IMPLEMENTATION OF THE HEALTH MONITORING DATA FOR ROTORCRAFT FATIGUE SPECTRUM

S. Rustici
Fatigue Chief Project
Leonardo Helicopter Division
Cascina Costa di Samarate, VA
Italy
sara.rustici@leonardocompany.com

G. Guadalupi
Fatigue Specialist
Leonardo Helicopter Division
Cascina Costa di Samarate, VA
Italy
gloria.guadalupi@leonardocompany.com

U. Mariani
Head of Fatigue Department
Leonardo Helicopter Division
Cascina Costa di Samarate, VA
Italy
ugo.mariani@leonardocompany.com

ABSTRACT

The typical approach for the usage spectrum definition for the purpose of fatigue analysis in rotorcraft industry is currently based on the analysis of theoretical mission profiles and pilots' experience feedback.

The Health and Usage Monitoring System (HUMS) installed on Leonardo Helicopters (LH) rotorcraft represents the alternative approach for the fleet usage definition, thanks to the Flight Condition Recognition tool (FCR).

The HUMS data is recorded and processed to determine the main parameters of usage, such as Take-off weight and centre of gravity position, Density Altitudes, Start and Stop events (SS) and Ground-Air-Ground cycles (GAG). Furthermore, the FCR routine allows determining the type of manoeuvres, monitoring the variation of some key parameters, like speed, acceleration, body angles, for similarity with the load survey flight tests.

Recently, an entire AW101 military fleet deployed in mixed SAR and Utility missions, that was assessed in terms of fatigue life limitation using two theoretical pre-assigned usage spectrums, has been analysed to identify in-service usage spectrum through FCR tool. A unique usage spectrum has been determined on the basis of the HUMS data, complemented with pilots' information when FCR could not provide sufficient details. Based on this analysis, an updated set of fatigue lives has been evaluated, leading to a beneficial impact on the maintenance limits and on the aircraft safety.

Results described above have brought to an improved version of the HUMS software, now installed on latest AW101 variants with continuous data recording function, to obtain a more precise recognition of the manoeuvres and, hence, more precise fatigue analysis.

1 INTRODUCTION

The Health and Usage Monitoring System (HUMS) installed on Leonardo Helicopters (LH) rotorcraft, thanks to the Flight Condition Recognition tool (FCR), represents the alternative approach for the fleet usage definition instead of pre-set usage flight spectrum.

This paper analyses the HUMS flight recognition capability and provides an example of application on an AW101 military fleet, deployed in mixed SAR and Utility scenarios, with more than 25,000 flight hours accrued. These aircraft are equipped with HUMS software designed for on-board flight data recognition. Engineering judgment complemented by pilots' feedback reduces the areas of uncertainties.

A unique usage spectrum has been derived from the HUMS data analysis and a comparison with the theoretical usage spectrums has been carried out, showing the most important deviations from the design assumptions.
New fatigue lives have been evaluated on the basis of the modified usage spectrum. The benefits obtained by using the HUMS recordings are highlighted as fatigue limits extension or increase in flight safety.

Future developments about the use of HUMS are described in this paper as matter of research in cooperation with some AW101 customers.

2 FCR TOOL DESCRIPTION

HUMS combines the Transmission Usage Monitoring (TUM) and the Structural Usage Monitoring (SUM). TUM is devoted to the acquisition of engine torquemeters and tail drive shaft torquemeter for the generation of a torque spectrum, while SUM is designed to record the helicopter flight conditions, by making use of already available sensors and limited computational resources in terms of computer cycles and allocated memory.

The current HUMS version installed on the earliest AW101 helicopter fleets consists of on-board computer for data acquisition and on-board data processing. Ref. [1] provides a deep description of the FCR structure, hereinafter briefly summarised.
Several flight parameters are monitored by SUM, as input data for the flight condition recognition, including:

- Helicopter configuration: Weight On Wheels (WOW); All up Weight (AUW); Centre of Gravity position (CoG); cargo hook weight; ACSR status (the Anti-vibration system peculiar of AW101 helicopters),
- Helicopter attitude (heading; roll, pitch and yaw positions); true air speed (TAS); vertical speed; engine parameters; main rotor speed NR; longitudinal acceleration; load factor (G),
- Environmental conditions (barometric, radar and density altitudes; outside ambient temperature OAT).

The helicopter flight conditions are recorded starting with at least one engine in Ground Idle and up to the aircraft WOW with all the Engines shut down. The recording is performed every Main Rotor revolution (beep), that is the lowest frequency of rotor induced forces, without any time delay between two consecutive time intervals.
Each time interval is partitioned in samples and analysed to obtain the mean values and the first derivative mean values for each parameter. Using the mean and first derivative values, the routine is able to distinguish the helicopter manoeuvres and to adequately correlate them with the load survey conditions in the Proprietary flight database.

For each flight condition, the relevant

- AUW
- CoG position
- TAS value
- Density Altitude
- Hook load
- ACSR status (for AW101 helicopters)
- Load factor (for flare, landing, pull up, autorotation)
- Roll angle (for Bank turns only)
- Vertical Speed (for climb/descent)
- Acceleration (for acceleration/deceleration)

are provided as output in terms of occurrences of level variation bands, pre-defined in analogy with the load survey data bands. No punctual values of the parameters are provided.

If the cross-checking of the flight parameters does not reflect any instructions in the stored control management for the identification of the type of manoeuvre, the flight condition is stored as “Anomalous” and filled with the information about CoG, AUW, Altitude, ACSR status, Hook load. If at least one of the key parameters is not detected or reliable, the FCR analysis is skipped and the flight condition is stored as “Unknown” and no other information is provided.

Number of Start-Stop cycles is directly obtained monitoring the rotor start conditions and the averaged rotor speed.
Number of GAG cycles is directly obtained from take-off (and landings) occurrences, derived monitoring WOW parameter that shall pass from ON to OFF status (and vice versa) in the beep.

