJE AL-7F-1 is a single shaft engine of the second generation with afterburning and controlled jet nozzle.

Compressor is axial, nine stage. Compressor rotor is drum and disk type with central coupling bolt.

Combustion chamber is annular.

Turbine is axial, two stage, reactive.

Jet nozzle is controlled, multifolding.

Serial manufacturing started in 1959.

Technical features

Takeoff mode ($\mathbf{H = 0\ m}$, $\mathbf{V_{fl} = 0\ \frac{km}{h}}$, ISA):

Thrust with afterburning	**90,2 kN (9200 kgf)**;
Specific fuel consumption with afterburning	$\mathbf{0{,}204\ \frac{kg}{N \cdot h}\left(2\ \frac{kg}{kgf \cdot h}\right)}$;
Total pressure ratio	**9,1**;
Turbine inlet temperature	**1133 K**;
Total air consumption	$\mathbf{114\ \frac{kg}{s}}$;
Specific fuel consumption on a cruise mode	$\mathbf{0{,}093\ \frac{kg}{N \cdot h}\left(0{,}91\ \frac{kg}{kgf \cdot h}\right)}$;
Overall sizes:	
length	**6630 mm**;
engine diameter	**1250 mm**.
Net engine mass	**2010 kg**.

Application. One engine driven fighter-bomber Su-7 ($\mathbf{V_{max} = 2120\ \frac{km}{h}}$, $\mathbf{M_0 = 13{,}6\ tonnes}$); one engine driven fighter-interceptor Su-9 ($\mathbf{V_{max} = 2120\ \frac{km}{h}}$, $\mathbf{M_0 = 14\ tonnes}$).

Modifications. ATJE Al-7F-2 for one-engine driven fighter-interceptor Su-11 ($\mathbf{V_{max} = 2340\ \frac{km}{h}}$, $\mathbf{M_0 = 14\ tonnes}$).

Technical features

Takeoff mode ($\mathbf{H = 0\ m}$, $\mathbf{V_{fl} = 0\ \frac{km}{h}}$, ISA):

Thrust with afterburning	**99,1 kN (10100 kgf)**;
Specific fuel consumption with afterburning	$\mathbf{0{,}204\ \frac{kg}{N \cdot h}\left(2\ \frac{kg}{kgf \cdot h}\right)}$;
Total pressure ratio	**9,3**;
Turbine inlet temperature	**1200 K**;
Total air consumption	$\mathbf{115\ \frac{kg}{s}}$;

Specific fuel consumption at cruise mode	$\mathbf{0{,}091\,\frac{kg}{N\cdot h}\left(0{,}89\,\frac{kg}{kgf\cdot h}\right)}$.
Overall sizes:	
length	**6650 mm**;
engine diameter	**1300 mm**.
Net engine mass	**2100 kg**.

2.4 Afterburning turbojet engine AL-21F-3

ATJE AL-21F-3 is a single shaft engine of the third generation with afterburning and supersonic controlled jet nozzle.

Compressor is axial, fourteen stage. Compressor rotor is drum and disk type with central coupling bolt. Inlet guide vanes, vanes of first four stages and last five stages are movable. They are controlled according to the engine operating mode.

Combustion chamber is tube-annular.

Turbine is axial, three stage, reactive.

Jet nozzle is supersonic, controlled, multifolding.

Serial manufacturing since 1970.

Technical features

Takeoff mode ($\mathbf{H=0\,m}$, $\mathbf{V_{fl}=0\,\frac{km}{h}}$, ISA):

Thrust with afterburning	**110 kN (11200 kgf)**;
Thrust without afterburning	**76,4 kN (7800 kgf);**
Specific fuel consumption with afterburning	$\mathbf{0{,}190\,\frac{kg}{N\cdot h}\left(1{,}86\,\frac{kg}{kgf\cdot h}\right)}$;
Specific fuel consumption without afterburning	$\mathbf{0{,}090\,\frac{kg}{N\cdot h}\left(0{,}86\,\frac{kg}{kgf\cdot h}\right)}$;
Total pressure ratio	**14,6**;
Turbine inlet temperature	**1385 K**;
Total air consumption	$\mathbf{104\,\frac{kg}{s}}$;
Specific fuel consumption at cruise mode	$\mathbf{0{,}078\,\frac{kg}{N\cdot h}\left(0{,}76\,\frac{kg}{kgf\cdot h}\right)}$.
Overall sizes:	
length	**5340 mm**;
engine diameter	**1030 mm**.
Net engine mass	**1720 kg**.

Application. One engine driven fighter-bomber Su-17M, Su-20, Su-22M4 ($\mathbf{V_{max} = 1850 \frac{km}{h}}$, $\mathbf{M_0 = 19{,}5\ tonnes}$); two engines driven frontal bomber Su-24 ($\mathbf{V_{max} = 1400 \frac{km}{h}}$, $\mathbf{M_0 = 36\ tonnes}$), one engine driven fighter-bomber MiG-23B.

2.5 Afterburning turbofan engine AL-31F

ATFE AL-21F-3 is a two shaft engine of the fourth generation with low bypass ratio, with primary and secondary flows mixing, with common afterburning and supersonic controlled jet nozzle. Modular designing concept is applied in this engine.

Compressor is axial, thirteen stage, two spool, has a four stage low pressure compressor and a nine stage high pressure compressor. Inlet guide vanes, vanes of first and second stages of HPC are movable.

Combustion chamber is annular.

Turbine is axial, two stage, reactive, has an one stage high pressure turbine and an one stage low pressure turbine.

Afterburning is common for both ducts. Flows are mixed before frontal device (flame stabilizers).

Jet nozzle is supersonic, fully variable.

Serial manufacturing started in 1982.

Technical features

Takeoff mode ($\mathbf{H = 0\ m}$, $\mathbf{V_{fl} = 0 \frac{km}{h}}$, ISA):

Thrust with afterburning	**122,6 kN (11500 kgf)**;
Thrust without afterburning	**77 kN (7850 lgf);**
Specific fuel consumption with afterburning	$\mathbf{0{,}2 \frac{kg}{N \cdot h}} \left(\mathbf{1{,}96 \frac{kg}{kgf \cdot h}} \right)$;
Total pressure ratio	**23**;
Bypass ratio	**0,571;**
Turbine inlet temperature	**1660 K**;
Total air consumption	$\mathbf{104 \frac{kg}{s}}$;
Specific fuel consumption on a cruise mode	$\mathbf{0{,}069 \frac{kg}{N \cdot h}} \left(\mathbf{0{,}68 \frac{kg}{kgf \cdot h}} \right)$.

Overall sizes:

length	**4950 mm**;
engine diameter	**1240 mm.**
Net engine mass	**1530 kg**.

Application. Two engines driven fighter-interceptor Su-27 and its modifications ($\mathbf{V_{max} = 2500 \frac{km}{h}}$, $\mathbf{M_0 = 30\ tonnes}$); two engines driven frontal bomber Su-34 ($\mathbf{V_{max} = 1900 \frac{km}{h}}$, $\mathbf{M_0 = 45\ tonnes\ M_{payload} = 8\ tonnes}$).

3 AIRCRAFT GAS-TURBINE ENGINES

Moscow aeroengine scientific-production complex (SPC) “Sojuz”

Scientific-production complex was founded in 1943 and was known as State experimental enterprise №300 (Ministry of aviation of the USSR).

Chief designers:

Hero of Socialist Labour, academician	A. A. Mikulin (1943-1955 years);
Hero of Socialist Labour, academician	S. K. Tumansky (1955-1973 years);
Academician of the USSR National Academy	O. N. Favorsky (1973-1987 years);
PhD	V. K. Kobchenko (1987-2001 years);
PhD	V. A. Belousov (from 2001).

3.1 Turbojet engine AM-3 (RD-3)

TJE AM-3 is a single shaft engine. In the 50th it was the most powerful turbojet engine in the world.

Compressor is axial, eight stage, and subsonic.

Combustion chamber is tube-annular with 14 flame tubes.

Turbine is axial, two stage, reactive.

Jet nozzle is uncontrolled with central body.

Serial manufacturing started in 1952.

Technical features

Takeoff mode ($\mathbf{H = 0\ m}$, $\mathbf{V_{fl} = 0\frac{km}{h}}$, ISA):

Thrust	**85,3 kN (8700 kgf)**;
Specific fuel consumption	$\mathbf{0{,}102\ \frac{kg}{N \cdot h}\left(1{,}0\ \frac{kg}{kgf \cdot h}\right)}$;
Total pressure ratio	**6,2**;
Turbine inlet temperature	**1130 K**;
Total air consumption	$\mathbf{150\ \frac{kg}{s}}$.
Overall sizes:	
length	**5380 mm**;
engine diameter	**1400 mm.**
Net engine mass	**3100 kg**.

Application. Two engines driven bomber Tu-16 ($\mathbf{V_{max} = 1050\frac{km}{h}}$, $\mathbf{M_0 = 72\ tonnes}$, $\mathbf{M_{payload} = 9\ tonnes}$); two engines driven passenger airplane Tu-104 ($\mathbf{V_{cr} = 750...800\frac{km}{h}}$,number of passengers **–50 peop.**); four engines driven strategic bomber M-4 ($\mathbf{V_{max} = 800\frac{km}{h}}$, $\mathbf{M_0 = 184\ tonnes}$).

Modifications. RD-3M ($\mathbf{P_{takeoff} = 94{,}6kN\left(9650kgf\right)}$) for Tu-16 (from 1953) and Tu-104A (from 1956) with number of passengers from **70** to **115 peop.**

3.2 Turbojet engine AM-5

TJE AM-5 is a single shaft engine, which was designed by geometric and gas dynamic scaling of AM-3.It was the lightest turbojet engine in 50th.

Compressor is axial, eight stage, subsonic.

Combustion chamber is annular.

Turbine is axial, two stage, reactive.

Jet nozzle is uncontrolled with central body.

Serial manufacturing started from 1953.

Technical features

Takeoff mode ($\mathbf{H = 0\,m}$, $\mathbf{V_{fl} = 0\frac{km}{h}}$, ISA):

Thrust	**19,6 kN (2000 kgf)**;
Specific fuel consumption	$\mathbf{0{,}09\,\frac{kg}{N \cdot h}\left(0{,}88\,\frac{kg}{kgf \cdot h}\right)}$;
Total pressure ratio	**5,8**;
Turbine inlet temperature	**1130 K**;
Total air consumption	$\mathbf{37{,}5\,\frac{kg}{s}}$;
Overall sizes:	
length	**2770 mm**;
engine diameter	**670 mm.**
Net engine mass	**445 kg**.

