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"A NEW PROPOSAL FOR AN OLD PROBLEM"
- The right engine for the right helicopter -

by
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Abstract

The advantages of gas turbine engines have made them the most common propulsion system for helicopters in use today.

The design of the helicopter determines the functional and economic requirements of the propulsion system. It is an aim to establish the system with the lowest overall cost (LCC/DOC) which also satisfies all defined requirements. Mandatory requirements are e.g. safety aspects, flight profile, mission task etc., while further items are desirable, to be optimised with less restrictions (dimensions, engine weight, specific fuel consumption, rating structure, acquisition and maintenance cost etc.) as well as other parameters which are not so easy to quantify (business politics etc.).

The achievement of the objectives is greatly influenced by the freedom to develop a new engine or by the constraint to use an existing engine in a more or less modified design. The focal points are different for civil and military helicopters. As a basis for the optimisation the helicopter manufacturer provides trade-off factors which affect the overall system cost.

Within these requirements the engine manufacturer defines the thermodynamic cycle and the engine configuration. The technologies which are available or can be developed within a set time period e.g. aerodynamics, materials, manufacturing processes, quality control procedures etc., are of great significance. Alternative applications and requirements for engine growth potential must also be considered. The design is an iterative process between the engine and helicopter manufacturers in order to derive an optimum overall system.

These features were considered when the MTR390 turboshaft engine was designed. The engine for the "Tiger" helicopter is used as an example of the described procedure and its programme status is shown.

1. Introduction

Considering the propulsion system of helicopters, a predominance of the gas turbine engine is evident. Nearly two thirds of the helicopters flying today utilize gas turbine propulsion, the remainder is powered by piston engines (Fig. 1). The importance of the gas turbine engine is underlined if the type of propulsion with respect to the size of the helicopter is shown. Whilst the piston engine is only used for very light helicopters, the gas turbine covers the complete remaining size range.

The reason for this are price and fuel consumption advantages for the piston engine in the very low power class (let us say below about 200kW). Beyond that only gas turbine engines are used as only they can provide the required high specific power (power output per kg engine) and the compact exterior dimensions. Moreover, they offer better operational characteristics, higher reliability, and their disadvantage in specific fuel consumption becomes less and less the higher the power class is.

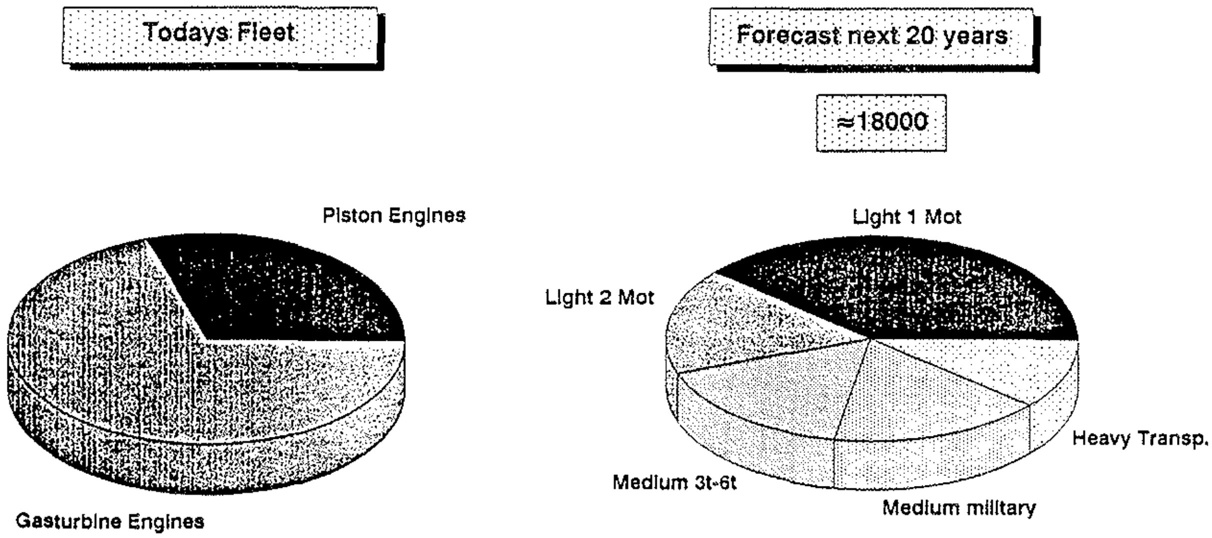


Fig. 1: Helicopter (Western) World Market

In order to get the "right" helicopter with the "right" engine, the target requirements set up have to be met perfectly both on the helicopter and engine side. These target requirements can differ considerably depending on the type of missions and operations in civil or military use. Naturally, the real optimum can only be achieved if both the helicopter and the engine are new designs for the required missions. If an existing engine has to be selected, it is very important to find the right weighting of its performance and operational features.

2. Requirements and Evaluation Criteria

To find an answer to the question "what is the right engine", one has to analyze the overall system, here the helicopter or another rotary wing aircraft, together with its operational scenario. The operations can cover a very wide spectrum of missions, civil or military, cargo or passenger transportation, high speed or low speed, and so on and it is impossible therefore to set up an ever valid procedure as well for the evaluation or selection of the right vehicle as for the right engine.

However, some very helpful design or evaluation guidelines can be summarized if one takes the principle view of the operator of the vehicle or engine under discussion, and here lies the main difference between military and civil applications. Whilst the civil operator will finally measure everything in terms of profit, the military operation will ask for low life cycle costs i.e. the sum of money spent within the complete lifetime of the system should be as low as possible. The way to calculate life cycle costs differs very much from user to user and depends strongly on the type of mission(s). Therefore, only the civil operation shall be analyzed here in more detail.

Profit for the civil operator is nothing else but the difference between revenues and costs. His easy formula therefore runs "achieve a maximum of revenues with a minimum of costs".

Costs

Generally, costs are summed up as it is shown in Fig. 2. The direct operating costs (DOC) are associated with the depreciation, the financing and the insurance of the flying material, all flight and ground expenses due to flight operations, the fuel and the costs for maintenance and overhaul. Indirect operating costs (IOC) include the operator's other costs associated with servicing, administration and sales, maintenance and depreciation of the ground properties. DOC and IOC sum up to the total costs.

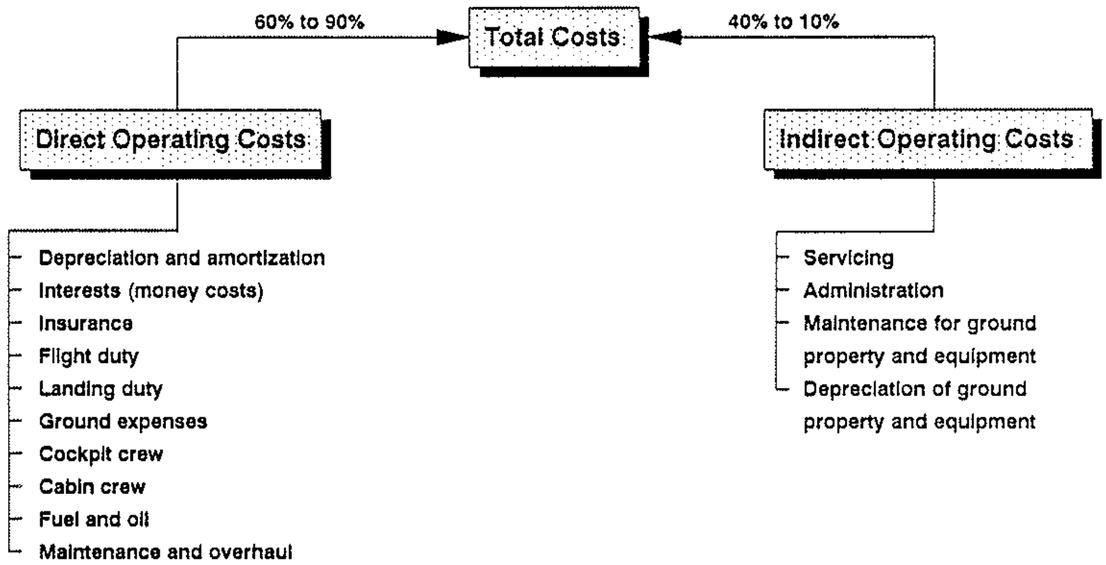


Fig. 2: Calculation of Operating Costs

Depending on the type of transportation task or mission, e.g. carrying cargo or passengers, landing on airports (with expensive landing fees) or not, the share between DOC and IOC differs a lot. For a regular passenger duty similar to fixed wing operation, the IOC can range up to 40% of the total costs whilst they can be only 10% or even less for an operator with simple transportation tasks.

