HELICOPTER VIBRATION HEALTH MONITORING SYSTEMS FEATURING ENGINE VIBRATION MONITORING

Stefan BENDISCH
Airbus Helicopters Deutschland GmbH
Donauwörth
Germany

Fabien LAMAZERE
Safran Helicopter Engines
Tarnos
France

Valerio CAMERINI
Airbus Helicopters Deutschland GmbH
Donauwörth
Germany

Gianni NACCARATO
Airbus Helicopters S.A.S.
Marignane Cedex
France

Philippe STREIFF
Safran Helicopter Engines
Tarnos
France

ABSTRACT

Airbus Helicopter's Health Monitoring System (HMS) offers a broad range of functions like rotor tuning, vibration health monitoring of the helicopter drive train and Engine Vibration Monitoring (EVM). For the latter, Airbus Helicopters cooperates with Safran Helicopter Engines concerning system design and performance for data collection, data processing and data transfer to assure the maximum of benefit for the customer. A clear objective is to provide HUM system compliant with regulations and guidelines from UK CAA, CAA Norway, industry associations like SAE and working groups like IHST.

Classical vibration based health algorithms require information from analogic speed sensors for signal processing methods like order tracking, averaging and feature extraction. Airbus Helicopters proposes an approach without analogic speed interface, but extracting necessary information from the vibration with approximation given from digital speed signals. This technique makes use of the engine speeds which are collected by baseline helicopter systems and thus omitting any additional electrical interfaces of the HMS with the engine speed sensors. This paper presents the approach used by Airbus Helicopters in cooperation with Safran Helicopter Engines in the area of feature extraction and condition indicator computation using vibration signals and digital information from Engine Electronical Control Unit (EECU) through the helicopter avionic system HELIONIX®.

1 INTRODUCTION

Health and Usage Monitoring encompasses a variety of techniques including monitoring of operational cycles and loads, vibration, oil and wear debris analysis. Airbus Helicopters' innovative modular avionic system HELIONIX® is a family concept featuring the usage monitoring function as part of the baseline aircraft. Vibration Health Monitoring (VHM) function is provided by a new generation of Health Monitoring System (HMS) with improved functionalities tailor-made for helicopters equipped with HELIONIX® avionic system. In the recent years Health Monitoring Systems (HMS) have been introduced not only to medium and heavy helicopters[1] as required by national regulations like the Civil Aviation Authority (CAA) UK and Norway, but also to light twin helicopters like EC135 and BK117 D-2 following guidelines and recommendation from industry associations like SAE [SAE05] and working groups like IHST [IHST13].

The permanent installation of a Health Monitoring System with automatic data collection of each flight has certain advantages. First, the system is able to process and store data from operations enabling detailed post-flight data analysis. By this mean, it is possible to detect unexpected malfunction or degradation of mechanical components. Mechanical faults may be detected in the beginning of its evolution, thus, preventing the parts from failing and alerting the maintenance crew in order to visually inspect those parts carefully. Second, the data collected by the operator can be shared with the Original Equipment Manufacturer (OEM) in order to enable the development of improved Condition Indicators (CI) and thresholds alerting the maintenance crew in case of abnormal behaviour.

Automatized data collection and immediate post-flight analysis with on-ground tools could spare dedicated maintenance flights since vibration inspection is performed during normal operations. Installation of standalone tools can be omitted with positive effect on the aircraft availability. Permanent monitoring of helicopter mechanical parts and vibration alerts from the system may be used for pro-active maintenance and pre-ordering of spare parts, thus reducing aircraft downtime during component replacements as presented by Airbus Helicopters in [HOFF14]. By these means permanent installed VHM systems have the potential to reduce Direct Operating Costs (DOC) of the aircraft and engines [SAER05].

[1] With a maximum approved seating configuration for more than nine passengers operations in hostile environment [CAA15]

2 VIBRATION HEALTH MONITORING OF THE BK117 D-2

2.1 Health Monitoring System

The Health Monitoring System (HMS) of BK117 D-2 has been EASA approved in 2015 enabling incipient fault detection and preventive maintenance of the current helicopter health status. The HMS consists of 11 accelerometers located on helicopter drive train covering monitoring of main gearbox, tail drive shaft and tail gearbox components. Three accelerometers in cockpit and cabin compartment measure main rotor vibrations in order to alert in case of rotor maladjustments or incipient wear and to improve the dynamic behavior by rotor tuning. Phase information is provided by two tachometer speed probes installed on the main and tail rotor. The BK117 D-2 is powered by two ARRIEL2E engines from SAFRAN Helicopter Engines. Both engines are monitored by the EVM function of the HMS using two high temperature accelerometers mounted on each engine. An overview of the BK117 D-2 HMS monitoring positions is shown in Figure 1.

Figure 1 – BK117 D-2 Health Monitoring System

The Health Monitoring System is designed to acquire vibration and component speed during H/C operations, automatically or manually triggered by the crew. Automatic acquisitions are recorded multiple times during similar and pre-defined operational conditions to ensure similarity of data quality. The acquisition module pre-processes and stores measurement data intermediately. After each flight, data are transferred to a centralized data transfer device (DTD) which is in the cockpit. The operator is required to transfer the data manually to the ground station via removable memory storage device. Data processing by health monitoring algorithms is done automatically by the ground-based software (Maintenance Groundstation) which indicates the health status of helicopter drive train components and both engines. The overall architecture of the system incl. data transfer is depicted in Figure 2.

