LOW NOISE DESIGN AND ACOUSTIC TESTING OF THE AIRBUS HELICOPTER H160-B

Frédéric Guntzer, frederic.guntzer@airbus.com, Airbus Helicopters (France)

Vincent Gareton, vincent.gareton@airbus.com, Airbus Helicopters (France)

Jean-Paul Pinacho, jean-paul.pinacho@airbus.com, Airbus Helicopters (France)

Julien Caillet, julien.caillet@airbus.com, Airbus Helicopters (France)

Abstract

The noise certification and low noise levels of the newly developed Airbus Helicopters model, the H160-B, are presented in this paper. In the first part, the helicopter low-noise characteristics, as well as the certification methodology are described. In the second part, the noise certification results of the helicopter are presented and compared to available world fleet data, underlining the low noise levels of the H160-B helicopter. A detailed analysis, focusing on the approach condition, is then presented in a third part, relying on one hand on measurement data treated with a time-based source separation software (ROSI) and on the second hand on comprehensive code (ONERA HMMAP) numerical results. This analysis allows again validating of the effectiveness of the Blue Edge™ main rotor blade design in terms of noise.

1. INTRODUCTION

In May 2015, Airbus Helicopters performed the first flight of the H160-B introducing its next generation of 6 tons helicopter. For modern aircraft, environmental impact including noise and emissions, is a key driver of the design. Former noise certifications [1],[2], as well as research projects, show continuous effort in lowering the environmental footprint of Airbus Helicopter fleet, either through design improvements [3]-[6] or Low Noise Procedures design and implementation [7][9].

In this ambitious context, the external noise behavior of the aircraft was essential from the beginning of the H160-B program. This resulted in very challenging noise specifications that require acoustic design considerations to be an integral part of the complete development process – from the very first sizing to the final evaluation during the noise certification flight tests and future in-operation support. This paper presents the new medium class helicopter H160-B, with focus on the implemented noise reduction technologies, the methodology and processes used for noise certification of the aircraft and related results. A comparison with the existing helicopter world fleet is processed. Detailed analysis of the results with help of the noise prediction tools available at Airbus Helicopters is also provided.

This paper is the first to disclose some detailed H160-B acoustic results from its noise certification test campaign. <u>Please note that at the time of publication of this paper, the H160-B noise levels shown below are still preliminary and may not represent the exact final values to be officially certified, pending on design modifications.</u>

2. H160-B HELICOPTER

The H160-B (Figure 1) is a medium twin engine helicopter developed by Airbus Helicopters to extend its offer in the 6 ton class. Its maximum take-off weight is of 6050 kg.

Figure 1: Pre serial H160-B helicopter.

The H160-B design makes it versatile in answering customers' needs for a wide array of missions:

- Oil & Gas,
- Commercial & Air Transport (CAT),
- VIP & Stylence ®,

Presented at 45th European Rotorcraft Forum, Warsaw, Poland, 17-20 September, 2019

- EMS, Public Service / Rescue.

As a major evolution of the Dolphin family the H160-B includes the features inherited of the Dolphin, and introduces breakthrough technologies including an advanced NR law, modern avionics, an enhanced cockpit visibility, a new blade design with an innovative planform, a bi-plane horizontal stabilizer and a canted Fenestron™ anti-torque system.

The challenging and ambitious design in the H160-B development was to carefully balance the good helicopter performance, the low vibration comfort [10], while improving the sound characteristics of this medium weight helicopter. The resulting acoustic design – based on the large experience gained during the development of H155, H135 and H145, as well as from various acoustic research projects such as Blade 2005 project for the advanced blade planform design - comprises all advanced low noise features of the Airbus Helicopters fleet:

- Advanced main rotor planform design : Blue Edge™ to reduce noise in the approach phase,
- RPM law including automatically adapted rotating speed when close to ground and populated area for all flight phases,
- Low-Noise Fenestron™ with canted design.

2.1. Main rotor system

The Blue Edge™ Blade double swept planform was developed aiming to reduce Blade Vortex Interaction (BVI) noise [3]], [4]. This blade equips the H160-B main rotor as presented on Figure 2.

This blade concept reduces the strength of BVI noise in the most penalizing conditions/directions by avoiding strong parallel interactions simultaneously occurring over a large section of the blade span, which can be encountered with a straight blade, typically in approach condition. Moreover, it was previously demonstrated through full scale near-field and far-field noise measurements that the Blue Edge™ blade shape efficiently reduces BVI noise throughout the approach flight envelope of the aircraft [3], meaning not only in the certification approach flight condition, but also at various alternate slopes and speeds. This allows thus for additional operational noise reduction, also in flight conditions not assessed in noise certification, paving the way for the introduction of low noise approach procedures.