3 A CASE OF STUDY: AN AW101 MIXED ROLE MILITARY FLEET

The AW101 helicopter is a large multi-role rotorcraft, with extensive provisions to conduct a diverse range of primary and secondary roles.

The HUMS analysis has been performed on one of the AW101 Military variants, deployed in mixed SAR & Utility modes, with limited usage of the Extended Take Off Weight (ETOW).

The critical components have been so far assessed in terms of life limitations on the basis of design mixed SAR and ETOW fatigue spectrum. Specific design fatigue lives have been calculated for the time spent in Utility role, containing also severe tactical sortie profiles.

At least 300 hours per helicopter gathered in service are necessary for a robust statistical analysis of the HUMS data, which is a typical annual usage for AW101. For this exercise, more than 25,000 hours of the whole fleet have been processed, helicopter by helicopter, with minimum 1,400 hours accumulated per helicopter in about 5 years (reflecting the typical annual usage).

Having the helicopters flown in mixed role for the whole time, a unique usage spectrum has been obtained from the HUMS data. For the spectrum definition, the percentage of time of the flight conditions, CoG/AUW and altitudes distribution have been derived considering on a case by case basis:

a) the average values obtained from the whole HUMS dataset;
b) the max values;
c) the weighted values, obtained considering the occurrence of each helicopter on the total hours monitored.

FCR provides the percentage of time (%time) of macro-set of conditions. Wherever no deeper details are provided, the flight conditions have been split scaling the number of events and the percentage of time from the theoretical design missions. Then, the proposed distribution has been discussed with the Operator and refined according to the Pilots' feedback. An example is provided by the hovering operations. FCR recognises IGE and OGE conditions, checking the WOW status in combination with the True Air Speed mean value and the radar altitude. However, FCR does not distinguish the type of hovering as hovering steady conditions, spot turns or azimuth manoeuvres. Low speed flare and transitions are recognised without providing any information about the kind of transition (rapid, normal, etc).
The revised hovering distribution has been derived from the theoretical usage spectrum and refined according to the Operator instructions. In some other cases, like for Bank Turns manoeuvres, FCR provides full details about airspeed, roll angle and direction that properly define the bank turns distribution.

3.1 HUMS Data and Design Usage Spectrum

The HUMS data and the new proposed spectrum show in some cases significant differences from the design theoretical spectrums.
The most interesting cases are shown in this paper, as matter of discussion about the benefit of carrying out the HUMS data analysis as well as current limitations of FCR tool.

In all the plots presented hereinafter, the coloured columns represent the HUMS dataset and they are directly compared with the original design spectrums (blue patterned column for the SAR spectrum and orange dotted column for the Utility spectrum) and the new unique spectrum proposal (black column). In some plots, the two theoretical spectrums show the same values since some parameters are in common.

The proposed unique spectrum is characterized by an increase of the %time at the high weight band compared to the original design spectrums, associated to a reduction of very high weight band and mid weight band (see Figure 1).
The very high weight band is referred to the ETOW usage, which has been assumed in the design assumptions as additional fuel for longer range in limited flight envelope.

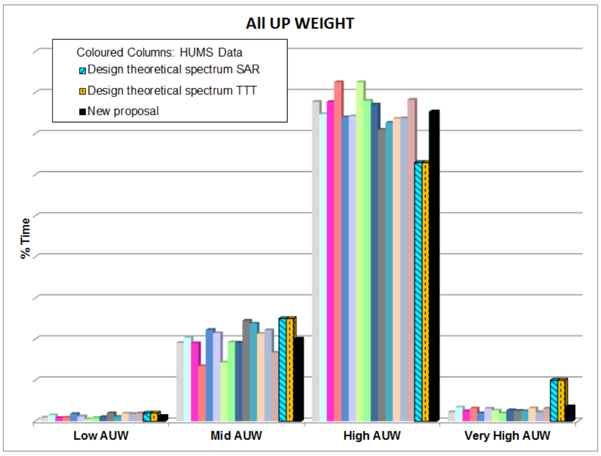

Figure 1 – AUW analysis

The analysis of the altitude distribution has highlighted anomalous trend for some helicopters, with higher %time of high altitude than the remaining fleet (Figure 2).

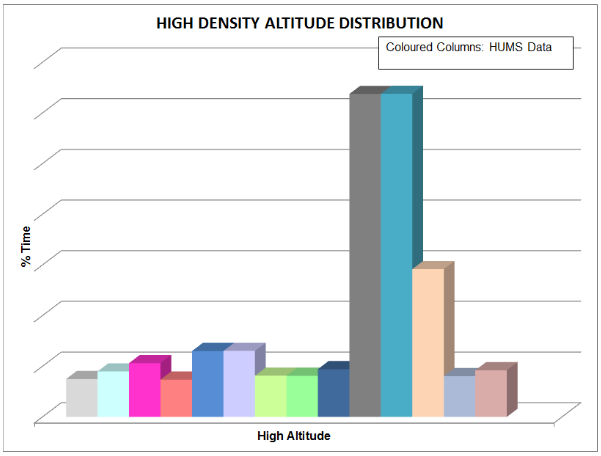

Figure 2 – Anomalous trend of high altitude distribution (HUMS data only)

According to the Operator information, these helicopters have been deployed in operative theatre at high OAT temperature (higher density altitude). A more refined analysis of the HUMS data, excluding the time period provided by the Operator, has shown data within the fleet average (Figure 3). The special missions have been detected and managed separately from the typical usage spectrum. The comparison of the original design spectrum with the HUMS data shows an overestimation of the theoretical occurrence of high altitude.

The new proposed unique spectrum maintains a conservative margin for the high altitude bands, to cover deviations due to short period deployments, but halves the original %time.