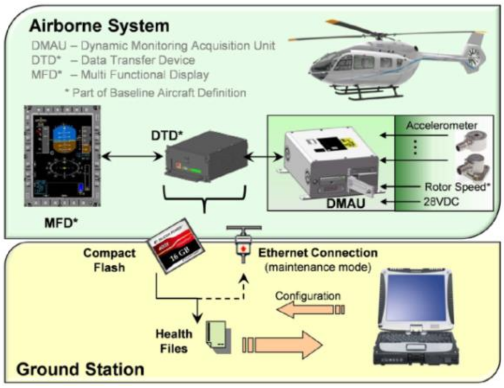

Figure 2 - System architecture

During operation, the crew has the possibility to start acquisitions manually for rotor balancing or so-called vibration check-ups. The HMS is able to process and display several vibration amplitudes on-board in order to check quickly on the vibratory levels of main and tail rotor as well as the tail drive shaft bearings. Rotor Balance information and tuning suggestions are provided by the HMS to improve the dynamical behavior of the H/C. The Health Monitoring System is designed to support BK117 D-2 maintenance by measurement and analysis means via Aircraft Maintenance Manual.

2.2 Engine Vibration Monitoring

Engine monitoring goes back to the 1973 and has its origin on airplane engines when the FAA mandated the installation of a vibration monitoring system to record the engine rotor imbalance [SAE08]. Health monitoring systems have been significantly improved over the last decades enabling early fault detection and diagnosis paving the way for engine health management. The first application to helicopter engines followed developments in the airplane sector for helicopter flying in the North Sea stimulated by the oil and gas industry in the early 1990s. Since 1999, helicopters with more than 9 passengers are required by the Civil Aviation Authority (CAA) to install a system monitoring mechanical components of the drive train and engines [CAA12].

Vibration Health Monitoring along with Engine Vibration Monitoring has been part of Airbus Helicopters HUMS applications from the early beginning. The first system monitoring helicopter drive train and engines developed in collaboration with Safran Helicopter Engines is called M'ARMS and was introduced on H155 and H225 helicopters. The M'ARMS system is able to monitor the engine vibration behaviour during the engine power up and during stabilized conditions in flight. The system contains multiple accelerometers attached to the drive train and high temperature accelerometers monitoring the MAKILA and ARRIEL engines following guidance from [CAA12] and [SAE08] regarding design and function. In the recent years, Airbus Helicopters has introduced an improved Health Monitoring System for helicopters containing the HELIONIX® avionic suite. The systems allows direct acquisition control and result display via the Multi-Functional Displays (MFD) inside the cockpit. The system processing unit is available for EC135 (H135), BK117 D-2 (H145), EC175 (H175) and H160 in the future.

The BK117 D-2 EVM function is part of the Health Monitoring System containing one high-temperature accelerometer mounted on each engine which is connected to a Remote Charge Converter (RCC). The RCC amplifies and integrates the accelerometer output signal, a charge proportional to the measured acceleration, to a voltage proportional to the corresponding vibration velocity. To reject low structural frequencies as well as the accelerometer resonance frequency, the RCCs contain appropriate high pass and low pass filters. Using remote charge converters makes the signal less sensitive to noise due to cable movement (triboelectric noise) or temperature fluctuations [SAE08]. The vibration data is stored synchronously with contextual flight data provided by the avionic system. The contextual data includes information about the engine usage, like torque, speeds and temperatures. In fact, this information is essential for Engine Vibration Monitoring on BK117 D-2. To reduce the overall complexity of system interfaces and keeping the weight at minimum, any analogic interface to the engine speed sensors of the ARRIEL2E engines was omitted.

Instead, the analogic speed signals of the engines are acquired by the Electronic Engine Control Unit (EECU) as part of the baseline aircraft, where they are digitalized and used to control the engine. From the EECU, the speed information is received by the helicopter avionics system and further transferred to the HMS amongst other flight parameters, so-called contextual (CTX) data. The digitalized contextual data is acquired by the HMS synchronously with vibration, but suffers from an unknown delay due to the intermediate transfer of the CTX data and lower sampling rates. Figure 3 sketches the data transfer architecture on-board highlighting the difference in the signal transfer of helicopter baseline architecture and HMS.

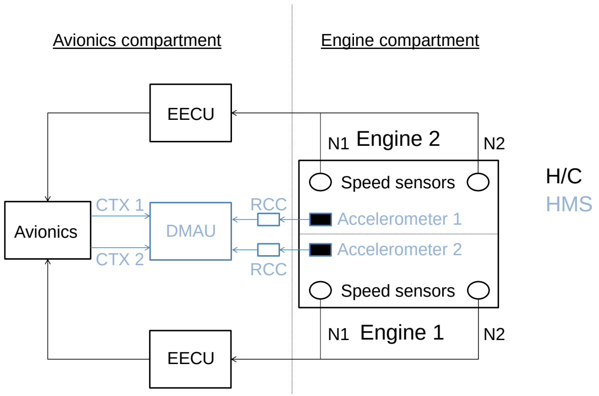

Figure 3 - Data architecture on BK117 D-2

3 EVM INDICATORS COMPUTATION

For proper analysis of engine vibration data, rotational speeds of the gas generator (N1) and the power turbine (N2) are essential. To enable advanced processing like order tracking and feature extraction, engine rotational speeds are digitally recorded and stored as contextual parameters (CTX) in the Dynamic Monitoring Acquisition Unit (DMAU) alongside other flight and operational parameters on BK117 D-2. Ideally, engine vibration and engine rotational speed are recorded synchronously in order to order track engine vibration over the rotational speed during engine run up and stabilized conditions during flight. Due to the analog-digital conversion in EECU and re-routing of signal via the avionic system, a significant delay is introduced. To overcome the disadvantages of the digital CTX speed signals, an algorithm has been developed capable of extracting the engine speeds N1 and N2 directly from the vibration signal itself, ensuring the synchronicity of the speed data with the vibration signal.