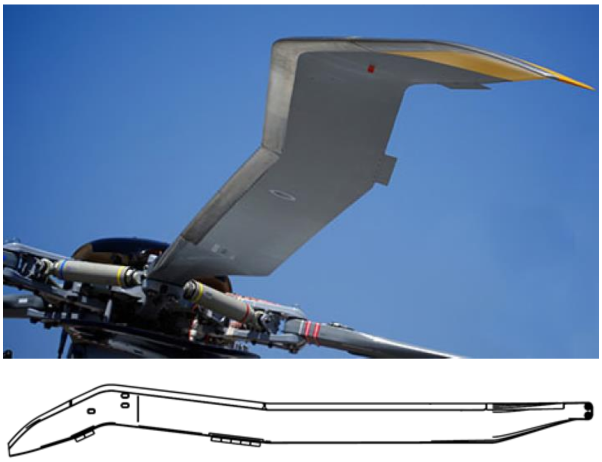

Figure 2: Blue Edge™ planform of H160-B main rotor.

2.2. Smart NR law

One of the most important noise reduction features on the H160-B is its advanced rotor RPM law, which is, among other functionalities, designed to reduce noise levels perceived on the ground. This smart NR law governing the rotational speed of the rotors reduces the emitted noise thanks to a precise ground height measurement triggering the RPM reduction. The RPM triggering is also a function of airspeed, pressure altitude, and outside air temperature to allow the best compromise between safety, required performance for take-off conditions, and reduced noise impact on the population.

When in the 'low noise' region (close to the ground, above 70 kts) the automatic NR law reduces smoothly the NR to 96% compared to a maximum possible value of 103.5% (depending on height, temperature, and flight condition). This yields to an important reduction of the sound emission of the H160-B in all flight conditions, and therefore leads to less noise emitted towards the population on the ground.

The sounds emitted by the rotors are also reduced in near field during on-ground operations thanks to a dedicated 'ground run' reduced rotational speed.

2.3. Fenestron™ anti-torque system

The H160-B Fenestron™ has inherited of previous design from the H155 (Dolphin), H130, H135, and the latest H145 [1].

The Fenestron™ integration into the H160-B development was driven by a trade-off design decision which takes into account firstly safety considerations and in a second line both

Presented at 45th European Rotorcraft Forum, Warsaw, Poland, 17-20 September, 2019

performance efficiency and noise reduction objectives. A detailed description of typical Fenestron™ design parameters is detailed in [1],[2],[11].

For performance reason the design blade tip speed of the H160-B Fenestron™ was increased with respect to H145, as well as blade radius and mean chord. By observing Table 1 below, the H160-B Fenestron™ presents the largest size ever built, at the edge of the Fenestron™ capabilities for such a heavy aircraft.

Table 1: Comparison of the Fenestron™ concepts

Helicopter	H135	H145	H160-B
Concept	Fenestron	Fenestron	Canted Fenestron
Diameter [m]	1.0	1.15	1.2
Number of blades	10	10	10
Mean Chord [mm]	50	63	100

Compared to a classical 'open' tail rotor, the modern Airbus Helicopters Fenestron™ offers the following three assets:

- An acoustic 'shielding' effect is provided by the duct in which the Fenestron™ blades are rotating and thus reduces the acoustic energy emitted. This is particularly efficient on the in-plane thickness noise. Interaction of the blade tips with the main rotor vortices are limited by the aerodynamic design of the shroud and transonic effects in high speed flyover are as well avoided.
- The aerodynamic design of the duct geometry with the particular canted design provides additional vertical thrust which is beneficial, especially in take-off flight phase where high thrust level is required.
- Lastly, modern Fenestron™ design benefits from unequal blade spacing which distributes the acoustic energy emitted by the rotating blades rather than concentrating the Fenestron acoustic energy at the Blade Passing Frequency (BPF). The resulting sound spectrum is more broadened than these of a classical tail rotor spectrum with high peaks at the BPF and its multiples. This mechanism is illustrated on Figure 3 and Figure 4, where the broadening of the acoustic energy over multiple frequencies is clearly to be observed.

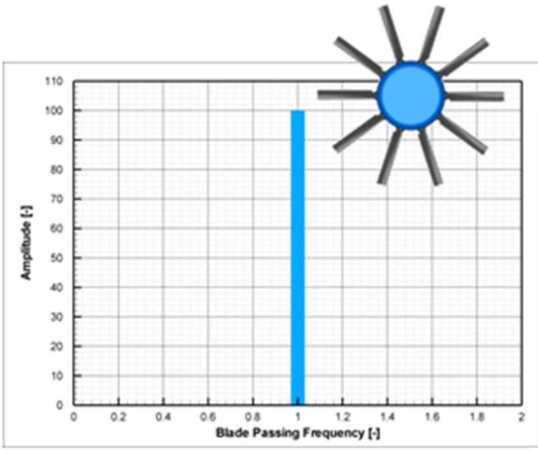

Figure 3: Simulated spectrum of a non-modulated Fenestron™ rotor from [6].