Application. Two engines driven fighter-interceptor Yak-25 and its modificati

ons ($\mathbf{V_{max} = 1090\frac{km}{h}}$, $\mathbf{M_0 = 9{,}22\ tonnes}$).

3.3 Afterburning turbojet engine RD-9B

ATJE RD9-B is a single shaft engine with afterburning and controlled jet nozzle.

Compressor is nine stage with first supersonic stage.

Combustion chamber is tube-annular with ten flame tubes.

Turbine is axial, two stage, reactive.

Serial manufacturing started in 1955.

Technical features

Takeoff mode ($\mathbf{H = 0\,m}$, $\mathbf{V_{fl} = 0\frac{km}{h}}$, ISA):

Thrust with afterburning	**31,9 kN (3250 kgf)**;
Thrust without afterburning	**26 kN (2650 kgf);**
Specific fuel consumption with afterburning	$\mathbf{0{,}163\,\frac{kg}{N \cdot h}\left(1{,}6\,\frac{kg}{kgf \cdot h}\right)}$;
Specific fuel consumption without afterburning	$\mathbf{0{,}096\,\frac{kg}{N \cdot h}\left(0{,}94\,\frac{kg}{kgf \cdot h}\right)}$;
Total pressure ratio	**7,14**;
Turbine inlet temperature	**1150 K**;

Total air consumption	**43,3** $\frac{\mathbf{kg}}{\mathbf{s}}$;
Specific fuel consumption on a cruise mode	**0,09** $\frac{\mathbf{kg}}{\mathbf{N \cdot h}}$ $\left(\mathbf{0,88}\ \frac{\mathbf{kg}}{\mathbf{kgf \cdot h}}\right)$.
Overall sizes:	
length	**5560 mm**;
engine diameter	**660 mm.**
Net engine mass	**700 kg**.

Application. Two engines driven multipurpose fighter MiG-19 ($\mathbf{V_{max} = 1452 \frac{km}{h}, H_{max} = 18700 m}$, $\mathbf{M_0 = 7,65\ tonnes}$), which was the primary soviet supersonic mass manufactured aircraft.

3.4 Turbojet engine RU19-300

TJE RU19-300 is a single shaft engine of simplified scheme for the sport airplane Yak-32 and trainer Yak-30. Besides, since 1969 it is used as an auxiliary power plant for airplanes An-26, An-30.

Compressor is axial, seven stage, and subsonic.

Combustion chamber is annular.

Turbine is axial, one stage, reactive.

Jet nozzle is uncontrolled.

The engine has been putting into operation since 1961.

Technical features

Takeoff mode ($\mathbf{H = 0\ m}$, $\mathbf{V_{fl} = 0 \frac{km}{h}}$, ISA):

Thrust	**8,83 kN (900 kgf)**;
Specific fuel consumption	**0,12** $\frac{\mathbf{kg}}{\mathbf{N \cdot h}}$ $\left(\mathbf{1,18}\ \frac{\mathbf{kg}}{\mathbf{kgf \cdot h}}\right)$;
Total pressure ratio	**4,6**;
Turbine inlet temperature	**1150 K**;
Total air consumption	**16** $\frac{\mathbf{kg}}{\mathbf{s}}$.
Overall sizes:	
length	**1730 mm**;
engine diameter	**550 mm**.
Net engine mass	**225 kg**.

3.5 Afterburning turbojet engine R11F2-300

ATJE R11F2-300 is a two shaft engine with afterburning and controlled supersonic jet nozzle. It is the most abundant modification of R11F-300.

Compressor is axial, six stage, two spool, has a three stage low pressure compressor and a three stage high pressure compressor. Five front compressor stages are supersonic because of relative air velocity at the blade inlets.

Combustion chamber is tube-annular with ten flame tubes.

Turbine is axial, two stage, has an one stage high pressure turbine and an one stage low pressure turbine.

Nozzle is controlled, supersonic.

The engine has been putting into operation since 1962. More than 20000 engines of different modifications were manufactured till 1997.

Technical features

Takeoff mode ($\mathbf{H = 0\,m}$, $\mathbf{V_{fl} = 0\frac{km}{h}}$, ISA):

Thrust with afterburning	**60,2 kN (6120 kgf)**;
Thrust without afterburning	**41,2 kN (4200 kgf);**
Specific fuel consumption with afterburning	$\mathbf{0{,}225\frac{kg}{N\cdot h}\left(2{,}2\frac{kg}{kgf\cdot h}\right)}$;
Specific fuel consumption without afterburning	$\mathbf{0{,}096\frac{kg}{N\cdot h}\left(0{,}94\frac{kg}{kgf\cdot h}\right)}$;
Total pressure ratio	**8,75**;
Turbine inlet temperature	**1175 K**;
Total air consumption	$\mathbf{65{,}7\frac{kg}{s}}$.
Overall sizes:	
length	**4622 mm**;
engine diameter	**825 mm.**
Net engine mass	**1088 kg**.

Application. One engine driven frontal fighter MiG-21PF ($\mathbf{V_{max} = 2175\frac{km}{h}}$, $\mathbf{H_{max} = 19000m}$, $\mathbf{M_0 = 7{,}75\ tonnes}$), Two engines driven frontal bomber Yak-28B ($\mathbf{V_{max} = 1900\frac{km}{h}}$, $\mathbf{H_{max} = 16200m}$, $\mathbf{M_0 = 13{,}6\ tonnes}$), two engines driven fighter-interceptor Su-15 ($\mathbf{V_{max} = 2230\frac{km}{h}}$, $\mathbf{H_{max} = 18500m}$, $\mathbf{M_0 = 16{,}67\ tonnes}$).

3.6 Afterburning turbojet engine R29B-300

ATJE R29B-300 is a two shaft engine with afterburning and controlled supersonic jet nozzle.

Compressor is axial, eleven stage, two spool, has a five stage low pressure compressor and a six stage high pressure compressor.

Combustion chamber is annular.

Turbine is axial, two stage, has an one stage high pressure turbine and an one stage low pressure turbine.

Nozzle is controlled, supersonic.

The engine has been putting into operation since 1972.

Technical features

Takeoff mode ($\mathbf{H = 0\,m}$, $\mathbf{V_{fl} = 0\,\frac{km}{h}}$, ISA):

Thrust with afterburning	**112,7 kN (11500 kgf)**;
Thrust without afterburning	**78,45 kN (8000 kgf);**
Specific fuel consumption with afterburning	$\mathbf{0{,}184\,\frac{kg}{N \cdot h}\left(1{,}8\,\frac{kg}{kgf \cdot h}\right)}$;
Total pressure ratio	**12,2**;
Turbine inlet temperature	**1400 K**;
Total air consumption	$\mathbf{105\,\frac{kg}{s}}$;
Overall sizes:	
length	**4992 mm**;
engine diameter	**986 mm**.
Net engine mass	**1782 kg**.

Application. One engine driven multipurpose fighter MiG-23 ($\mathbf{V_{max} = 2445\,\frac{km}{h}}$, $\mathbf{H_{max} = 18600 m}$, $\mathbf{M_0 < 20\ tonnes}$) and MiG-27.

4. AIRCRAFT GAS-TURBINE ENGINES

Saint-Petersburg scientific-production enterprise(SPC) “Klimov plant”

The plant was founded in 1914, and design bureau – in 1946.

Chief designers:

Two times hero of Socialist Labour, academician	V. Y. Klimov (1946-1960 years);
Hero of Socialist Labour, PhD	S. P. Izotov (1960-1983 years);
PhD	A. A. Sarkisov (1983-2003 years);
Hero of the Soviet Union, PhD	A. I. Vatagin (from 2003).

4.1 Turbojet engine VK-1A

TJE VK-1A is a single shaft engine with centrifugal compressor.

Compressor is centrifugal, one stage, with two-side blades arrangement. Leaving the compressor, air enters nine individual combustion chambers. Then, gases enter turbine nozzle guide vanes through nine pipes of gas collector.

Turbine is axial, single stage, reactive.

Jet nozzle is uncontrolled, with central body.

The engine was put into operation from 1949 till 1958.

Technical features

Takeoff mode ($\mathbf{H = 0\ m}$, $\mathbf{V_{fl} = 0\ \frac{km}{h}}$, ISA):

Thrust	**26,5 kN (2700 kgf)**;
Specific fuel consumption	$\mathbf{0{,}109\ \frac{kg}{N \cdot h}}\left(\mathbf{1{,}07\ \frac{kg}{kgf \cdot h}}\right)$;
Total pressure ratio	**4,2**;
Turbine inlet temperature	**1170 K**;
Total air consumption	$\mathbf{48{,}2\ \frac{kg}{s}}$;
Overall sizes:	
length	**2640 mm**;
engine diameter	**1273 mm**.
Net engine mass	**872 kg**.

Application. One engine driven fighters MiG-15bis ($\mathbf{V_{max} = 1076\ \frac{km}{h}}$, $\mathbf{M_0 = 5\ tonnes}$), MiG-17 ($\mathbf{V_{max} = 1132\ \frac{km}{h}}$, $\mathbf{M_0 = 5{,}2\ tonnes}$), two engines driven bomber Il-28 ($\mathbf{V_{max} = 900\ \frac{km}{h}}$, $\mathbf{M_0 = 23{,}2\ tonnes}$).

4.2 Afterburning turbojet engine VK-1F

ATJE VK-1F is a two shaft engine with centrifugal compressor and afterburning. It is the modification of VK-1A and the first soviet ATJE.

Compressor is centrifugal, one stage with two-side blades arrangement. Leaving the compressor, air enters nine individual combustion chambers. Then, gases enter turbine nozzle guide vanes through nine pipes of gas collector.

Turbine is axial, one stage, reactive.

Engine has afterburning and jet nozzle.

The engine has been putting into operation since 1951.

