Acoustic Design and Testing of the Eurocopter EC145T2 and EC175B – a harmonized Franco-German Approach

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The noise certifications of two newly developed Eurocopter helicopters, the EC175B and the EC145T2, are presented in this paper. In the first part, the common German-French certification methodology used for test measurements and certification validation is recalled. In the second part, the characteristics of the EC175B and EC145T2 are detailed with an emphasis on the low-noise design choices. The certification noise levels of the two rotorcrafts are then presented and compared with the helicopter world fleet. Finally for the EC145T2, the low-noise design evolution is presented, starting from early BK117 variants.

1 INTRODUCTION

In the beginning of the mid-1980's, the first noise regulations for helicopters were published in order to face the growing number of public complaints in terms of community annoyance issues. In 2002, the International Civil Aviation Organization (ICAO) imposed more stringent noise limits to incite manufacturers to include on their new helicopters the latest available (and economically viable) low-noise technologies. The Federal Aviation Administration (FAA) has also recently included these more stringent limits in the regulation. The market availability of helicopters incorporating more innovative noise reduction features accelerated the fleet renewal, leading to eventual retirement of a generation of aircraft which did not include any noise considerations in their initial design. Moreover in some situations, low noise design has become a key-buying factor due to local regulations (e.g., Grand Canyon National Park, [1]) or the increased sensitivities of populated areas.

On the manufacturer's side, the low-noise technologies tackling the main sources of helicopter noise appeared thanks the internal research funding investments, often in close collaborations with universities or research centers: the low noise anti-torque system (Fenestron™, [2]), advanced rotor RPM scheduling laws, blade tips incorporating sweep, taper, and thin airfoils (see [3] and [4]), low noise procedure design, and more recently the innovative planform design of main rotor blades named Blue Edge™ (see [5] and [6]).

At Eurocopter, low noise design considerations are integrated in the complete development process: from the feasibility or sizing phase, to the noise certification, and up to operational support to customers. Accordingly, new product developments or upgrades are typically assigned challenging noise specifications.

In recent years, the certification methodology at Eurocopter has evolved into a common Franco-German effort striving to design the helicopters that best meet the acoustic objectives of each project, while reducing the cost of flight test campaigns and efficiently fulfilling the ICAO and FAA noise certification requirements.

In this manner, the EC175B and EC145T2 were designed, tested, and certified using a common methodology. In the following paper, this methodology is introduced, followed by a presentation of the noise characteristics of each rotorcraft. The preliminary certification noise levels of the EC175B and EC145T2 are then discussed and evaluated versus the noise levels of the worldwide helicopter fleet. Finally a dedicated subchapter is focusing on the analysis of the low-noise design of the EC145T2 related to earlier BK117 variants.

2 CERTIFICATION METHODOLOGY

The certification methodology at Eurocopter has been progressively built up thanks to the experience acquired over the past forty years through research and certification noise testing and analysis. This has recently resulted in shared measurement devices, and common analysis and certification tools. The next subsections detail the test means, the post-processing tools and the certification methodology.

2.1 Test Means

The data required to demonstrate compliance to noise regulations through flight testing are of three different types: the acoustic data, the flight mechanics parameters, and the meteorological information. These three types of data are obtained through different measurement means.

The acoustic data are third-octave band spectra measured during each certification run of the helicopter. These spectra are measured using a dedicated noise measurement system called DIAPASON [7]. The DIAPASON system is composed of an autonomous measurement computer with three microphone channels linked to one beacon recording pressure-time signal and simultaneously calculating 1/3-octave band spectra for each channel. The slow-weighted 1/3-octave band spectra are stored and sent every 0.5 seconds to a remote visualization computer for real-time checking. In accordance with ICAO regulations [8], calibration, spectrum corrections with pink noise signal and background noise measurements are executed and saved before and after each measurement sequence. GPS synchronization is used to correctly label the 1/3-octave band spectrum and pressure-time measurement samples.

The sites used for French and German certification tests are different, but the setup methodology remains the same. Figure 1 presents the La Fare-Les-Oliviers airfield used for French testing with the particular "cross arrangement" of the microphone array: this positioning allows being flexible depending on the two predominant wind directions.