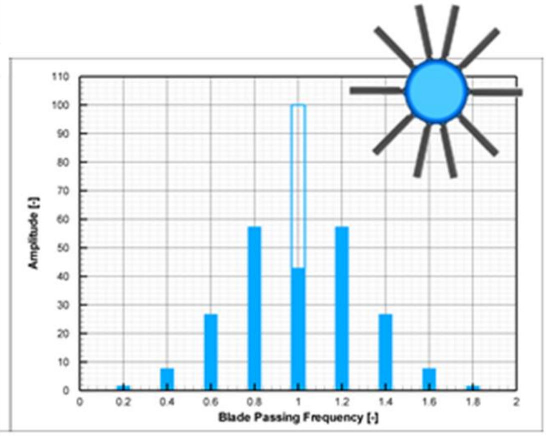

Figure 4: Simulated spectrum of a modulated Fenestron™ rotor from [6].

3. NOISE CERTIFICATION TESTING

From the set-up and the implementation of noise regulation to latest noise directive evolutions, Airbus Helicopters has always been involved in noise certification matters thanks to ICAO working group's active participation.

Since the first introduction of Helicopter Noise limits in January 1985, Airbus Helicopters has developed an evolving knowledge and methodology for measuring, processing, analyzing, and providing consistent results to Certification Authorities (EASA, FAA, and Aviation Authorities from others countries).

This knowledge is efficiently enhanced through a continuous update of the measurements technologies (digitalization, evolution of the processing, best practices, experience sharing) gathered from each measurement campaign.

Presented at 45th European Rotorcraft Forum, Warsaw, Poland, 17-20 September, 2019

For H160-B certification campaign, Airbus Helicopters certification methodology has benefited from a new acoustic measurement system which is presented hereafter.

3.1. Measurement system

The acoustic data are measured thanks to a newly-acquired noise measurement system comprising of noise recording, noise analysis, and wireless liaison means, meeting the complex requirements of ICAO Annex 16.

The flight mechanics parameters are obtained thanks to on-board instrumentation including DGPS-based position information.

Meteorological information is obtained with a dedicated instrumentation which is handled by the noise measurement system: the temperature, the relative humidity, the atmospheric pressure, and both the wind direction and speed are continuously measured using a 10m-height tower meteorology station.

Eventually, the post-processing of flight parameters, meteorology, and acoustic data is performed using in-house tools. For more details about noise measurements and associated analysis tools one can refer to [1].

Thanks to a well-adapted process and good cohesion between ground and flight test teams, Airbus Helicopters managed to measure 75 certification runs within two consecutive days of measurements with only 12 rejected flights (mainly for meteorological reason, too high wind). Note that extra flights at 100% RPM were also acquired to allow a good assessment of the RPM law influence in certification conditions.

3.2. Noise Results

The present section displays the H160-B certification noise levels and compares them with available world fleet data.

<u>Please note that at the time of publication of this paper, the H160-B noise levels shown below are still preliminary and may not represent the exact final values to be officially certified.</u>

Figures 5 to 7 display a subset of the Airbus Helicopters noise certification levels - including preliminary H160-B values - against world fleet data from TCDSN [12], respectively for take-off, flyover and approach flight conditions. The H160-B preliminary certification levels are shown in green. ICAO noise limits (pre- and post-2002) are also plotted as function of maximum take-off weight to allow reading the relative margins.

At a general level, on the 3 flight conditions, the H160-B achieves very low noise levels in comparison with world fleet data. Looking more accurately at each specific flight condition, the following conclusions are stated.

- In take-off condition, the H160-B achieves a margin of 5.2 EPNdB with respect to post-2002 noise limit. As displayed, this margin is one of the best in its mass class, along with the H175-B one.
- In flyover condition, the margin is of 4.0 EPNdB, making the H160-B the best helicopter in terms of noise in its mass category.
- The very good results in take-off and flyover conditions are attributed to the H160-B NR law and the Fenestron™ anti-torque system.
- In approach condition, the margin is of 6.8 EPNdB. Such a margin makes – by far – the H160-B the best helicopter in terms of approach noise in its mass class. This is attributed to the H160-B NR law and above all to the introduction of the Blue Edge™ blade on the main rotor.

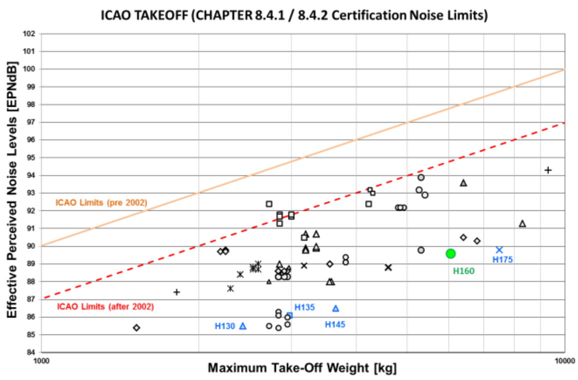

Figure 5: World fleet take-off certification noise levels as from EASA TCDSN.