Technical features

Takeoff mode ($\mathbf{H = 0\ m}$, $\mathbf{V_{fl} = 0\ \frac{km}{h}}$, ISA):

Thrust with afterburning	**33,1 kN (3380 kgf)**;
Thrust without afterburning	**26,0 kN (2650 kgf);**
Specific fuel consumption with afterburning	$\mathbf{0{,}204\ \frac{kg}{N \cdot h}\left(2{,}0\ \frac{kg}{kgf \cdot h}\right)}$;
Specific fuel consumption without afterburning	$\mathbf{0{,}114\ \frac{kg}{N \cdot h}\left(1{,}12\ \frac{kg}{kgf \cdot h}\right)}$;
Total pressure ratio	**4,36**;
Turbine inlet temperature	**1170 K**;
Total air consumption	$\mathbf{48{,}5\ \frac{kg}{s}}$;
Overall sizes:	
length	**4720 mm**;
diameter	**1273 mm**.
Net engine mass	**989 kg**.

Application. One engine driven frontal fighter MiG-17F.

4.3 Turboshaft engine TV2-117

TShE TV2-117 is a turboshaft engine with free turbine.

Compressor is axial, nine stage, one spool, with movable inlet guide vanes and next three stages guide vanes.

Combustion chamber is annular.

Turbine is axial, two shaft, four stage, reactive, has a two stage high pressure turbine and a two stage free turbine.

Divergent duct provides gases withdrawal to the atmosphere to the left or to the right, depending on the engine position in helicopter power plant.

Serial manufacturing started in 1965. More than 22000 engines were manufactured till 1997.

Technical features

Takeoff mode ($\mathbf{H = 0\,m}$, $\mathbf{V_{fl} = 0\,\frac{km}{h}}$, ISA):

Power	**1103 kW (1500 hp)**;
Specific fuel consumption	$\mathbf{0{,}375\,\frac{kg}{kW \cdot h}\left(0{,}275\,\frac{kg}{hp \cdot h}\right)}$;
Pressure ratio	**6,6**;
Turbine inlet temperature	**1125 K**;
Total air consumption	$\mathbf{8{,}4\,\frac{kg}{s}}$;
Overall sizes:	
length	**2842 mm**;
width	**555 mm**;
height	**748 mm**.
Net engine mass	**338 kg**.

Application. Two engines driven multipurpose helicopter Mi-8 ($\mathbf{V_{max} = 250\,\frac{km}{h}}$, $\mathbf{M_0 = 11{,}1\,tonnes}$, number of passenger is **24…28 peop.**).

4.4 Turboshaft engine TV3-117

TShE TV3-117 is a turboshaft engine with free turbine.

Compressor is axial, twelve stage, one spool, with movable inlet guide vanes and guide vanes of the next four stages.

Combustion chamber is annular.

Turbine is axial, two shaft, four stage, reactive, has a two stage high pressure turbine and a two stage free turbine.

Divergent duct provides gases withdrawal to the atmosphere to the left or to the right, depending on the engine position in helicopter power plant.

Serial manufacturing started in 1972.

Technical features

Takeoff mode ($\mathbf{H = 0\,m}$, $\mathbf{V_{fl} = 0\,\frac{km}{h}}$, ISA):

Power	**1635 kW (2235 hp)**;
Specific fuel consumption	$\mathbf{0{,}313\,\frac{kg}{kW \cdot h}\left(0{,}230\,\frac{kg}{hp \cdot h}\right)}$;
Pressure ratio	**9,5**;
Turbine inlet temperature	$\mathbf{1190\,K\left(TIT^{*}_{max} = 1263\,K\right)}$;

Total air consumption	$\mathbf{9\,\frac{kg}{s}}$.
Overall sizes:	
length	**2055 mm**;
width	**650 mm**;
height	**728 mm**.
Net engine mass	**285 kg**.

Engine TV3-117 has more than 15 modifications.

Application. Two engines driven cargo-combat helicopter Mi-24 ($\mathbf{V_{max} = 270\,\frac{km}{h}}$, $\mathbf{M_0 = 11{,}5\ tonnes}$, paratrooper number is **8 peop.**); naval helicopters Ka-27, Ka-29; cargo helicopter Ka-32, combat helicopter Ka-50 “Black shark” ($\mathbf{V_{max} = 350\,\frac{km}{h}}$, $\mathbf{M_0 = 10{,}8\ tonnes}$) and helicopters Mi-17, Mi-14, Mi-28, Mi-34, Mi-40, etc.

4.5 Turboprop engine TV7-117

TPE TV7-117 is an engine of the fourth generation. Modular designing concept is applied in this engine. It operates with six blade, reversible-feather propeller SV-34, designed by DB “Aerosila”.

Compressor is combined (has five axial stages and one centrifugal). Inlet guide vanes and guide vanes of the next two stages are movable.

Combustion chamber is annular, reverse flow.

Turbine has a two stage high pressure turbine and a two stage free turbine.

Propeller gearbox is designed according to the loop differential mechanism scheme.

Serial manufacturing started in 1991.

Technical features

Takeoff mode ($\mathbf{H = 0\,m}$, $\mathbf{V_{fl} = 0\,\frac{km}{h}}$, ISA):

Equivalent power	**1840 kW (2500 hp)**;
Specific fuel consumption	$\mathbf{0{,}272\,\frac{kg}{kW \cdot h}}\left(\mathbf{0{,}200\,\frac{kg}{hp \cdot h}}\right)$;
Pressure ratio	**16**;
Turbine inlet temperature	**1525 K**;
Total air consumption	$\mathbf{8{,}7\,\frac{kg}{s}}$.

Cruise mode ($\mathbf{H = 6000\,m}$, $\mathbf{V_{fl} = 575\frac{km}{h}}$):

Equivalent power	**1250 kW (1700 hp)**;
Specific fuel consumption	$\mathbf{0{,}245\frac{kg}{kW\cdot h}\left(0{,}180\frac{kg}{hp\cdot h}\right)}$.
Overall sizes:	
length	**2140 mm**;
width	**940 mm**;
height	**886 mm**.
Net engine mass	**530 kg**.

Application. Two engines driven passenger airplane of local airlines Il-114 ($\mathbf{V_{cr} = 500\frac{km}{h}}$, $\mathbf{M_0 = 21\,tonnes}$, number of passengers is **60…64 peop**.).

4.6 Turboprop engine VK-1500

TShE TV3-117VMA was a prototype for TPE VK-1500. Compressor, combustion chamber and turbine were improved significantly.

Compressor is axial, nine stage, one spool, with movable inlet guide vanes and guide vanes of the next two stages.

Combustion chamber is annular, shortened.

Turbine is axial, two shaft, reactive, has a two stage high pressure turbine and a two stage free turbine.

Free turbine shaft is lead in front and connected to the propeller gearbox.

Rig tests were carried out in 2001-2002.

Technical features

Takeoff mode ($\mathbf{H = 0\,m}$, $\mathbf{V_{fl} = 0\frac{km}{h}}$, ISA):

Power	**1102 kW (1500 hp)**;
Specific fuel consumption	$\mathbf{0{,}313\frac{kg}{kW\cdot h}\left(0{,}230\frac{kg}{hp\cdot h}\right)}$;
Pressure ratio	**7,4**;
Turbine inlet temperature	**1187 K**;
Total air consumption	$\mathbf{7{,}3\frac{kg}{s}}$.

Cruise mode ($\mathbf{H = 3000\,m}$, $\mathbf{V_{fl} = 400\frac{km}{h}}$):

Equivalent power	**772 kW (1050 hp)**;
Specific fuel consumption	$\mathbf{0{,}313\frac{kg}{kW\cdot h}\left(0{,}230\frac{kg}{hp\cdot h}\right)}$;

Overall sizes:	
length	**1714 mm**;
width	**708 mm**;
height	**847 mm**.
Net engine mass	**340 kg**.

Application. Two engines driven passenger airplane of local airlines An-38 ($\mathbf{V_{cr} = 400\frac{km}{h}}$, $\mathbf{M_0 = 8{,}8\ tonnes}$, number of passengers is **26 peop.**).

4.7 Afterburning turbofan engine RD-33

ATFE RD-33 is an engine of the fourth generation, two shaft with low bypass ratio, with primary and secondary flows mixing with common afterburning and supersonic controlled jet nozzle. Modular designing concept is applied in this engine.

Compressor is axial, thirteen stage, two spool, has a four stage low pressure compressor and a nine stage high pressure compressor. Inlet guide vanes, vanes of first and second stages of HPC are movable.

Combustion chamber is annular, through flow.

Turbine is axial, two stage, reactive, has an one stage high pressure turbine and an one stage low pressure turbine.

Afterburning is common for both ducts. Flows are mixed before frontal device (flame stabilizers) and near them.

High quality materials and most modern technologies were used in this engine manufacturing. Engine is equipped with multipurpose diagnostic system to monitor its condition.

The engine has been putting into operation since 1981.

Technical features

Takeoff mode ($\mathbf{H = 0\ m}$, $\mathbf{V_{fl} = 0\frac{km}{h}}$, ISA):

Thrust with afterburning	**81,4 kN (8300 kgf)**;
Thrust without afterburning	**49,4 kN (5040 kgf);**
Specific fuel consumption with afterburning	$\mathbf{0{,}214\ \frac{kg}{N \cdot h}\left(2{,}1\ \frac{kg}{kgf \cdot h}\right)}$;
Specific fuel consumption without afterburning	$\mathbf{0{,}0785\ \frac{kg}{N \cdot h}\left(0{,}77\ \frac{kg}{kgf \cdot h}\right)}$;
Total pressure ratio	**21**;
Bypass ratio	**0,49;**
Turbine inlet temperature	**1680 K**;

Total air consumption	**76,5** $\frac{\mathbf{kg}}{\mathbf{s}}$;
Specific fuel consumption on a cruise mode	**0,098** $\frac{\mathbf{kg}}{\mathbf{N \cdot h}}$ $\left(\mathbf{0,96}\ \frac{\mathbf{kg}}{\mathbf{kgf \cdot h}}\right)$.
Overall sizes:	
length	**4300 mm**;
width	**2000 mm**;
height	**1100 mm**.
Net engine mass	**1055 kg**.

Application. Two engines driven frontal fighter MiG-29 ($\mathbf{V_{max} = 2450}\frac{\mathbf{km}}{\mathbf{h}}$, $\mathbf{H_{max} = 17500\,m}$, $\mathbf{M_0 = 15,3\ tonnes}$) and its modifications MiG-29S (since 1986), MiG-29K (since 1988), MiG-29M (since 1989).

5 AIRCRAFT GAS-TURBINE ENGINES

Samara scientific-production complex(SPC) n.a. N.D. Kuznezov

The complex was founded in 1946.