The composition of the direct operating costs can also vary widely from operator to operator. Considering again the regular passenger duty, the DOC are typically distributed as shown in Fig. 3. First of all, the DOC per flight hour strongly depend on the utilization and it is of utmost importance to achieve a high rate here. Used as a civil transporter, the helicopter or any other rotary wing configuration (e.g. tilt rotor) has to reach a utilization similar to fixed wing aircraft otherwise its DOC/Fh will never be competitive.

The cake shown was calculated for a future civil tilt rotor but would not differ too much if a helicopter was considered. Amortization, financing and partly insurance are related to the price of the vehicle. For expensive aircraft (as tilt rotors or also helicopters), they together sum up to more than 40% of the DOC (for less utilization they can exceed 50%). Crew costs and flight/ground expenses in this type of operation are very high and amount to more than 20% of the DOC. Maintenance and overhaul has always been an extremely unfavourable parameter for any helicopter. The tilt rotor, although promising some advantages compared to helicopters, will still have maintenance and overhaul costs around twice that of a comparable fixed wing aircraft. Assuming a fuel price of 1$ per US gallon (~26cents/l), the fuel amounts to only 12% of the DOC. Typically, the fuel share for fixed wing aircraft is around 14% and the helicopter in this mission will also be close to these values.

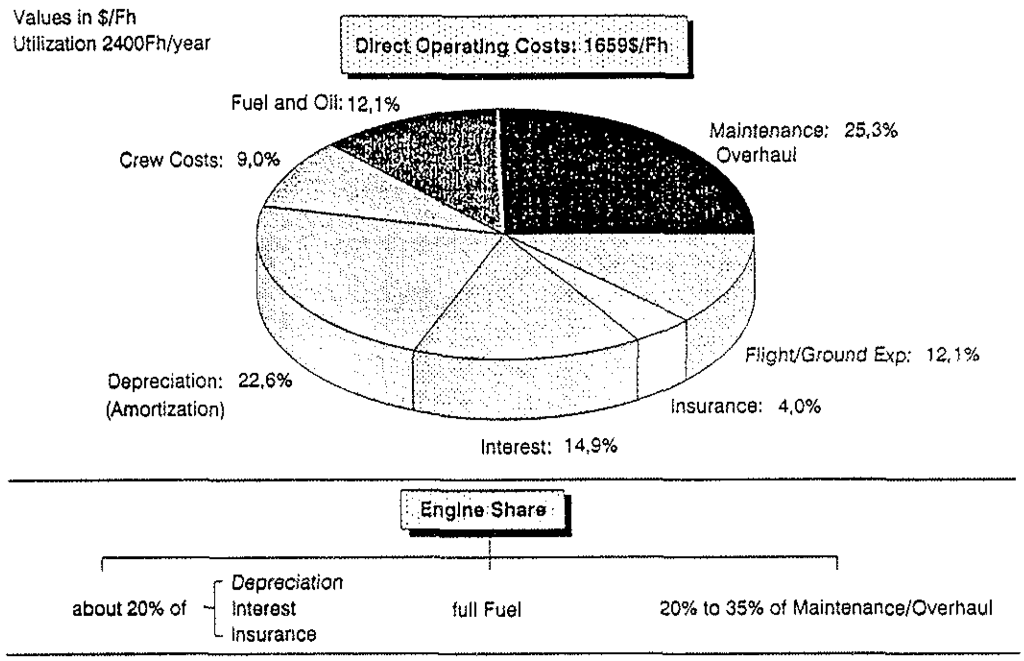


Fig. 3: Civil 30 Pax Tiltrotor DOC

Mainly for helicopters, there will be a lot of missions with less crew costs and flight/ground expenses than shown in Fig. 2. In this case, naturally the share of the other parameters will increase and the price related costs will be yet more dominant.

The share of the engines within the DOC can be roughly considered as follows: around 20% of the price related costs (amortization,...), between 20% and 40% of the maintenance/overhaul costs (here for the tilt rotor 20% are estimated) and last but not least the fuel/oil costs. Related to the total DOC this yields the following engine share:

- engine price : 8% to 10% of the DOC
- engine maintenence/overhaul: 5% to 10% of the DOC
- engine SFC (i.e. fuel) : 12% to 14% of the DOC

Revenue

The revenue is the sum of payload times price for all the missions flown within a certain time, normally one year. As the price for the payload or the fare for the passenger is normally dictated by the market competition, the remaining "free" parameter is the sum of the transported payload. This "payload integral" will depend firstly on the actual available payload for the mission respectively and secondly on the number of missions flown.

The actual payload for a vehicle with a given take off weight (TOW) is influenced by the engine through the following three parameters (see Fig. 4):

- the power output defines the allowable TOW for the mission to be flown;
- the mass of the engine(s) plus the fuel reserves (a result of the SFC of the engine) define the operating empty mass;
- the SFC of the engine defines the mission fuel.

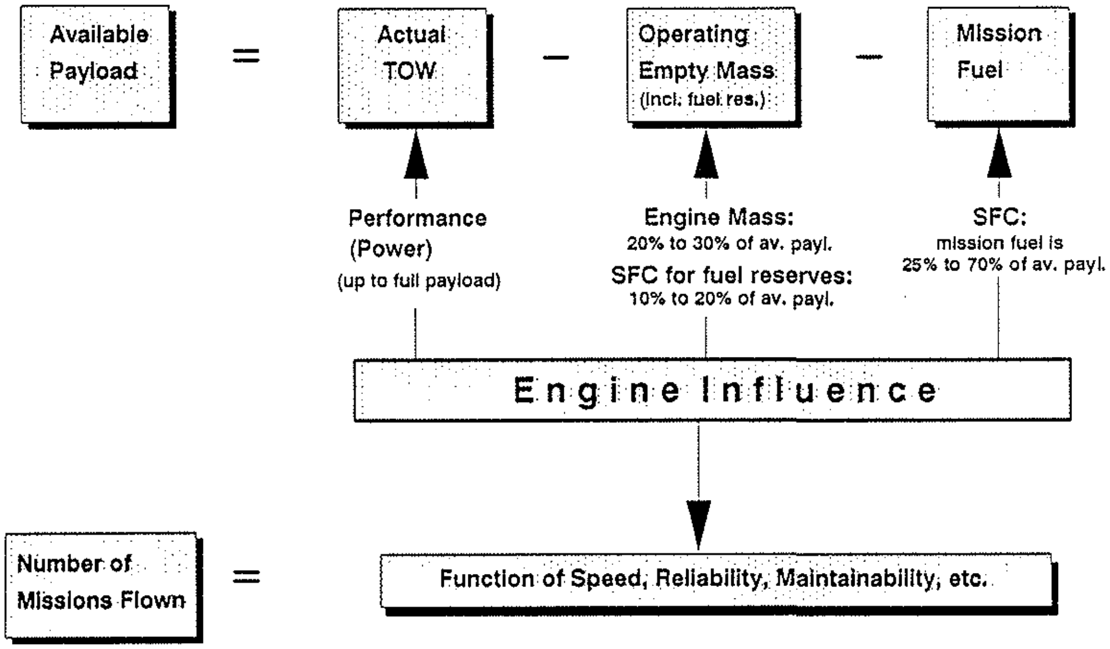


Fig. 4: Influence of the Engine on the Payload Integral

The "right" engine is a best compromise. It must not be too powerful otherwise it is too heavy and may consume too much fuel due to low loading during the average mission. If it is not powerful enough, its low mass, naturally increasing the payload for a certain share of the overall mission spectrum, does not counteract the necessary reductions of the actual TOW and the corresponding drastic reduction of the payload for the power-limited missions. Thus, the chioce of the "right" engine strongly depends on what the operator's mission spectrum is.

