Generations of GTEs for Helicopters

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Continuos improvement of developed industrial products results in emerging new goods of higher quality. It is common practice to classify all produced goods or products under manufacturing according to so-called generations. New generations of goods differ from the previous by a number of attributes providing these goods with better consumer quality. Technical or engineering solution considerably improving the quality or providing the product with a new characteristic is called "an event". A set of several " events" results in emerging the next generation of goods on the market

In aviation engineering three are also generations of products under development: flight vehicles, engines, navigation systems, flight-and-directional systems, airborne armament, etc., and appearance of a new generation of aircraft engines largely predetermine the development of flight vehicles of a new generation.

The engine-building is a very dynamic branch of engineering. In particular, several generations of gas-turbine engines were developed in aviation within the last 50 years. Every generation uses own methods and concepts of designing which are continuously improving as dependant on changeable technical, technological, organizational, and economic conditions.

Since 1960s, a great number of turboshaft engines of different power have been developed in our country – starting from 400-hp GTD-350 to 11,500-hp D-136 – which met all requirements of Russian helicopter fleet and provided a parity and even advantages over foreign competitors (Fig.1).

A special power-dimension-type classification of GTEs was developed for the purpose of systematization and unification of turboshafts and turboprops. Originally, the classification included 4 positions which differed from one another by twice increased power (Fig.2). The engine of 1st dimension–type has power about 400 hp, 2nd dimension-type – 800 hp, and so on up to 3,200 hp. Each dimension-type is developed with an opportunity of power increase by 20-25%. Therefore, a helicopter or plane designer has a chance to choose an engine with required power. Later on, two extra dimension-types were added to these four types – 0 dimension-type - 250 hp and 5th dimension-type – 5,000-6,000 hp.

Simultaneously, standards of technical level of these engines were developed considering engine basic parameters: N_{sp}, sfc, γ_{en}, parameters of reliability and accident-free operation.

Nowadays, three new engines are under test development – RD-600V (Fig.2) , TV7-117VK and VM. Moreover, the development of VK-800 engine has been launched.

Turboshaft engines for helicopters are also classified by generations but their development started directly from IInd generation. It was caused by the fact that actual helicopter manufacturing was launched in post-war years. These first helicopters were powering by piston engines, e.g. Mi-4 was powered by ASh-82V piston engine, Ka-15 – by AI-14V. Next generation of helicopters - Mi-1, Mi-6, Mi-8 , and K-15 – were powered by gas-turbine engines of II^{nd} generation. Main tendencies in the development of these engines are in compliance with general trends in aircraft GTEs of large overall dimensions but there are some specific features of these engines mainly depending on their schemes, parameters, dimensions and operating conditions. In particular, operation of turboshaft engines is characterized by dusty air, mixture of air and sea water, in regions of thermal and gasdynamic instability, presence of water and other adverse conditions (Fig.4).

Basic technical characteristics of turboshafts have been improved within the last 40 years - N – from 180-200 hp/kg/s to 300-320 hp/kg/s, sfc – from 260-300 g/hp.hr to 180- 200 g/hp.hr, γ - from 0.22-0.25 kg/hp to 0.12-0.15 kg/hp – with a concurrent increase in service life – from several hundred hours to 8,000-12,000 cycles (4,000-6,000 hr). The up-to-date level of turboshafts can be illustrated by a decreased number of components in engines of the IV^{th} generation - about 2000 units as compared with the II^{nd} generation – 6000 units with keeping the same base thermodynamic cycle (Brayton cycle) . The structural layout of a turboshaft has passed through modifications – a mutli-satge axial compressor with π^*_c=5-8 has changed into an axial/centrifugal compressor with π^*_c=12-17, a straight flow combustion chamber with θ =1.35-1.45 has transformed into a reverse-flow or inclined combustion chamber with θ =1.25-1.30, a two-stage uncooled compressor turbine with T^*_g=1,050-11,50K has been converted into a single-stage cooled turbine with T^*_g=1,400-1,500K, a free turbine shaft has a forward output instead of rear, the turboshaft is provided with a built-in gearbox, an integral torquemeter, etc. Turboshafts of IV^{th} generation are provided with a built-in dust-protective device, which had been installed earlier on-board a helicopter (Fig.5).