Presented at 45th European Rotorcraft Forum, Warsaw, Poland, 17-20 September, 2019

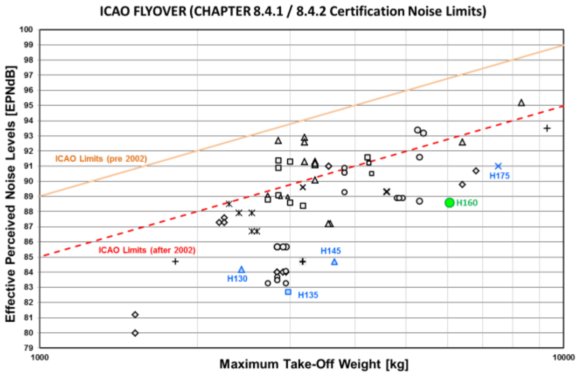

Figure 6: World fleet flyover certification noise levels as from EASA TCDSN

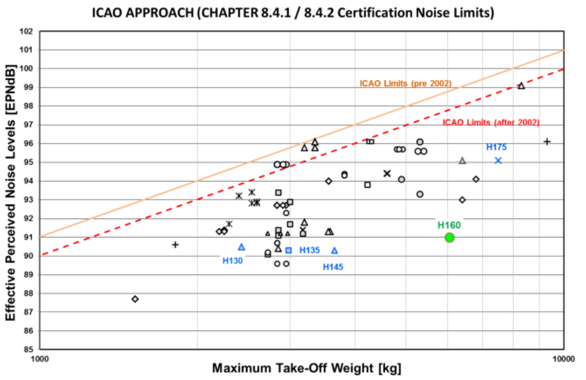

Figure 7: World fleet approach certification noise levels as from EASA TCDSN.

The H160-B very good results in all certification flight conditions is illustrated by its 'A' Sound Efficiency Rating (SER). The Sound Efficiency Rating as proposed within the "Green metrics philosophy" is a noise scale meant to be easily understood by the public for a straightforward communication regarding acoustic efficiency of helicopters.

The SER is based on certification noise levels: since for noise the certification framework is already well established, and the data for all certified helicopters are available in either EPNL or SEL metrics. This rating allows thus easy comparison of the environmental impact of helicopters with respect to noise. The ratings are based on the cumulative noise certification margins with respect to ICAO Annex 16, Chapter 8.4.1 limits. For helicopters with Chapter 11 certification data, an equivalent Chapter 8 cumulative margin was derived based on the analysis of the existing certification data.

Figure 8 displays the SER of the different helicopters against their maximum take-off weights. Clearly, the H160-B achieves the best SER in its mass class. This is to be underlined, as it is empirically observed that good SER values are more difficult to achieve with increasing weight.

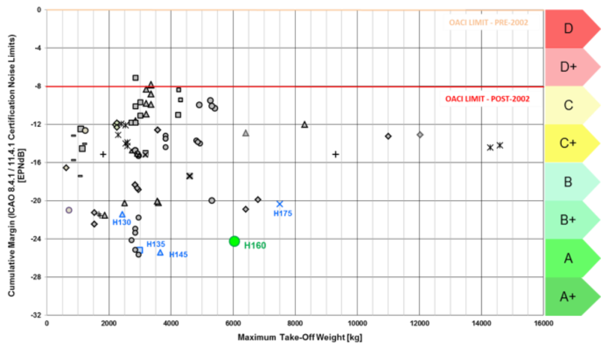

Figure 8: World fleet Sound Efficiency Rating as from EASA TCDSN.

4. DETAILED ANALYSIS OF APPROACH RESULTS

To provide an insight about the contributions of the main noise sources (in the present case main rotor and Fenestron™) to the overall noise levels, an in-house source noise extraction algorithm (the so-called ROSI software) is applied on a subset of the flight test data, focusing on the approach flight condition. The ROSI software was originally developed at formerly Airbus Group Innovation, and processes to tonal source extraction in the time domain (no broadband source extraction is processed).

As the ground-measured signal is highly affected by the Doppler effect, a de-dopplerization is processed starting from the known, measured RPM data as recorded on the helicopter, which yields the emission Blade-Passing Frequency (BPF) of the extracted source. Through a Hilbert transform, the reception BPF is computed at each time-step for comparison with the emission one. The result is illustrated on Figure 9, where the reception signal is shown in blue, the reference emission BPF signal in black and the calculated reception BPF in red.

