Implementation of a New Inlet Protection System into HEMS[1] Fleet

Bartosz Przybyła
Polish Medical Air Rescue (LPR), HEMS Base Szczecin, 72-100 Goleniów, Poland

Radosław Przysowa
Air Force Institute of Technology (ITWL), ul. Księcia Bolesława 6, 01-494 Warszawa, Poland

Zbigniew Zapałowicz
West Pomeranian University of Technology (ZUT), al. Piastów 19, 70-310 Szczecin, Poland

ABSTRACT

EC-135P2+ helicopters operated by the LPR are highly exposed to environmental particles entering the engine during HEMS missions. The organisation adopted a comprehensive set of measures to predict and limit the impact of dust ingestion including gas path analysis, health and usage monitoring, and visual inspections. Finally, helicopters had modified inlets to install air filtration system which minimises the number of particles ingested by the engine. CFD simulation has been performed to check whether the upgrade has an impact on helicopter aerodynamics. The consequence of using filters is to extend the lifetime of engines, reduce operating costs and the number of maintenance tasks.
Keywords: Environmental Particles, FOD, IBF, IPS, turboshaft, HUMS, performance calculation

1.0 INTRODUCTION

Polish Medical Air Rescue-LPR is a medical organisation directly subordinate to the Ministry of Health which performs rescue operations, i.e. HEMS - Helicopter Emergency Medical Service and health transport (EMS). Until 2009, the LPR fleet was based on helicopters Mi-2+, one helicopter Agusta A109E Power, and the transport aircraft Piaggio Avanti I/II. Due to non-compliance with the standards and regulations contained in JAR-OPS 3 regarding the performance of HEMS missions, i.e. helicopter performance, flight safety in built-up areas and medical standards, the Mi-2+ helicopters have been decommissioned. Starting from 2009, they were replaced with the EC135P2+/H135P3 helicopters (figure 1) equipped with PW206B2/PW206B3 turboshafts (figure 2).

Figure 1. EC-135P2+ helicopter operated by LPR

[1] Abbreviations are defined in the Nomenclature section at the end of article

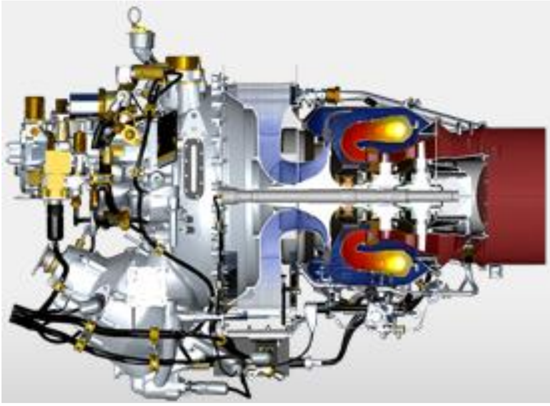


Figure 2. PW 206B2 turboshaft [12].

These engines are characterised by compact structure, relatively high power and lower operating costs compared to other engines of this class. They consist of a centrifugal compressor, manoeuvrable ring-shaped combustion chamber, two one-stage turbines, driving respectively the compressor rotor, starter-generator, FMM and the drive shaft through the main rotor and fenestron.

Performing rescue or transport missions the helicopters are usually exposed to adverse conditions. A significant number of relatively short flights results in the exposure of engines, in particular, compressors, to foreign object damage. The characteristic feature of HEMS missions is operating in places other than airports, i.e. beaches, unpaved roads, meadows, city areas and construction sites. Additionally, LPR helicopters perform flights in the coastal belt and the vicinity of chemical plants. It all makes that the engines during the operation ingest the particles present in the air such as sand, salt mist, dirty water or other impurities which negatively affect the engine components, causing damage, e.g. to the compressor. Besides, the corrosion caused by particles in the industrial and urban environment is particularly visible in the hot section (hot corrosion). These changes have a direct impact on performance parameters of helicopters.

In the first years of the operation of EC135 helicopters in Poland, the only measure of inlet protection was a protective mesh, which did not stop dust and gravel entering engines. Consequently, gas paths were exposed to various foreign object damage (FOD) and rapid erosion, which was observed as a decline in helicopters' performance. Due to the deterioration and damage to gas-path components, which required an immediate repair in the overhaul plant in the majority of cases, engines could not reach the nominal lifetime (TBO) of 3500-4000 FH. The observed degree and rate of the deterioration of efficiency of EC135 were much higher than of the previously operated helicopters in LPR: Mi-2, Mi 2 Plus and Agusta A109 Power. Due to various reasons, the ad-hoc repairs included more than half of the PW 206B2 engines, most of them in the years 2011-2013.

Presumably, the problem was not noticed among users of the countries of Western Europe; however, in some HEMS organisations there were rumours concerning similar issues, but not on such a scale. Most probably other types of soils dominate in the Central and Eastern Europe than in the West. The countries, which reported the problem of excessive erosion and FOD include the Netherlands, the vast part of Germany, Hungary and Spain. No problems were reported in Norway, the Czech Republic, Austria and Great Britain. There are no data on France, Sweden and Italy.

Inlet protection systems and procedures for reducing the impact of ingested particles are mainly used by military users. There are publications that describe in detail the topics of FOD [11], dust ingestion [24] [13][3][26] and erosion [10]. Commercial operators in developed countries use clean airports and rarely have to deal with these problems, so the inlets of civilian helicopters are usually weakly protected.