Chief designers:

Two times hero of Socialist Labour, academician	N. D. Kuznezov (1949-1993 years);
PhD, professor	E. A. Grizenko (1993-2004 years);
PhD, professor	D. F. Fedorchenko (from 2004).

5.1 Turboprop engine NK-12

TPE NK-12 is a single shaft engine with two coaxial, contra rotating propellers ($\mathbf{D = 5,6\,m}$), with four blades each.

Compressor is axial, fourteen stage.

Combustion chamber is annular.

Turbine is axial, five stage, reactive.

Propeller gearbox is done according to planetary, differential type scheme.

Serial production was in 1954-1957.

Technical features

Takeoff mode ($\mathbf{H = 0\,m}$, $\mathbf{V_{fl} = 0\,\frac{km}{h}}$, ISA):

Equivalent power	**9200 kW (12500 hp)**;
Specific fuel consumption	$\mathbf{0{,}305\,\frac{kg}{kW \cdot h}\left(0{,}225\,\frac{kg}{hp \cdot h}\right)}$;
Pressure ratio	**9,5**;
Turbine inlet temperature	**1150 K**;
Total air consumption	$\mathbf{55\,\frac{kg}{s}}$;

Cruise mode ($\mathbf{H = 11000\,m}$, $\mathbf{V_{fl} = 720\,\frac{km}{h}}$):

Equivalent power	**4780 kW (6500 hp)**;
Specific fuel consumption	$\mathbf{0{,}224\,\frac{kg}{kW \cdot h}\left(0{,}165\,\frac{kg}{hp \cdot h}\right)}$.
Overall sizes:	
length	**6000 mm**;
engine diameter	**1050 mm**.
Net engine mass	**2900 kg**.

Application. Engine NK-12 passed flight testing jointly with experimental four engines driven strategic bomber Tu-95 ($\mathbf{V_{max} = 882\,\frac{km}{h}}$, $\mathbf{H_{max} = 11000\,m}$, $\mathbf{M_0 = 172\ tonnes}$) and also was used in power plant of some first airplanes Tu-95.

Modifications. NK-12MV (serial manufacturing in 1958-1979, $\mathbf{N_{eq\ takeoff} = 11030\,kW}$, $\mathbf{C_{sp\ eq\ takeoff} = 0{,}286\,\frac{kg}{kW \cdot h}\left(0{,}210\,\frac{kg}{hp \cdot h}\right)}$) to power four engines driven serial strategic bomber Tu-95 ($\mathbf{V_{max} = 860\,\frac{km}{h}}$, $\mathbf{H_{max} = 11600\,m}$, $\mathbf{M_0 = 182\ tonnes}$); NK-12MA (serial manufacturing in 1966-1980) to power four engines driven passenger airplane An-22 ($\mathbf{V_{max} = 600\,\frac{km}{h}}$, $\mathbf{M_0 = 205\ tonnes}$, $\mathbf{M_{payload} = 60\ tonnes}$).

5.2 Turboprop engine NK-4

TPE NK-4 is a single shaft with controllable-pitch propeller. Propeller gearbox is done according to planetary scheme with two-wheel planetary gears.

Compressor is axial, six stage.

Combustion chamber is annular.

Turbine is axial, three stage, reactive.

Flight testing was in 1957 – 1959.

Technical features

Takeoff mode ($\mathbf{H = 0\,m}$, $\mathbf{V_{fl} = 0\,\frac{km}{h}}$, ISA):

Equivalent power	**2940 kW (4000 hp)**;
Specific fuel consumption	$\mathbf{0{,}333\,\frac{kg}{kW \cdot h}\left(0{,}245\,\frac{kg}{hp \cdot h}\right)}$;
Pressure ratio	**7,7**;
Turbine inlet temperature	**1170 K**;
Total air consumption	$\mathbf{18{,}7\,\frac{kg}{s}}$.

Cruise mode ($\mathbf{H = 8000\,m}$, $\mathbf{V_{fl} = 630\,\frac{km}{h}}$):

Equivalent power	**1680 kW (2300 hp)**;
Specific fuel consumption	$\mathbf{0{,}282\,\frac{kg}{kW \cdot h}\left(0{,}207\,\frac{kg}{hp \cdot h}\right)}$.

Overall sizes:

length	**2770 mm**;
engine diameter	**1050 mm.**
Net engine mass	**870 kg**.

Application. Engines NK-4 provided flight testing of the four engines driven experimental airplanes An-10 and Il-18.

5.3 Turbofan engine NK-8

TFE NK-8 is a two shaft engine with primary and secondary flows mixing. Engine is equipped with thrust reversal.

Compressor is axial, a two spool, has a two stage fan (a low pressure compressor) with two boosters and a six stage high pressure compressor.

Combustion chamber – annular, has big number of fuel nozzles.

Turbine is axial, three stage, reactive, has an one stage high pressure turbine and a two stage low pressure turbine.

Mixing chamber is petaloideous.

Thrust reversal is arranged after mixing chamber before jet nozzle. It is equipped with set of deflecting ports, which are arranged on the opposite sides of the duct and with two flaps, which block the duct at reverse thrust mode and guide the gas flow through set of deflecting ports.

Serial production was in 1964 – 1969.

Technical features

Takeoff mode ($\mathbf{H = 0\,m}$, $\mathbf{V_{fl} = 0\,\frac{km}{h}}$, ISA):

Thrust	**93,2 kN (9500 kgf)**;
Specific fuel consumption	$\mathbf{0{,}0632\,\frac{kg}{N \cdot h}\left(0{,}62\,\frac{kg}{kgf \cdot h}\right)}$;
Total pressure ratio	**10,25**;
Bypass ratio	**0,984**;
Turbine inlet temperature	**1140 K**;
Total air consumption	$\mathbf{214\,\frac{kg}{s}}$.

Cruise mode ($\mathbf{H = 11000\,m}$, $\mathbf{V_{fl} = 850\,\frac{km}{h}}$):

Thrust	**22 kN (2250 kgf)**;
Specific fuel consumption	$\mathbf{0{,}0846\,\frac{kg}{N \cdot h}\left(0{,}83\,\frac{kg}{kgf \cdot h}\right)}$.

Overall sizes:	
length	**4766 mm**;
engine diameter	**1442 mm.**
Net engine mass	**2500 kg**.

Application. Long-ranged three engines driven passenger airplane Il-62 ($\mathbf{V_{cr} = 850\,\frac{km}{h}}$, $\mathbf{L_{fl} = 7550...10000\,km}$, $\mathbf{M_0 = 161{,}6\ tonnes}$, number of passengers – **168…186 peop.**).

5.4 Turbofan engine NK-8-2U

TFE NK-8-2U is a two shaft engine with primary and secondary flows mixing. Engine is equipped with thrust reversal. This is the most abundant modification of NK-8.

Compressor is axial, two spool, has a two stage fan (a low pressure compressor) with two boosters and a six stage high pressure compressor.

Combustion chamber is annular, has big number of fuel nozzles.

Turbine is axial, three stage, reactive, has a two stage high pressure turbine and a two stage low pressure turbine.

Mixing chamber is petaloideous type.

Thrust reversal is arranged after mixing chamber before jet nozzle. It is equipped with set of deflecting ports, which are arranged on the opposite sides of the duct and with two flaps, which block the duct at reverse thrust mode and guide the gas flow through set of deflecting ports.

The engine has been putting into operation since 1973.

Technical features

Takeoff mode ($\mathbf{H = 0\ m}$, $\mathbf{V_{fl} = 0\ \frac{km}{h}}$, ISA):

Thrust	**103 kN (10500 kgf)**;
Specific fuel consumption	$\mathbf{0{,}0591\ \frac{kg}{N \cdot h}\left(0{,}58\ \frac{kg}{kgf \cdot h}\right)}$;
Total pressure ratio	**10,8**;
Bypass ratio	**1,05**;
Turbine inlet temperature	**1156 K**;
Total air consumption	$\mathbf{228\ \frac{kg}{s}}$.

Cruise mode ($\mathbf{H = 11000\ m}$, $\mathbf{V_{fl} = 850\ \frac{km}{h}}$):

Thrust	**21,6 kN (2200 kgf)**;
Specific fuel consumption	$\mathbf{0{,}0785\ \frac{kg}{N \cdot h}\left(0{,}77\ \frac{kg}{kgf \cdot h}\right)}$.
Overall sizes:	
length	**4762 mm**;
engine diameter	**1442 mm**.
Net engine mass	**2350 kg**.

Application. Middle-range three engines driven passenger airplane Tu-154 ($\mathbf{V_{cr} = 850\ \frac{km}{h}}$, $\mathbf{L_{fl} = 3300...4500\ km}$, $\mathbf{M_0 = 98\ tonnes}$, number of passengers – **164…180 peop.**).

5.5 Turbofan engine NK-8-4

TFE NK-8-4 is a two shaft engine with primary and secondary flows mixing. This engine is the modification of NK8. The structure of the engine is very similar to the prototype NK8.

Serial production is in 1969 – 1979.

Technical features

Takeoff mode ($\mathbf{H = 0\,m}$, $\mathbf{V_{fl} = 0\frac{km}{h}}$, ISA):

Thrust	**103 kN (10500 kgf)**;
Specific fuel consumption	$\mathbf{0{,}061\frac{kg}{N \cdot h}\left(0{,}598\frac{kg}{kgf \cdot h}\right)}$;
Total pressure ratio	**10,8**;
Bypass ratio	**1,042**;
Turbine inlet temperature	**1190 K**;
Total air consumption	$\mathbf{227\frac{kg}{s}}$.

Cruise mode ($\mathbf{H = 11000\,m}$, $\mathbf{V_{fl} = 850\frac{km}{h}}$):

Thrust	**27 kN (2750 kgf)**;
Specific fuel consumption	$\mathbf{0{,}0826\frac{kg}{N \cdot h}\left(0{,}81\frac{kg}{kgf \cdot h}\right)}$.
Overall sizes:	
length	**5101 mm**;
engine diameter	**1442 mm**.
Net engine mass	**2440 kg**.

Application. Long-ranged four engines driven passenger airplane Il-62 ($\mathbf{V_{cr} = 850\frac{km}{h}}$, $\mathbf{L_{fl} = 7550...10000\,km}$, $\mathbf{M_0 = 161{,}1\,tonnes}$, number of passengers –**168…186 peop.**).

5.6 Turbofan engine NK-86

TFE NK-86 is a two shaft engine with primary and secondary flows mixing. Engine is equipped with thrust reversal.