3.1 Engine speed tracking based on vibration data

The method for speed signal extraction from vibration spectra assumes that both the gas generator and the power turbine are clearly recognizable in the vibration spectrum and that both are clearly distinguishable from random noise at every point of time. Figure 4 shows a typical time-frequency diagram of an engine run up. Typically, gas generator and power turbine account for strong tones in the spectrum during operation with significant signal-to-noise with respect to other instant vibratory sources. The engine passes the critical speeds of the gas generator and power turbine during the run-up resulting in a maximum vibration levels when the rotating frequency excites a resonance of the system.

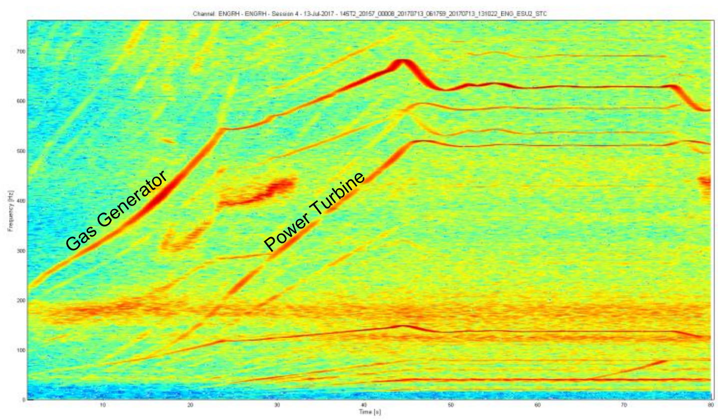

Figure 4 - Time-Frequency diagram of an engine run-up

The algorithm identifies and tracks the amplitude of gas generator and power turbine in the frequency domain corresponding to the component of interest step-wise for multiple sequences of the time signal. For each sequence, also called time interval in the subsequent sections, the Short Time Fourier Transform (STFT) is computed using a window and applying a band-pass filter. The filter is centered on the assumed rotational frequency of the component of interest, which is approximated using the speed information from the CTX data. Inside the narrow band, the highest peak is identified and its frequency and amplitude values are stored, since they are assumed to correspond to the component of interest. The process is iterated over every time interval of the acquisition signal applying an overlap to ensure smooth transition between each sequence. Figure 5 below illustrates a general processing flow of the algorithm.

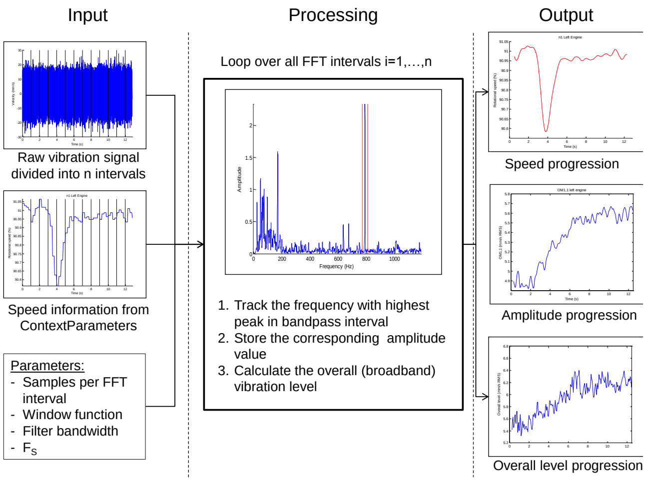

Figure 5 – Process flowchart

The computation is repeated for the whole signal resulting in the vectorised engine speed based on the vibration spectra. The result of the maxima tracking algorithm is illustrated in Figure 6. Note the visible delay between the real speed progression and the digital CTX data.

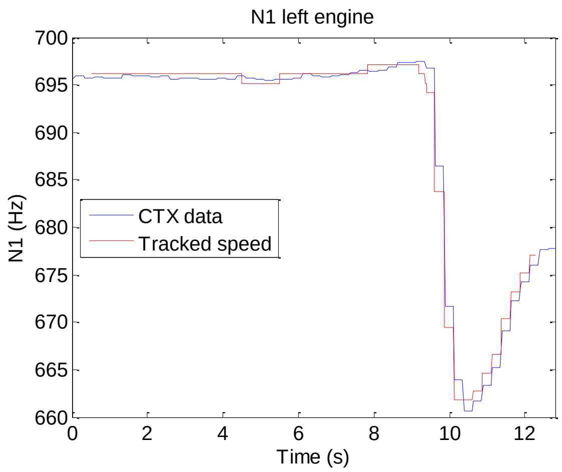

Figure 6 – Engine speed tracked using vibration data

The previous illustrations showed the working principle of the maxima tracking algorithm to track the gas generator speed, N1. The extraction of speed and amplitude of power turbine works the same way applied on the corresponding CTX data.