2.0 MONITORING PERFORMANCE DETERIORATION

As part of ensuring continued airworthiness, as well as to limit the influence of dust ingestion and related losses, the LPR performed many analyses and took a number of precautions, some of which are presented below. Due to the fact that it was not possible to avoid missions in harsh conditions and eliminate environmental factors, it was necessary to limit the impact of ingested particles, predict the pace and degree of degradation, as well as make decisions on postponing flights and replacing the engine.

The known modelling methods of engines were used to quantify the observed and expected degradation of engines. Building upon the obtained parameters of the new and degraded engine, the general assumptions adopted to calculate the turbine engines [16][23] and data available in the publicly available literature [2], the calculations of operational parameters of both engines were made. To this end, the GasTurb software [4] was used, thanks to which, the parameters were calculated for characteristic cross-sections (Figure 3) of the engine.

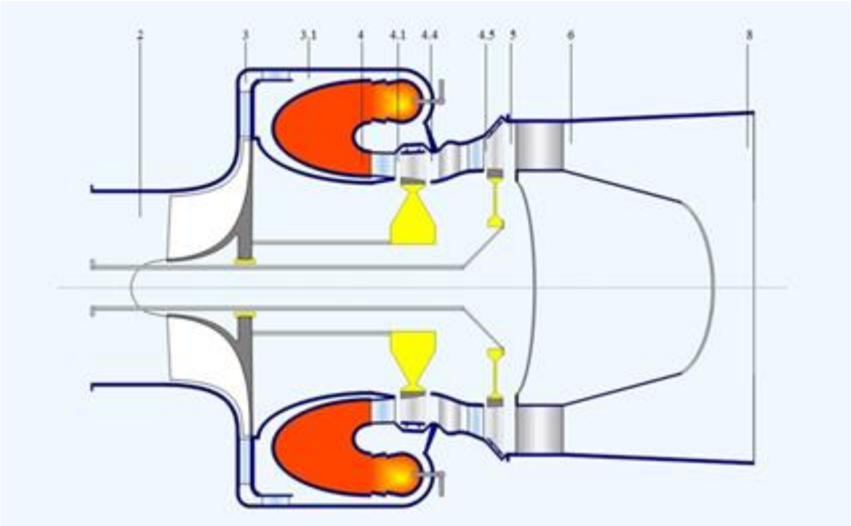


Figure 3. Specific cross section of the turboshaft: 2 - inlet, 3 - diffuser, 3.1 - combustion chamber, 4 - outlet of the combustion chamber, 4.1 - rotor of the compressor's turbine, 4.4- outlet of the compressors turbine, 4.5 - power turbine, 5 - outlet of the power turbine, 6-inlet to the exhaust system, 8 - exhaust outlet [22]

Most important parameters calculated by GasTurb for the individual engine sections are total pressure, total temperature and mass flow of the working medium (Figure 4).

It was observed that in each of the investigated cross-sections, the parameters for the degraded engine changed in relation to the new engine. The most noticeable change of values occurred in the engine hot section, i.e. from the outlet of the combustion chamber (cross-section 4) to the exhaust (cross-section 7). In the example under consideration, the engine was required to be overhauled after less than 500TFH which was mainly caused by the decrease of the efficiency of compressors and the efficiency of the generator and power turbine. Taking into consideration that between cross-sections 2-3 (engine inlet - diffusor) the changes in parameters' value are small ($\Delta T \approx 3$ K, $\Delta P \approx 7$ Pa), in the cross-section from 4 to 8 (i.e. from the outlet of the combustion chamber to the exhaust) these changes are more significant ($\Delta T \approx 50$ K, $\Delta P = 6 \div 19$ Pa).