Compressor is axial, two spool, has a two stage fan (low pressure compressor) with three boosters and a six stage high pressure compressor.

Combustion chamber is annular, has big number of fuel nozzles.

Turbine is axial, three stage, reactive, has a single stage high pressure turbine and a two stage low pressure turbine.

Mixing chamber is petaloideous type.

Thrust reversal is arranged after mixing chamber before jet nozzle. It is equipped with set of deflecting ports, which are arranged on the opposite sides

of the duct and with two flaps, which block the duct at reverse thrust mode and guide the gas flow through set of deflecting ports.

The engine has been putting into operation since 1980.

Technical features

Takeoff mode ($\mathbf{H = 0\,m}$, $\mathbf{V_{fl} = 0\,\frac{km}{h}}$, ISA):

Thrust	**127 kN (13000 kgf)**;
Specific fuel consumption	$\mathbf{0{,}053\,\frac{kg}{N \cdot h}\left(0{,}52\,\frac{kg}{kgf \cdot h}\right)}$;
Total pressure ratio	**12,93**;
Bypass ratio	**1,18**;
Turbine inlet temperature	**1172 K**;
Total air consumption	$\mathbf{288\,\frac{kg}{s}}$.

Cruise mode ($\mathbf{H = 11000\,m}$, $\mathbf{V_{fl} = 850\,\frac{km}{h}}$):

Thrust	**31,6 kN (3220 kgf)**;
Specific fuel consumption	$\mathbf{0{,}0754\,\frac{kg}{N \cdot h}\left(0{,}739\,\frac{kg}{kgf \cdot h}\right)}$.
Overall sizes:	
length	**5278 mm**;
engine diameter	**1455 mm**.
Net engine mass	**2750 kg**.

Application. Middle-ranged, wide-body, four engines driven passenger airplane Il-86 ($\mathbf{V_{cr} = 900...950\,\frac{km}{h}}$, $\mathbf{L_{fl} = 3600...5800\,km}$, number of passengers **–350 peop.**).

5.7 Afterburning turbofan engine NK-144A

ATFE NK-144A is a two shaft engine with low bypass ratio, with primary and secondary flows mixing, common afterburning and supersonic controlled jet nozzle.

Compressor is axial, two spool, has a three stage fan (low pressure compressor) with three boosters and a six stage high pressure compressor.

Combustion chamber is annular with big number of fuel nozzles.

Turbine is axial, three stage, reactive, has a two stage high pressure turbine and a two stage low pressure turbine.

Mixing chamber is petaloideous type.

Afterburning is common for both flows, flows mixing takes place before frontal device (flame stabilizers).

Jet nozzle is supersonic, variable.
Serial production was in 1971 – 1978.

Technical features

Takeoff mode ($\mathbf{H = 0\,m}$, $\mathbf{V_{fl} = 0\,\frac{km}{h}}$, ISA):

Thrust with afterburning	**196,7 kN (20000 kgf)**;
Thrust without afterburning	**148,2 kN (15000 kgf)**;
Specific fuel consumption with afterburning	$\mathbf{0{,}168\,\frac{kg}{N \cdot h}\left(1{,}65\,\frac{kg}{kgf \cdot h}\right)}$;
Total pressure ratio	**14,75**;
Bypass ratio	**0,6**;
Turbine inlet temperature	**1390 K**;
Total air consumption	$\mathbf{236\,\frac{kg}{s}}$.

Cruise mode ($\mathbf{H = 18000\,m}$, $\mathbf{V_{fl} = 2350\,\frac{km}{h}}$):

Thrust	**49 kN (5000 kgf)**;
Specific fuel consumption	$\mathbf{0{,}1845\,\frac{kg}{N \cdot h}\left(1{,}81\,\frac{kg}{kgf \cdot h}\right)}$.
Overall sizes:	
length	**7690 mm**;
engine diameter	**1355 mm**.
Net engine mass	**3540 kg**.

Application. Four engines driven supersonic passenger airplane Tu-144 ($\mathbf{V_{cr} = 2000...2350\,\frac{km}{h}}$, $\mathbf{L_{fl} = 3240\,km}$, $\mathbf{M_0 = 195\ tonnes}$, number of passengers – **100 peop.**). In 1987 project Tu-144 was closed. Existing airplanes are used as flying laboratories for developing supersonic airplanes of the secondary generation.

5.8 Afterburning turbofan engine NK-25

ATFE NK-25 is three shaft engine of the fourth generation, with primary and secondary flows mixing, common afterburning and supersonic variable jet nozzle. Modular designing concept is applied in this engine.

Compressor is axial, fifteen stage, three spool, has three stage fan (low pressure compressor), a five stage intermediate pressure compressor and a seven stage high pressure compressor.

Combustion chamber is annular with big number of fuel nozzles. It provides smokeless combustion.

Turbine is axial, four stage, reactive, has a two stage high pressure turbine with cooled one-crystal blades, an one stage intermediate pressure turbine and a two stage low pressure turbine.

Afterburning is common for both flows, flows mixing takes place before frontal device (flame stabilizers).

Jet nozzle is supersonic, variable.

The engine has been putting into operation since 1977.

Technical features

Takeoff mode ($\mathbf{H = 0\ m}$, $\mathbf{V_{fl} = 0\ \frac{km}{h}}$, ISA):

Thrust with afterburning	**245 kN (25000 kgf)**;
Thrust without afterburning	**142 kN (14500 kgf)**;
Specific fuel consumption with afterburning	$\mathbf{0{,}212\ \frac{kg}{N \cdot h}\left(2{,}08\ \frac{kg}{kgf \cdot h}\right)}$;
Total pressure ratio	**25,9**;
Bypass ratio	**1,45**;
Turbine inlet temperature	**1600 K**.

Application. Long-ranged two engines driven supersonic bomber Tu-22M-3 ($\mathbf{V_{max} = 2300\ \frac{km}{h}}$, $\mathbf{M_0 = 124\ tonnes}$, flight range – **2200 km**).

5.9 Afterburning turbofan engine NK-32

ATFE NK-32 is three shaft engine of the fourth generation, with primary and secondary flows mixing, common afterburning and supersonic variable jet nozzle. Modular designing concept is applied in this engine. This is the primary engine, where special technologies to reduce radar and infrared visibility were applied. Engine is the modification of ATFE NK-25.

Compressor is axial, fifteen stage, three spool, has three stage fan (low pressure compressor), a five stage intermediate pressure compressor and a seven stage high pressure compressor.

Combustion chamber is annular with big number of fuel nozzles. It provides smokeless combustion.

Turbine is axial, four stage, reactive, has an one stage high pressure turbine with cooled one-crystal blades, an one stage intermediate pressure turbine and a two stage low pressure turbine with directional solidification blades.

Afterburning is common for both flows, flows mixing takes place before frontal device (flame stabilizers).

Jet nozzle is supersonic, controlled, self-similar.

Serial production is since 1983.

Technical features

Takeoff mode ($\mathbf{H = 0\,m}$, $\mathbf{V_{fl} = 0\frac{km}{h}}$, ISA):

Thrust with afterburning	**245 kN (25000 kgf)**;
Thrust without afterburning	**137 kN (14000 kgf)**;
Total pressure ratio	**28,2**;
Bypass ratio	**1,36**;
Turbine inlet temperature	**1630 K**.
Overall sizes:	
length	**7430 mm**;
engine diameter	**1700 mm**.
Net engine mass	**3650 kg**.

Application. Four engines driven supersonic strategic bomber Tu-160 ($\mathbf{V_{max} = 2200\frac{km}{h}}$, $\mathbf{M_0 = 275\ tonnes}$, maximal flight distance – **13950 km**).

6 AIRCRAFT GAS-TURBINE ENGINES

Perm engine design bureau (EDB) “Aviadvigatel”

The engine design bureau was founded in 1938, and was known as RDB-19, since 1953 it designs gas turbine engines.

Chief designers:

Hero of Socialist Labour, PhD	A. D. Shvetsov (1938-1953 years);
Hero of Socialist Labour, corr. memb. of AS of the USSR	P. A. Soloviev (1953-1989 years);
PhD, professor	Y. E. Reshetnikov (1989-1997 years);
PhD, professor	A. A. Inozemzev (from 1997).

6.1 Turbofan engine D-20P

TFE D-20P is two shaft engine without primary and secondary flows mixing. It was the primary serially manufactured TFE, which was designed in the USSR.

Compressor is axial, eleven stage, two spool, has three stage low pressure compressor (LPC) and an eight stage high pressure compressor (HPC).

Combustion chamber – tube-annular.

Turbine is axial, three stage, reactive, has an one stage high pressure turbine (HPT) and a two stage low pressure turbine (LPT).

Jet nozzle is uncontrolled.

Serial production was in 1960 – 1977.

Technical features

Takeoff mode ($\mathbf{H = 0\,m}$, $\mathbf{V_{fl} = 0\,\frac{km}{h}}$, ISA):

Thrust	**53 kN (5400 kgf)**;
Specific fuel consumption	$\mathbf{0{,}0734\,\frac{kg}{N \cdot h}\left(0{,}72\,\frac{kg}{kgf \cdot h}\right)}$;
Total pressure ratio	**14**;
Bypass ratio	**1,0**;
Turbine inlet temperature	**1330 K**;
Total air consumption	$\mathbf{113\,\frac{kg}{s}}$.

Cruise mode ($\mathbf{H = 11000\,m}$, $\mathbf{V_{fl} = 800\,\frac{km}{h}}$):

Thrust	**11,3 kN (1150 kgf)**;
Specific fuel consumption	$\mathbf{0{,}0897\,\frac{kg}{N \cdot h}\left(0{,}88\,\frac{kg}{kgf \cdot h}\right)}$.
Overall sizes:	
length	**3304 mm**;
engine diameter	**915 mm**.
Net engine mass	**1468 kg**.

Application. Short-haul two engines driven passenger airplane Tu-124 ($\mathbf{V_{cr} = 750...850\,\frac{km}{h}}$, $\mathbf{M_0 = 37{,}6\ tonnes}$, number of passengers – **44…56 peop.**).

6.2 Turboshaft engine D-25V

TShE D-25V is a turboshaft engine with free turbine, which was designed using D-20P gas generator as a prototype.

Compressor is axial, nine stage, one spool.

Combustion chamber is tube-annular.

Turbine is axial, two shaft, three stage, reactive, has an one stage high pressure turbine (HPT), a two stage free turbine.