Another precondition for a new generation of aircraft engines is the development of new materials. In particular, engines of IInd generation were based on available post-war structural materials of general engineering. Later on, new aluminum, titanium and high-temperature alloys were developed which were subsequently followed by special-property alloys and composite materials.

Application of these materials was accompanied by development of new technologies – investment casting of turbine blades, electron-beam welding of rotor components, isostatic pressing of disks from nickel granular powder, electrochemical treatment of compressor blades, casting of monocrystalline ingots, etc.

It is important to note that in many cases the core of a helicopter turboshaft engine is used in a aircraft turboprop engine and vice versa. These examples are known in Russia and abroad – General Electric the T700 and the CT17, the TV7-117S and the TV7-117VK/VM manufactured by Klimov Company (Fig.6).

The engine classification by generations is conditional because the engine of one generation can fit into the next generation by considerable modernization and implementation of new “events”. As a rule, these engines are dubbed as “generation plus”. For example, the TV3-117, a rather progressive engine of IIIrd generation, was developed in 1970s. It was the basis for the development of TV3-117- SBM1 turboprop and VK2500 turboshaft of III+ generation.

The main requirements to engines of new generation for military aviation (fighters and combat helicopters) are increased reliability and service life (by 50-80%), decreased labor input in manufacturing and maintenance (1.5-2 times), decreased specific weight (by 20-30 % for turboshafts) and improved economy in use (by 15-30%). New engines of civil aviation should provide a decrease in cost of ownership (1.5-2 times), an improved in economy in use (by 15-20%), an improvement of reliability and service life (1.5–2 times) and better ecological characteristics.

Actually, a transition from developed and operating turboshaft engines of IVth generation to engines of Vth generation which is characterized by a drastic improvement of characteristics is a revolutionary process demanding introduction of new technical “events” that, in its turn , calls for achievements in aerodynamics of GTE components, materials and technologies. Fig.7 shows a possible layout of an advanced base GTE which can be used in a turboshaft or a turboprop of Vth generation. The main goals are also shown there.

It should be emphasized that simultaneous introduction of many new events in one engine is very problematic. Therefore, it is advisable to test new engineering solutions in the system of well-tested series engines followed by demonstration tests of a core or an engine with introduced complex of new “events”.

The implementation of "events" is the result of working out a scientific and technical program (STP) which development should be the main task of CIAM. However, the development of STP is a rather expensive and time-consuming process and, consequently, calls for consolidation and cooperation of the institute with design bureaus and manufacturing companies. For example, engines of the next generation are assumed to use such engineering solutions as swept-forward compressor blades, a multi-hole segmental combustion chamber, a duel annular combustion chamber with low emissions, turbine guide vanes produced from ceramic composite materials, turbine rotor blades of a long service life with transpiration cooling, rotor blings, composite cases, ceramic or hybrid bearings, oil-free bearings, brush seals, etc.

These engineering solutions – “ events” – result in a considerable sophistication of component structures but only their implementation will make possible to achieve predicted parameters. The development of STP for engines of the next generation takes many years but the achievable results enable to shorten the work cycle of a new engine development from its project to certification.

Traditionally, new engineering solutions, materials and technologies initially find application in military engines and after that they are used in civil aviation. Recently, a new conversion area is emerging which is based on aviation technologies.

Aviation engines of the next generation demand not only technical achievements in compliance with Russian programs of advanced GTEs or such foreign programs as IHPTET, VATE , 3E, etc, but also implementation of certain organizational principles allowing to shorten time period of a new engine development.