Presented at 45th European Rotorcraft Forum, Warsaw, Poland, 17-20 September, 2019

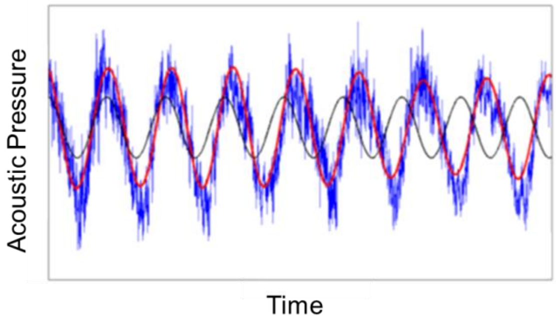

Figure 9: Example of extraction of reception BPF using ROSI.

Once done, the de-dopplerized signal is computed through contraction/dilatation of the time vector according to the ratio of the reception BPF to the emission BPF. The known Least Mean Squares algorithm is then used for source extraction on the de-dopplerized signal. For conventional helicopters, the classical ROSI outputs are main rotor and anti-torque tonal signals as well as residual signal (i.e. total signal minus extracted ones) along reception time. Relevant acoustic metrics are then processed. In the present study, the analysis of the filtered signals is processed using A-weighted noise level metric, as Tone corrected Perceived Noise Level (PNLT) tone correction is deemed as unrepresentative when dealing with extracted isolated sources tonal signals.

A practical additional feature of the software is that it provides an estimation of the helicopter overflight time over the analysed microphones through the analysis of the Doppler factor. The instant of the minimal Doppler effect being approximated as time of overflight.

ROSI software is now used frequently at Airbus Helicopters, and integrated in the working environment. Providing an insight of the various tonal contributors - mostly main rotor and anti-torque system - is a clear asset in order to strive for minimal noise emission. It is in particular very useful in approach condition, for which Blade Vortex Interaction (BVI) occurs and is usually preponderant. The BVI phenomenon is knowingly tonal and classically distributed within the 6 to 40 main rotor BPF frequency domain. Yet, from Airbus Helicopters experience, the ROSI analysis process is not perfect, and tends to some underestimation of the tonal sources, as it is observed that the residual signal still holds some tonal content (although significantly diminished with respect to the original signal). Additionally, the analysis is processed on raw-measured (but calibrated) acoustic pressure signal data: no adjustment as described in ICAO Annex 16 is introduced. Recall that these adjustments account for deviations with respect to nominal flight path, velocity or meteorological conditions during the measurements. The corrections are mostly frequency-dependent and not easily applicable to a time-based analysis. It is currently a point of improvement which is to be addressed. Therefore, results provided in the current section are to be interpreted with care. Furthermore, in the present section, only a single approach flight, deemed as representative, is analysed (on the 3 certification microphones), whereas the certification noise levels are generated through averaging on several flights.

The focus is herein put on the approach in order to underline the effectiveness of the H160-B Blue Edge™ equipped main rotor on BVI mitigation. In order to allow for comparison, the H160-B noise results are plotted against the H175-B ones. Recall that the H175-B helicopter is a twin-engine helicopter with a maximum take-off weight of 7800 kg. Its noise certification test campaign took place in 2012. The H175-B features a five-bladed, 14.8-meter diameter main rotor equipped with parabolic blade tips. The airfoil sections used on the outer portion of the blades are thin (7% thickness-to-chord ratio) in order to limit thickness noise in the high Mach number regions of the rotor. It is equipped with a 3-bladed tail rotor canted at 20°.

It is considered as a state-of-the-art helicopter in terms of noise and achieves a B+ SER rating. It particularly features an ambitious RPM scheduling law and also benefits from a high best-rate-of-climb in the take-off phase, yielding noticeably low take-off noise levels due to slope effect. Therefore, the helicopter used as a reference in the present study can be considered as already well above the ‘average’.

Figure 10: H175-B during its certfication noise flight tests.

In order to account for the higher mass of the H175-B helicopter, a 10*log10 scaling was applied to the H175-B A-weighted noise levels,

Presented at 45th European Rotorcraft Forum, Warsaw, Poland, 17-20 September, 2019

consistently with noise certification maximal noise levels mass law, although this latter is to be normally applied on EPNL levels.

To consolidate the analysis methodology, it is firstly verified that the Sound Exposure Levels (integration of A-weighted noise level along reception time) and EPNL variations on H160-B and H175-B are consistent. Table 2 displays the certified EPNL of the two helicopters and the corresponding variations. The 'Delta certified EPNL' column shows the absolute difference between the two helicopters in terms of certification noise levels. In particular, a reduction of 4.1 EPNdB is observed in the approach condition for the H160-B. In the take-off flight condition, the noise levels are roughly equivalent, as the H175-B is particularly well placed due to its important best-rate-of-climb. The 'Delta corrected EPNL' column displays the same variations but corrected from the 10log10 law. The variations are therefore all a bit shifted towards positive values.