3.2 Engine vibration feature extraction

Engine vibration monitoring uses vibration features like the engine order magnitudes of gas generator ($OM1_{N1}$) and power turbine ($OM1_{N2}$) to monitor the behavior of the engine components. Both vibration features are derived for each time interval according to the following equation. The amplitudes X_i are extracted from the vibration spectrum in order to compute the vibration energy around the engine rotational frequency at index m using $\pm k$ adjacent frequency bins. The result is normalized by the normalized equivalent noise bandwidth ($NENBW$) introduced by the window function (ref. [HEINZ02]) and taking the square root of this ratio:

$$OM1 = \sqrt{\frac{\sum_{i=m-k}^{m+k} {X_i}^2}{NENBW}} \quad (1)$$

The first order magnitude of mechanical elements typically is generated by its unbalance. The evaluation of the order harmonics is typically required during engine certification through a dedicated unbalance test program according to [CS-E].

The overall level (OVR) of the engine is considered as an indicator corresponding to the general vibration level generated by all the engine rotating parts. It describes the average energy of the signal in a certain pre-defined bandwidth, ranging from the lower boundary frequency f_l to the upper boundary frequency f_u. For each time interval i, the overall level is calculated by summing up the squared amplitudes X_j of all frequency bins j representing the selected bandwidth, normalizing the result by the $NENBW$ and taking the square root:

$$OVR = \sqrt{\frac{\sum_{j=l}^{u} {X_j}^2}{NENBW}} \quad (2)$$

Finally, the overall level OVR, order magnitudes $OM1_{N1}$ and $OM1_{N2}$ are obtained over time for each time interval i. Using the derived engine speed information, it is now possible to represent the engine vibration levels over gas generator and power turbine speeds. Abnormal vibration levels can be assigned to the corresponding engine rotational frequency during engine run-up which enables the identification of vibration exceedance due to incipient mechanical wear or maintenance errors.

3.3 Benchmarking and optimization

The performance and reliability of the algorithm concerning engine speed tracking and vibration feature extraction is influenced by parameters used during computation. The engine run up phase can be divided in different rotational speed states with various accelerations. An analytical engine vibration model is developed to analyse the influence of the speed fluctuations during run up on the performance of the algorithm.

The signal $x(t)$ includes oscillations of gas generator with amplitude A_{N1} and of the power turbine with amplitude A_{N2} for accelerating rotational speeds $f_{N1}(t)$ and $f_{N2}(t)$ and random noise ε.

$$x(t) = \mathrm{A}_{N1}\sin(2\pi f_{N1}(t) * t) + \mathrm{A}_{N2}\sin(2\pi f_{N2}(t) * t) + \varepsilon \qquad (3)$$

In addition, the contextual engine speed is simulated with a low sampling rate and delay with respect to the vibration signal. Finally, the mean relative error (MRE) is derived for each time interval by normalizing the absolute error of the obtained value Y_i with respect the expected value $\hat{Y}_i$.

$$MRE = \frac{1}{N}\left(\sum_{i=1}^{N}\left|\frac{\hat{Y}_i - Y_i}{\hat{Y}_i}\right|\right) \cdot 100\% \qquad (4)$$

The benchmark analyses the number of frequency bins used for feature extraction of OM_{1N1} and the frequency resolution as a function of the number of samples per time interval (SPI). Figure 7 shows the mean error of the amplitude computation during engine acceleration phases for different configurations of SPI and adjacent frequency bins k used for feature extraction, see equation (1).

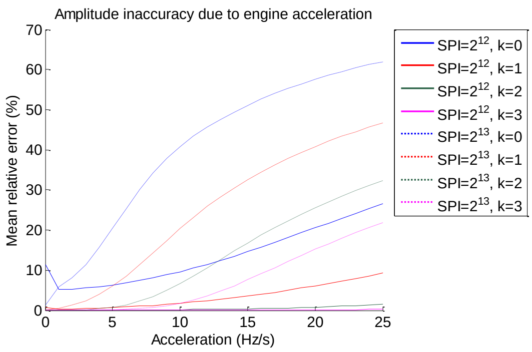

Figure 7 – Engine vibration amplitude accuracy during engine acceleration as function of samples per interval (SPI) and number of adjacent samples

The algorithm performs better using shorter STFT intervals (smaller SPI) ensuring the accuracy of the algorithm in terms of speed tracking and amplitude extraction and to anticipate engine speed changes during run up phase. The simulation demonstrates the sensitivity of the computation to the time interval length and hence the sampling resolution. Settings will be evaluated during flight and ground testing of the system and EVM function. In addition, the number of adjacent frequency bins for amplitude computation during feature extraction is analyzed. Using ideal settings during simulation of an engine run-up, the amplitude could be extracted with theoretically less than 0.2% mean relative error, while the measured minimum speed error was less than 0.003%.

Benchmarking has been performed on the window type applied during vibration processing. Figure 8 shows the mean error of the vibration magnitude OM1 extracted as a function of the window type used and number of adjacent samples. Clearly, both parameters influence the result with best performance of Flattop for no or one adjacent sample used during feature extraction. In fact, using few adjacent samples improves and stabilizes the result reducing the influence of the window type (apart from the rectangular window).

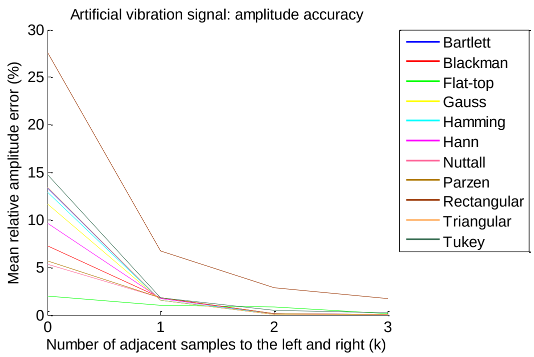

Figure 8 – Engine vibration amplitude accuracy during engine acceleration as function of Window type and number of adjacent samples

Finally, the benchmarking study pointed out the parameters effecting the results accuracy and thus, being able to fine-tune the setting to obtain most reliable results.