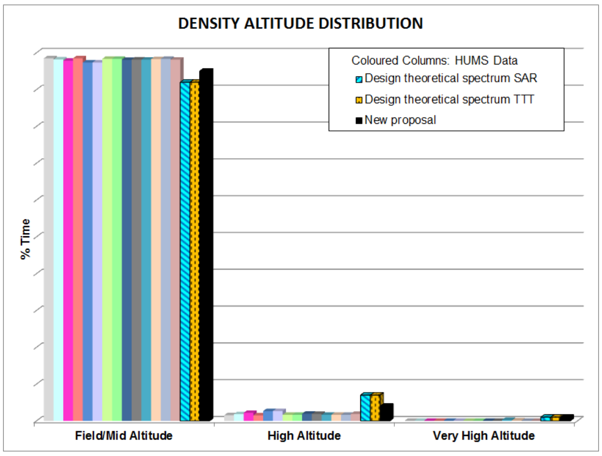

Figure 3 – Altitude analysis without special deployment

A large difference for the hovering conditions has been found between the operational data and the design SAR spectrum. Instead a good similarity was found with the Utility spectrum.

The proposed revised spectrum is aligned with the weighted average values from HUMS (Figure 4).

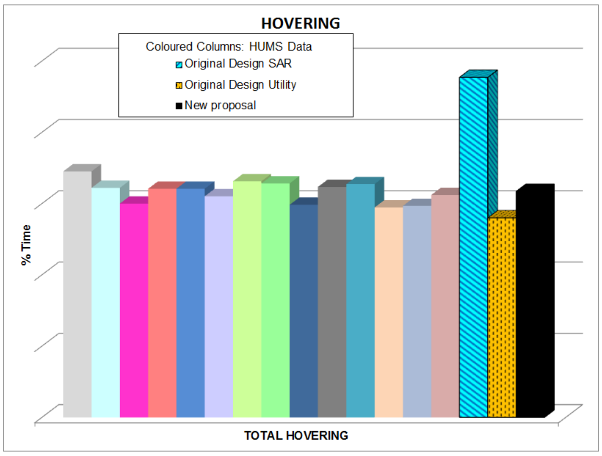

Figure 4 – Hovering analysis

A more detailed analysis of the HUMS data shows the split between IGE/OGE status, which is quite different from the design, and a significant reduction of low speed flare and hovering transitions compared to the Utility spectrum (Figure 5). However, more information from the Operator is requested, to reduce the approximation due to missing details about the other hovering operations performed for the position adjustments or for lateral flights.

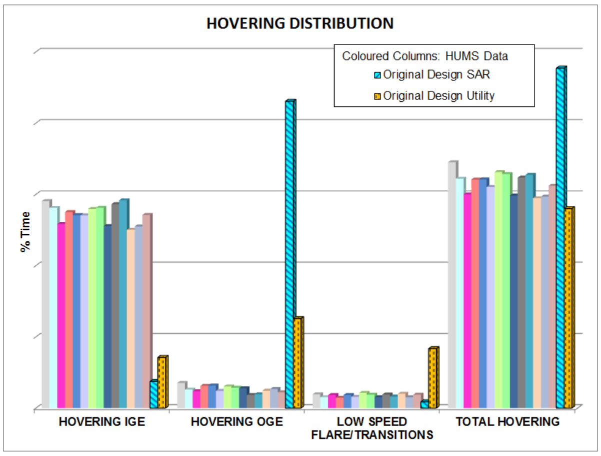

Figure 5 – Hovering split from HUMS

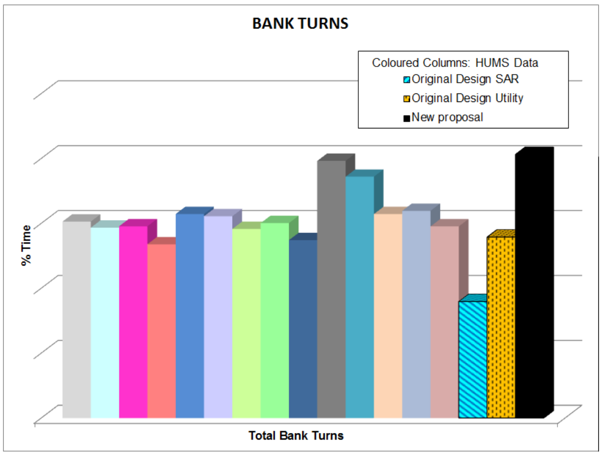

Figure 7 – Bank Turns

The HUMS %time stored as Climbs shows a deep reduction compared to the design usage spectrums, especially to the Utility role (Figure 6). This is in accordance with the reduction of the time flown at high altitude (Figure 3). The Operator experience confirms that take offs are usually followed by level flights without climbing to higher altitudes.

The HUMS %time allocated as Descents is close to the Utility spectrum and well below the SAR usage spectrum. HUMS provides also the helicopter speed. For both Climbs and Descents, the new unique spectrum reflects the recorded data.

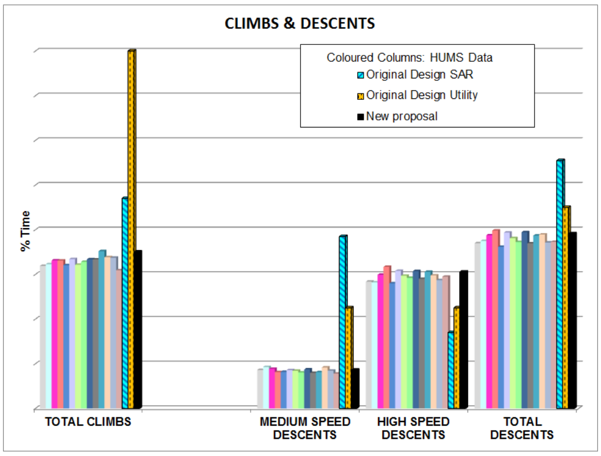

Figure 6 – Climbs & Descents

A significant increase of bank turns compared to the original design spectrums has been recorded (Figure 7).

The bank turns are then sorted by increasing severity from typical roll angle, to medium roll angle, to high roll angle (Figure 8).