The 'Delta corrected SEL' column displays the variations in measured SEL (using the very same signals as in the ROSI analysis). The analysis in measured SEL seems to emphasize the trends. This results in higher noise reductions in flyover and approach phases, and higher noise increase in take-off. This can be explained by the different noise metrics used, but also by the absence of adjustments applied to SEL noise levels and the fact that a single run per flight condition is used for SEL analysis whereas several ones are used for certified EPNL values. Yet the SEL and EPNL variations show similar tendencies, and the ROSI analysis on measured A-weighted noise levels is deemed as sufficiently representative.

Table 2: Comparison of H160-B and H175-B certificaton EPNL and measured SEL values.

	H160 EPNL as certified	H175 EPNL as certified	Delta certified EPNL	Delta corrected EPNL	Delta corrected SEL
Take-off	89.6	89.8	-0.1	0.8	1.5
Flyover	88.6	91.0	-2.4	-1.5	-3.0
Approach	91.0	95.1	-4.1	-3.2	-4.3

Figure 11 to 13 show the A-weighted noise level time histories on each certification microphone in approach condition for H160-B and H175-B, centred around the estimated microphone overflight time (i.e. 0 sec), the 10log10 mass correction being applied. A-weighted total (solid lines) and ROSI-extracted main rotor (dashed lines) noise levels are plotted against reception time.

Significant noise reductions are generally observed on the three certification microphones. The maximal A-weighted noise levels (LAmax) drops respectively off 5.8 dB(A), 6.7 dB(A) and 3.4 dB(A) on left, centre and right microphones. Moreover, the noise reduction is observed on most of the time history and the H160-B noise levels are much smoother than the H175-B ones. This is attributed to the introduction of the Blue Edge™ blade on H160-B, which knowingly yields less directive footprint than the H175-B straight blade [3].

On the left (advancing blade) microphone, the noise reduction is mostly located before overflight time. In particular, a significant noise reduction is observed roughly 5 sec before overflight. This indicates for a directivity lobe on the advancing blade side towards helicopter front on the H175-B, which is mitigated on H160-B thanks to its main rotor. Contribution of the main rotor to the total noise levels is diminished on both helicopter after overflight time, associated to the lesser noise reduction on total levels.

On the centre microphone, the gains are located before, at and shortly after overflight time, indicating for noise reduction at the front of and below the helicopter. Main rotor contribution to total noise is very important before overflight but then diminishes along time, the diminution being much more important on H160-B.

On the right microphone (retreating blade), very important noise reduction is located before overflight time, again indicating for gains at the front of the H/C. On the right microphone the ROSI-filtered main rotor noise is clearly much lower on H160-B than on H175-B. After overflight, total and main rotor noise levels tend to comparable values.

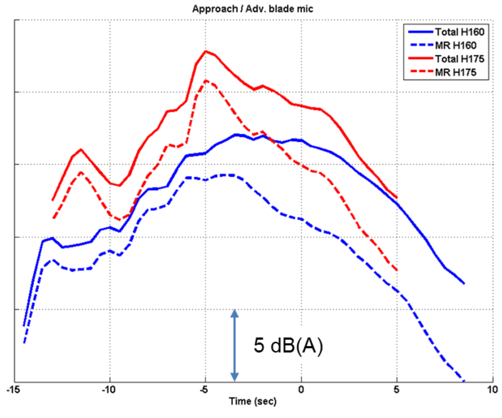

Figure 11: Total and main rotor tonal A-weighted noise level along observer time on H160-B and H175-B on advancing-side microphone.

Presented at 45th European Rotorcraft Forum, Warsaw, Poland, 17-20 September, 2019

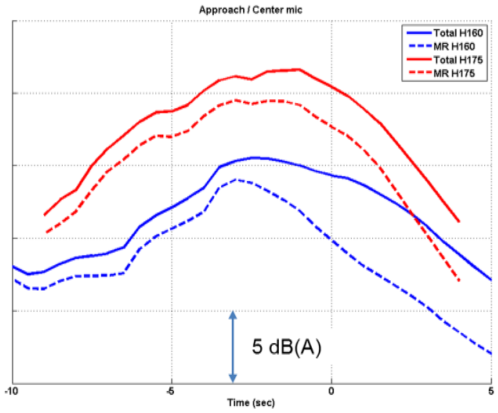

Figure 12: Total and main rotor tonal A-weighted noise level along observer time on H160-B and H175-B on center microphone.