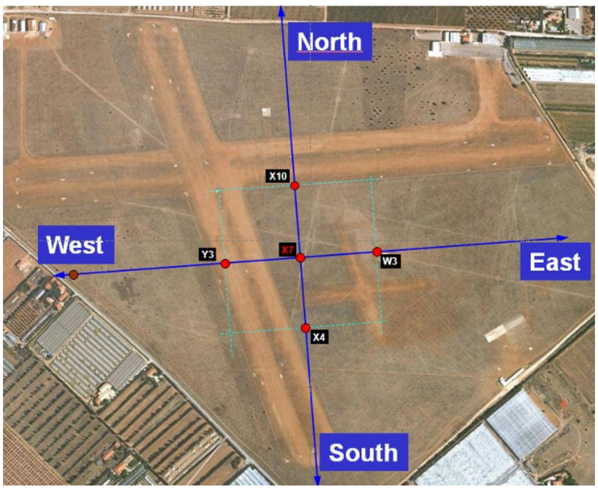

Figure 1: Microphone test set-up during EC175B noise test campaigns.

Low wind conditions allow the preferred East-West flight track to be used. When dominant North-West wind is blowing, the North-South flight track is privileged.

In Figure 2, the respective microphone layout for the dropping area near Manching in Germany is displayed. Due to a very predominant wind direction along the main track, no "cross arrangement" is necessary. Free channels in the measurement system can therefore be used to record additional microphone positions in between and beyond the certification points, for research purposes.

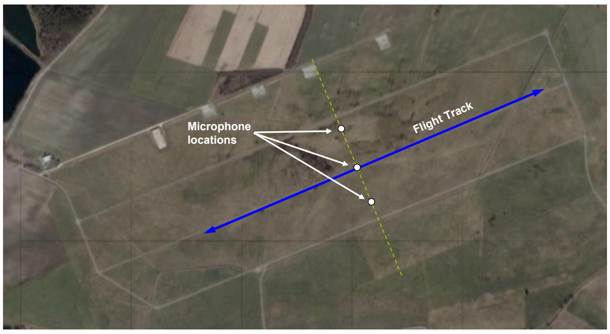

Figure 2: Microphone test set-up during EC145T2 noise test campaigns.

The flight mechanics data are recorded on-board to obtain the useful parameters for certification: position, attitudes, main rotor speed, engine torque, airspeed, rate of climb, etc. The measured data are synchronized with the GPS-time signal. The position of the helicopter is closely monitored after each certification run with a dedicated on-board visualization tool. This device allows the flight test engineer to check whether the trajectory flown is within lateral and horizontal limits imposed by regulations. This on-board verification is a valuable gain of time and allows a preliminary validation of the trajectory during certification runs. The system is also used for trajectory and airspeed guidance during the flight.

Detailed meteorological information is required for regulation purposes: temperature and relative humidity, as well as wind speed and direction. These measurements are obtained using a 10-meter height equipment. Temperature and humidity data guarantee that the noise emitted by the rotorcraft is correctly propagated with limited atmospheric attenuation. The wind measurements ensure that the limitations of 10 kt of total wind and 5 kt of lateral wind are fulfilled. A real-time monitoring of the wind characteristics confirms the validation of the meteorological data after each run.

Flight mechanics, acoustics, and meteorological measurements are synchronized with GPS time. The complex task of processing all available data is completed with two different tools: one is a pure post-processing tool and the other is dedicated to processing data according the certification requirements.

2.2 Post processing and certification analysis

The large amount of data gathered during a noise test justifies the automated processing of data, and Eurocopter developed an internal code for that specific purpose. This code directly processes raw data from different sources (acoustic data, flight mechanics parameters, and meteorology information) and formats data for different purposes: parameter visualization, data formatting, and export to other tools such as certification or noise footprint prediction software. This software allows in addition a first processing of the as-measured 1/3-octave band sound pressure levels by including all measurement corrections to be taken into account for a noise certification: calibration, windshield effect, frequency response of the system, and incidence corrections.

In order to analyze and process results according to noise certification regulations, a second software was developed and validated. This software can apply adjustments to the as-measured 1/3-octave band sound pressure levels due to background noise, sound attenuation, position and speed variations during the certification runs, all in full agreement with ICAO Annex 16, Chapter 8 [8] and the ICAO Environmental Technical Manual [9], as well as FAR Part 36, Appendix H. The software also includes modules for ICAO Chapter 11 and FAR Part 36 Appendix J certification.

3 ACOUSTICS DESIGN FEATURES

In this section the design features of the EC175B and EC145T2 are detailed with a main emphasis on the low-noise characteristics.

3.1 Low noise characteristics of the EC175B

The EC175B helicopter is a twin-engine helicopter with a maximum take-off weight of 7500 kg [10]. Designed from the outset with the close involvement of operators, the 16-18-seat EC175B is suited for a wide range of missions, including offshore, search and rescue, VIP, utility and MEDEVAC operations. It features an advanced avionics suite, including a digital 4-axis autopilot, and provides occupants with the highest standards of safety. As the first Eurocopter aircraft designed to meet the more stringent noise certification limits of ICAO Annex 16, Chapter 8.4.2, the EC175B incorporates design features that strive for the best compromise between environmental constraints and programme objectives. This mainly translates in Eurocopter's most ambitious rotor RPM scheduling law developed for a serial aircraft to date.