The real usage highlights a higher number of low/medium speed conditions performed at the typical roll angle and a significant decrease of high speed bank turns compared to the Utility spectrum. An increase of bank turns performed at medium and high roll angles is recorded.

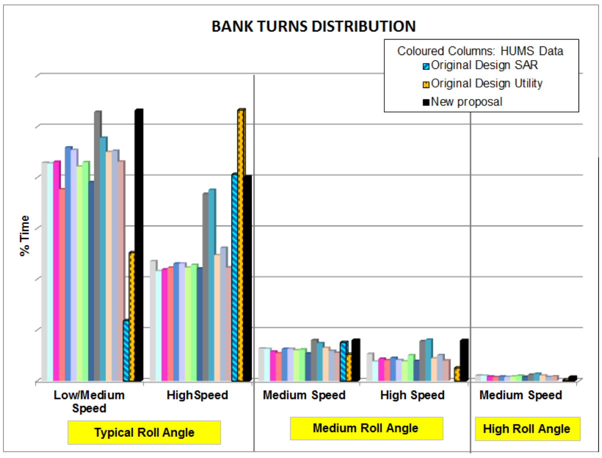

Figure 8 – Bank Turns analysis

The %time of Level Flights is very close to the original SAR design spectrum; however a more severe distribution of speed has been found (Figure 9):

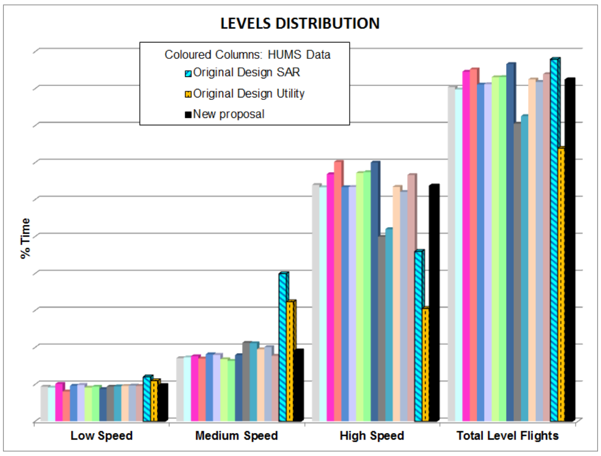

Figure 9 – Levels analysis

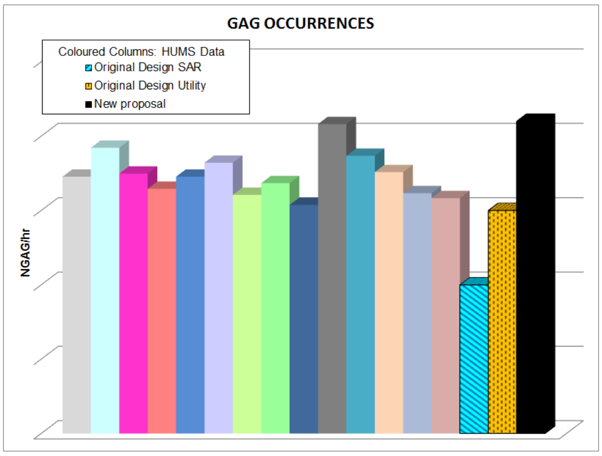

Figure 11 – GAG cycles analysis

The total amount of Accelerations and Decelerations recorded by HUMS is higher than both the design usage spectrums. However, a reduction of the most severe rapid deceleration has been recorded compared to the Utility design (Figure 10).

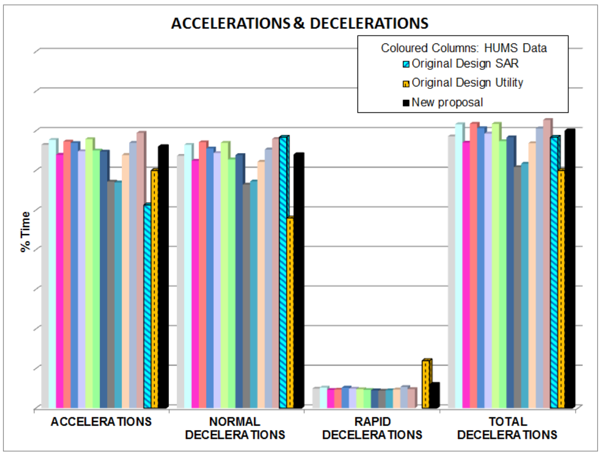

Figure 10 – Accelerations & Decelerations

The analysis of take - off and landing occurrences has highlighted shorter missions compared to the original design missions. GAG occurrences have been set in order to cover the worst case recorded by HUMS, which is about twice the original SAR Design value. Also the minimum GAG occurrence recorded by HUMS is well above the original SAR theoretical assumption and more similar but still higher than the occurrences in the Utility spectrum (Figure 11).

Moreover, HUMS has gathered rolling take offs and running landings, that are not part of the SAR design usage spectrum. They are instead present in the Utility usage spectrum with higher occurrences (Figure 12).

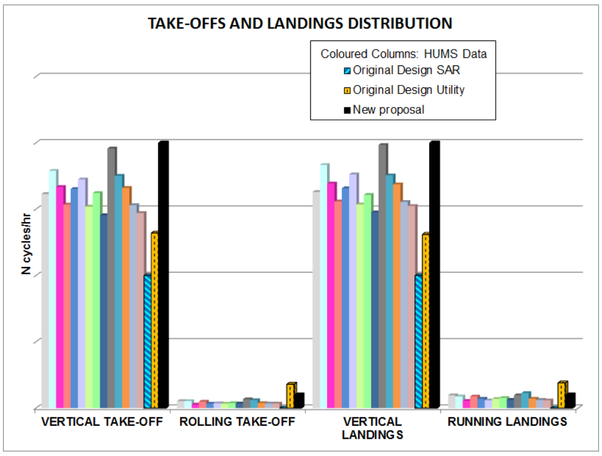

Figure 12 – Take Offs and Landings distribution

As already pointed out by Figure 1, the HUMS data shows that the original design spectrum overestimated the ETOW %time and also suggests a revision of the ETOW mission profile, in several cases addressing additional payload rather than fuel. The assumption is sustained by the fact that the take-off occurrences for mixed basic & ETOW mission are slightly higher than the take-off occurrences of the basic only. Moreover, some landings at high weight have been recorded, with an occurrence lower than the take off in ETOW: this suggests that not all the ETOW flights are completed by landings and, therefore, some of them are flown according to the design mission of additional fuel for longer range.