Returning to the "payload-integral", the engine also influences the number of missions flown. Again, the most important parameter will be a high continuous power output to achieve a high cruise speed but high reliability, long lifetimes, low and easy maintenance etc. have also to be considered.

For military operation the situation is less complex. The few missions defined have to be fulfilled and an optimum matching between airframe and engine can easily be achieved (at least if both airframe and engine are new designs).

Summary of Evaluation Criteria

As discussed above, the civil operator will look at the aircraft from a cost/revenue point of view. However, analyzing in detail it turns out that not everything can really be measured in $ or kg and some aspects have to be evaluated due to former experience, due to confidence or politics. For helicopters, normally the manufacturer has to select an engine already during the design and development of the airframe and naturally he will do that with respect to his potential customers. Although the mission requirements are not known in detail, the principal lead idea for the selection process should be the benefit/cost analysis and as far as possible everything should be transferred into effects on kg and/or $. The classification of the criteria is shown in Fig. 5.

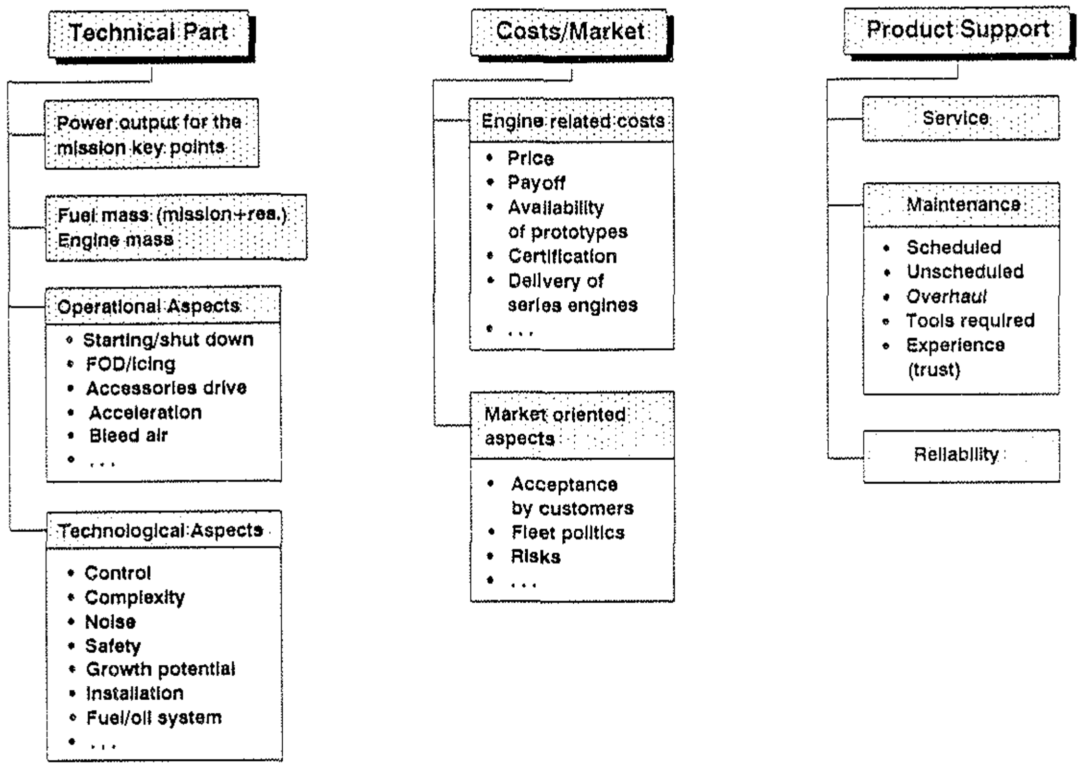


Fig. 5: Criteria for the Engine Evaluation

3. Engine Design Aspects

3.1 Power Requirements

Once the missions the aircraft is designed for are known and the separate mission sections are defined in detail, the power requirements can be calculated by means of computer programs dedicated to performance estimation. This yields a list of requirements for the separate mission sections, the main points being ambient conditions, power required, the time it is required and output speed.

The next step is on the engine manufacturer to do. He will try to tailor the engine behaviour to these requirements and to find the best solution, naturally also considering the cost side. Moreover, he has to look for further applications for this type of engine and this may ask for some compromise in the design.

As an example for the theme of this study the MTR390 engine was selected (see chapter 4). It was specifically tailored to the power requirements of the TIGER missions. Besides this it is intended to power a civil helicopter in the 5t to 6t class. High cruise speed is a major requirement for this helicopter and the resulting power situation is shown in Fig. 6. Design ambient conditions could be 1000m/ISA+20K, the TOW around 5000kg. Considering the power polars it can be seen that the cruise power becomes predominant for speeds above 300km/h even if a very low drag area can be achieved. Generally, high speed requirements will drive the continuous power rating but will alleviate the need for high excess power to takeoff.

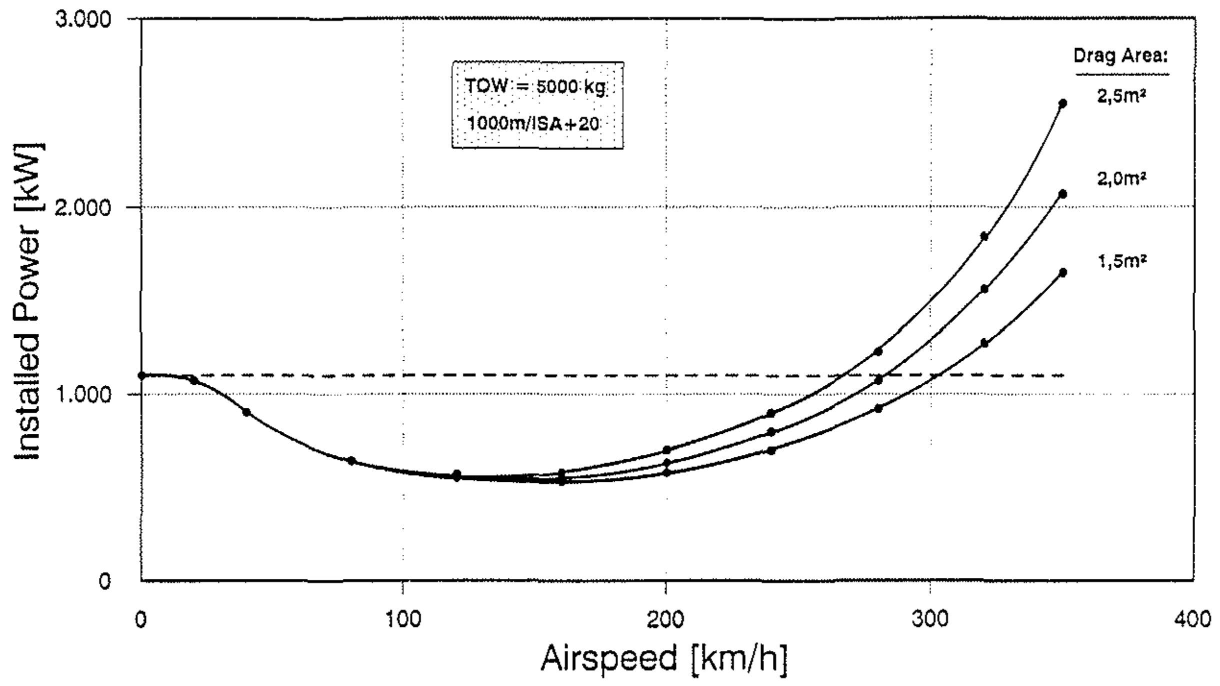


Fig. 6: Typical Power Polar

The second design driver especially for twin engine helicopters in civil transportation duty will be the Category A takeoff (loss of one engine). Simulations have shown that the safe continuation (or rejection) of the takeoff will require around 95% of the equivalent HOGE power required for a time period of around 30s. It is apparent that an enormous short time excess power is required from the remaining engine(s) to provide satisfying Cat. A performance (see Fig. 7). Practically, if Cat. A is required for most of the missions, a well balanced power matching for a twin engine helicopter cannot be kept.