The EC175B 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. The three-bladed tail rotor is canted 20°, which slightly modifies the directivity of tail rotor noise.

Figure 3: EC175B during noise flight tests.

As mentioned above, the main noise reduction feature on the EC175B is the rotor RPM law, which is designed specifically to reduce noise levels perceived on the ground. Indeed, this RPM schedule is mainly triggered by the proximity of the aircraft to the ground (and therefore to populations). The RPM schedule is also a function of airspeed, pressure altitude, and outside air temperature. For acoustics, in conditions close to the ground, this automatic RPM schedule reduces the RPM from 102.5% in hover at sea level ISA to a minimum value of 97% above 70 kts. This allows significant noise reduction in most flight conditions susceptible of impacting ground observers. The RPM can reach a maximum of 105% in certain flight conditions (combination of high pressure altitude, low temperature).

3.2 Low noise characteristics of the EC145T2

The EC145T2 is a twin-engine, multi-purpose helicopter with a maximum takeoff weight of 3650 kg. As a major evolution of the successful EC145 / BK117 family the EC145T2 combines breakthrough technologies, including an advanced cockpit design, modern avionics, 4-axis autopilot, more powerful engines and a Fenestron™ anti-torque concept [11].

Figure 4: EC145T2 during noise test campaign.

The ambitious design challenge in the EC145T2 development was to considerably improve helicopter performance and increase takeoff weight while maintaining the excellent sound characteristics of the EC145. The resulting acoustic design – based on the large experience gained during the development of EC135 and EC145 as well as from various acoustic research projects – comprises all advanced low noise features of the EUROCOPTER fleet introduced in one helicopter:

- Advanced main rotor design
- Variable rotor rotational speed
- Very good climb performance
- Low noise Fenestron™ design

3.2.1 Main rotor and rotational speed law

The EC145T2 thus features the highly successful EC145 main rotor design and its low noise rotational speed law with only minor adaptations. Both features are described in detail in the respective previous publications [4], [12], [13]. The basic philosophy in the rotational speed variation is an increase of main rotor tip speed only in flight conditions where it is really required while keeping it at low values in the noise relevant flight regime. This automatic control law allows the parallel realization of otherwise contradictory requirements from performance, flight mechanics and acoustics.

3.2.2 Fenestron™

The major novelty in the EC145T2 in comparison to the EC145 is obviously the new anti-torque system, namely a low noise Fenestron™ replacing the formerly used classical tail rotor. The decision to integrate a Fenestron™ into a helicopter is driven by many aspects – including above all increased safety and efficiency – that cannot be treated within the scope of this paper. A detailed description of typical Fenestron™ design parameters is extensively given in [2] and [14]. The following section is thus not dedicated to in-depth Fenestron™ design but focuses rather on the acoustic effects detected in latest flight test data.

Figure 5: EC145T2 Fenestron**™** design.

The Fenestron™ design of the EC145T2 is derived from the EC135 with careful adaptation of blade loading and tip speed to achieve low noise emission and yet to reliably provide high thrust characteristics in specifically demanding areas of the flight envelope.

The design blade tip speed of the Fenestron™ was kept at the same level as for the EC135 while blade radius and mean chord were increased by 15% or 13% respectively.

Table 1: Comparison of anti-torque concepts

Helicopter	EC145	EC135	EC145T2
Concept	Classical TR	Fenestron	Fenestron
Diameter [m]	1.956	1	1.15
Number of blades	2	10	10
Mean Chord [mm]	220	50	63
Nominal RPM	2169	3584	3144

In terms of acoustic design the Fenestron™ offers three particularly advantageous characteristics in comparison to a classical tail rotor:

- Fenestron™ blades are running inside a duct which provides an acoustic shielding effect and thus reduces the sound energy emitted to the ground. Furthermore the blade tips are better protected from interaction with the main rotor vortices and transonic effects due to high Mach number regions in high speed flight.

- The aerodynamic layout of the duct geometry provides additional thrust and thus makes the Fenestron™ more efficient which is especially beneficial in high thrust states such as takeoff.

- Unequal blade spacing is easily realized in modern Fenestron™ design. The acoustic energy is thus not concentrated at the blade passing frequency (BPF) but rather distributed over a wide range of side bands. The resulting sound spectrum is much less annoying than a classical tail rotor spectrum with high peaks at the BPF and its multiples.