4 EVM QUALIFICATION CAMPAIGN

The EVM function has been tested extensively during the qualification campaign which took place in Donauwörth. The test objective was to compare the HMS on-board acquisition and data processing for engine speed tracking and engine feature extraction with results obtained by a Safran Helicopter Engines reference system. Therefore, a BK117 D-2 prototype helicopter was instrumented with a standalone acquisition reference system called B&K LAN-XI NOTAR. This reference system measured vibration and engine analogic speed vibration synchronously and in parallel to the HMS as shown in Figure 9

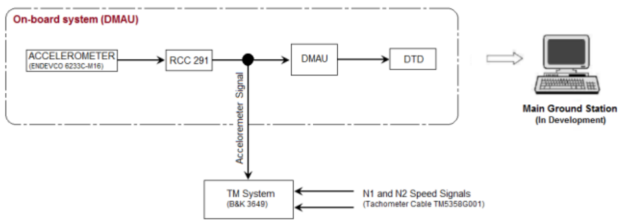

Figure 9 – Signal processing during qualification test

The reference system acquisition recorder was installed in the cabin compartment connected to the engine vibration sensors and a harness interfacing the engine speed sensors was routed externally to obtain the rotational speeds of the gas generator and power turbine in real-time. Figure 10 and Figure 11 show the instrumentation applied to both engines and the Safran Helicopter Engines acquisition reference system located inside the cabin compartment. This reference system is able to acquire, process and display the vibration results in real time.

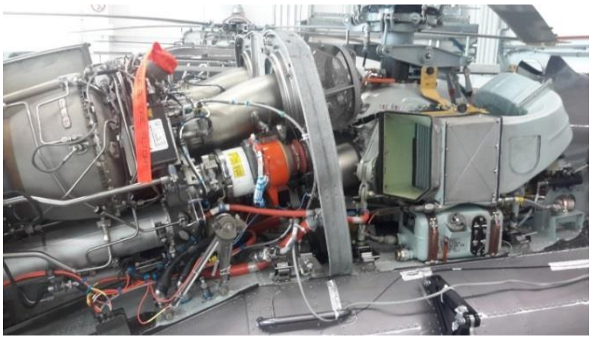

Figure 10 – Instrumented ARRIEL2E engine during qualification campaign

4.1 Test program definition

The qualification campaign test program contained several ground runs including normal and quick starts of both engines and a flight to test the EVM function during engine run ups and in stabilized phases. The BK117 D-2 HMS and the reference standalone system acquired engine vibration during all operational conditions synchronously to ensure comparability of the results. The objective of the test program was to evaluate the capability of the system to acquire, record the raw data and process the condition indicators.

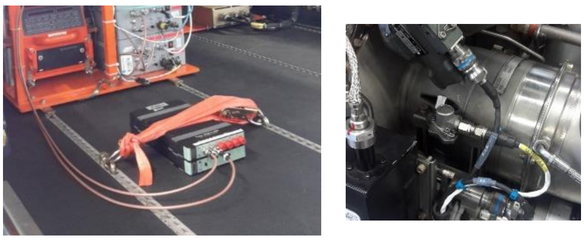

Figure 11 – Safran Helicopter Engines reference system installed in the BK117 D-2 cabin compartment during flight test campaign

4.2 Test results

The measurements performed during the different ground runs have not shown any significant discrepancies between the EVM function and SAFRAN Helicopter Engines reference system. The Overall (OVR) level and order magnitudes $OM1_{N1}$ and $OM1_{N2}$ have been compared for an engine run up (as shown in Figure 12) in order to evaluate both the data processing implemented into the on-board part of the system (signal conditioning, data acquisition and data storage logics) and the data processing done on ground (indicator computation).

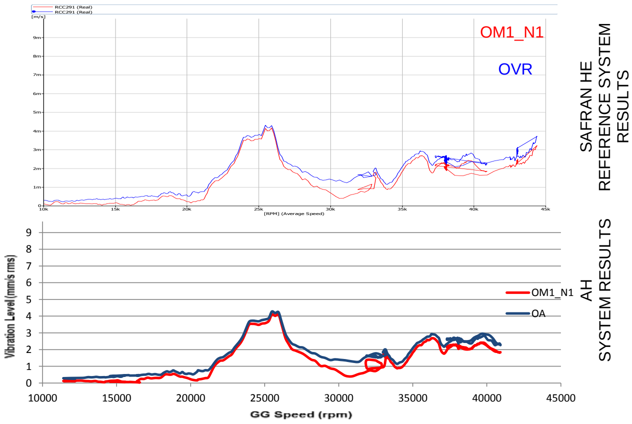

Figure 12 – Ground Test Results: comparison of AH system processing (top) and SAFRAN HE reference system (bottom) results for an engine run up

In addition to the tests performed during ground runs, the EVM functionalities to record engine vibration data in flight (periodically or on specific event) have been checked. Safran Helicopter Engine reference system was used to record continuously the vibration signal coming from the engine accelerometers during the complete mission synchronously to HMS. The engine indicators computed are shown in Figure 13. The periodic vibration acquisition performed by the EVM function have been dated and synchronized with the continuous records performed by the reference system in order to compare the levels of the indicators computed. In addition to the vibration levels computed by the EVM function, the acquisition logics to ensure the conditions of acquisition have been evaluated and validated.