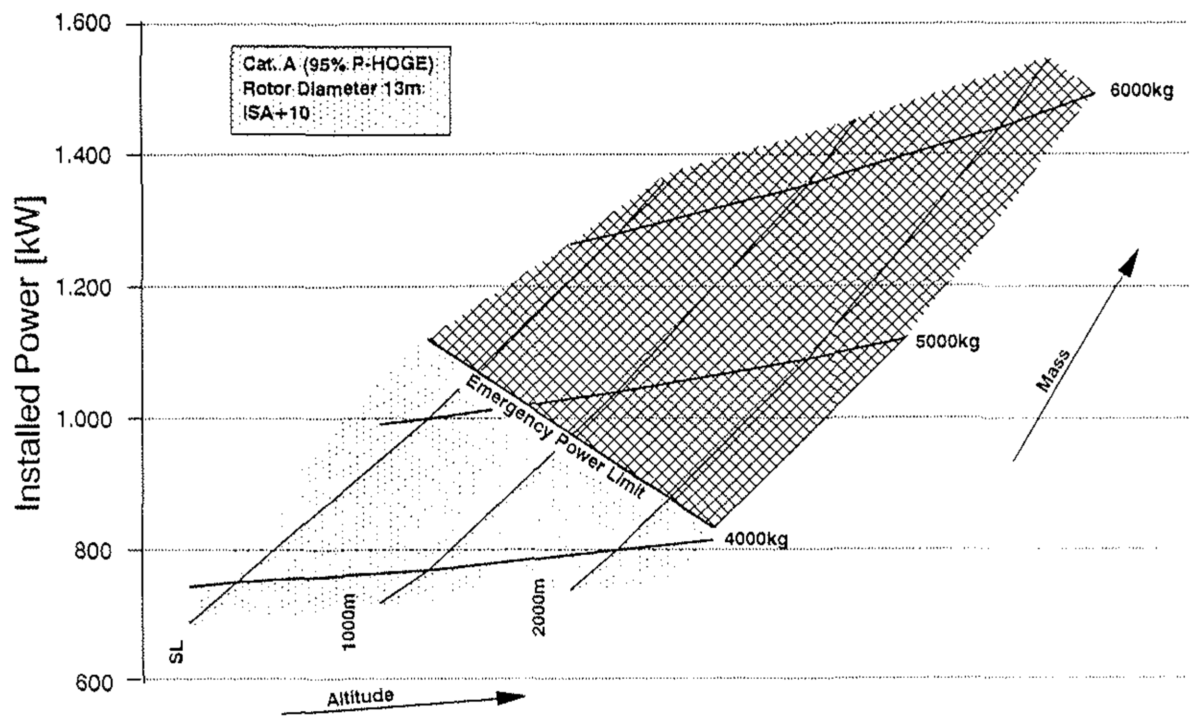


Fig. 7: Cat. A: Power Required and Performance

3.2 General considerations

The criteria presented in Fig. 5 can be split into three groups: functional or technical requirements, economic requirements, and "political" aspects.

A list of technical requirements and ways to cope with them is given in Fig. 8. Obviously, the individual requirements would yield diverging solutions, e.g. with respect to engine size and mass, and cycle parameters. The dilemma is overcome by a more complex engine design and the use of sophisticated materials. Hence, satisfying technical solutions tend to be more expensive, but are justified as long as the higher procurement cost is balanced by improved parts life, or additional payload, or increased reliability, etc.

Range, endurance, performance	Shaft power level Optimum power matching Low (part power) fuel consumption High performance retention
Growth potential	Built-in capability to increase mass flow, pressure ratio, turbine temperature and cooling with limited modifications
Agility, handling (climb, acceleration)	Sufficient shaft power in the operating envelope Engine response High alternating load capability to withstand high maneuvre loads
Low mass (engine + fuel), small installation envelope	High specific shaft power, low specific fuel consumption, Advanced Technologies (efficiencies materials high temperatures and pressure ratios, cooling)
Safety	Rugged design Containment after failure Ample emergency power in OEI case
Reliability	High parts life Ruggedness Low complexity, low parts count Insensitivity to adverse ambient conditions (FOD, icing, dust, ...) High Mean Time Between Failures Failure Mode Effect Analysis Quality control (in-house, sub-contractors) Reliability programme Accelerated mission testing
Maintainability	Interchangeability (full modularity, i.e. module change without pass-off test or trimming) Simple and quick replacement of engines and modules Accessibility for inspection (e.g. accessories) Standard tools Health monitoring
Environmental impact	Burner design (low pollutant emissions, low noise)
IR signature (mil.)	Exhaust temperature: Flow mixing Hot end visible parts: cooling

Fig. 8: Functional Requirements and Realisation

Thorough optimisation studies must be carried out at the beginning of a programme to derive the best overall solution, and the optimisation process must continue during the development phase. It must include the aircraft as well, and take into account, as far as possible, the "boundary conditions" in terms of market, business politics, and the expected political situation.

Given this scenario, how can the optimum engine lay-out be determined?

3.3 Thermodynamics

First of all, the basic shaft power level is more or less a datum. To provide sufficient emergency power means to operate the engines under normal circumstances below the optimum matching. A suitable design altitude and temperature, say 2000 m, ISA+20 K, leads to a further throttling back in a wide range of operating conditions.

Thermodynamics dictate a higher specific fuel consumption, if the engines are run at part power. However, also a low level of SFC is a strong requirement, not because of the fuel cost, but because the fuel consumption per mission will determine the size of the tank, and affect the payload.

For the same reason a low engine mass is desired. This means a small engine, too, with high specific shaft power.

Low SFC and high specific shaft power can be achieved with high turbomachinery efficiencies and low internal losses, and with a careful choice of the thermodynamic cycle.

Fig. 9 shows some typical relations between efficiencies and SFC. Aerodynamics, materials, design and manufacture determine the level of efficiencies and losses.

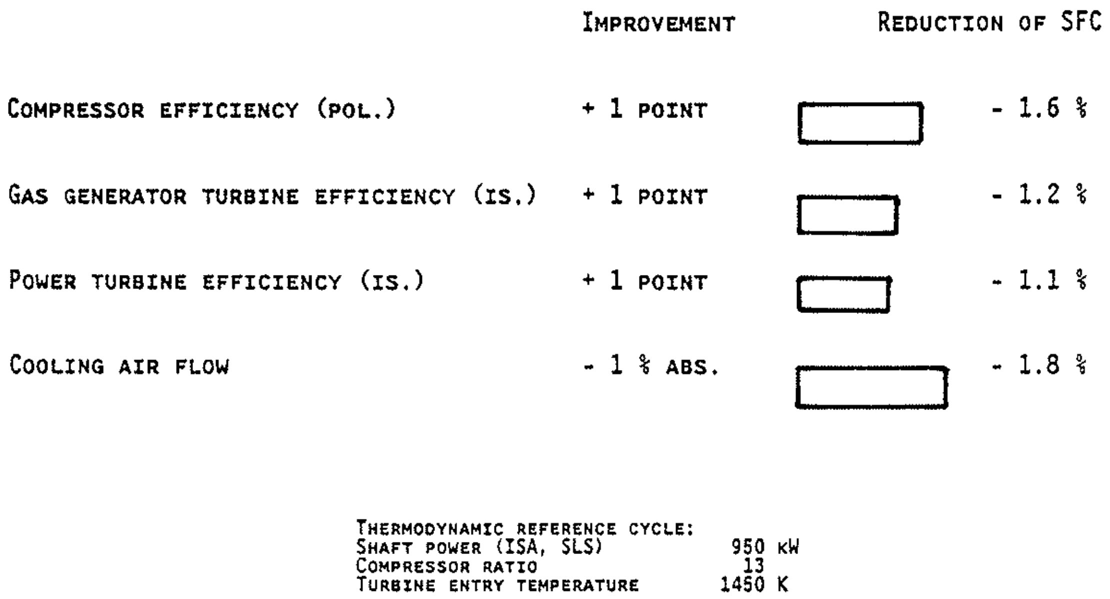


Fig. 9: Typical Performance Trades

The thermodynamic key parameters are the compressor pressure ratio and the turbine temperature. In Fig. 10 the general relationship of the cycle parameters on the specific performance is shown.