These principles are cooperation in aviation industry, merging of funds, e.g. 50% budget financing + 50% allocated funds of developers, as well as competition of projects.

Despite of a rather difficult situation in Russia aviation and, in particular, engine-building, this branch of industry possesses a great scientific and technical potential making possible the development of aircraft engines of Vth generation for military and civil aviation.

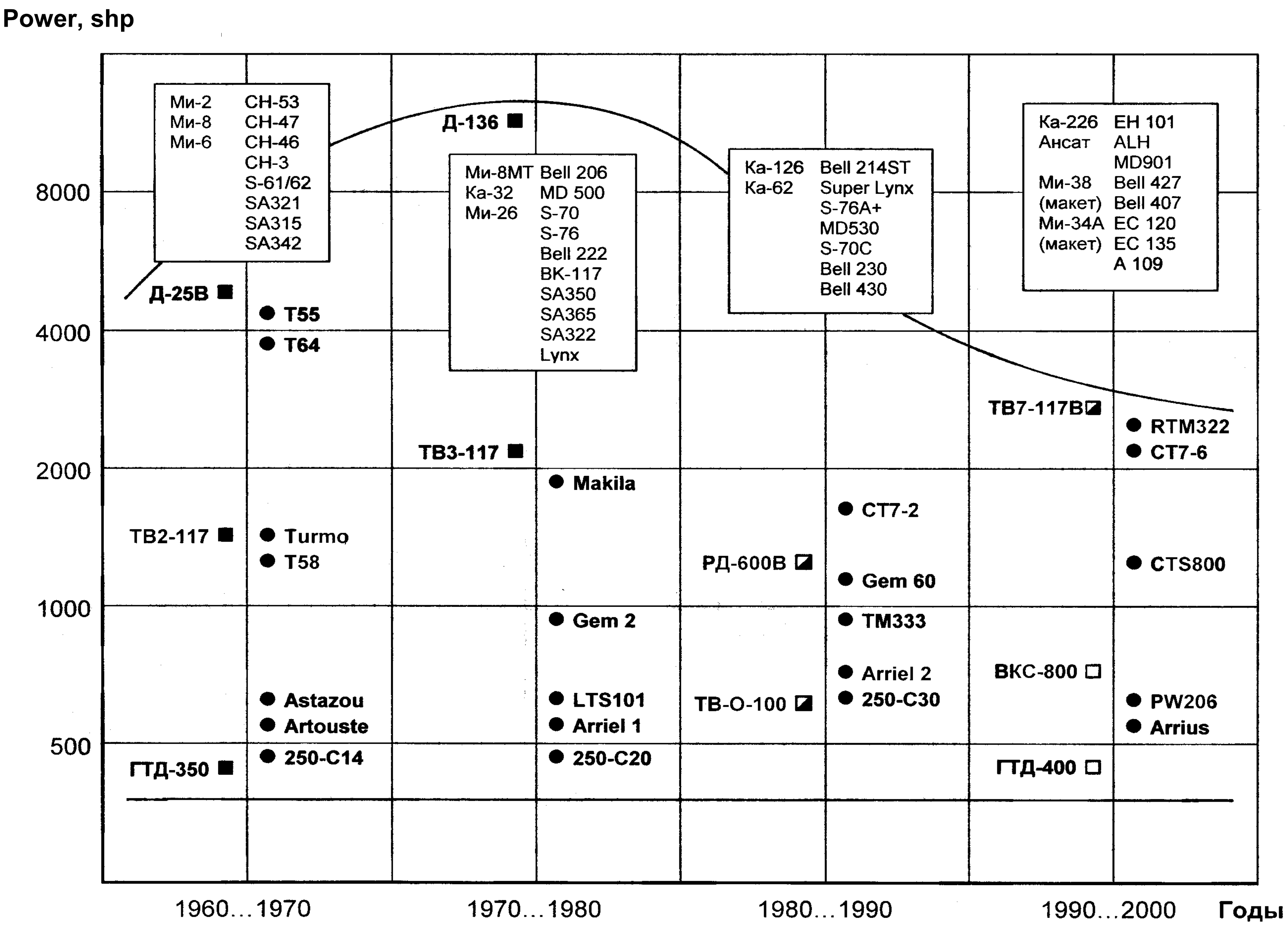


Fig.1. Turboshaft engines for helicopters

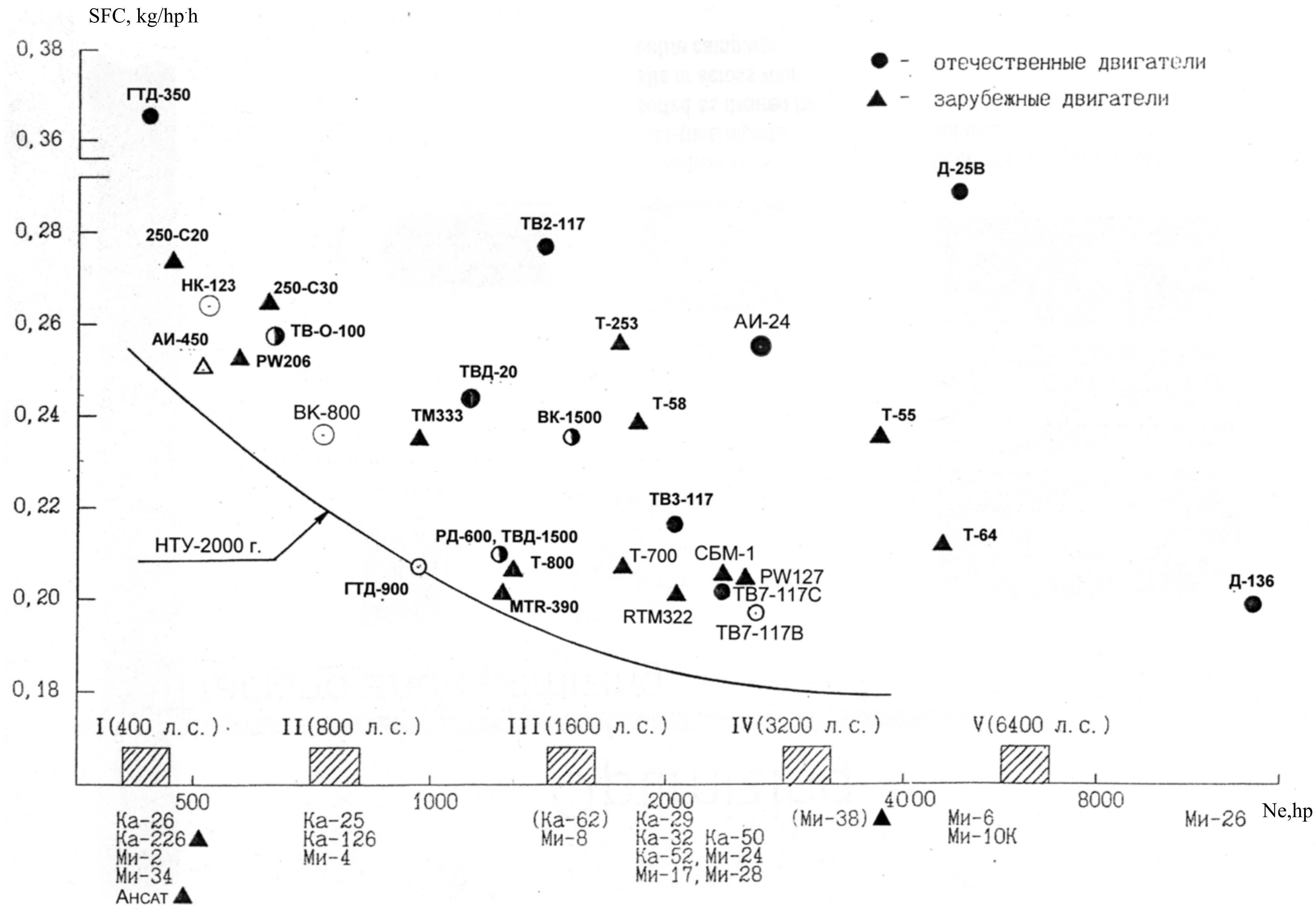


Fig.2.Dimension-type classification of turboshaft and turboprop engines:

- ● - Russian engines
- ▲ - Foreign engines

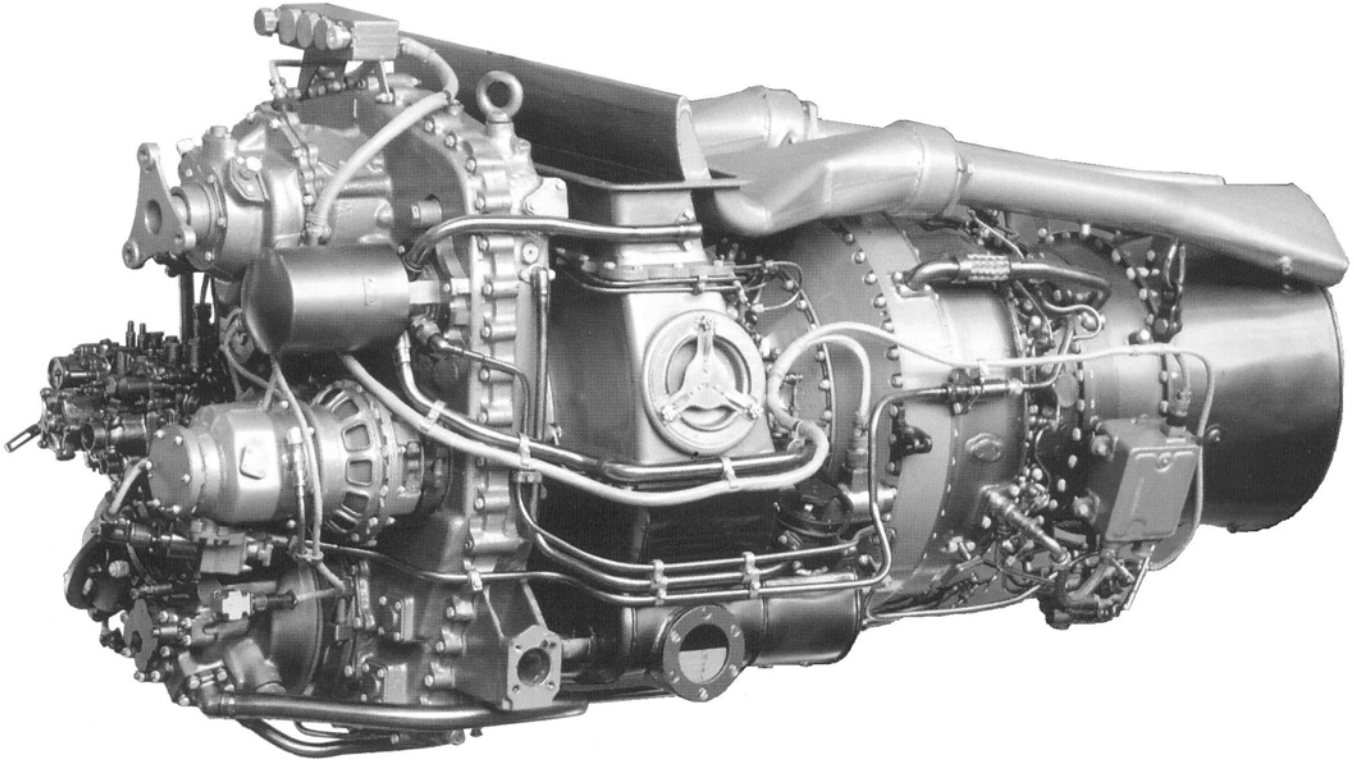


Fig.3. RD-600V turboshaft engine for Ka-60 helicopter

- Emergency power conditions as a normal power setting: $Ne_{em} \geq 110\%$ of $Ne_{take\text{-}off}$ – for military engines and $Ne_{em} \geq 130\%$-150% of $Ne_{take\text{-}off}$ – for civil engines
- Flight cycle - τ=0.02-1.5 hr
- Prolonged exposure to environmental factors: dust, snow, water, salt
- Independent operation for military aviation (the mandatory requirement to helicopter GTEs)
- Alternative applications in the powerplant (forward or rear power shaft output; compensation of torque by an anti-torque rotor, a finistron or a controllable propelling nozzle; a tilt main rotor
- Application of ejectors to decrease visibility
- Possibility of exhaust-gas ingestion at the engine inlet
- Relatively high cruise regimes (60-70% of $Ne_{take\text{-}off}$)