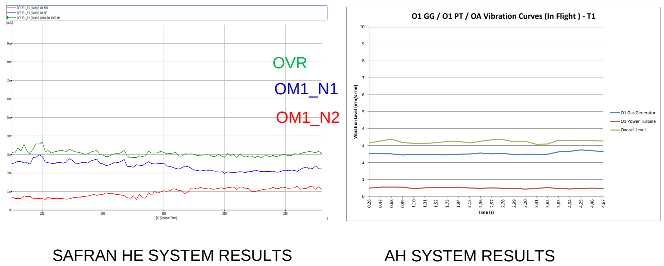

Figure 13 – Flight Test Results: comparison of SAFRAN HE reference system (left) and AH system processing (right) in stabilized conditions

4.3 Operational evaluation period

An operational evaluation period has just been started with the first BK117D-2 customers equipped with the EVM function. The main objective is to ensure that there is no regression of the EVM functions and that the whole system operates correctly in operational conditions. During this period, the data are systematically downloaded by the customer and transferred to Safran Helicopter Engines and Airbus Helicopters for post-analysis.

5 GROUND-BASED SOFTWARE

5.1 Airbus Helicopters Ground-Based Software

Airbus Helicopters provides the Maintenance Groundstation (MGS) as a primary mean managing the Health and Usage status of each aircraft and for immediate post-flight fault diagnosis. The software is available for several Airbus Helicopters helicopter including EC135 (H135), BK117 D-2 (H145), EC175 (H175). Usage data like cycles and counters acquired by the HELIONIX avionic system and vibration data acquired by the HMS is processed automatically by MGS updating the dashboard according to the status of the aircraft.

The Maintenance Groundstation includes vibration limits of the engines and of the helicopter drive train developed by Safran Helicopter Engines and Airbus Helicopters respectively. An alarm is raised automatically if any red limit exceedance has been detected requiring maintenance action. For the helicopter drive train, the MGS raises a warning alert if a vibration level is out of amber limits and requires attention. By this means, the user has the ability to obtain the status of the aircraft immediately after each flight and to benefit from the vibration monitoring to anticipate incipient faults and perform component troubleshooting. In case of an engine vibration exceedance during run up or in-flight, the user is alerted by the Maintenance Groundstation on the dashboard, see Figure 14.

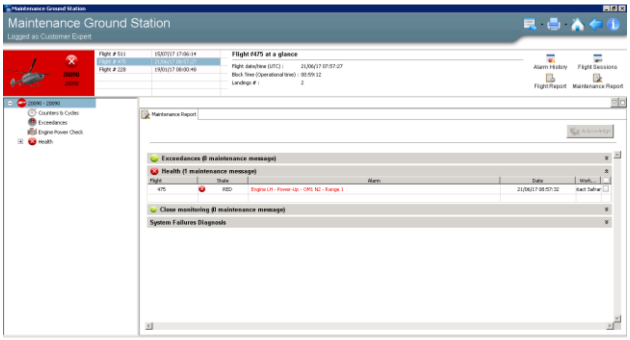

Figure 14 – Airbus Helicopters Maintenance Groundstation Dashboard showing alarms

Each alarm refers to work cards defining potential inspection tasks or close monitoring as recommended per [CAA12]. Airbus Helicopters and Safran Helicopter Engines have worked together in order to develop and qualify the BK117 D-2 Health Monitoring System with the Maintenance Groundstation as a primary mean for engine vibration monitoring replacing standalone tools for engine vibration checks of ARRIEL2E engines.

Engine vibration results are displayed of the gas generator and power turbine for each engine run up, see Figure 15.

Figure 15 – Airbus Helicopters Maintenance Groundstation Engine Vibration Monitoring (engine run up)

Engine indicators OVR, $OM1_{N1}$ and $OM1_{N2}$ are displayed over the respective engine rotational speed to allow the identification of any engine vibration exceedance related to any specific fault frequency. HUMS specialists on operator and OEM side are able to interpret vibration exceedance using the run up and initiate measures to be performed on the engine for deeper investigation and troubleshooting.

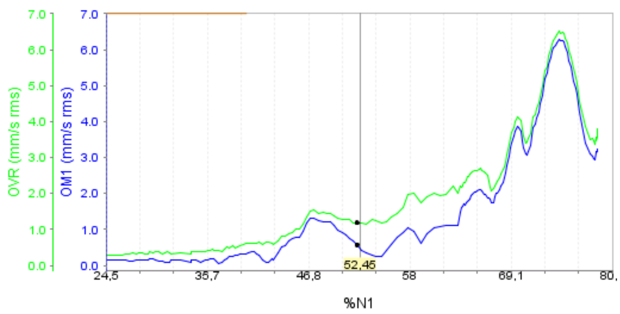

Figure 16 – Engine indicators OVR and $OM1_{N1}$ over N1 (quick start)

Data of the helicopter drive train and engines are collected automatically during flight enabling the interpretation using the MGS. Figure 17 shows the engine indicators computed from data collected in stabilized N1 phases, displayed in multiple ranges. In addition, vibration data is collected in case of engine events like over-torque, engine chips, temperature and engine speed exceedances. The collected vibration data allows the interpretation of the overall engine health after such an event using the Maintenance Groundstation. In case of alarm, the MGS allows to submit engine data directly to Safran Helicopter Engines for deeper investigation of the HUMS data collected during flight.