4 CERTIFICATION RESULTS

The present chapter describes the noise certification flight tests according to ICAO Annex 16 Chapter 8 that were both performed in mid-2012 for the EC175B and EC145T2. Both test campaigns were conducted with the same acoustic instrumentation and equivalent test means for the measurement of meteorological and helicopter parameters by a highly integrated bi-national team.

Note that at the time of publication of this paper, the noise levels shown below are still preliminary and may not represent the exact final values to be officially certified.

4.1 EC175B Noise Certification

The EC175B acoustic tests took place over the airfield at "La-Fare-Les-Oliviers" on September 25 and 27, 2012. The test was witnessed by a representative from the certificating authority.

The EC175B ICAO certification noise levels are shown in Table 2. The EC175B is the first Eurocopter rotorcraft to be certified according to ICAO Annex 16 Chapter 8.4.2 limits. As mentioned above, since 2002, ICAO imposes more severe noise limits to newly-developed rotorcraft. The different noise limits were reduced by 3 EPNdB in take-off, 1 EPNdB in approach, and 4 EPNdB in overflight with respect to ICAO 8.4.1 limits. On Figure 6 to Figure 8, these noise limits (which are a logarithmic function of the maximum take-off weight of the rotorcraft) are illustrated by black dashed lines for the pre-2002 ICAO Annex 16 Chapter 8.4.1 limits and by a solid grey line for the updated Chapter 8.4.2 limits.

Table 2: ICAO noise levels for EC175B helicopter

<table>
<tr><th colspan="2">EC175B @ 7500 kg</th><th>Left Mic.</th><th>Center Mic.</th><th>Right Mic.</th><th>Mean Value</th></tr>
<tr><td rowspan="3">Take-Off</td><td>EPNL</td><td>88.6</td><td>90.4</td><td>90.4</td><td>89.8</td></tr>
<tr><td>ICAO 8.4.1 limit</td><td></td><td></td><td></td><td>98.8</td></tr>
<tr><td>Margin</td><td></td><td></td><td></td><td>9.0</td></tr>
<tr><td rowspan="3">Flyover</td><td>EPNL</td><td>91.1</td><td>91.4</td><td>90.6</td><td>91.0</td></tr>
<tr><td>ICAO 8.4.1 limit</td><td></td><td></td><td></td><td>97.8</td></tr>
<tr><td>Margin</td><td></td><td></td><td></td><td>6.8</td></tr>
<tr><td rowspan="3">Approach</td><td>EPNL</td><td>95.0</td><td>98.0</td><td>92.3</td><td>95.1</td></tr>
<tr><td>ICAO 8.4.1 limit</td><td></td><td></td><td></td><td>99.8</td></tr>
<tr><td>Margin</td><td></td><td></td><td></td><td>4.7</td></tr>
<tr><td colspan="5">Total Margin wrt to ICAO 8.4.1 limits</td><td>20.5</td></tr>
</table>

Though certified relative to the more stringent limits of ICAO 8.4.2, the EC175B margins shown in Table 2 are displayed with respect to 8.4.1 in order to compare the results with the rest of the helicopter worldwide fleet.

4.2 EC145T2 Noise Certification

The EC145T2 acoustic tests were conducted over the military dropping area near Manching, Germany on June 27, 2012.

As for the EC175B, the test was witnessed by a representative from the authorities. The preliminary EC145T2 noise certification levels are summarized in Table 3. Since the EC145T2 is derived from the BK117, the ICAO 8.4.1 limits are applicable. The resulting margins towards these limits are respectively for Takeoff, Flyover and Approach: 9.1, 9.9 and 6.3 EPNdB. As displayed in Figure 6 to Figure 8, the EC145T2 is showing best-in-fleet noise levels for each individual certification flight condition.

Due to its exceptionally low certification noise limits in flyover, the EC145T2 with 10 passenger seats fulfills the US Grand Canyon National Park noise limit [1], with a margin of 2.3 EPNdB. It can therefore be designated a Quiet Technology Aircraft.

Table 3: ICAO noise levels for EC145T2 helicopter

EC145T2 @ 3650 kg		Left Mic.	Center Mic.	Right Mic.	Mean Value
Take-Off	EPNL	86.1	87.3	86.2	86.5
	ICAO 8.4.1 limit				95.6
	Margin				9.1
Flyover	EPNL	84.5	84.5	85.1	84.7
	ICAO 8.4.1 limit				94.6
	Margin				9.9
Approach	EPNL	88.6	93.6	88.8	90.3
	ICAO 8.4.1 limit				96.6
	Margin				6.3
Total Margin wrt to ICAO 8.4.1 limits					25.4

4.3 Worldwide Fleet Noise Certification Levels

Figure 6 to Figure 8 present the Effective Perceived Noise Levels (in EPNdB) as a function of the maximum take-off weight for the different certification flight phases: take-off (Figure 6), approach (Figure 7), and overflight (Figure 8). Aside from the EC145T2 and EC175B, which are not yet officially certified at the time of writing this paper, all data is extracted from the EASA Type Certificate Data Sheet for Noise (TCDSN) database [15].