Fig.4. Specific features of helicopter GTEs

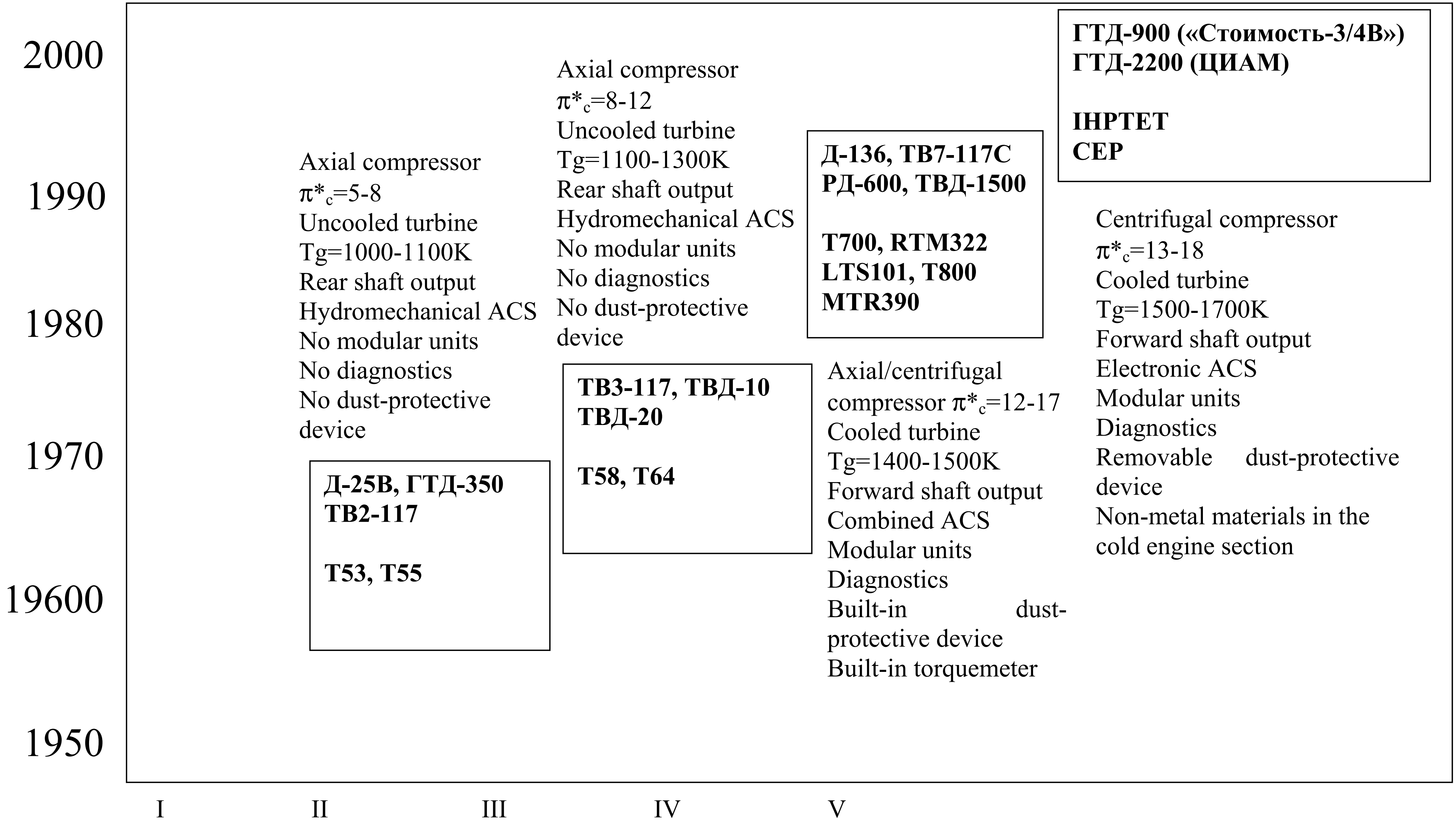


Fig.5 Generations of helicopter turboshaft and turboprop engines

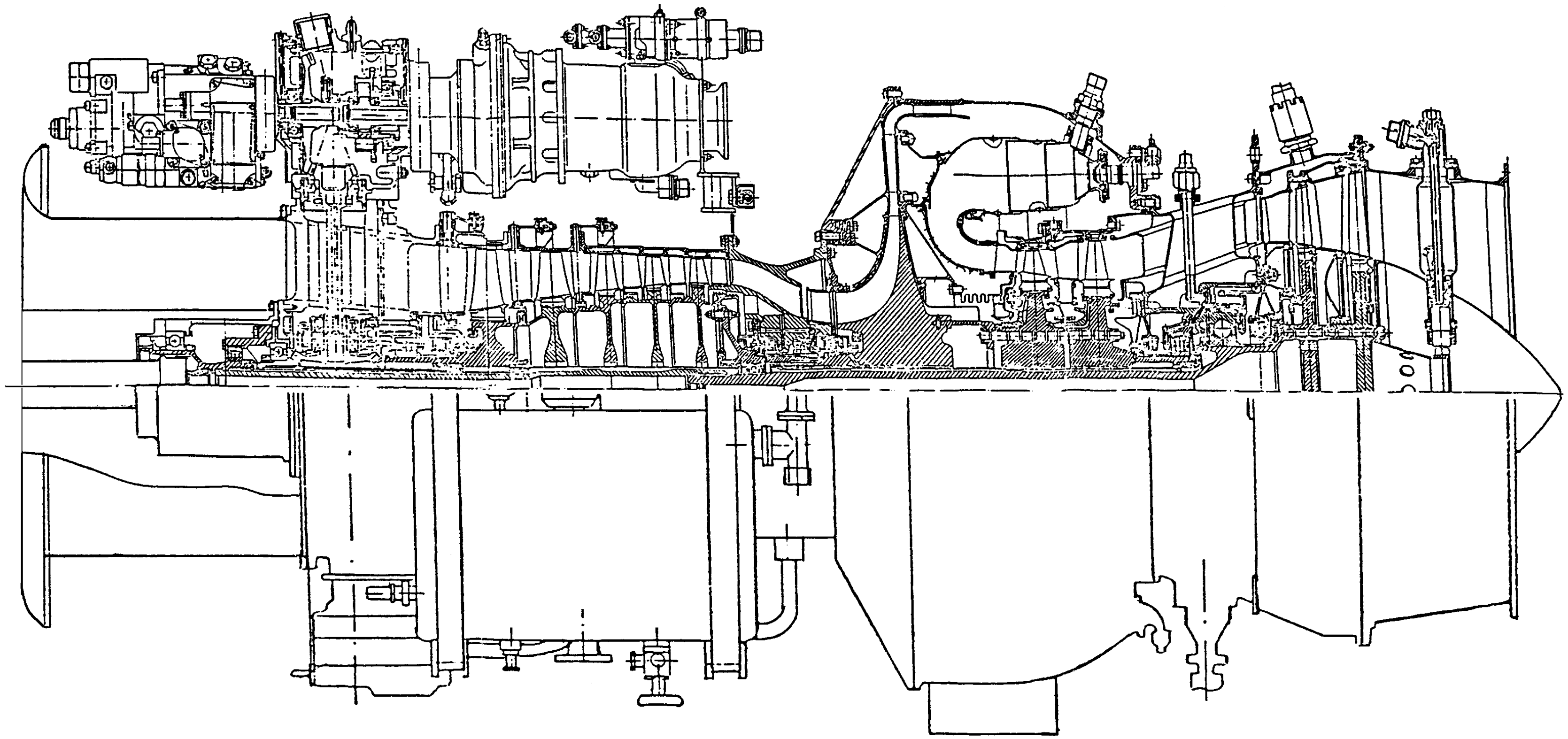


Fig.6. TV7-117V engine version for Mi-38 helicopter

Goals:

- Increased service life:
  Time-between-overhauls – 4,000-5,000 hr
  Total - 12,000-15,000 hr
- Improved reliability.
  Mean-time-between-failures - 20,000-50,000 hr
- Decreased man-hours for servicing – 0.25-0.3 hr per flight hr.