High specific shaft power leads, for a prescribed shaft power level, to a relatively smaller engine. High pressure ratios yield, in addition, smaller dimensions of the hot section.

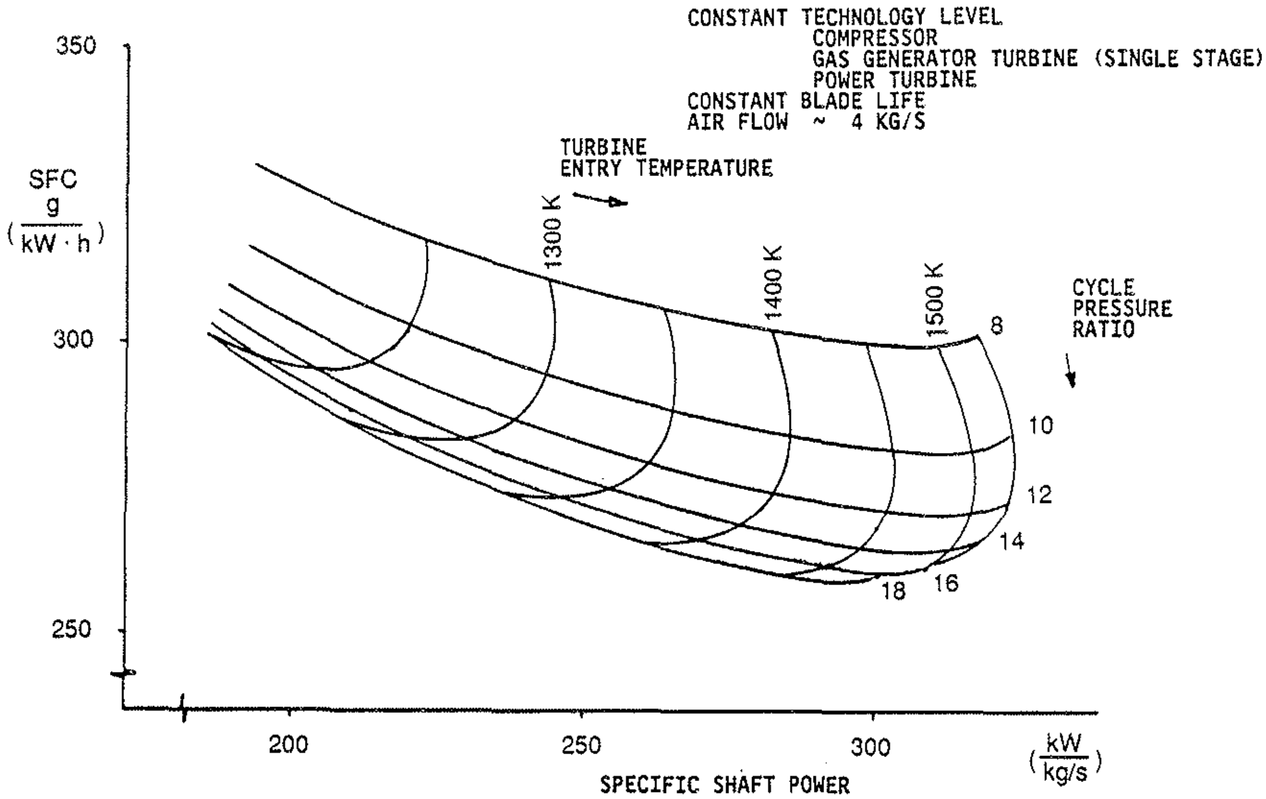


Fig. 10: SFC vs Specific Shaft Power

A small engine would well cope with the mass and envelope requirements. However, the theoretical gain of specific performance is partially offset by the adverse effect of scale, i.e. the increasingly unfavourable influence of Reynolds Numbers, secondary flows, seal clearances, and other geometric tolerances which do not scale down directly. Fig. 11 shows, as an example, the magnitude effect for a gas generator turbine.

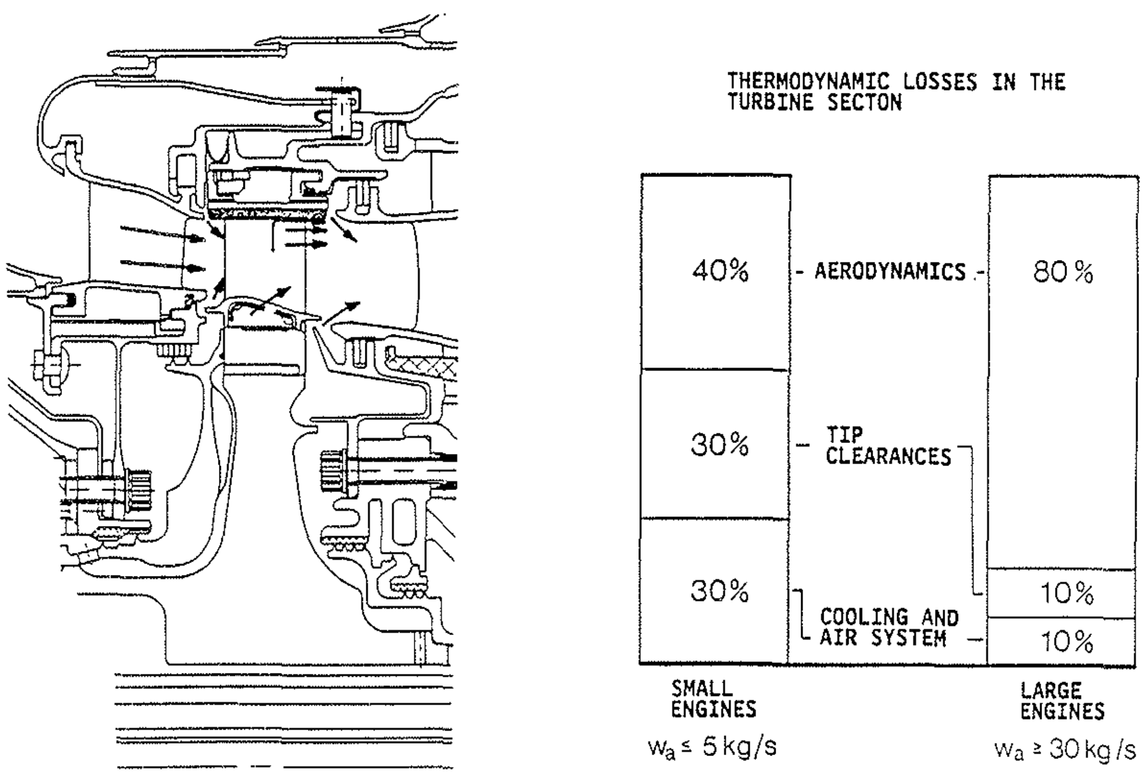


Fig. 11: Thermodynamic of the Turbine Module

In addition, too narrow tolerances would drive the production cost, and the performance gain often would be partially lost after few running hours.