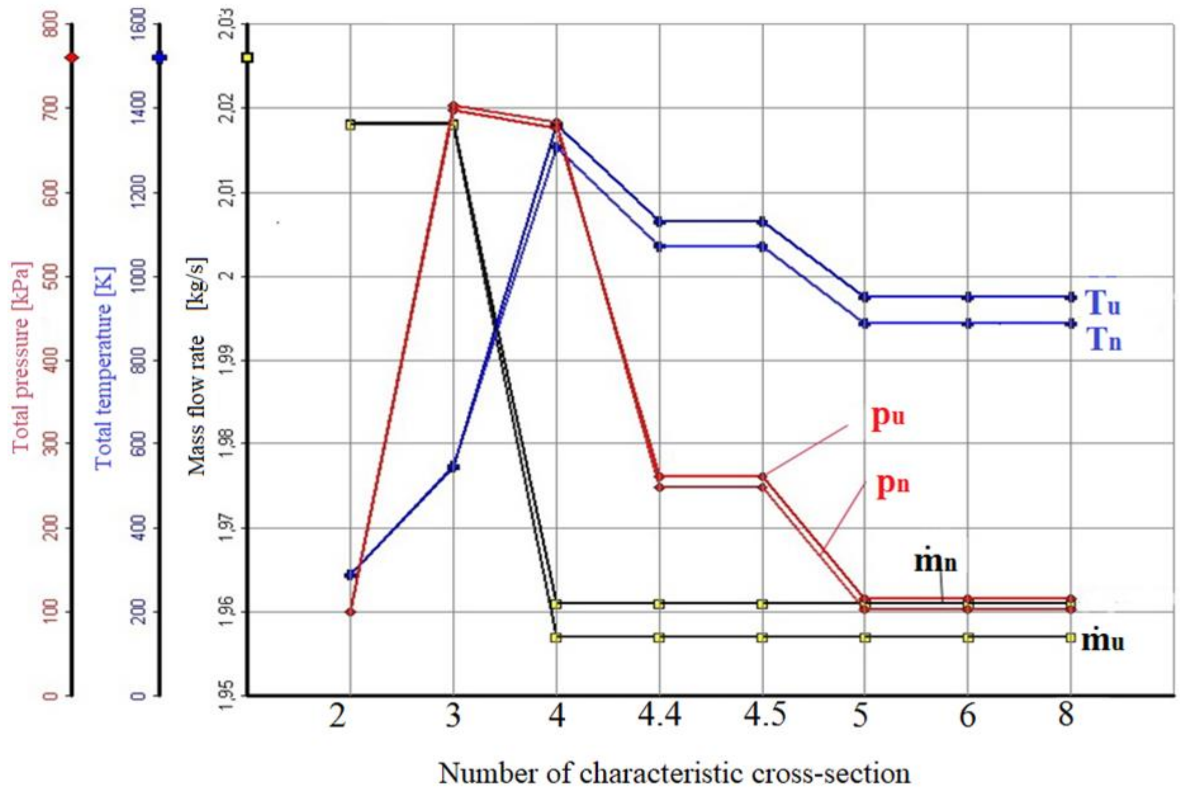


Figure 4. Distributions of total pressure, total temperature, and mass flow rate of air for the new ("n") and degraded ("u") engines [22]

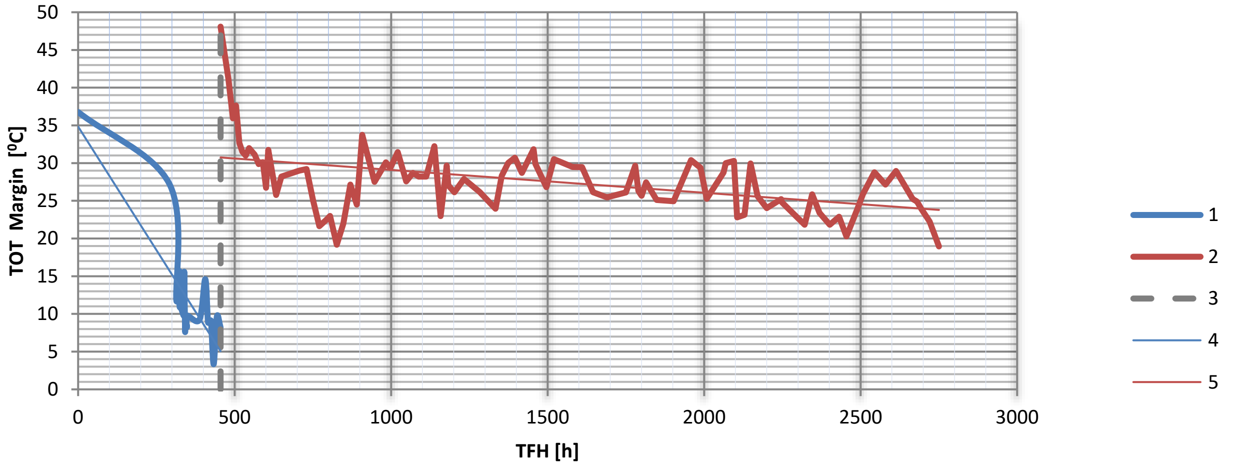
The other, equally important parameters (table 1) calculated by GasTurb, define the health of the power plant. One of them is the specific fuel consumption c_j, which is the fuel required to produce each watt of power in one second. This parameter is higher for the degraded engine. A slight change was also observed in the power delivered by the engine.

The degraded compressor is less efficient due to the failures of the impeller and stator. This means that a smaller amount of air is produced by the same rotational speed. To constantly deliver the required torque through the drive shaft, the EEC system controlling the engine increases the quantity of fuel supplied to the engine. The effect of this is an increased temperature in the combustion chamber and the increased pressure of exhaust gases, due to which the kinetic energy of exhaust gases is increased. The power turbine generates higher torque, which, drives the rotor of the compressor through the shaft and thanks to this, the compressor, by increasing its rotational speed, provides the amount of air essential for the proper operation of the engine. On the other hand, the increased gas temperature contributes to the reduced lifetime of turbines. Temperature margin ΔTOT measured during GPC, which initially equalled approx. 50°C, decreases even to 0 due to the dirt and erosion.