Divergent duct provides gases withdrawal to the atmosphere to the left or to the right, depending on the engine position in a helicopter power plant.

Serial manufacturing was in 1960 – 1981.

Technical features

Takeoff mode ($\mathbf{H = 0\ m}$, $\mathbf{V_{fl} = 0\ \frac{km}{h}}$, ISA):

Power	**4050 kW (5500 hp)**;
Specific fuel consumption	$\mathbf{0{,}390\ \frac{kg}{kW \cdot h}}\left(\mathbf{0{,}287\ \frac{kg}{hp \cdot h}}\right)$;
Pressure ratio	**5,6**;
Turbine inlet temperature	**1240 K**;
Total air consumption	$\mathbf{26\ \frac{kg}{s}}$.
Overall sizes:	
length	**2737 mm**;
width	**1086 mm**;
height	**1158 mm**.
Net engine mass	**1323 kg**.

Application. Heavy two engines driven transport helicopter Mi-6 ($\mathbf{V_{max} = 250\ \frac{km}{h}}$, $\mathbf{M_{payload} = 12\ tonnes}$ or number of passengers **65…90 peop.**); since 1963 – helicopter Mi-10.

6.3 Turbofan engine D-30 (II line)

TFE D-30 (II line) is a two shaft engine with primary and secondary flows mixing. Engine is equipped with thrust reversal. Primary line of this engine was not equipped with thrust reversal.

Compressor is axial, two spool, thirteen stage, has a four stage low pressure compressor with primary supersonic stage and a nine stage high pressure compressor.

Combustion chamber is tube-annular with nine flame tubes.

Turbine is axial, four stage, reactive, has a two stage high pressure turbine and a two stage low pressure turbine.

Mixing chamber is petaloideous type.

Thrust reversal is arranged after mixing chamber before jet nozzle. It is equipped with set of deflecting ports, which are arranged on the opposite sides of the duct and with two flaps, which block the duct at reverse thrust mode and guide the gas flow through set of deflecting ports.

Serial production was in 1967 – 1987.

Technical features

Takeoff mode ($\mathbf{H = 0\,m}$, $\mathbf{V_{fl} = 0\,\frac{km}{h}}$, ISA):

Thrust	**66,7 kN (8600 kgf)**;
Specific fuel consumption	$\mathbf{0{,}0633\,\frac{kg}{N \cdot h}\left(0{,}62\,\frac{kg}{kgf \cdot h}\right)}$;
Total pressure ratio	**18,66**;
Bypass ratio	**1,0**;
Turbine inlet temperature	**1357 K**;
Total air consumption	$\mathbf{127\,\frac{kg}{s}}$.

Cruise mode ($\mathbf{H = 11000\,m}$, $\mathbf{V_{fl} = 800\,\frac{km}{h}}$):

Thrust	**15,7 kN (1600 kgf)**;
Specific fuel consumption	$\mathbf{0{,}0796\,\frac{kg}{N \cdot h}\left(0{,}78\,\frac{kg}{kgf \cdot h}\right)}$.
Overall sizes:	
length	**3983 mm**;
engine diameter	**963 mm**.
Net engine mass	**1550 kg**.

Application. Short-haul, two engines driven passenger airplane Tu-134 and its modifications ($\mathbf{V_{cr} = 750...850\,\frac{km}{h}}$, $\mathbf{M_0 = 47{,}6\ tonnes}$, number of passengers –**72…96 peop.**).

6.4 Turbofan engine D-30KU

TFE D-30KU is a two shaft engine with primary and secondary flows mixing. Engine is equipped with thrust reversal.

Compressor is axial, two spool, fourteen stage, has a three stage low pressure compressor and an eleven stage high pressure compressor.

Combustion chamber – tube-annular with twelve flame tubes.

Turbine is axial, six stage, reactive, has a two stage high pressure turbine and a four stage low pressure turbine.

Mixing chamber is petaloideous type.

Thrust reversal is arranged after nozzle discharge section.

Serial production – since 1971.

Technical features

Takeoff mode ($\mathbf{H = 0\,m}$, $\mathbf{V_{fl} = 0\,\frac{km}{h}}$, ISA):

Thrust	**108 kN (11000 kgf)**;
Specific fuel consumption	$\mathbf{0{,}056\,\frac{kg}{N \cdot h}\left(0{,}55\,\frac{kg}{kgf \cdot h}\right)}$;
Total pressure ratio	**19,5**;
Bypass ratio	**2,42**;
Turbine inlet temperature	**1385 K**;
Total air consumption	$\mathbf{269\,\frac{kg}{s}}$.

Cruise mode ($\mathbf{H = 11000\,m}$, $\mathbf{V_{fl} = 850\,\frac{km}{h}}$):

Thrust	**27 kN (2750 kgf)**;
Specific fuel consumption	$\mathbf{0{,}0714\,\frac{kg}{N \cdot h}\left(0{,}7\,\frac{kg}{kgf \cdot h}\right)}$.
Overall sizes:	
length	**5698 mm**;
engine diameter	**1450 mm**.
Net engine mass	**2650 kg**.

Application. Since 1984 D-30KU has been used for middle-range, three engines driven passenger airplane Tu-154M ($\mathbf{V_{cr} = 850\,\frac{km}{h}}$, $\mathbf{M_0 = 100\ tonnes}$, number of passengers –**164…175 peop.**); since 1974 D-30KU is used for long-range, four engines driven passenger airplane Il-62M ($\mathbf{V_{cr} = 850...900\,\frac{km}{h}}$, $\mathbf{L = 10000\,km}$, $\mathbf{M_0 = 165\ tonnes}$, number of passengers –**138…156 peop.**).

Modification. D-30KP, which is produced since 1972 ($\mathbf{P_{takeoff} = 118\,kN}$, $\mathbf{T_G = 1427\,K}, \mathbf{G_{air} = 280\,\frac{kg}{s}}$) for four engines driven cargo airplane Il-76T ($\mathbf{V_{cr} = 800\,\frac{km}{h}}, \mathbf{L = 5000\,km}$, $\mathbf{M_0 = 190\ tonnes}$, $\mathbf{M_{payload} = 40\ tonnes}$) and for air refueller Il-78.

6.5 Afterburning turbofan engine D-30F6

ATFE D-30F6 is a two shaft engine with low bypass ratio, with primary and secondary flows mixing, common afterburning and controlled jet nozzle.

Compressor is axial, fifteen stage, two spool, has a five stage low pressure compressor and a ten stage high pressure compressor. Guide vanes of high pressure compressor stages are movable.

Combustion chamber – tube-annular with twelve flame tubes.

Turbine is axial, four stage, reactive, has a two stage high pressure turbine and a two stage low pressure turbine.

Afterburning is common for both flows.

Jet nozzle is supersonic, controlled.

The engine has been putting into operation since 1980.

Technical features

Takeoff mode ($\mathbf{H = 0\,m}$, $\mathbf{V_{fl} = 0\,\frac{km}{h}}$, ISA):

Thrust with afterburning	**151,9 kN (15500 kgf)**;
Thrust without afterburning	**93,1 kN (9500 kgf)**;
Specific fuel consumption with afterburning	$\mathbf{0{,}194\ \frac{kg}{N \cdot h}\left(1{,}96\ \frac{kg}{kgf \cdot h}\right)}$;
Specific fuel consumption without afterburning	$\mathbf{0{,}734\ \frac{kg}{N \cdot h}\left(0{,}72\ \frac{kg}{kgf \cdot h}\right)}$;
Total pressure ratio	**21,15**;
Bypass ratio	**0,57**;
Turbine inlet temperature	**1640 K**;
Fuel consumption	$\mathbf{150\,\frac{kg}{s}}$;
Net engine mass	**2416 kg**.

Application. Two engines driven fighter-interceptor MiG-31 and its modifications ($\mathbf{V_{max} = 2550\,\frac{km}{h}}$, $\mathbf{H_{max} = 25000\,m}$, $\mathbf{M_0 = 41\,tonnes}$).

6.6 Turbofan engine PS-90A

TFE PS-90A is a two shaft engine with primary and secondary flows mixing. Engine is equipped with thrust reversal arranged in bypass. Modular designing concept is applied in this engine.

Compressor is axial, two spool, fourteen stage, has one stage fan (low pressure compressor) with two boosters and a thirteen stage high pressure compressor. Inlet guide vanes and two next stages guide vanes of HPC are movable.

Combustion chamber is tube-annular.

Turbine is axial, six stage, reactive, has a two stage high pressure turbine and a four stage low pressure turbine (fan turbine).

Mixing chamber is petaloideous type, with next arranged jet nozzle.

Serial production – since 1993.

Technical features

Takeoff mode ($\mathbf{H = 0\ m}$, $\mathbf{V_{fl} = 0\ \frac{km}{h}}$, ISA):

Thrust	**157 kN (16000 kgf)**;
Specific fuel consumption	$\mathbf{0{,}0381\ \frac{kg}{N \cdot h}\left(0{,}374\ \frac{kg}{kgf \cdot h}\right)}$;
Total pressure ratio	**35,5**;
Bypass ratio	**4,5**;
Turbine inlet temperature	**1565 K**;
Total air consumption	$\mathbf{470\ \frac{kg}{s}}$.

Cruise mode ($\mathbf{H = 11000\ m}$, $\mathbf{V_{fl} = 850\ \frac{km}{h}}$):

Thrust	**34,4 kN (3500 kgf)**;
Specific fuel consumption	$\mathbf{0{,}06\ \frac{kg}{N \cdot h}\left(0{,}595\ \frac{kg}{kgf \cdot h}\right)}$.
Overall sizes:	
length	**5330 mm**;
engine diameter	**1900 mm**.
Net engine mass	**2950 kg**.

Application. Middle-range, two engines driven passenger airplane Tu-204 ($\mathbf{V_{cr} = 850\ \frac{km}{h}}$, $\mathbf{M_0 = 93{,}5\ tonnes}$, number of passengers – **214 peop.**); long-range, four engines driven passenger airplane Il-96-300 ($\mathbf{V_{cr} = 850...900\ \frac{km}{h}}$, $\mathbf{L = 10000\ km}$, $\mathbf{M_0 = 216\ tonnes}$, number of passengers – **300 peop.**);four engines driven cargo airplane Il-76MF ($\mathbf{V_{cr} = 750...800\ \frac{km}{h}}$, $\mathbf{M_0 = 270\ tonnes}$, $\mathbf{M_{payload} = 52\ tonnes}$).