Consequently, for a given level of component technology, an optimum cycle pressure ratio can be derived. This optimum pressure ratio still depends somewhat on the turbine temperature level, and both values increase with the engine size.

3.4 Design

The final choice of the design parameters is also influenced by the engine architecture. Some general trends in the turbomachinery part are highlighted here.

Engine architecture strongly influences the production and support cost and the reliability figures. The individual technological background of the engine manufacturer, or of the consortium, also plays an important role in finding the best solution.

Rotorcraft engines normally consist of a single spool gas generator, a free power turbine, eventually a reduction gearbox, the control system and the accessories. Twin spool gas generators are relatively complex designs.

Compressor

Compressor designs for the medium and high power class are axial/radial, in the modern medium-power engines also two stage radial, while in small engines, single stage centrifugal compressors seem to be an adequate solution.

Today's radial compressors achieve the same efficiency levels as axial compressors, even without variable geometry, and have cost advantages due to less complexity and lower parts count. Centrifugal stages without variable inlet guide vanes may also be more robust and insensitive to foreign object damage.

Burner

Modern burners normally are of annular type. Reverse-flow combustion chambers allow, in combination with radial compressors, a compact gas generator design. Burner efficiencies of above 99.5 per cent from idle to full power are attained. New developments tackle the unwanted pollutants.

Gas generator turbine

Gas generator turbines are single or two stage concepts. For small engines with moderate compressor pressure ratios, uncooled single stage turbines are the adequate solution, while the high power class is the domain of cooled two stage turbines. In the medium power range, the situation is not so clear. The two stage turbine profits from a higher aerodynamic efficiency, but the required high cycle temperature will offset this by the high amount of cooling air. In this case, with an advanced single stage turbine concept, higher specific performance can be achieved. Production and support cost should be in favour of the single stage turbine.

Power turbine

Power turbines have to cope with a wide range of aerodynamic operating conditions. With respect to low SFC at full and part power conditions, and high emergency power capability, a two stage concept is superior to the single stage turbine.

3.5 Materials

Boundary conditions for the engine design are defined by the available materials. Traditionally, materials have been the drivers in improving gas turbine performance by rendering possible increased cycle temperatures, components' stress levels and creep life (Fig. 12). Improved strength also allows reduction of part weight.

Corrosion and erosion resistant materials contribute to reduced repair and overhaul expenses. In several cases, coatings are used to prevent corrosion, erosion and temperature exposure of the base materials.

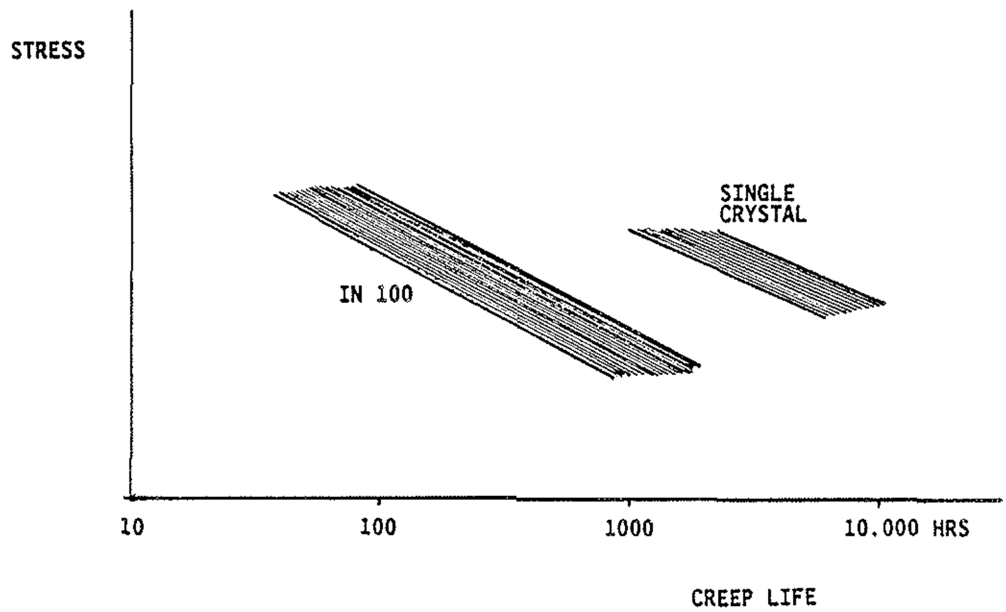


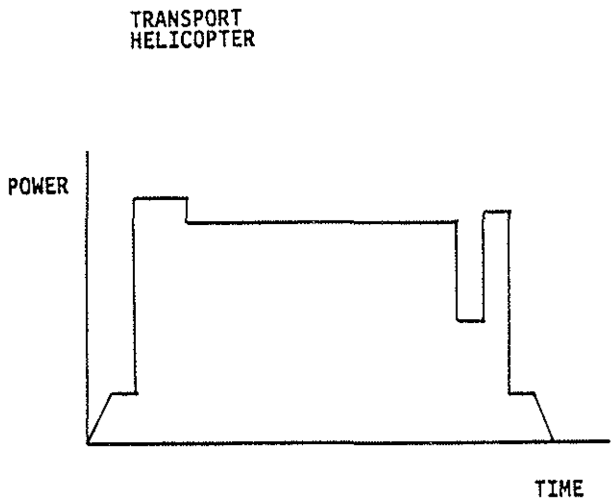
Fig. 12: Creep Life of IN 100 and Single Crystal

3.6 Operational aspects

For a military helicopter, the assigned employment usually is described by a mission profile, or a set of mission profiles, and related ambient conditions, from which the engine power requirements can be derived, and there are no concessions on mission fulfillment. The mission power requirements are taken into account in the process of engine definition and sizing. Fig. 13 shows typical mission profiles for combat and transport helicopters.

The impact of the mission on life usage is considered in the life cycle cost (LCC) optimisation. The rating structure will reflect the mission requirements, and the engine will be certified accordingly.

However, military pilots do not want the engine power to be restricted by the control system, as the predominant target is mission fulfillment. Limitations are accepted only to avoid damage to the engines or to the power transmission system.



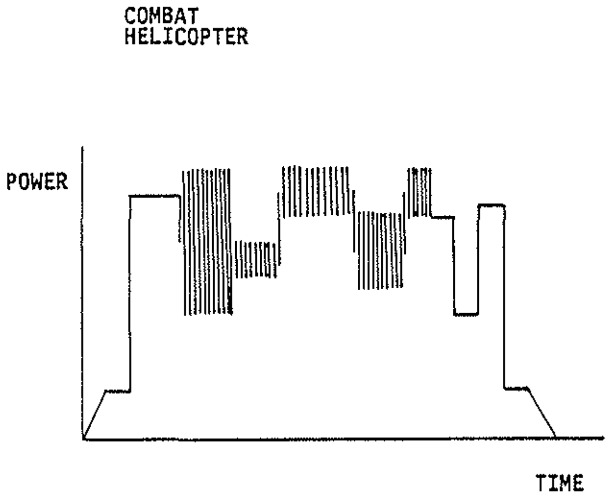


Fig. 13: Typical Helicopter Mission Profiles

In civil applications, an exact definition of mission requirements is not possible. The "typical" mission profile is based on a transportation task. But the aircraft operator is not in the position to define in advance the optimum compromise between payload, range, engine life consumption, etc. Moreover, the needs of the individual operators will be different, too.

In order to achieve profitable operation, low engine life consumption evidently is a very important factor. Operation limitations seem to be acceptable as they serve as a means to save money. The civil operator would rather reduce the payload a very hot day than tolerate excessive hot parts life consumption.

The inevitable production tolerances as well as some in-service deterioration are responsible for a certain performance scatter of the engines of a fleet. The rated turbine temperatures will cover the worst case. Depending on the control system philosophy, however, the "better" engines can be operated cooler, although providing the required shaft power, and thus, hot parts consume less of their life reserves.