The Operator has confirmed a mixed usage in ETOW with additional fuel or payload.

The ETOW mission has been re-assessed on the basis of HUMS data (Figure 13), assuming the average value of take-off occurrences, in place of the maximum value. The assessment considers that the ETOW mission is managed as fixed %time of the whole spectrum, with Low Frequency Spectrum encompassing both the mixed basic & ETOW mission and the pure basic mission.

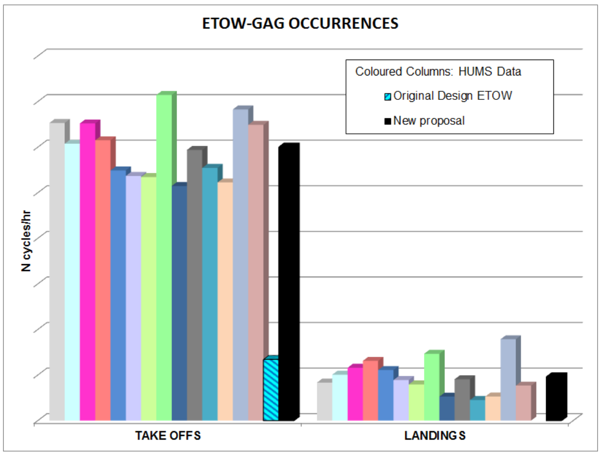

Figure 13 – ETOW - GAG cycles analysis

The rotor start occurrences are recorded by TUM accounting for the excursion of the rotor speed. The events collected by HUMS are well above the design values, strengthening the evidence of shorter missions, as already suggested by the GAG analysis. The new proposed occurrences cover the worst case in service, which doubles both the original design values (Figure 14).

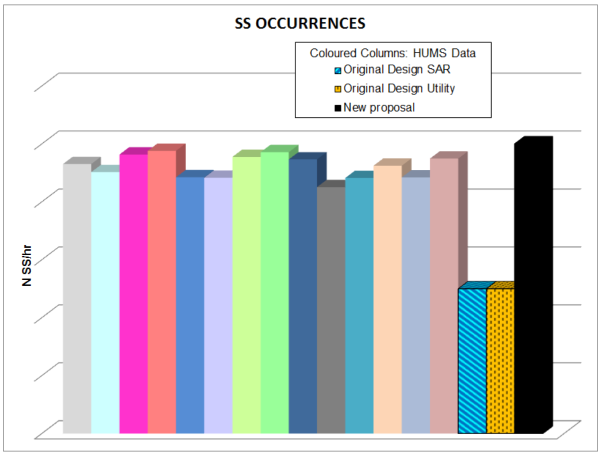

Figure 14 – Start-Stop cycles analysis

All the operations performed on ground and Weight On Wheels (WOW), with the exception of taxiing, are classified by HUMS as Ground Operations.
Ground operations %time provided by HUMS is well above the %time of the design usage spectrums (Figure 15). This increase is consistent with the higher GAG and SS occurrences but a more refined analysis allows reducing this discrepancy.

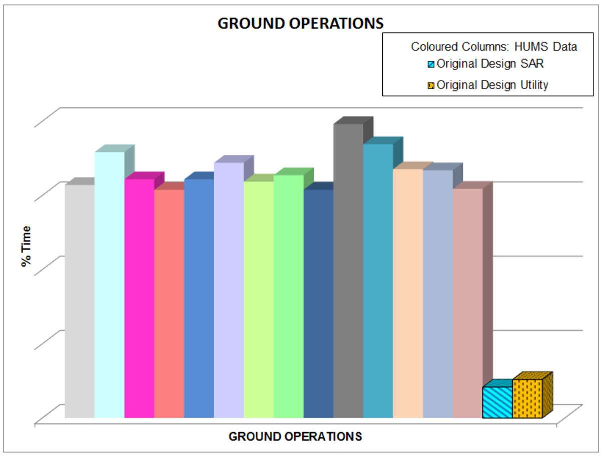

Figure 15 – Ground Operations

The FCR for take-offs and landings is set as counter of the instant (beep) when Weight On Wheels goes to Weight off Wheels, or viceversa. The counter is more representative of the event occurrence rather than %time, since it accounts just for the seconds associated to the WOW change. The remaining time of the manoeuvres, pre and post the WOW change, is stored by HUMS as ground operations. For this reason, despite the increase of GAG occurrences, the HUMS %time associated to take-offs and landings is lower than that in the design spectrums.
In the new unique spectrum, the %time for take-offs and landings has been defined considering the new GAG occurrences from the HUMS data and the fictitious duration per condition of the design usage spectrums (conservatively lower than the average time duration from the load survey).
Taxiing operations are recognized with WOW ON in combination with a value of TAS greater than zero but still low. This value is borderline for the recognition of ground operations and taxiing and sometimes they can be mismatched. Rolling take offs and running landings are stored by HUMS (see Figure 12) and contain part of taxiing, as foreseen in the Utility spectrum. A recurrent taxiing profile has been defined accounting for the airfield and the flight line generally used by the Customer. A similar number of taxiing manoeuvres to the Utility design has been addressed for the new unique spectrum.
With this evidence, part of the HUMS %time for Ground Operations needs to be distributed amongst take-offs, landings and taxiing (Figure 16). The total %time gathered by HUMS for ground operations,

take-offs, landings and taxiing is still above the design usage spectrums but with a reduced difference compared to the first comparison in Figure 15.