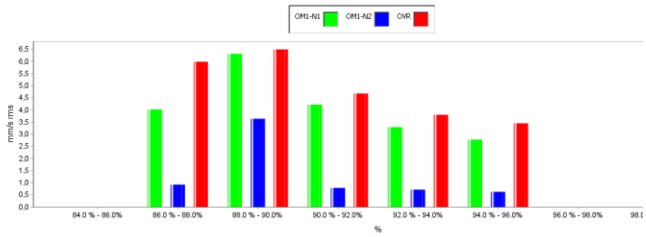

Figure 17 – Engine indicators OVR, $OM1_{N1}$ and $OM1_{N2}$ per N1 range during stabilized phase

Airbus Helicopters offers a web-based service tool, called webHEALTH for online interpretation of vibration data collected of the helicopter drive train, see Figure 18.

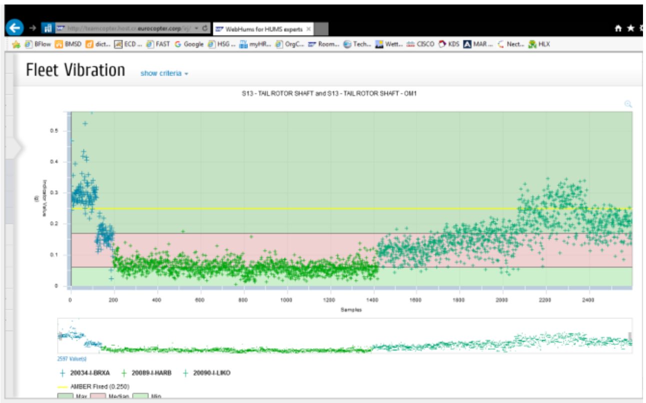

Figure 18 – Airbus Helicopter webHEALTH online service for expert analysis of drive train vibration

The web-based interface webHEALTH is available for the user enabling similar features as the Maintenance Groundstation. The user is able to file an online request in case of vibration anomaly directly inside the tool. The request is processed by the customer support of Airbus Helicopters using the available data for interpretation and work task suggestions. Airbus Helicopters offers advanced support services like FlyScan for HUMS data interpretation and potential anticipation of incipient component faults.

5.2 Safran Helicopter Engines Ground-Based Software

Since 1999, Airbus Helicopters and SAFRAN Helicopters Engines have collaborated for the development and support of HUMS Systems on many Helicopter/Engine applications with engine vibration function implemented. Safran Helicopter Engines has developed support engineering tools enabling to support the customers in case of an event and also to analyze the trend of the engine health indicators.

5.2.1 EVM: fault case examples

The analysis of the engine vibration data provided by the HUMS system in operation (qualified by Safran Helicopter Engines) has proven the benefits of an embedded vibration monitoring in the following domains:

1- Reduction of human factor risk: check the mechanical behavior of the engine following a maintenance task

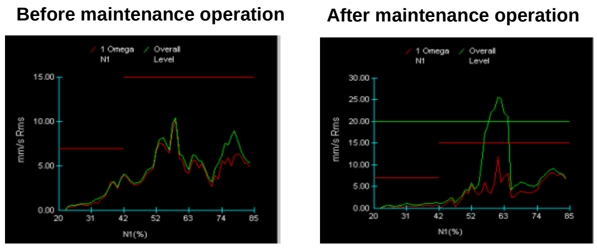

Figure 19 – Engine vibration curves recorded before and after a maintenance operation

In the example of Figure 19, an engine vibration exceedance occurred after a module change (*exceedance and incoherence between OM1_N1 and Overall level*). The spectral analysis performed by Safran Helicopter Engines has shown the presence of Order 2 and Order 3 of Gas Generator that corresponds to a misalignment.

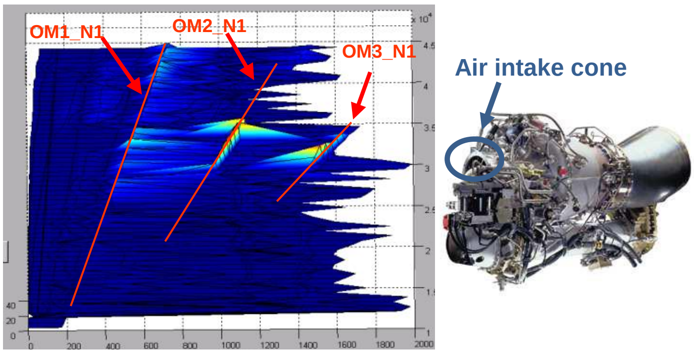

Figure 20 – Spectral analysis based on the raw data recorded by the EVM function

After exchanges with the operator, it appeared that during reassembly of the engine modules, not the right “air intake cone” has been reassembled on its associated module. In fact, the EVM function allowed to identify an abnormal behaviour and to apply the corrective maintenance actions.

2- Efficient Trouble-shooting in case of event

For this case, an exceedance on the Overall level has been raised as shown in Figure 21.

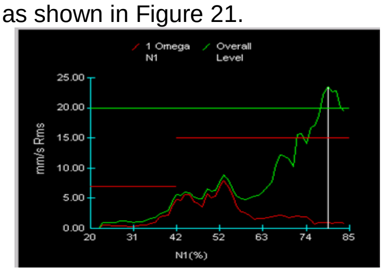

Figure 21 – Overall level alarm during engine power up acquisitions

The trend analysis of the overall level versus time showed that this abnormal behavior could have been detected 20 flying hours before the event (Figure 22).