3.7 Emergency power

In both, civil and military, applications, sufficient emergency power is of predominant importance, especially if Category A operation is to be permitted. The required emergency power level is excessive (Fig. 7). Unconventional means like water/methanol injection are not beloved because of safety, reliability and economy reasons. So, emergency power is created simply by "throttle push". Therefore it is felt that some compromises have to be found, e.g. restrictions of operating envelope or TOW for Category A operations.

In any case, the emergency power requirements drive the material temperatures in the hot section of the engine close to their limits. This is acceptable as the probability for the emergency case is very low, and as the duration is very short, say 30s, during which the emergency power is really needed.

On the other hand, the design to high emergency power provides power reserves for normal operation in hot-and-high conditions.

3.8 Certification

Certification rules must be established which include the emergency power requirements adequately. Beyond that, the new technological developments must be related to adequate procedures of testing and qualification in order to maintain the safety aspects. The engine manufacturer wants:

- harmonisation of civil and military qualification regulations
- suitable regulations for the qualification of new materials
- a consistent concept for the approval of emergency power.

Joint efforts of the industry, the civil and military users and airworthiness authorities are required to achieve these targets.

4. MTR390 turboshaft engine

Optimum fulfilment of the requirements of a military or civil helicopter operator can be attained when the complete helicopter including the powerplant can be newly developed. As an example, the MTR390, which is used to power the Franco-German "Tiger" helicopter, is described briefly and the programme status highlighted.

The engine is the result of collaboration between Europe's three leading producers of turboshaft engines, namely MTU Motoren- und Turbinen-Union München GmbH (Germany), Turboméca (France) and Rolls-Royce plc (Great Britain).

The work-split between the three partners is shown in Fig. 14, where each partner is responsible for the development and manufacture of his share. The work is co-ordinated in the parent companies by members of Functional Groups directed by a team of Senior Officials in MTU Turbomeca Rolls-Royce (MTR) with headquarters in Munich. MTR is the contracting organisation with the Customer and each partner holds an equal shareholding.

Turboméca: 40%	MTU: 40%	Rolls-Royce: 20%
• Compressor	• Gas generator turbine	• Power turbine with drive shaft
• Gearbox	• Combustor	
	• Combustor casing	
	• Intermediate casing	
• Control system and all accessories not MTU supply	• Accessories (oil cooler with fan, ignition system, gas temperature measuring system, drain tank with drain valve, fuel injectors)	

Fig. 14: MTR390 Workshare

The most important requirements of the customer and the helicopter manufacturer (Fig. 15) resulted in the engine according to Fig. 16, which consists of the three modules gear, gas generator and power turbine (Fig. 17).

+ AMPLE EMERGENCY POWER FOR OEI

+ HIGH ALTERNATING LOAD CAPABILITY AND COMPETITIVE LOW FUEL CONSUMPTION UNDER PART LOAD

+ EXCELLENT ACCELERATION CHARACTERISTICS

+ EASY HANDLING

+ SIMPLE AND ON-CONDITION MAINTENANCE AND MINIMUM STANDARD TOOLS REQUIRED

+ GOOD BALLISTIC TOLERANCE

+ MODULAR DESIGN AND INTEGRATED MAIN GEARBOX

+ MINIMIZED PHYSICAL ENVELOPE

+ COMPATIBLE WITH IPS AND IRS

+ LOW LIFE CYCLE COST

Fig. 15: Main Requirements for the MTR390

The simple, robust design of the 2-stage centrifugal compressor makes the engine insensitive to erosion and foreign object damage. A short engine is achieved by the incorporation of an annular combustion chamber, which with its air-blast fuel-injection system ensures low-pollutant combustion. The gas generator turbine, which features cooled single-crystal blades and powder metal disk for long life, is of single-stage design for sake of cutting costs and engine weight. The speed of the 2-stage power turbine is matched to the 8000 rpm requirement of the helicopter manufacturer via a reduction gear. The engine accessories are easily accessible and can be speedily changed without the need for special tooling.