The EC175B is the current best-in class in terms of noise levels in the take-off phase. The EC175B benefits from a noticeable best-rate-of-climb in the take-off phase which allows substantial noise reductions on the ground compared to the direct competitors in the same range of weight.

Although the EC175B's targeted missions do not call for extremely ambitious acoustic targets, the strong project specifications resulted in the aircraft being very well positioned, especially in the approach and flyover phases. These results highlight the strong role played by the advanced RPM law in the noise reduction close to ground, and will directly be reflected in reduced nuisance in populated areas. As pointed out in [16], the good certification noise results due to RPM reduction are beneficial within a large part of the flight envelope. In other words, the noise reductions obtained for particular certification phases are also valid for other flight speeds, and descent or climb angles.

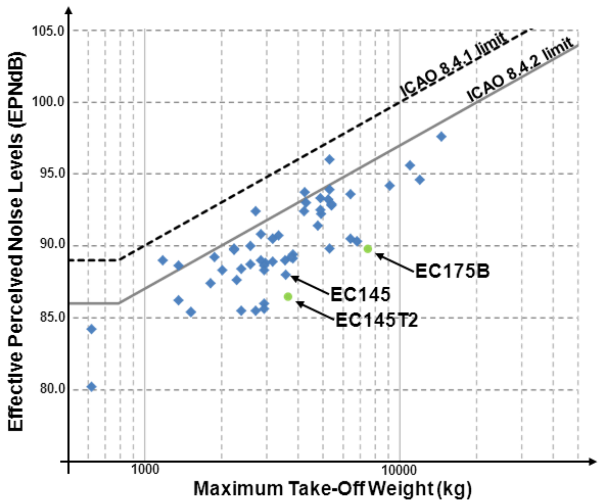

Figure 6 : Noise certification take-off levels versus maximum take-off weight compared for ICAO Annex 16, Chapter 8 helicopters.

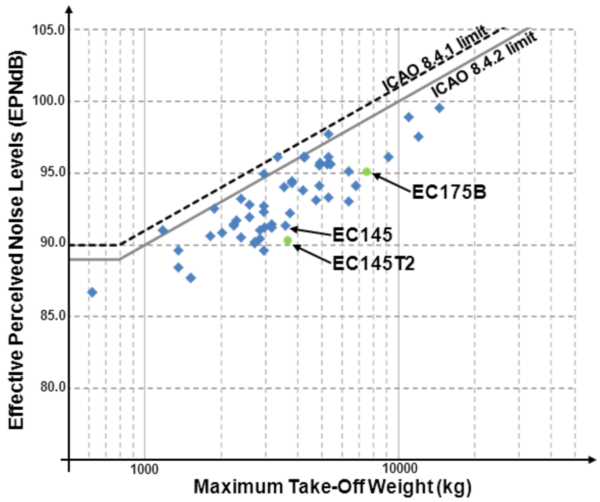

Figure 7 : Noise certification approach levels versus maximum take-off weight compared for ICAO Annex 16, Chapter 8 helicopters.

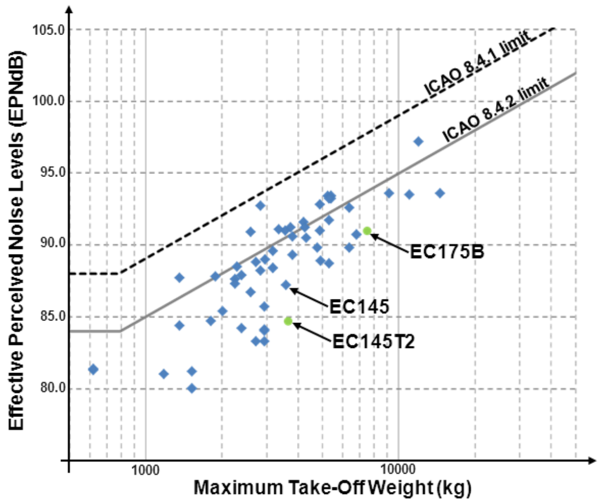

Figure 8 : Noise certification overflight levels versus maximum take-off weight compared for ICAO Annex 16, Chapter 8 helicopters.