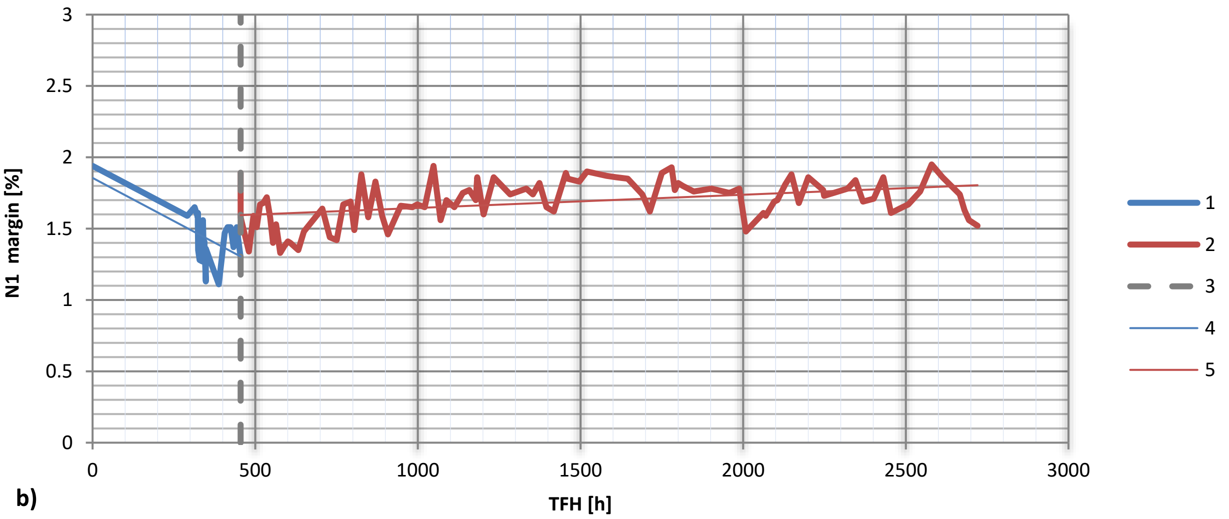
The health and performance of the power plant are verified by conducting a series of checks at the system and component level, which include gas path inspections, measurement of the power on the ground (GPC) and analysis of flight data. GPC is the measurement of the engine performance on the ground, and is used to estimate the condition of the engines. It consists in checking the first and then the second engine respectively. By switching off all energy receivers in the examined engine, the appropriate engine load, defined in the instruction, is applied by increasing the torque expressed in percents – TRQ. The following percentage values are then read: N1- rotational speed of the shaft of compressor rotor, N2 – rotational speed of the shaft of power turbine, TOT- gas temperature at the outlet of the turbine driving the compressor and $\dot{m}_p$- fuel flow rate. Then, the read parameters with the known air temperature and pressure are compared with boundary values determined for each engine: N1 margin and TOT margin. In this way, the trend of the engine is measured (figure 5), and it is assessed whether the engine is safe to operate.

Table 1. Calculated parameters of the new and degraded PW206B2 turboshaft

Parameter	Symbol	Unit	New engine	Degraded engine
Effective power	P_e	kW	343.2	343.4
Specific fuel consumption	c_j	kg/(s·W)	$1.11 \cdot 10^{-7}$	$1.21 \cdot 10^{-7}$
Rotation speed of high-pressure rotor's turbine	N1	rev/min	53300	53526
Nominal power turbine spool speed	N2	rev/min	39130	39130
Temperature of gases at outlet of high-pressure turbine	$T^*_{4.2}$	K	1030	1088
Mass flow rate of fuel	$\dot{m}_p$	kg/s	0.038	0.042
Pressure ratio of compressor	π_s	-	7.1	6.95
Coefficient of pressure loss at inlet	σ^*_{wl}	-	0.99	0.99
Burner exit temperature	T^*_4	K	1308	1361
Isentropic efficiency of combustion chamber	η^*_{ks}	-	0.99	0.99
Fuel heating value	W_u	MJ/kg	42.8	42.8
Overboard bleed	$\dot{m}_{pl}$	kg/s	0.1015	0.1015
Power offtake	P_{WX}	kW	30	30
Mechanical efficiency of compressor turbine	η_{mHP}	-	0.99	0.98
Burner pressure ratio	β_{KS}	-	0.97	0.97
Pressures ratio in a channel between turbines	β_{IT}	-	0.975	0.98
Pressures ratio in a channel after a power turbine	β_{KT}	-	0.98	0.98
Pressures ratio at engine outlet	β_{RW}	-	1.03	1.15



a)



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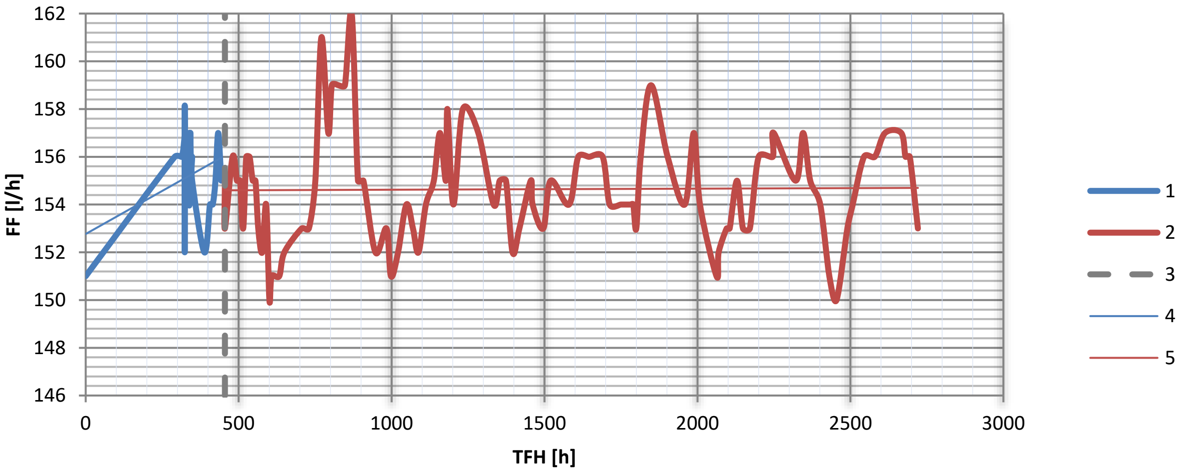

c)

Figure 5. TOT margin, N1 margin and fuel flow FF as the function of flight hours TFH: 1- before the overhaul and IBF installation, 2 - after the overhaul, 3 – time of the overhaul, 4,5 - trend lines

Another method for evaluating the health of the power plant is reading flight data recorded by the UMS system on the memory card (PCMCIA). Then, after the flight or on-ground inspection, these data are read in the PGS Vision software, to analyse the operational parameters with sampled once per second and check if values do not exceeded thresholds, as, e.g. TOT or rotational speeds (figure 6). The dataset includes key flight and engine parameters which are automatically displayed: TRQ - torque, N1 – generator speed, N2 - power turbine speed, TOT – turbine outlet temperature, NR - main rotor speed, IAS - indicated flight speed, ZP - pressure altitude, OAT- ambient temperature. After moving the cursor over the checked flight time, the individual values assigned to the relevant curve are displayed.