7 AIRCRAFT GAS-TURBINE ENGINES

Rybinsk engine design bureau (REDB)

The development design bureau was founded in 1943, since 1952 it designs gas turbine engines.

Chief designers:

PhD	V. A. Dobrinin (1943-1960 years);
PhD	P. A. Kolesov (1960-1984 years);
PhD	V. I. Galigusov (1984-1988 years);
PhD	A. S. Novikov (1988-1998 years);
PhD	M. L. Kuzmenko (from 1998).

In 1997 REDB was associated with vehicle “Rybinsk engines”, and in 1998 there enterprise “Rybinsk motors”.

In July, 2001 enterprise ”DDB “Saturn” was founded by association of “Rybinsk motors” and DDB “Saturn”.

7.1 Turbojet engine VD-7

TJE VD-1 is a single shaft engine with uncontrolled nozzle.
Compressor is axial, nine stage with primary supersonic stage.
Combustion chamber is tube-annular.
Turbine is axial, two stage, reactive.
Jet nozzle is uncontrolled with central body.
The engine has been putting into operation since 1958.

Technical features

Takeoff mode ($\mathbf{H = 0\ m}$, $\mathbf{V_{fl} = 0\ \frac{km}{h}}$, ISA):

Thrust	**107,8 kN (11000 kgf)**;
Specific fuel consumption	$\mathbf{0{,}082\ \frac{kg}{N \cdot h}\left(0{,}8\ \frac{kg}{kgf \cdot h}\right)}$;
Total pressure ratio	**11,2**;
Turbine inlet temperature	**1090 K**;
Total air consumption	$\mathbf{187\ \frac{kg}{s}}$;

Cruise mode ($\mathbf{H = 11000\ m}$, $\mathbf{V_{fl} = 800\frac{km}{h}}$, ISA):

Thrust	**20,1 kN (2050 kgf)**;
Specific fuel consumption	$\mathbf{0{,}0866\frac{kg}{N \cdot h}\left(0{,}85\frac{kg}{kgf \cdot h}\right)}$.
Overall sizes:	
length	**4247 mm**;
engine diameter	**1288 mm**.
Net engine mass	**2765 kg**.

Application. Four engines driven strategic bomber 3M (by V. M. Myasishchev) ($\mathbf{V_{max} = 950\frac{km}{h}}$, $\mathbf{M_0 = 190\ tonnes}$).

Modification. ATJE VD-7M2 ($\mathbf{P_{takeoff\ afterburning} = 157kN(160000\ kgf)}$, $\mathbf{M_0 = 190\ tonnes}$), which was serially manufactured from 1965 till 1977 for two engines driven supersonic bomber Tu-22K (($\mathbf{V_{max} = 1740\frac{km}{h}}$, $\mathbf{H_{max} = 13500\ m}$, $\mathbf{M_0 = 92\ tonnes}$, $\mathbf{M_{payload} = 9\ tonnes}$).

7.2 Turbojet engine RD36-51A

TJE RD-51A is a powerful single shaft turbojet engine with controlled supersonic jet nozzle.

Compressor is axial, fourteen stage with primary supersonic stage. Five front and five rear stages guide vanes are movable.

Combustion chamber is tube-annular.

Turbine is axial, three stage, reactive.

Jet nozzle is supersonic, controlled, variable.

Flight testing was in 1974 - 1978.

Technical features

Takeoff mode ($\mathbf{H = 0\ m}$, $\mathbf{V_{fl} = 0\frac{km}{h}}$, ISA):

Thrust	**196,7 kN (20000 kgf)**;
Specific fuel consumption	$\mathbf{0{,}09\frac{kg}{N \cdot h}\left(0{,}882\frac{kg}{kgf \cdot h}\right)}$;
Total pressure ratio	**15,8**;
Turbine inlet temperature	**1355 K**;
Total air consumption	$\mathbf{274\frac{kg}{s}}$.

Cruise mode ($\mathbf{H = 18000\ m}$, $\mathbf{V_{fl} = 2350\frac{km}{h}}$, ISA):

Thrust	**49 kN (5000 kgf)**;
Specific fuel consumption	$\mathbf{0{,}125\ \frac{kg}{N \cdot h}\left(1{,}23\ \frac{kg}{kgf \cdot h}\right)}$;
Overall sizes:	
length	**5976 mm**;
engine diameter	**1486 mm**.
Net engine mass	**3900 kg**.

Application. Four engines driven supersonic passenger airplane Tu-144D ($\mathbf{V_{cr} = 2000...2350\frac{km}{h}}$, $\mathbf{L_{fl} = 5800...6200\ km}$, $\mathbf{M_0 = 207\ tonnes}$ number of passengers – **100…150 peop.**).

7.3. Turboprop engine TVD-1500B

TPE TVD-1500B is a turboprop engine with external propeller gearbox. Modular designing concept is applied in this engine.

Compressor is combined, consists of three axial stages and an one centrifugal stage.

Combustion chamber is annular, reverse flow.

Turbine is axial, two shaft, four stage, reactive, has a two stage high pressure turbine and a two stage free turbine.

Jet nozzle is uncontrolled with central body.

Rig tests were carried out in 1996.

Technical features

Takeoff mode ($\mathbf{H = 0\ m}$, $\mathbf{V_{fl} = 0\frac{km}{h}}$, ISA):

Equivalent power	**1028 kW (1400 hp)**;
Specific fuel consumption	$\mathbf{0{,}284\ \frac{kg}{kW \cdot h}\left(0{,}209\ \frac{kg}{hp \cdot h}\right)}$;
Pressure ratio	**14,4**;
Turbine inlet temperature	**1540 K**;
Total air consumption	$\mathbf{4{,}3\ \frac{kg}{s}}$.

Cruise mode ($\mathbf{H = 3000\ m}$, $\mathbf{V_{fl} = 400\frac{km}{h}}$):

Power	**736 kW (1000 hp)**;
Specific fuel consumption	$\mathbf{0{,}282\ \frac{kg}{kW \cdot h}}\left(\mathbf{0{,}208\ \frac{kg}{hp \cdot h}}\right)$;
Overall sizes:	
length	**1950 mm**;
width	**620 mm**;
height	**780 mm**.
Net engine mass	**240 kg**.

Application. Two engines driven passenger airplane of local airlines An-38 ($\mathbf{V_{cr} = 400\frac{km}{h}}$, $\mathbf{M_0 = 8{,}8\ tonnes}$, number of passengers – **26 peop.**).

8 AIRCRAFT GAS-TURBINE ENGINES

Omsk engine design bureau (EDB)

The engine design bureau was founded in 1956.

Chief designers:

PhD, Professor	V. A. Glushenkov (1956 – 1973 years);
PhD	V. C. Paschenko (1973 – 1985 years)
PhD	V. G. Kostogriz (from 1985).

8.1 Turboshaft engine GTD-3F

TShE GTD-3F is a two shaft engine with free turbine.

Compressor is combined, has 6 axial stages and an one centrifugal stage.

Combustion chamber is annular, semi reverse-flow type with rotating fuel spray nozzle.

Turbine is axial, two shaft, three stage, reactive, has a two stage high pressure turbine (HPT), an one stage free turbine.

Divergent duct provides gases withdrawal to the atmosphere to the left or to the right, depending on the engine position in a helicopter power plant.

Serial manufacturing started in 1966.

Technical features

Takeoff mode ($\mathbf{H = 0\,m}$, $\mathbf{V_{fl} = 0\frac{km}{h}}$, ISA):

Power	**662 kW (900 hp)**;
Specific fuel consumption	$\mathbf{0{,}407\ \frac{kg}{kW \cdot h}\left(0{,}3\ \frac{kg}{hp \cdot h}\right)}$;
Pressure ratio	**6,5**;
Turbine inlet temperature	**1142 K**;
Total air consumption	$\mathbf{4{,}65\ \frac{kg}{s}}$.
Overall sizes:	
length	**2295 mm**;
width	**900 mm**;
height	**580 mm**.
Net engine mass	**240 kg**.

Application. Two engines driven transport helicopter Ka-25K ($\mathbf{V_{cr} = 200\frac{km}{h}}$, $\mathbf{M_0 = 7{,}1\,tonnes}$, $\mathbf{M_{payload} = 2\,tonnes}$); two engines driven antisubmarine carrier-based helicopter Ka-25.

8.2 Turboprop engine TVD-10B

TPE TVD-10B is an engine with free turbine with the controllable-pitch propeller.

Compressor is combined, has 6 axial stages and an one centrifugal stage.

Combustion chamber is annular, semi reverse-flow type with rotating fuel spray nozzle.

Turbine is axial, two shaft, three stage, reactive, has a two stage high pressure turbine (HPT), an one stage free turbine. Free turbine is connected with front gearbox through shafting and rear gearbox.

Serial manufacturing started in 1984 in Poland.

Technical features

Takeoff mode ($\mathbf{H = 0\,m}$, $\mathbf{V_{fl} = 0\frac{km}{h}}$, ISA):

Power	**706 kW (960 hp)**;
Specific fuel consumption	$\mathbf{0{,}347\ \frac{kg}{kW \cdot h}\left(0{,}255\ \frac{kg}{hp \cdot h}\right)}$;
Pressure ratio	**7,4**;

Turbine inlet temperature	**1160 K**;
Total air consumption	$\mathbf{4{,}58\ \frac{kg}{s}}$.
Overall sizes:	
length	**2060 mm**;
width	**1100 mm**;
height	**900 mm**.
Net engine mass	**225 kg**.

Application. Two engines driven passenger airplane for local airlines An-28 ($\mathbf{V_{cr} = 335\ \frac{km}{h}}$, $\mathbf{M_0 = 6{,}5\ tonnes}$, number of passengers – **17 peop.**). One hundred and seventy three airplanes were imported to the USSR.

8.3 Turboprop engine TVD-20

TPE TVD-20 is an engine with free turbine. The flow in this engine is codirected with airplane flight direction (intake provides airflow half turn).

Compressor is combined, has seven axial stages and an one centrifugal stage.

Combustion chamber is annular, semi reverse-flow type with rotating fuel spray nozzle.

Turbine is axial, two shaft, four stage, reactive, has a two stage high pressure turbine (HPT), a two stage free turbine. Free turbine is connected to propeller gearbox (two stage, with primary planetary stage).