4.4 Sound Efficiency Rating

As part of its efforts to advance the environmental agenda, Eurocopter introduced its concept for environmental performance indicators related to sound levels and CO2 emissions at Heli-Expo 2010. Regarding noise, Eurocopter proposed that certification data be used to derive values which could be expressed on a color scale from A+ to D. This type of presentation is already widely used for efficiency ratings in other industries, and it provides a simpler presentation of certification noise levels that could foster transparent environmental communication.

Other helicopter manufacturers – along with engine manufacturers and research institutes – followed Eurocopter's initiative, resulting in the creation of an ad hoc Environmental Committee that was formed under the governance of the American Helicopter Society. Specialists from this committee worked on refining the technical details of Eurocopter's rating proposal. The committee's efforts resulted in proposals for slight modifications to the initially proposed environmental performance indicators, and although the committee was terminated before its final recommendations were made public, Eurocopter integrated these recommendations in its definitions of the Sound Efficiency Rating.

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. This is outside the scope of this paper, as only Chapter 8 aircraft are presented herein. The following figure shows the cumulative margins of Chapter 8 helicopter with respect to ICAO Annex 16, Chapter 8.4.1, as a function of maximum takeoff weight. Overlaid on the graph is the color scale defining the values of the Sound Efficiency Rating. On this scale, a value below 'D' (no margin) corresponds to an aircraft that could not meet Chapter 8.4.1 noise regulations. An aircraft below 'C' could not meet Chapter 8.4.2 noise limits.

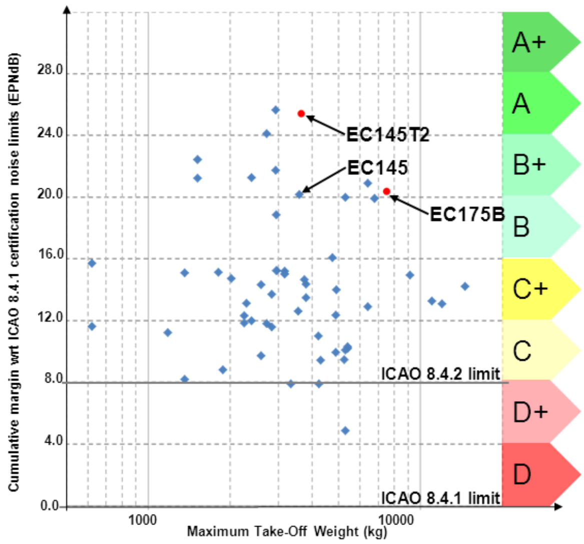

Figure 9 : Sound Efficiency Rating as a function of maximum take-off weight.

A few observations can be derived from Figure 9. Firstly, the scale is quite challenging, as no aircraft are in the 'A+' category, and very few are in 'A'. Indeed, most of the current fleet is in the 'C' and 'C+' categories. Secondly, it can be seen that globally the margins decrease as a function of the maximum takeoff weight. This is also evidenced in Figure 6 through Figure 8.

As Figure 9 shows, the EC145T2 is one of the best helicopters of the worldwide fleet in terms of noise certification levels, while the EC175B is also among the best aircraft of its category. This highlights that significant progress can be made when helicopter development or upgrade programs include strong noise reduction objectives from the start. As stated in reference [16], these noise reductions were achieved by applying the best available noise reduction technologies, and slight improvements are probably possible using these available means. Further improvements will require the development of more advanced technologies, and possibly a technological 'leap' in terms of design for low-noise.

5 ACOUSTIC DESIGN EVOLUTION OF THE EC145T2 STARTING FROM THE BK117

The EC145T2 acoustic design clearly represents the peak achievement of a continuous improvement process beginning with its early predecessor – the BK117. In comparison with for example a BK117-B2 all noise relevant parts of the helicopter (namely main rotor, tail rotor and engines) have been replaced in the meantime by innovative new designs with increased performance characteristics. Despite a continuous increase of maximum takeoff weight the certification noise levels were significantly reduced with each new helicopter type.

5.1 Evolution of Noise Certification Margins

The individual steps in the design evolution between the BK117 variants and derivatives are clearly mirrored in the respective certification noise levels. In order to provide an overview independent from the varying maximum takeoff weight, Figure 10 displays the growing margin of the different helicopter noise certification levels with respect to the weight-dependent ICAO 8.4.1 / FAA stage 2 noise limits.