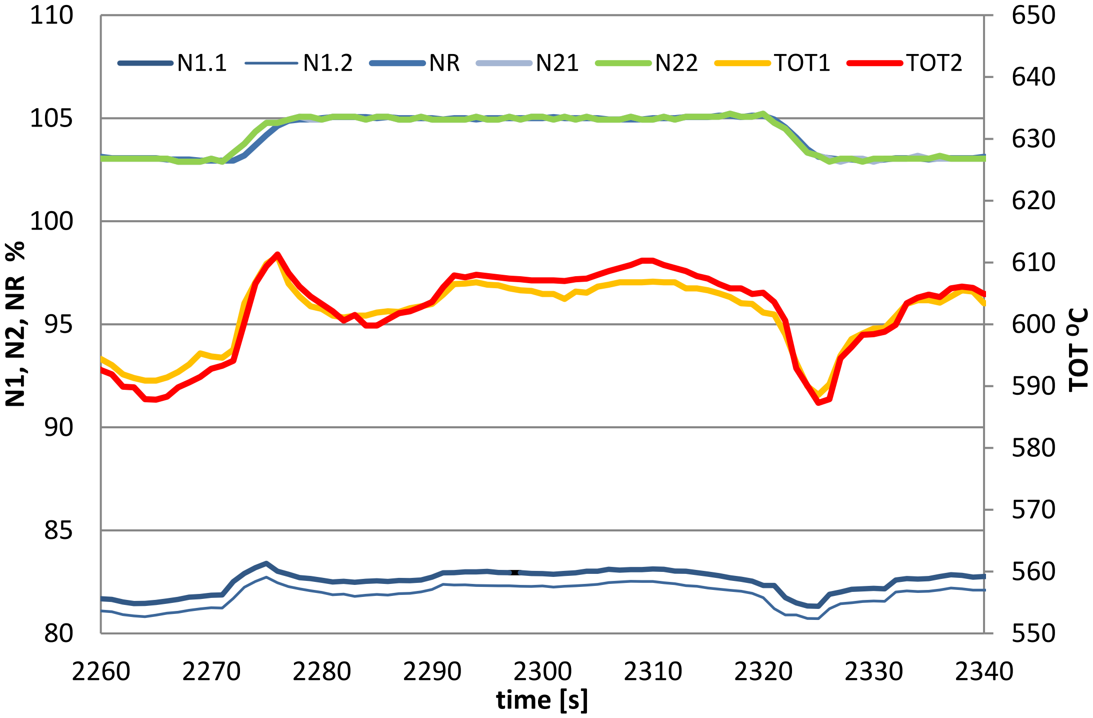

Figure 6. Results of a GPC; N2 threshold exceeded for both engines: N2 > 104ºC

Knowing the parameter values and the duration period of the potential exceedance it can be determined whether it is necessary to conduct additional maintenance works as, e.g. the inspection of the main rotor blades or, e.g. engine replacement due to exceeding the N2 threshold. The manufacturers in helicopter maintenance manual (AMM) [8] and engine maintenance manual (EMM) [25] defined the allowable values of parameters, what and when shall be done in case of an exceedance. For example, if N2 speed has gone above the threshold of 104%, it is not always associated with the engine replacement. In such a case, data are sent directly to the engine manufacturer and they, based on their models, decide whether the engine can be operated further or should be overhauled.

The mentioned inspections aim to determine the engine condition and to accept it to or remove it from further service. At the same time, engine and the helicopter manufacturer, taking into account the minimisation of the occurrence of failure of the power plan, in the AMM [8], EMM [25] and MSM [9] oblige the user to perform specific maintenance works as, e.g. replacement of fuel filters, visual inspection of the engine, replacement of injectors, etc. These inspections should be performed by the given engine/airframe flying time or according to the calendar. Additionally, day-to-day inspections are done, after a day in flight, by checking the levels of liquids, potential leakages of the engine, hydraulic systems, main transmission, etc. A frequent phenomenon, which occurs during the scheduled maintenance of helicopters, is detecting a failure, which is not described in any maintenance manual. In such a case, the problem is reported to the manufacturer, and he issues an appropriate document – RDAS along with the overhaul instruction. In the event of the occurrence of the same failure several times on different helicopters, the manufacturer, in the next revision of AMM, supplements the instruction to include the new overhaul procedure.

3.0 GAS PATH INSPECTION

The visual inspection of the gas path consists in inserting the borescope through the engine inlet, checking the compressor impeller, measurement of potential failures (figure 7) and the comparison of results with permissible values defined by the manufacturer.