- A decrease in specific mass by 0.01-0.015 kg/hp
- An increase in economy in use by 10 –20%

Dust-protective device

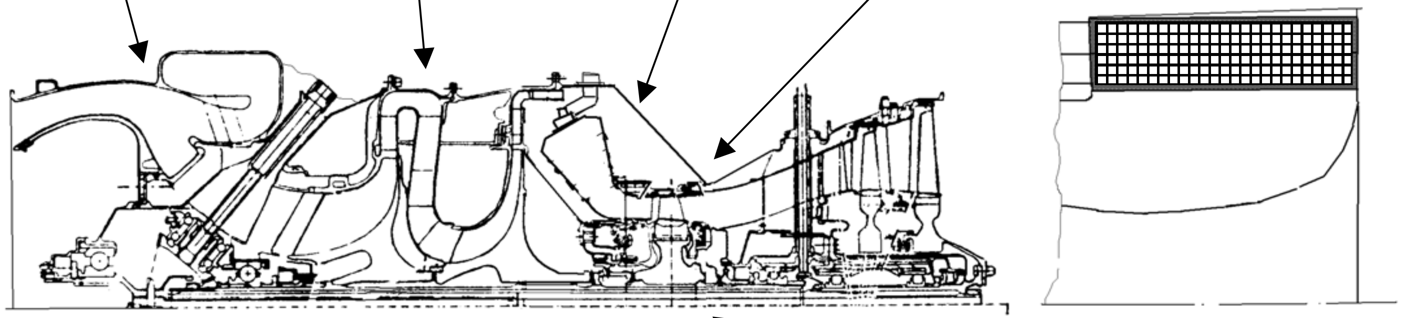
- High separation efficiency
- Application of non-metals

Combustion chamber

- ceramic combustion liner
- multi-fueled combustion chamber
- air starting up to 10 km ecology-friendly

Compressor turbine

- metal rotor blades with improved cooling system
- variable G_{cool}
- advanced materials (C-C, ceramics)
- controllable tip clearance



Systems

- integrated electronic ACS (engine + aircraft)
- distributed diagnostic system with application of fiber optics
- a decrease in weight of sub-units by 20-30%

Free turbine

- 3-D profiling (free turbine + transition duct)
- counter-rotating rotors
- composite shaft

Heat exchanger
(for the GTE version with heat regeneration)

- ceramic matrix

Fig.7. The advanced base GTE