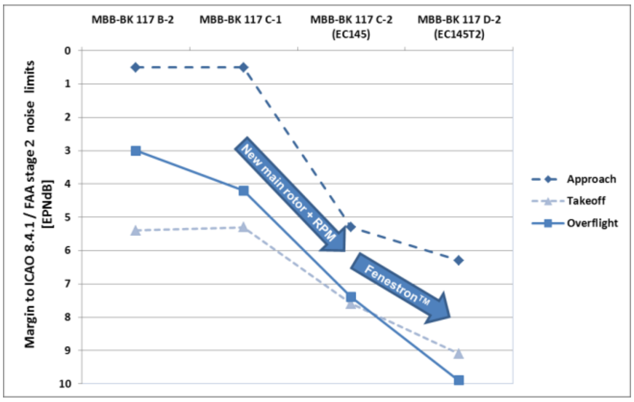

Figure 10: Evolution of noise levels vs. certification limits from BK117B2 to EC145T2

Looking at the evolution of noise levels in Figure 10, the significant impact of introducing low-noise technologies becomes evident (for example replacing the rectangular-shaped main rotor blades of the BK117 C-1 with the advanced technology rotor of the EC145, in combination with the innovative rotational speed law mentioned above). Using the EC145 as a baseline, the margin to certification noise limits was even further increased for the EC145T2 by installing the Fenestron™ anti-torque concept instead of a classical tail rotor. This leads to an additional margin with respect to certification limits of 1.0, 1.5 and even 2.5 EPNdB in approach, takeoff and overflight condition.

5.2 Comparison of EC145 and EC145T2

In order to study the benefits in more detail, a comparison between the EC145T2 and EC145 for each certification flight condition and microphone is displayed in Figure 11. The EC145 levels were logarithmically scaled to a weight of 3650 kg to allow a more meaningful comparison.

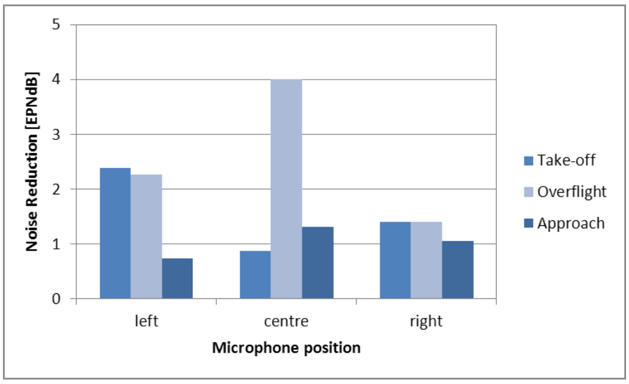

Figure 11: Noise certification level reduction of the EC145T2 versus the EC145

The graph clearly shows that the introduction of the Fenestron^{TM} is beneficial not only in all relevant flight conditions but also for all three microphone locations. This is especially interesting since requirements and operational environment for the Fenestron^{TM} differ considerably between the investigated flight conditions.

5.2.1 Approach

The noise certification approach condition is defined such that helicopters are operating in an inherently noisy flight state with the main rotor blades hitting the tip vortices of preceding blades. This phenomenon – the so called blade vortex interaction (BVI) – leads to significantly high impulsive noise peaks that typically dominate the noise perceived on the ground. The anti-torque requirement is relatively low. So naturally the main rotor is clearly predominant in the approach phase. The helicopter has to fly the approach with its best rate of climb airspeed, V_Y. In this case the EC145T2 takes advantage of a V_Y 5 kt higher in comparison to the EC145. This means in terms of noise impact on the ground that the time needed to pass by an observer is slightly reduced. In terms of effective perceived noise level, this effect can be approximated as 0.3 EPNdB. The introduction of the Fenestron^{TM} as well as possibly positive effects of the higher airspeed on the very sensitive vortex system around the main rotor add up to reduce the noise impact on the ground at all microphone locations by 1 EPNdB.

5.2.2 Takeoff

In the certification takeoff case the EC145T2 is flying at its maximum takeoff power rating. The abovementioned effect of the 5 kt increase on V_Y is applying here as well, leading to a 0.3 EPNdB reduction on all microphones. In takeoff the anti-torque system is normally required to provide a considerable amount of thrust since the contribution of the fin at 70 kt is rather low. The noise reduction characteristic in Figure 11 shows that in comparison with a classical tail rotor, especially the lateral noise levels are reduced. The higher aerodynamic efficiency of the Fenestron^{TM} and its unique frequency and directivity characteristics are considered the major effects leading to up to 2 EPNdB lower noise levels in this flight state.