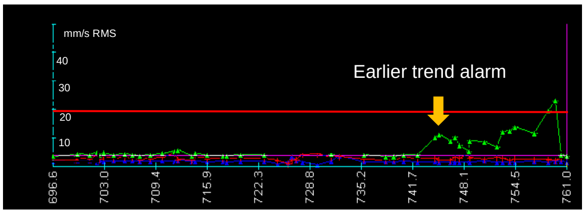

Figure 22 – Trend on Overall level

A post analysis has been performed by Safran Helicopter Engines that enables to identify the starter generator item as root cause (Figure 23). Once changed the overall vibration level came back to a normal situation. The advanced trouble-shooting session enabled to identify precisely the faulty accessory and avoid an unjustified engine removal. Moreover the maintenance workload and associated costs have been reduced.

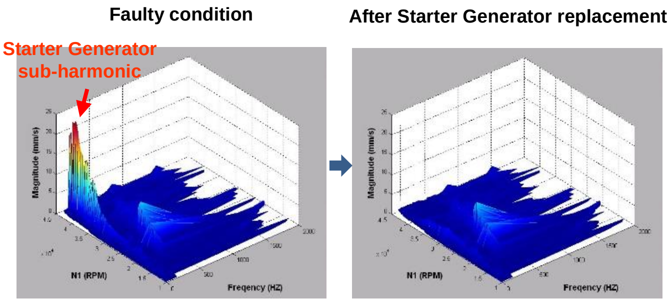

Figure 23 – Spectral analysis with Safran Helicopter Engines dedicated vibration tool

3- Health Monitoring: detection of damage at an early stage in order to take preventive action and avoid aircraft unavailability.

On previous case, starter generator spare supply and replacement could have been anticipated of a couple of days (20 FH), avoiding any impact on aircraft availability. Indeed, the advanced analysis of the engine vibration data recorded by the embedded system enables to improve the capabilities to monitor the engine and its accessories. The main objective is to detect at an early stage an abnormal behavior by computing advanced health indicators (HI) and performing trend analysis of these HI.

Also, maintenance recommendation can be provided by Safran Helicopter Engines to the operators in order to schedule preventive maintenance operations and recover a normal situation before to impact aircraft availability. The Figure 24 shows the difference of behavior between 2 populations. Health monitoring tools developed by Safran Helicopter Engines ensured a detection of alternator damage at least 100 flight hours before an event that could potentially impact the aircraft availability.

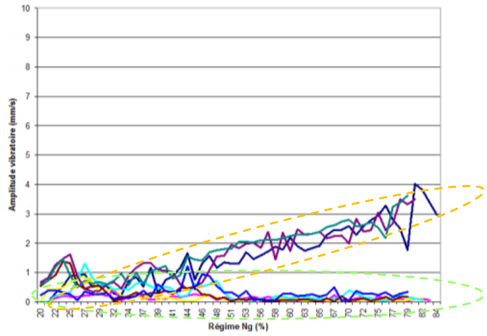

Figure 24 – Advanced health monitoring analysis performed by Safran Helicopter Engines on the alternator accessory

5.2.2 Safran Helicopter Engines Advanced Health Monitoring

The recorded engine vibration raw data plus the computed health indicators enable predictive maintenance actions to be defined optimizing aircraft availability. In addition, vibration Health Indicators can be merged with other indicators extracted from various sources of data (configuration, usage, performance, continuous flight records, etc.). The fusion of all these Health Indicators along with Safran Helicopter Engine expertise will allow an outstanding health monitoring efficiency. The target remains to provide the operator with the right recommendation at the right time in order to improve engine life and availability through Safran Helicopter Engines support and technical expertise.

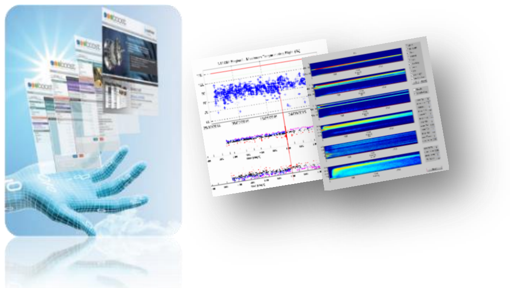

Figure 25 – Safran Helicopter Engines analysis tools

6 CONCLUSIONS

In order to tap the full potential of Health and Usage Monitoring Systems (HUMS), Airbus Helicopters and Safran Helicopter engines have developed jointly an Engine Vibration Monitoring (EVM) function for BK117 D-2. The function is part of the Health Monitoring System (HMS) in complementary to the usage monitoring function which is part of the helicopter avionic system HELIONIX®.

This paper has outlined the design features of HMS of BK117 D-2 highlighting the ability to provide EVM without directly interfacing the analogic engine speed signals on-board. Vibration signal processing and engine speed tracking has been tailored to identify the engine speed from the vibration spectra with approximation provided by avionic system digitalized information. The reliability of the result computation of the EVM function has been demonstrated during a qualification campaign organized between Airbus Helicopters and Safran Helicopter Engines. By these means, both companies contribute to an enhanced monitoring of the overall helicopter including engines as recommended by industry and working groups.

Operators benefit from the cooperation by being offered a system with tailored functions for improving aircraft availability and a wide range of support services for helicopter and engine health monitoring. A Controlled Service Introduction (CSI) phase will provide feedback during operation for supporting engine troubleshooting or incipient fault diagnosis. Both companies will continue in their cooperation for the next generation of engine vibration monitoring.

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