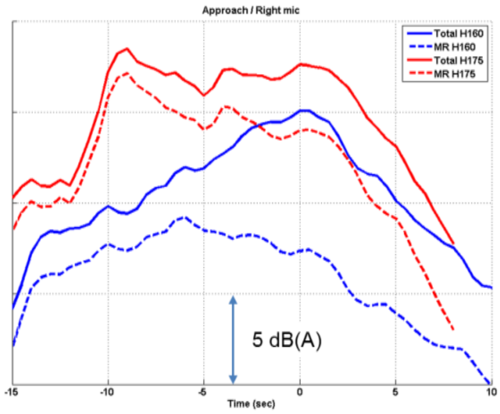

Figure 13: Total and main rotor tonal A-weighted noise level along observer time on H160-B and H175-B on retreating side microphone.

Figure 14 shows the H160-B and H175-B SEL values (including 10log10 correction) averaged on the three certification microphones for the approach condition. The 4.3 dB(A) drop on the total levels is observed, in accordance with Table 2. A significant noise reduction of 5.5 dB(A) is also observed on the ROSI-extracted main rotor noise levels, again highlighting the effectiveness of the H160-B main rotor concept. The drop between total and main rotor noise is also more important on H160-B than on H175-B, respectively 3.7 dB(A) and 2.5 dB(A). Nevertheless, as main rotor tonal noise remains after extraction in the residual signal, such values should be interpreted with more care.

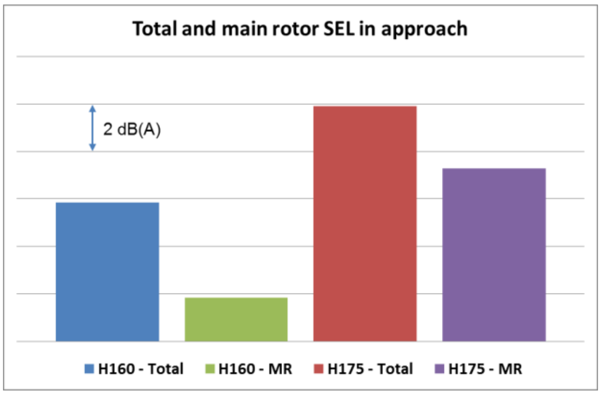

Figure 14: Total and ROSI-extracted main rotor SEL values on H160-B and H175-B.

To push forward the analysis, numerical computations of the two main rotors were also processed, using the HMMAP solver. This comprehensive computation chain is based on the HOST solver [13] and has been developed at ONERA in the 1990 [14]. Numerous improvements have been implemented since then, among them recent ones in the frame of the French national-funded CHARME project (for example regarding BVI modelling, see [15]). This feature is currently in use in Airbus Helicopters working environment.

Figure 15 shows the HMMAP-calculated noise footprints of the H175-B and H160-B (respectively above and below) main rotors. Note that the H175-B results include the 10log10 mass correction. The helicopter is located at (0;0) point, 150 m above ground. Same color scale is used on both footprints, using 1 dB(A) per contour line.

The overall noise level is clearly diminished on the H160-B main rotor with respect to the H175-B one. The mean A-weighted noise level reduction is of 4.8 dB(A) a value which can be compared with the processed ROSI analysis (5.5 dB(A) main rotor noise reduction). Furthermore, the H160-B simulated noise footprint is also much less directive, also consistently with the ROSI analysis. In particular, a parallel interaction on the advancing blade (towards helicopter front) observed on the H175-B is mitigated on the H160-B thanks to the Blue Edge™ equipped main rotor. Significant noise reductions are also observed on the (Y = 0 m) and (Y = 150 m) lines, respectively corresponding to the center and retreating blade certification microphones.

Presented at 45th European Rotorcraft Forum, Warsaw, Poland, 17-20 September, 2019

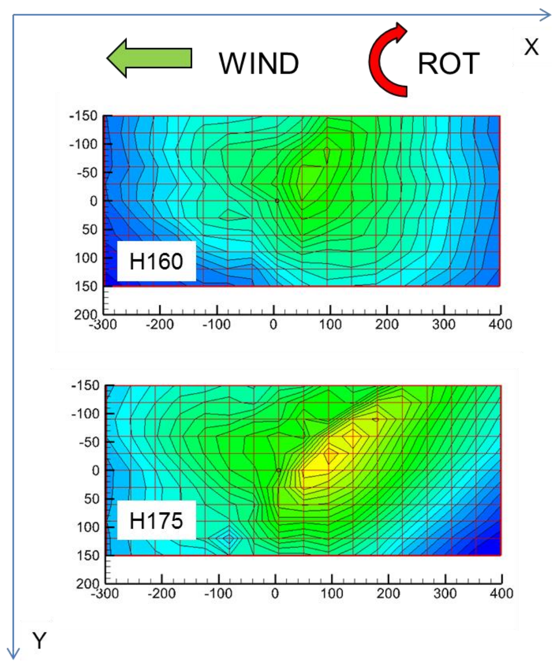

Figure 15: HMMAP simulated noise footprints for H160-B (above) and H175-B (below), 1 dB(A) / contour line.