The proposed total %time on ground is lower than the HUMS average and this is due, in small portion, to the approximation of the fictitious duration for take-offs/landings/rotor start and stops and, mostly, to the time allocated to MPOG in the new spectrum. The exceeding MPOG time has been allocated in the new spectrum to conditions more significant for fatigue, being MPOG not damaging. The consequences of this choice are mitigated providing the retirement fatigue lives in flying hours.

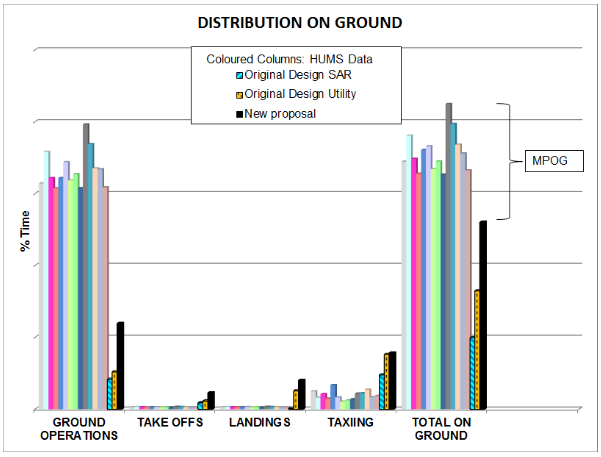

Figure 16 – Ground Operations distribution

The FCR routine has been designed to recognize normal usage flight conditions. Special flight conditions, like tactical manoeuvres, cannot be properly recognized by the FCR. However, HUMS provides the %time of Unknown/Anomalous conditions that in this case has been conservatively allocated to the Special conditions. Compared to the original design usage spectrum, a reduction of the aggressive usage is proposed, in agreement with a combination of SAR & Utility missions (Figure 17).

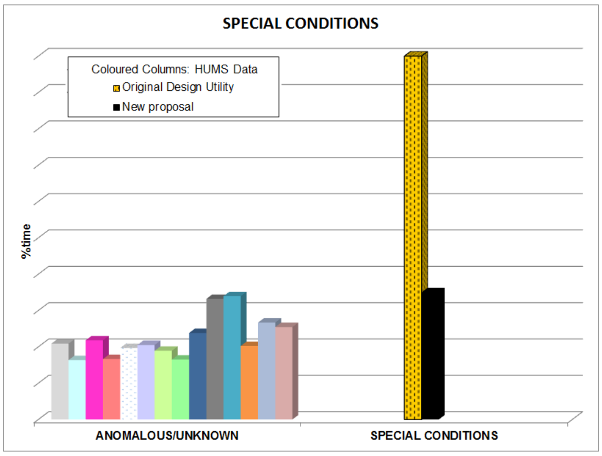

Figure 17 – Special conditions analysis

The summary comparison between the HUMS data and the design usage spectrums is reported in Figure 18, together with the new spectrum proposal. The major groups of Flight Conditions confirm a mixed SAR & Utility usage.

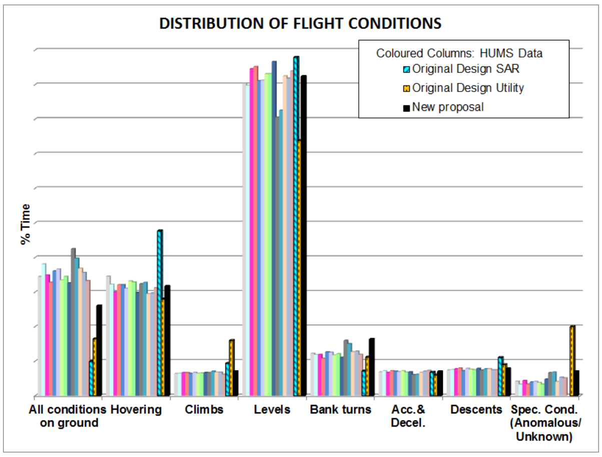

Figure 18 – Flight Conditions Summary

3.2 Impact on Fatigue Lives

New fatigue lives have been calculated with the unique spectrum derived by the HUMS data. The following charts show the variations of life limitations, expressed in terms of percentage compared to the SAR design (blue patterned column) and compared to the Utility design (orange dotted column).

The main changes from the issued design lives are derived from the Low Frequency (LF) Spectrum.

The components subject to the centrifugal force excursion during the Start-Stop cycles are subject to

a significant life reduction, as consequence of the increase of SS occurrences.
Figure 19 shows the trend for some of the Main Rotor and Tail Rotor components. In some cases the impact on the fatigue life is mitigated by the High Frequency spectrum changes, with reduction of the contribution of high altitude and hovering conditions. The life of one MR component increases compared to the Utility issued life, thanks to the reduction of the high speed Bank turns occurrences and hovering transitions (see Figure 5 and Figure 8).

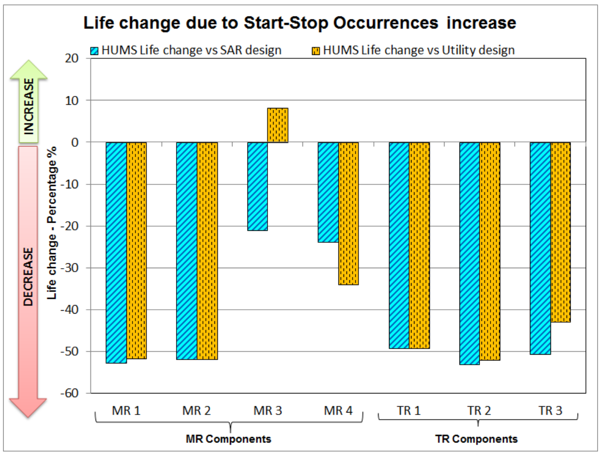

Figure 19 – Life change due to Start-Stop cycles

The components affected by the Ground-Air-Ground cycles are mainly subject to a significant life reduction, due to the GAG occurrences increase.
Figure 20 shows the trend for some of the Transmission components.
The introduction of loading peaks from special conditions, not present in the SAR design usage spectrum, has amplified the life decrease compared to the issued SAR lives. Instead compared to the Utility case, in some cases the reduction of the occurrences of special conditions has mitigated the reduction in life.