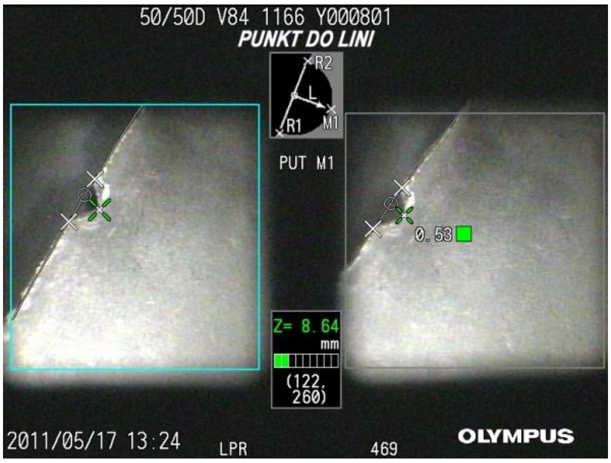

Figure 7. Flaw in the compressor aerofoil measured with the use of a calibrated borescope (photo J. Haliniak)

In the case of the lack of inlet protection or high exposure to environmental factors, various types of FOD as well as the erosion of the compressor impeller, inlet guide vanes, diffusor behind the compressor and some aircraft structures are observed. The most common failures of the compressor observed in engines operated by LPR include:

- Nicks (figure 8)
- Dents (figure 9)
- Tears (figure 10)
- Erosion of compressor impeller (figure 11)
- Erosion of compressor stator (figure 12)

Figure 8. Nicks in compressor aerofoils (photo B. Przybyła).

Figure 9. Dents of a compressor aerofoil (photo J. Haliniak).

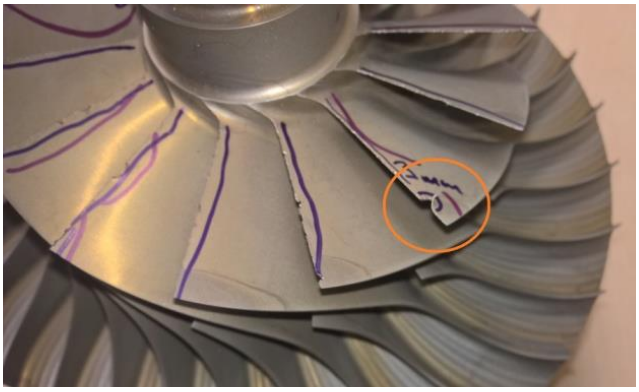

Figure 10. Tears of a compressor aerofoil (photo B. Przybyła)

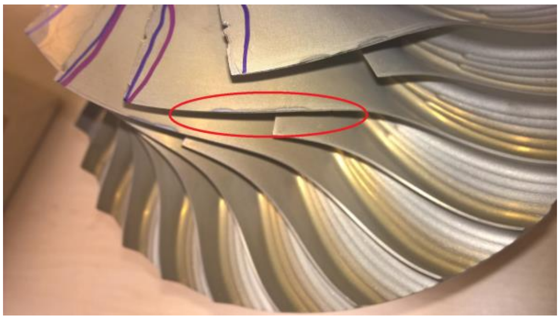

Figure 11. Erosion wear of the edges of the impeller (photo B.Przybyła)

Figure 12. Erosion of the compressor stator (photo P. Rutkowski)

Additionally, the borescope is introduced into the engine through the slot of a disassembled injector. In this way, the hot section is checked, i.e. combustion chamber and turbine. Then, the cracks are searched for, and it is assessed whether there was no local overheating of the elements; the sealing of turbines and the turbines themselves are also checked. The visual inspection of the engine inlet is conducted every 1000h. Having disassembled the IBF filtering element, the inlet protection mesh is examined in view of its deformation and inlet guide vanes as well as the leading edges the compressor impeller. The inspection is made using the borescope when the trend of GPC results shows deterioration. In the first part of the operation of EC-135 helicopters by LPR, rapid damage was observed in the gas path, sometimes already at 300-400 TFH.

4.0 COMPARISON OF INLET PROTECTION SYSTEMS

Attempts were made to limit the impact of the dust ingestion by watering the landing strips or landing on the wet part of the beach, which is possible in rare cases of HEMS missions. Regeneration cleaning was regularly conducted (every 100 FH), which increases TOT by several degrees. Desalination cleaning is done every day after landing on the beach or after the flight along the sea lane or within seven days after the flight in the coastal belt (in the distance of 0 to 10-12 nautical miles from the coastline).

These temporary measures did not solve the problem of premature wear of engines, that’s why in the years 2011-2012 analysis and activities were performed aimed at introducing the system limiting the entry of dust and foreign particles to the engine. The possible solutions were discussed with the helicopter manufacturer and independent suppliers of filters and particle separators.

In 2012 there were three filtration solutions to EC135 on the market: Pall PUREair, AHD IBF and FDC/aerofilters. PUREair IPS was designed mainly to be used in the desert and areas of high dust concentration. It was a mutual project of Pall and AHD and was certified in TC. Its considerable weight (~64 kg) [18] introduces performance limitations. Its operation is based on the use of centrifugal force to expel contamination particles (figure 13).

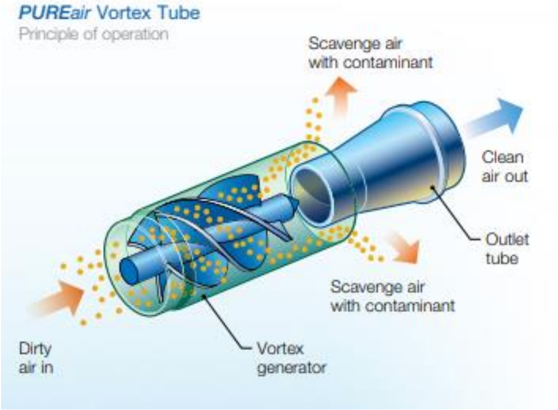

Figure 13. Operating principle of a particle separator (IPS)

This type of inlet protection drew moderate interest in Europe. One of the operators using this solution, is ADAC. The main disadvantage is the necessity to turn on the system fans to work correctly. They take a lot of helicopter power. The pilots, who fly with this system, frequently switch off the fans during take-off/landing to have more power in the case of a heavy payload. Thus, when the protection is necessary, the filtration is scarce. Additionally, the location of the system results in many leakages through the shield and the swash plate (Figure 14). Sealing leakages is problematic and arduous. Although failures do not often occur, it is indispensable to replace the nozzles.