5. CONCLUSION

Striving for minimal environmental impact, the H160-B is designed for low-noise footprint since its early beginning, despite its multimission purpose. It features numerous innovations leading to reach a breakthrough in terms of external noise, as for example Blue Edge™, canted Fenestron™ design and ambitious RPM law.

These technologies allow the H160-B to be a ‘good citizen’ helicopter with a low-noise footprint, which achieves good margins to certification limits in all flight conditions (take-off, flyover and approach). This results in an ‘A’ Sound Efficiency Rating, well better than the competitors holding comparable masses. In particular, the H160-B holds significantly low noise levels in the approach flight condition. This is attributed to the mitigation of BVI noise thanks to the Blue Edge™ main rotor blade planform.

The ROSI source separation software allows getting an insight about the main rotor contribution to total noise. This software was used on sample H160-B and H175-B results in approach condition. The H160-B main rotor appears less noisy than the H175-B one, holding additionally less directive content. This tendency is confirmed by numerical simulations of the two rotors, which outputs on the overall consistent tendencies with measurement values.

6. REFERENCES

[1] Gareton, V., Gervais, M., Heger, R., “Acoustic Design and Testing of the Eurocopter EC145T2 and EC175B – a harmonized Franco-German Approach”, European Rotorcraft Forum 39th, Moscow, September 2013.

[2] Niesl, G., Arnaud, G., ‘Low Noise Design of the EC135 Helicopter,’ Presented at the 52nd Annual Forum of the AHS, Washington DC, June 1996.

[3] Gervais, M.; and Gareton, V.: “Analysis of Main Rotor Noise Reduction due to Novel Planform Design – The Blue Edge™ Blade”, 37th European Rotorcraft Forum, Gallarate, Italy, Sept. 2011.

[4] Rauch, P.; et all.: “Blue Edge™: the Design, Development and Testing of a new Blade Concept, Experiment”, Proceedings of the American Helicopter Society 67th Annual Forum, Virginia Beach, VA, May 2011.

[5] Allongue, M.; Marze, H. J.; Potdevin, F.: “The Quiet Helicopter « From Research to Reality »”, American Helicopter Society 55th Annual Forum, Montreal, Canada, May 25-27, 1999.

[6] Schneider, S., Heger, R., Konstanzer, P., “Bluecopter™ Demonstrator: the State-of-the-Art in low Noise Design”, 42nd European Rotorcraft Forum, Lille, France, September 2016.

[7] Marze, H.-J., Gervais, M., Martin, P., Dupont, P., “Acoustic Flight Test of the EC130 B4 in the Scope of the FRIENDCOPTER Project”, 33rd European Rotorcraft Forum, Kazan, Russia, September 2007.

[8] Gervais, M., Gareton, V., Dummel, A., Heger, R., “Validation of EC130 and EC135 Environmental Impact Assessment using HELENA”, American Helicopter Society 66th Annual Forum, Phoenix, USA, May 2010.

[9] Guntzer, F., Gareton V., Gervais, M. Rollet, P. “Development and testing of optimized IFR noise abatement procedures on EC155”, American Helicopter Society 70th Forum, Montreal, Canada, May 2014.

[10] Skladanek Y., Hocquette J., Cranga P., “H160 Dynamics Development : Setting New Standards”, American Helicopter Society 75th Forum, Philadelphia, USA, May 2019.

[11] Vialle, M., Arnaud, G.,: “A New Generation of Fenestron Fan-in-Fin Tail Rotor on EC135”, 19th European Rotorcraft Forum, Cernobbio, Italy, 1993.

[12] European Aviation Safety Agency (EASA) database of Type Certificate Data Sheets – Noise, TCDSN Rotorcraft.

[13] Benoit B., Dequin A.-M., Kampa K., Gruenhagen W., Basset P.-M., Gimonet B., "HOST: A General Helicopter Simulation Tool for Germany and France“, 56th American Helicopter Society Annual Forum, Virginia Beach, Virginia, USA, May 2000.

Presented at 45th European Rotorcraft Forum, Warsaw, Poland, 17-20 September, 2019

[14] Beaumier P., Delrieux Y., "Description and validation of the ONERA Computational Method for the Prediction of Blade-Vortex Interaction Noise", Aaerospace Science and Technology Journal, AST Vol.9 issue 1, Elsevier.

[15] Reboul, G., Falissard, F., "On the Use of CFD for improvement of Low-Fidelity Blade-Vortex Interaction Prediction Code", Proceedings of the Vertical Flight Society 75th Annual Forum and Technology Display, Philadelphia, Pennsylvania, May 2019.

ACKNOWLEDGEMENTS

The authors would like to thank the great teams involved in the development and noise certification of the H160-B helicopter.

COPYRIGHT STATEMENT