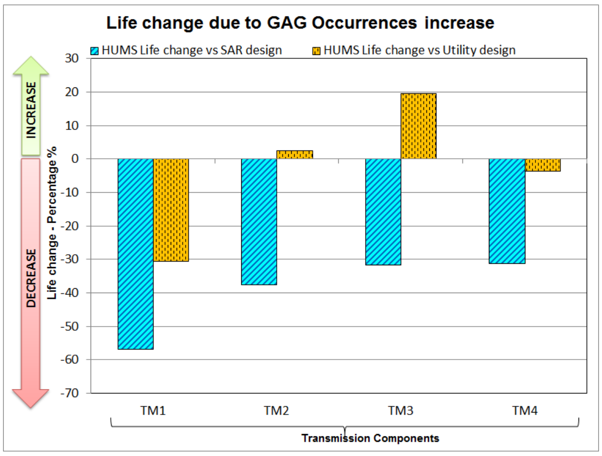

Figure 20 – Life change due to GAG cycles

The modifications applied to the HF loading spectrum generally causes a reduction of the design SAR fatigue lives and the increase of the Utility design lives. Figure 21 shows some examples from MR components, MR Rotating Controls, TR components and Structure components.

The life decrease compared to the SAR design usage spectrum is mainly due to:

- a more severe forward flight speed spectrum (Figure 9),
- the addition of special conditions not present in the SAR spectrum (Figure 17),
- the increase of hovering transitions (Figure 22),
- the increase of bank turns occurrences, especially those flown with medium/high roll angle (Figure 8).

Compared to the Utility design spectrum, the improvement of the fatigue life is generally associated to:

- the reduction of %time at very high AUW (Figure 1) associated to conditions proper of the Utility profile, more demanding than SAR,
- the reduction of %time for conditions proper of the Utility profile like the rapid deceleration (Figure 10),
- the reduction of %time at Special conditions (Figure 17).

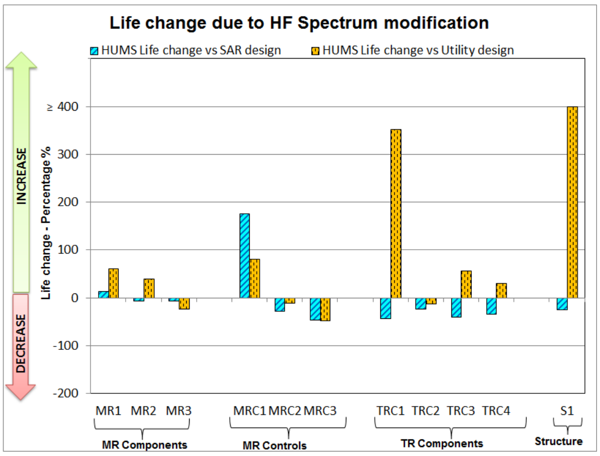

Figure 21 – Life change due to the HF spectrum

4 MAIN LIMITATIONS OF THE FCR ROUTINE

The HUMS version installed on the AW101 variant analysed consists of on-board FCR real-time computation. The analysis is based on time interval discretised as the Main Rotor revolution. Once the flight condition is recognised, it is stored in the SUM Log and the whole process is repeated for the following time interval. In this way, the flight is thoroughly analysed without losing information and with reasonable computer workload and use of memory. However, due to storage capability limitations, some parameters are not recorded, the source flight data is not available and just the output data post-processing is provided.

In details, no HUMS data is available for wind speed during Start-Stop, folding/sailing operations, special usages not included in the FCR routine.
The flight parameters monitored are stored referring to value level bands and no punctual values are provided.
Large level bands lead to conservative engineering assumptions.
For instance, from Figure 2, some helicopters data has been associated to a more severe altitude distribution compared to the remaining fleet. The Operator has addressed special deployment in hot temperature, which has affected the density altitude reading. However, according to the Operator information, during this mission only a small %time allocated at the high density altitude band was actually flown as high density altitude. The most of the %time has been declared close to the corner point low/mid altitude. In order to avoid unnecessary penalization, this information has been taken into account for the spectrum definition, even if no specific occurrences have been surveyed.

Moreover, some flight conditions are not distinguished in details by the FCR routine. An example is provided by the hovering conditions. HUMS FCR is able to recognize the hovering status and the IGE/OGE conditions; however it is not designed to distinguish the type of the manoeuvres, like spot turns, sideways, azimuth conditions (Figure 22). The conditions distribution has been based on the Operator instructions and on the flight data available from the load survey activities, where more conditions in OGE have been recorded.

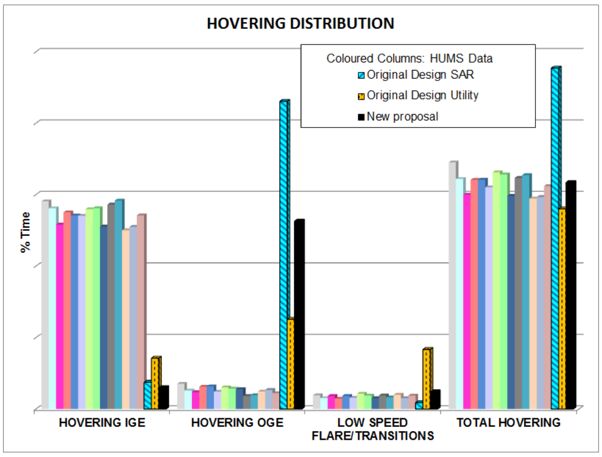

Figure 22 – Hovering conditions split

Also, only the %time of the flight conditions can be derived from the HUMS recordings and no number of manoeuvres is stored, with the exception of take-offs, landings and rotor starts. The number of occurrences is derived for the new spectrum from the HUMS %time and the design fictitious time duration per manoeuvre, that is conservatively lower than the average duration from the load survey dataset, in order to evaluate a higher number of manoeuvres.