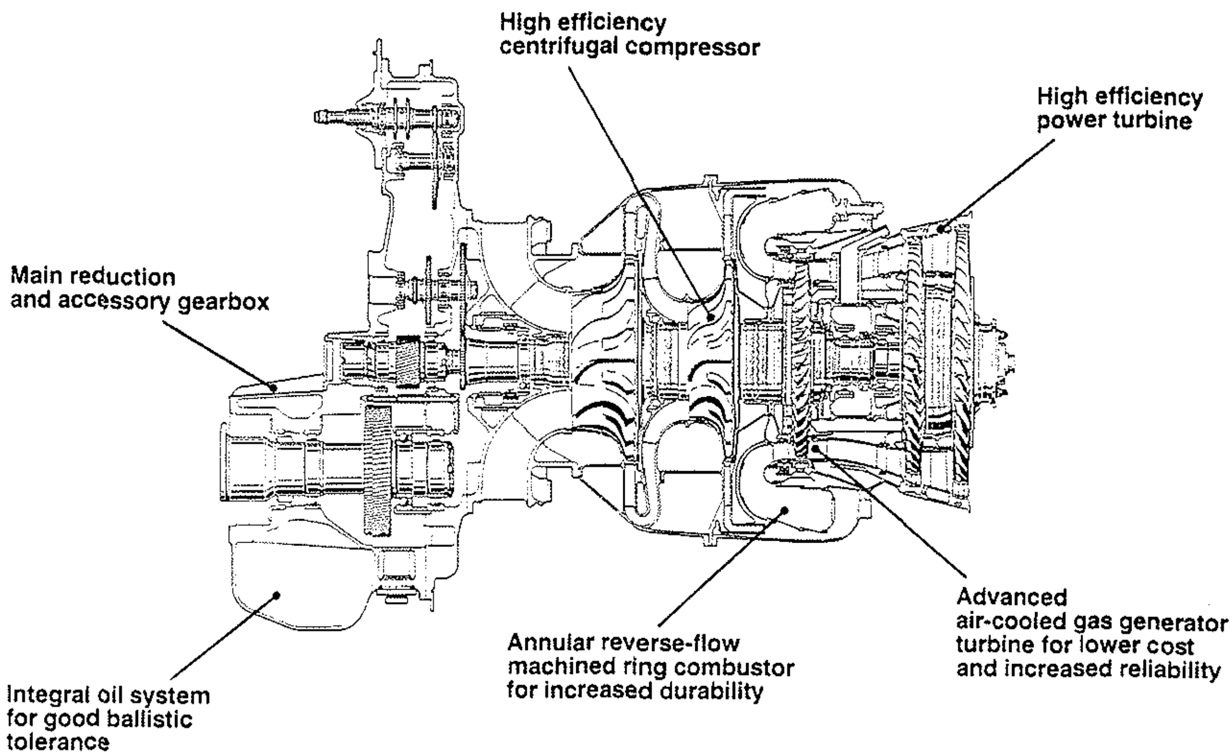


Fig. 16: Engine Design

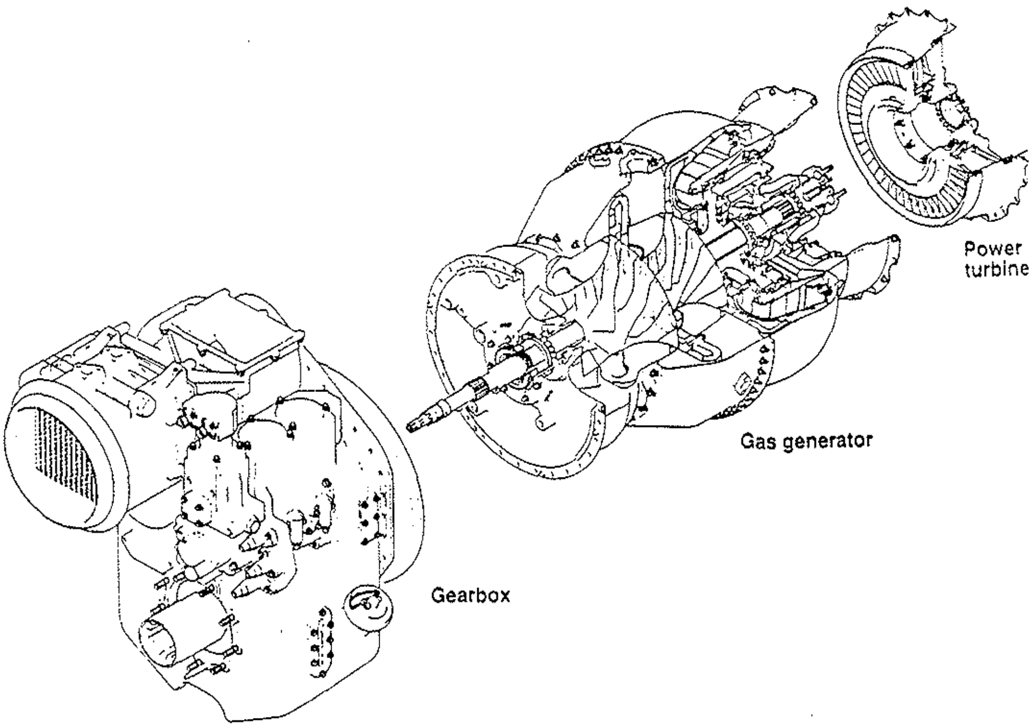


Fig. 17: MTR390 Modular Breakdown

Since protection against the ingress of foreign bodies at the engine intake is not necessary for all flight attitudes, an integral particle separator (IPS) is not fitted. A screen is provided for trapping coarser particles, and if required, a sand separator can be fitted by the helicopter manufacturer. As experience in the recent Gulf war showed, this is necessary for operations in a sandy atmosphere, even with engines fitted with IPS. The helicopter's vulnerability is markedly reduced by appropriate exhaust control and by the use of an infrared suppressor (IRS).

The various engine ratings have been set such that on the one hand the high emergency power in the event of failure of one engine of the helicopter, which operates predominantly at low altitudes, will not result in critical situations, and on the other hand a potential power increase of up to 50% can be achieved (Fig. 18).

Ratings	Outer shaft power		Specific fuel consumption	
	kW	shp	g/kW h	lb/shp/h
Normal operation				
Take-off (5 min)	958	1285	274	0.451
Maximum continuous	873	1171	277	0.458
One engine inoperative				
Super emergency (20s)	1160	1556	—	—
Super emergency (30s)	1138	1526	—	—
Contingency (2.5 min)	1027	1378	—	—
Intermediate (30 min)	958	1285	274	0.451

Average new engine
SLS/ISA
Uninstalled
Output shaft speed 8000 rpm

Fig. 18: Engine Performance

The engine is supplied complete with all accessories and systems necessary for independent operation. The integral oil system has been designed with special emphasis on reduced vulnerability. Automatic engine start, gas generator and power turbine speed, torque equalization between the engines (twin-engined versions) and the observance of limits are all controlled by a modern FADEC system based on experience gained with other engines. An engine condition-monitoring system supplies all information necessary for rapid fault diagnosis and correction.

For sake of harmonization, the engine specification, which defines the requirements for the development and certification of the engine, is based on the European specification JAR-E, derived from the British BCAR specification. To allow for specific requirements associated with military operation, relevant provisions from the specifications MIL-E-8593 A and E as well as German and French national standards have been taken into consideration.

The engine is used to power the Franco-German helicopter "Tiger". With 427 helicopters to be procured for the armed forces of the two countries, including spares this means a total of more than 1000 MTR390 engines. The mile-stone chart covering the development and production of the engine is shown in Fig. 19. By the time that the first series-production "Tiger" in the French anti-tank version "HAC" is supplied in 1997, the engine will have acquired a total of 6000 running hours plus a further 2400 hours of accelerated mission tests (AMT).

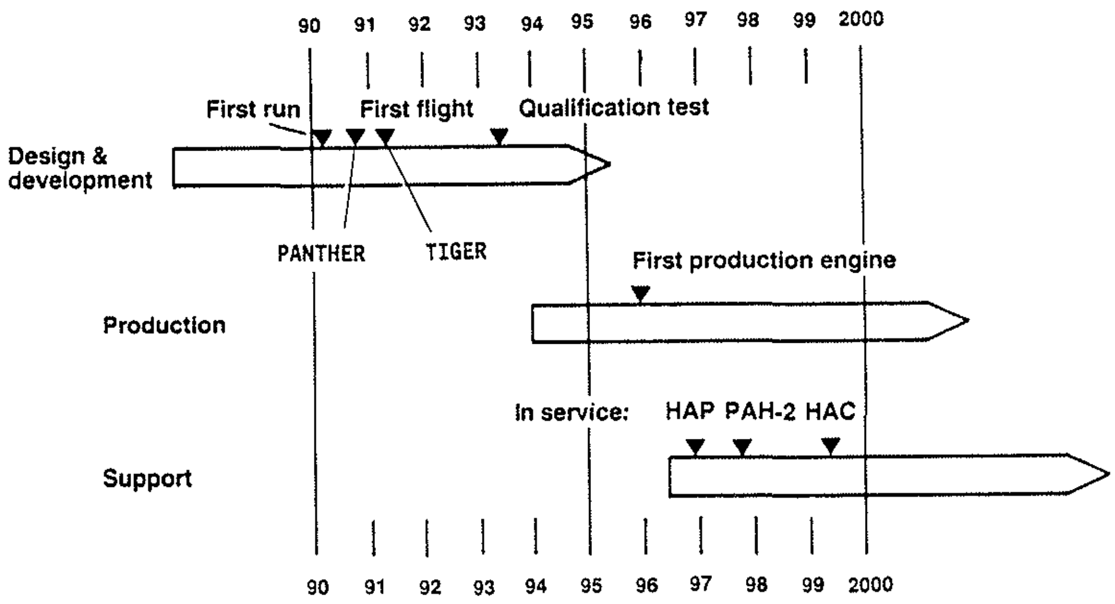


Fig. 19: MTR390 Programme

The most important milestones, determined three years ago during the signing of the development contract, have been attained according to schedule (Fig. 20).

1987	SIGNING OF MAIN DEVELOPMENT CONTRACT
DECEMBER 1989	ENGINE FIRST RUN AT MTU MUENCHEN
FEBRUARY 1991	PRELIMINARY FLIGHT QUALIFICATION TEST
14 FEBRUARY 1991	FIRST FLIGHT OF THE "PANTHER" HELICOPTER WITH TWO MTR390 ENGINES
27 APRIL 1991	FIRST FLIGHT OF THE "TIGER"-PROTOTYPE WITH TWO MTR390

Fig. 20: MTR390 Programme Milestones Achieved

The first run of the fully-equipped engine took place at MTU in Munich, and the engine was awarded preliminary flight certification after a 60-hour endurance run. The test programme was split into 10 cycles each of six hours duration. All programme points were attained successfully. The turbine entry temperature and specific fuel consumption were in accordance with expectations, and the oil consumption and acceleration of the engine were within the specified limits. Final inspection proved all components to be in satisfactory condition.

Trials in a "Panther" flying test bed (the Panther is the military version of the Aerospatiale "Dauphin") are being conducted at CGTM in Pau, France.

The first of five prototype "Tigers" fitted with two MTR390 engines had its maiden flight at Aerospatiale in Marignane, France. It lasted for approximately one hour and featured hover, forward and backwards flight at low speeds, sideways manoeuvres in both directions, rotations around the yaw axis, vertical climb and descent and several landings. All systems operated trouble-free and the engine performance was superior to the specified requirements.

The various engine tests are being continued with 6 ground use engines at the respective partners. By the mid of July, these engines plus those used in the "Panther" and "Tiger" helicopters had accumulated more than 1000 running hours, including 140 flying hours.