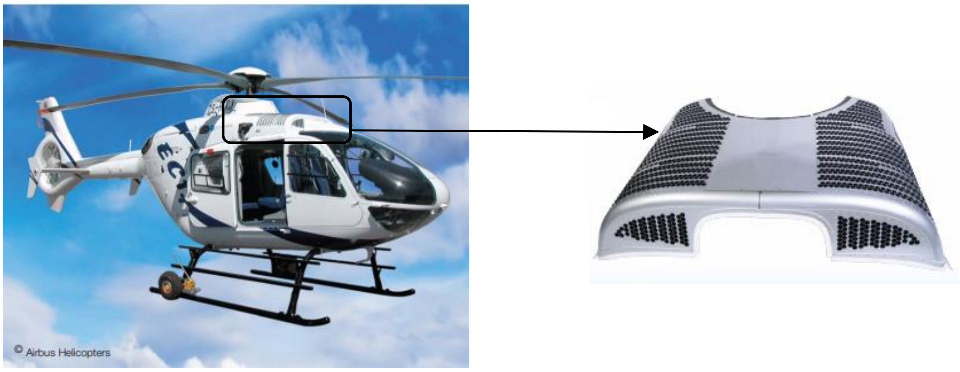

Figure 14. EC135 helicopter with PUREair system

The system by FDC/aerofilters (now Aerometals) combines some advantages of PUREair and AHD IBF (figure 15). It consists of filters of air-ducts, control panel, bypasses, new ducts of oil cooling system and sealing system of the main rotor. The FDC system has similar problems with deformation of filters as the AHS IBF system. The price is still an advantage. The biggest drawback of this system is the lack of the possibility to carry out further modifications of the helicopter from the P2 to P3 version.

AHD IBF was an OEM's response to the FDC/aerofilters system and operators' problems with erosion inside the engines. AHD wanted to avoid significant changes in the structure. Side inlets were mounted while the existing central inlet was used only as a bypass. In emergencies, the opening bypass doors restored the initial flow, which substantially facilitated the fast certification. The AHD solution using the Italian BMC filter has the advantage over the competitive systems because it does not decrease the power output of the engine and the pilot's activity is limited to pre-flight test and the control of filter clogging indicator on the control panel.

Figure 15. EC135 with FDC/aerofilters system

Currently, Pall Corporation collaborates with ADAC (for two years) to replace the current IBF system with filters which will not have to be oiled. This project is in progress, but there are a few problems resulting from the recent tests carried out on a different helicopter in heavy rain. The new filters should be much cheaper and durable. The response of AHD to this project is the price reduction of current IBF by approx. 30% and the works on the non-oil filter. In the meantime, (when Pall/ADAC project kicked off) AHD developed a new IBF filter removing the defects of the current one (replaced the filtering material, strengthened material of the mesh and reduced the number of lamellae) to prevent them from deforming.

5.0 IMPLEMENTATION OF IBF

In the years 2013-2014, LPR equipped all 23 operated EC-135P2+ helicopters with the AHD IBF system. The air filtration minimises the possibility of foreign particles being ingested into the engine. The overall weight of the installed system amounts to 26.5 kg [1]. Its implementation involved substantial modification of the airframe related to the reconstruction of the inlet system (figure 16).

At that time, there were 17 HEMS permanent bases in Poland and a seasonal one operating during the holiday season. An extremely difficult task was to ensure continuous HEMS readiness of each of them, due to the fact that LPR had only 6 spare helicopters. The continuous process of pilot training and the need to perform scheduled maintenance tasks required that incorporating the IBF system into all helicopters was planned well in advance. It was necessary to determine which databases are less loaded with HEMS missions, predict which helicopters need maintenance first and deploy helicopters appropriately. In many cases, the key factor was the technical condition of the engines, which did not allow the completion of on-going operations of the aircraft and put it first in line.

Continuous Airworthiness Department (CAMO), by monitoring helicopter operations and managing logistics, commissioned service bases in Szczecin and Warsaw to perform helicopter modifications combined with scheduled maintenance works - after 500h or 1000h. The first helicopter was rebuilt in AHD Donaworth but the next one in the LPR base in Szczecin, with the support of technicians from Germany. All others were modified in one of two LPR service stations - in Szczecin and Warsaw. Despite the fact that each step of the modification was precisely described in the Service Bulletin [1], fitting the IBF system, due to its complexity and limited experience of technical personnel, initially went relatively slow. The service time was also influenced by defects detected in the aircraft. With each subsequent helicopter, the IBF installation process was progressing more efficiently. This was due to the experience gained, better organisation of the assembly process and enlarging the teams servicing composite structures.

Figure 16. AHD IBF system installed on EC135: a) bypass door, b) internal port of static pressure c) intake - filter box, d) differential pressure sensor, e) IBF control panel, f) external port of static pressure

The new side inlets c) created for both engines replaced the existing central inlet which has been dedicated for emergency use only since then. Currently, it hosts bypasses a), which open automatically in the event of excessive accumulation of particles in the filter. In the cockpit, the IBF control panel (e) is installed. Static pressure ports inside the engine inlet (b) and on the fuselage (f) transfer the signal to the IBF control panel through the appropriate differential pressure sensor (d). There, the signals are compared with each other, processed by the computer and depending on the degree of filter clogging; the information is displayed in the form of switching diodes (figure 17).The control panel (figure 17) consists of:

1. Filter clogging indicator for the inlet 1;
2. Button used for testing system No. 1 – after pressing it, the system conducts a mini test by opening bypasses of the left engine;
3. Button applied for displaying the clogging degree of both filters; and resetting it, e.g. after filters' cleaning;
4. Button for testing the system No. 2;
5. Filter clogging indicator No. 2;
6. Switch of the manual opening of bypass No. 1;
7. Switch of the manual opening of bypass No. 2;

The filter itself consists of a cotton mat, reinforced at both sides with a metal mesh. Such a mat is in the form of lamellae, thanks to which the surface of the filtration system is adequately large by relatively small external dimensions. The system is moistened with special oil, which impacts even more precise filtration of the ingested air.