5 FUTURE DEVELOPMENTS

Some AW101 military variants are fitted with dual usage monitoring programme. Another data recording programme has been developed together with HUMS and focused on flight loads monitoring. The programme has been also used for the Flight Condition Recognition analysis for a complete

monitoring in terms of both loading spectrum and conditions spectrum.
A comparison of the FCR outputs from the secondary data recording programme and HUMS is under consideration. This research would provide a further FCR validation.

Thanks to the improvement of memory storage and information technology, a new version of the HUMS software has been recently developed.
All the parameters monitored are recorded for the whole time history and the Flight Condition Recognition is performed in post-processing on ground, after downloading the HUMS data.
This allows recording a larger set of parameters, redefining the level bands on a case by case basis, defining new criteria for the manoeuvre recognition in order to obtain a more detailed distribution (for instance for the hovering operations) and deriving a criterion for the detection of the number of events in addition to the %time.

A new specification has been drawn up for the Combat manoeuvres recognition. The Combat manoeuvers are characterized by dynamic and manoeuvred flights conducted also at field altitude and/or with possible rapid attitude variations. The peculiarity of this kind of operations requires monitoring several parameters per condition, which can be easily provided by the new FCR.
The validation of the routine is thought to be performed in collaboration with some Customers during their usual missions. The Customers will be requested to provide detailed flight log sheets for a direct match with the FCR outputs.
Once validated, the new HUMS tool will be used as flight tracking of Combat role and could be also tuned for other special usages and kits. This will relieve the Customers to count the time spent out of the basic usage, which in some circumstances, like war scenarios, could be difficult to monitor.

The immediate future will be focused on the flight condition recognition in post-processing.
Thanks to the availability of the source signals, the conditions distribution will be more detailed.

At this phase, the new FCR tool still needs the Specialist Engineer for data management and interpretation.

6 CONCLUSIONS

The HUMS installed on the AW101 helicopters has accrued several hours in service.
The SUM platform allows the recording of flight parameters that are analysed in order to monitor and define the actual operational usage of the helicopters.
A complete analysis of one of the AW101 military variants has been performed, processing about 25,000 hours of fleet service usage. The HUMS structure of this variant is designed for the on-board analysis of the flight parameters, with data discretised in time intervals and monitored by the Flight Condition Recognition (FCR) tool.
The FCR tool has been set in accordance with the load survey databank in order to assure the best association of the flight data in service with the load survey manoeuvres.
The flight data is processed by the FCR on-board and then downloaded on ground in the form of information already elaborated.

The analysis of the HUMS data has allowed a redefinition of the usage spectrum for the LF occurrences and the HF loading spectrum.
Limited-in-time usage in special mission has been detected and highlighted by HUMS and confirmed by the Customer.
Some details are still missing from the FCR results and need engineering judgement and the Operator feedback to avoid severe assessment and unnecessary penalization.
A full fatigue life re-evaluation has been carried out. Some of newly issued fatigue limitations have been relaxed compared to original value, while in some other cases the safety in service has been strengthened reflecting the actual helicopter usage, even if Retirement Lives of those components affected by more demanding conditions or occurrences have been lowered.

Another data recording programme has been installed on some AW101 variants, which includes the FCR tool. This programme is in addition to HUMS. A comparison of the FCR outputs from HUMS and the secondary data recording programme is under consideration for a further validation.

An improved version of the FCR tool is now under development. Thanks to the greater memory storage

capability, the new SUM version allows recording flight data as whole time history, then downloaded in pre-processing format and the FCR analysis is performed on ground on the original signals. In this way, more flight parameters can be monitored and the recognition criteria can be tailored for each manoeuvre set, thanks to the availability of the source data.
This improvement allows a more refined selection of the type of manoeuvres and the discretisation of the number of events, in addition to the %time.

Taking advantage of the new capability, a specification dedicated to peculiar Military profiles has been drawn up in order to enlarge the current FCR databank. Validation of the new routine is planned to be performed in cooperation with some Customers during their usual sorties.

Thanks to the reliability of the routine, HUMS could be used as counter of the time spent in special usages, in order to deal with limited roles and fatigue life penalties. This will relieve the Customers to track the mission, especially when aircraft are used in real operative theatres.

The oldest FCR version needs a deep intervention by the specialist engineer for data interpretation and managing.
The more recent FCR version still requires the specialist engineer for the flight data processing.
Future developments will be focused on easing this implementation.

7 ACRONYMS AND SYMBOLS

ACSR	Active Control of Structural Response
AUW	All up Weight
CoG	Centre of Gravity
ETOW	Extended Take-Off Weight
FCR	Flight Condition Recognition
G	Load Factor
GAG	Ground Air Ground cycle
HF	High Frequency
HIGE	Hovering In Ground Effect
HOGE	Hovering Out of Ground Effect
HUMS	Health and Usage Monitoring System
IGE	In Ground Effect
LF	Low Frequency
MPOG	Minimum Pitch On Ground
MR	Main Rotor
NR	Main Rotor round per minute rpm
OAT	Outside Air Temperature
OGE	Out of Ground Effect
SAR	Search and Rescue
SS	Start-Stop cycle
SUM	Structural Usage Monitoring
TAS	True Airspeed
%TIME	Percentage of Time
TR	Tail Rotor
TUM	Transmission Usage Monitoring
WOW	Weight On Wheels

8 REFERENCES

[1]. Mariani U; R. Molinaro (2012), Effectiveness of Structural Usage in Monitoring (SUM) and Transmission Usage Monitoring (TUM) in Military and Civil Applications.

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