Certification tests were finished in 1999.

Technical features

Takeoff mode ($\mathbf{H = 0\ m}$, $\mathbf{V_{fl} = 0\ \frac{km}{h}}$, ISA):

Equivalent power	**1066 kW (1450 hp)**;
Specific fuel consumption	$\mathbf{0{,}333\ \frac{kg}{kW \cdot h}\left(0{,}245\ \frac{kg}{hp \cdot h}\right)}$;
Pressure ratio	**9,55**;
Turbine inlet temperature	**1220 K**;
Total air consumption	$\mathbf{5{,}9\ \frac{kg}{s}}$.
Overall sizes:	
length	**1770 mm**;
width	**850 mm**;
height	**845 mm**.
Net engine mass	**270 kg**.

Application. One engine driven multipurpose airplane An-3 ($\mathbf{V_{cr} = 300\frac{km}{h}}$, $\mathbf{H_{max} = 6000\,m}$).

9 AIRCRAFT GAS-TURBINE ENGINES

Ufa Petersburg scientific-production enterprise (SPE) “Motor”

The development-design bureau №26 of the Ministry of aircraft industry (DDB-25 MAI) was founded in 1955. The engine design bureau was founded in 1956. From 1999 the enterprise changed its name to State SPE “Motor”

Chief designers:

Hero of Socialist Labour, PhD	S. A. Gavrilov (1962 – 1983 years);
PhD, Professor	A. A. Ryzhov (1983 – 2000 years);
	A. F. Ivah (from 2000).

9.1 Afterburning turbojet engine R13-300

ATJE R13-300 is a two shaft engine with afterburning and controlled jet nozzle. The engine uses R11-300 as a prototype.

Compressor is axial, eight stage, two spool, has a three stage low pressure compressor and a five stage high pressure compressor. To improve the gas stability, engine was primary equipped with slot separator arranged under the primary stage runner.

Combustion chamber is tube-annular.

Turbine is axial, two stage, two shaft, has an one stage high pressure turbine and an one stage low pressure turbine.

Jet nozzle is supersonic, controlled.

Serial manufacturing was in 1968…1986.

Technical features

Takeoff mode ($\mathbf{H = 0\,m}$, $\mathbf{V_{fl} = 0\frac{km}{h}}$, ISA):

Thrust with afterburning	**64,68 kN (6600 kgf)**;
Thrust without afterburning	**40,18 kN (4100 kgf)**;
Specific fuel consumption with afterburning	$\mathbf{0{,}229\,\frac{kg}{N\cdot h}\left(2{,}25\,\frac{kg}{kgf\cdot h}\right)}$;
Specific fuel consumption without afterburning	$\mathbf{0{,}098\,\frac{kg}{N\cdot h}\left(0{,}96\,\frac{kg}{kgf\cdot h}\right)}$;

Total pressure ratio	**9,25**;
Turbine inlet temperature	**1223 K**;
Total air consumption	**66** $\frac{\mathbf{kg}}{\mathbf{s}}$.
Overall sizes:	
length	**4600 mm**;
engine diameter	**907 mm.**
Net engine mass	**1135 kg**.

Application. One engine driven frontal fighters MiG-21SM, MiG-21SMT and MiG-21MF, two engines driven fighter-interceptors Su-15M and Su-15TM.

9.2 Afterburning turbojet engine R25-300

ATJE R25-300 is a two shaft engine with afterburning and the controlled jet nozzle. The engine uses R13-300 as a prototype.

Compressor is axial, eight stage, two spool, has a three stage low pressure compressor and a five stage high pressure compressor. Broad chord titanium blades are mounted in the low pressure compressor primary stage.

Combustion chamber is tube-annular.

Turbine is axial, two stage, two shaft, has an one stage high pressure turbine and an one stage low pressure turbine.

Jet nozzle is supersonic, controlled.

Serial manufacturing was in 1972 – 1986.

Technical features

Takeoff mode ($\mathbf{H = 0\ m}$, $\mathbf{V_{fl} = 0}\frac{\mathbf{km}}{\mathbf{h}}$, ISA):

Thrust with afterburning	**67,1 kN (6850 kgf)**;
Thrust without afterburning	**41,2 kN (4200 kgf)**;
Specific fuel consumption with afterburning	$\mathbf{0{,}229}\ \frac{\mathbf{kg}}{\mathbf{N \cdot h}}\left(\mathbf{2{,}25}\ \frac{\mathbf{kg}}{\mathbf{kgf \cdot h}}\right)$;
Specific fuel consumption without afterburning	$\mathbf{0{,}093}\ \frac{\mathbf{kg}}{\mathbf{N \cdot h}}\left(\mathbf{0{,}91}\frac{\mathbf{kg}}{\mathbf{kgf \cdot h}}\right)$;
Total pressure ratio	**9,5**;
Turbine inlet temperature	**1313 K**;
Total air consumption	**68,5** $\frac{\mathbf{kg}}{\mathbf{s}}$;
Overall sizes:	
length	**4615 mm**;
engine diameter	**907 mm**.
Net engine mass	**1215 kg**.

Application. One engine driven frontal fighters MiG-21bis ($\mathbf{V_{max} = 2230\frac{km}{h}}$, $\mathbf{H_{fl} = 11000\,m}$, $\mathbf{M_0 = 7{,}96\ tonnes}$).

9.3 Turbojet engine R95SH

TJE R95SH is a pure, two shaft turbojet engine with the uncontrolled jet nozzle.

Compressor is axial, eight stage, two spool, has a three stage low pressure compressor and a five stage high pressure compressor

Combustion chamber is tube-annular.

Turbine is axial, two stage, two shaft, has an one stage high pressure compressor and an one stage low pressure compressor.

Jet nozzle is uncontrolled.

Flight testing was from 1980.

Technical features

Takeoff mode ($\mathbf{H = 0\,m}$, $\mathbf{V_{fl} = 0\frac{km}{h}}$, ISA):

Thrust	**40,2 kN (4100 kgf)**;
Specific fuel consumption	$\mathbf{0{,}088\frac{kg}{N\cdot h}\left(0{,}86\frac{kg}{kgf\cdot h}\right)}$;
Total pressure ratio	**8,66**;
Turbine inlet temperature	**1148 K**;
Total air consumption	$\mathbf{65{,}7\frac{kg}{s}}$.
Overall sizes:	
length	**3300 mm**;
engine diameter	**914 mm**.
Net engine mass	**990 kg**.

Application. Two engines driven attack plane Su-25 for direct support of land forces ($\mathbf{V_{max} = 970\frac{km}{h}}$, $\mathbf{L_{fl} = 7000\,km}$, $\mathbf{M_0 = 14{,}53\ tonnes}$), trainer Su-25UT.

9.4 Turbojet engine R195

TJE R195 is a pure, two shaft turbojet engine with uncontrolled the jet nozzle, which is the modification of R95SH. Engine has higher thrust, lower infrared visibility and higher operation stability during missile launching.

Compressor is axial, eight stage, two spool, has a three stage low pressure compressor and a five stage high pressure compressor.

Combustion chamber is tube-annular.

Turbine is axial, two stage, two shaft, has an one stage high pressure compressor and an one stage low pressure compressor.

Jet nozzle is uncontrolled.

The engine has been putting into operation since 1987.

Technical features

Takeoff mode ($\mathbf{H = 0\ m}$, $\mathbf{V_{fl} = 0\ \frac{km}{h}}$, ISA):

Thrust	**44,12 kN (4300 kgf)**;
Specific fuel consumption	$\mathbf{0{,}091\ \frac{kg}{N \cdot h}}\left(\mathbf{0{,}89\ \frac{kg}{kgf \cdot h}}\right)$;
Total pressure ratio	**9,0**;
Turbine inlet temperature	**1200 K**;
Total air consumption	$\mathbf{66\ \frac{kg}{s}}$.
Overall sizes:	
length	**2880 mm**;
engine diameter	**805 mm**.
Net engine mass	**860 kg**.

Application. Two engines driven attack plane Su-25T, Su-25TK, Su-25UB, Su-39 for direct support of land forces.

REFERENCES

1. Авиация: энциклопедия / гл. ред. Г. П. Свищев. – М.: Большая Российская энциклопедия, 1994. – 736 с.

2. Двигатели 1944 – 2000: авиационные, ракетные, морские, промышленные. – М.: ООО «АКС-Конверсалт», 2000. – 434 с.

3. Авиационный справочник России и СНГ. – М.: ООО «АКС-Конверсалт», 1996. – 896 с.

4. Ильин, В. Е. Бомбардировщики / В. Е. Ильин, М. А. Левин. – М.: Виктория, АСТ, 1997. – 176 с.

5. Ружицкий, Е. И. Вертолеты / Е. И. Ружицкий. – М.: Виктория, АСТ, 1997. – 192 с.

6. Пономарев, А. Н. Советские авиационные конструкторы / А. Н. Пономарев. – М.: Воениздат, 1980. – 247 с.

7. Корниенко, О. О. Путь к прогрессу / О. О. Корниенко – Запорожье: ИПК «Запорожье», 2000. – 176 с.

8. «Мотор Сич». От поршневых – к газотурбинным. – Запорожье: ИК ОАО «Мотор Сич», 2000. – 231 с.

9. Зрелов, В. А. Основные данные отечественных авиационных ГТД и их применение при учебном проектировании: учеб. пособие / В. А. Зрелов, В. Г. Маслов. – Самара: Самар. гос. аэрокосм. ун-т, 1999. – 160 с.

10. Технические описания авиационных газотурбинных двигателей.

11. Проспекты ГТД и другие материалы авиационных выставок и выставок авиационных двигателей. – 1992 – 2014.

Навчальне видання

Шошин Юрій Сергійович
Сіренко Фелікс Феліксович

ОСНОВНІ ТЕХНІЧНІ ДАНІ МАРШОВИХ АВІАЦІЙНИХ ГАЗОТУРБІННИХ ДВИГУНІВ УКРАЇНИ, СРСР, РОСІЇ

(Англійською мовою)

Редактор Н. Б. Зюбанова
Технічний редактор Л. О. Кузьменко

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Видавець і виготовлювач
Національний аерокосмічний університет ім. М. Є. Жуковського
«Харківський авіаційний інститут»
61070, Харків-70, вул. Чкалова, 17
http://www.khai.edu
Видавничий центр «ХАІ»
61070, Харків-70, вул. Чкалова,17
izdat@ khai.edu

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