The maintenance of IBF system is limited to:

- Testing pressure sensors every 500h;
- Monitoring the clogging degree of the filter by the pilot
- Performing bypass tests every 500h;

In the event that excessive filter clogging is indicated, it is replaced with a filter which was previously cleaned and oiled. Filter cleaning consists in physical shaking out the loose deposits, moistening it with a proper cleaning medium, cleaning under running water and drying at the room temperature (increasing the temperature to approx. 600 C substantially shortens the drying process). The useful life of a filter depends on its technical condition, but it should be no longer than seven years. There is no rule stating how long a given filter can be installed on a helicopter. It depends on its technical condition. Sometimes, there are filters, which, without being cleaned, can fulfil their functions for 50-80h. However, the low resistance of filter to humidity or rain can trigger a need for cleaning after the first flight. The dust accumulated in the filter swells in connection with water, simultaneously reducing the flow capacity of the filter. Due to this, every 15 days, during maintenance works, the filter is disassembled and cleaned by shaking it out or gently dusting.

Figure 17. IBF control panel

IBF system requires maintenance as every system, but the occurring defects are not difficult to remove. The most common malfunctions include:

- Failures of servo-motors of bypasses' doors – Fighting in humid conditions contribute to blocking the servo-motors and inability to open/close doors, which is detected during the pre-flight test and indicated on the control panel;
- Failures of electrical transmitters – blocking them is also indicated as the lack of correct performance of pre-flight test;
- Failures of transmitters changing the read pressure into the appropriate electrical signal have an impact on the incorrect operation of the whole system and incorrect readings on the control panel.

It has to be taken into consideration that during checking one of the engines in GPC, when the second engine is IDLE – activated but not loaded, the bypasses are open. It is contingent upon the fact that the control systems of both engines do not cooperate and understand this condition as a demand for indispensable power in the event when one of the engines is cut off. The similar situation occurs during FMM check-auto to manual to auto mode respond check.

After the completed maintenance works, the opening of bypasses does not cause serious consequences due to the fact the whole deck, along with the intra-engine duct, has been cleaned. When the helicopter performs the HEMS mission, and there is a need to conduct GPC, one of the solutions eliminating the opening of bypasses is switching off the system by pulling out the fuse. However, sometimes it happens that during such a check the fuse is not pulled out and the bypasses will be opened. It results in cleaning the engines and performing the GPC once again.

The consequence of using filters, in spite of some additional work, is the extension of TBO, reduction of the maintenance tasks that need to be carried out (borescope inspections, engines' replacement) and smaller helicopter operating costs. The number of necessary overhauls decreased to two yearly from 12 in 2012.

6.0 CONCLUSIONS

The article shows us that accelerated engine deterioration can be mitigated even if the platform is continuously exposed to environmental particles. The OEM did not ignore the problem and decided to redesign the inlet system and implement the filters. Based on the data collected during periodic GPCs, it was found that the installation of the IBF system significantly extended the lifetime of the engines. The change of TOT margin and N1 margin before the installation of the IBF system and the engine overhaul, clearly indicates a reduction in compressor performance caused by foreign object damage. However, after the installation of the IBF system, a change in these parameters indicates the deterioration not only of the compressor impeller but also of the hot section components, i.e. the turbine stator. Changes in these parameters, however, are definitely slower and smaller than before the installation of the IBF system. It is believed that this is a natural process of engine wear, and the declared lifetime of the engine is achievable.

LPR is the example of the advanced user, which is able to monitor and manage the engine health and also predict the remaining lifetime in most cases. Increased availability of helicopters contributes to improved emergency services and more saved lives.

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NOMENCLATURE

ADAC	Allgemeiner Deutscher Automobil-Club (German HEMS organization)
AHD	Airbus Helicopters Deutschland GmbH
AMM	Aircraft Maintenance Manual
BMC	BMC Air Filter (Italian company)
CAMO	Continuing Airworthiness Management Organization
EEC	Electronic Engine Control
EMM	Engine Maintenance Manual
FDC	FDA/aerofilters now: Aerometals Engine Inlet Barrier Filter Systems
FF	fuel flow
FH	flight hour
FMM	Fuel Management Module
FOD	Foreign Object Damage
GPA	Gas Path Analysis
GPC	Ground Power Check
HEMS	Helicopter Emergency Medical Service
HUMS	Health and usage monitoring system
IAS	Indicated airspeed
IBF	Inlet Barrier Filter
IPS	Inlet Particle Separator
LPR	Polish Medical Air Rescue
MSM	Master Service Manual
N1	generator speed
N2	power turbine speed
OEM	Original Equipment Manufacturer
NR	main rotor speed
PW	Pratt Whitney
RDAS	Repair design approval
TBO	time between overhaul
TC	type certificate
TOT	turbine outlet temperature
TRQ	torque
TKE	turbulence kinetic energy
UMS	Usage Monitoring System

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