5.2.3 Flyover

In level flight at 90% maximum level flight speed (which is the same for both helicopters) the anti-torque is mostly provided by the vertical stabilizer. For the EC145 the tail rotor blade tip speed of nominally 222 m/s and the airspeed of the helicopter are adding up to produce high Mach numbers at the advancing tail rotor blade tip. The resulting noise is emitted largely in-plane of the tail rotor, which means towards the ground. The Fenestron^{TM} blades of the EC145T2 on the contrary are operating at a considerably lower design tip speed of only 188 m/s in a duct, so that the airspeed of the helicopter is not added to the blade tip speed. Furthermore the acoustic shielding effect of the duct avoids a direct propagation to the ground. The effect is a strong reduction of 4 EPNdB in the global noise levels at the center microphone and 2.3 EPNdB on the retreating side of the main rotor blade. Even on the advancing side a reduction of 1.4 EPNdB is obtained. This finding is fully in line with previous flight test experience gathered during EC135 development in comparison to the BO108 which was equipped with a classical tail rotor [14].

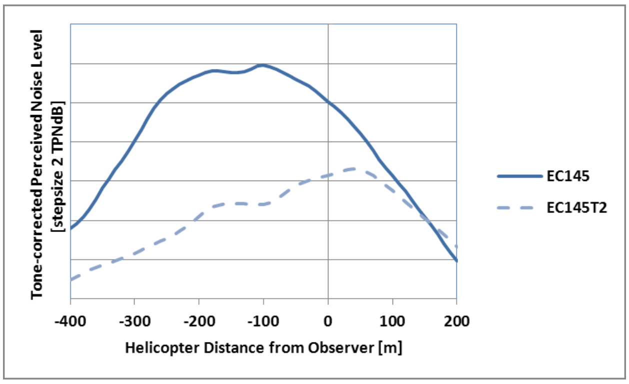

Figure 12: Perceived noise level versus helicopter distance at the center microphone position for a certification overflight 150 m above ground

In Figure 12 the perceived noise level for flyover (averaged over all valid certification runs) is displayed versus helicopter distance from the microphone. The graph reveals the massive effect of replacing the classical tail rotor with the silent Fenestron^{TM} design. Whereas a classical tail rotor is radiating considerable sound energy in its rotational plane particularly towards the front of the helicopter, the Fenestron^{TM} noise levels are so low, that they are actually not appearing in the global helicopter spectrum. The remaining signal of the EC145T2 is thus dominated by main rotor harmonic and broadband noise. This observation is strongly supported by recent studies on the noise contribution of main rotor and classical tail rotor [17]. In particular, the characteristic shape presented in the article for a PNLT time history of an isolated main rotor including broadband noise is very similar to the overall characteristic of the EC145T2.

The benefit of up to 4 EPNdB of the EC145T2 with respect to the EC145 in flyover and the very characteristic shape of its perceived noise level time history in Figure 12 basically mean that an EC145 flying at 350 m distance towards an observer on the ground has the same noise impact as an EC145T2 already passing directly overhead. This fact illustrates the impressive noise reduction achieved by the EC145T2 design. The fact that the Fenestron™ is hard to recognize in the overall spectrum is certainly not only relevant for civil consideration but also contributes to safety in military applications due to a decreased radius of aural detectability [18].

5.2.4 Hover

Aside from the purely certification relevant flight conditions, measurements were also conducted in hover 100 ft above ground to assess the acoustic behavior during this very common flight phase.

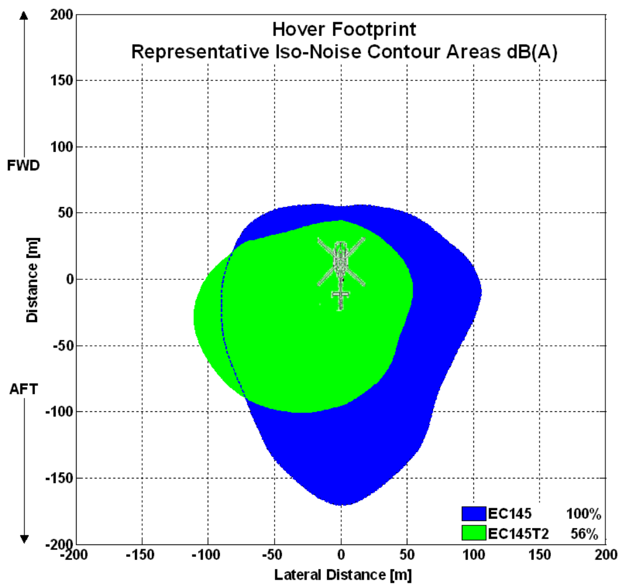

Figure 13: Comparison of hover noise contour area between EC145 and EC145T2

The difference between the EC145T2 and EC145 for a representative iso-noise contour area of A-weighted noise levels is presented in Figure 13. The plot displays very clearly the completely different characteristic of the Fenestron™ noise radiation in comparison to a classical tail rotor. Whereas the noise footprint of the EC145 with classical tail rotor is rather symmetric and extending mainly towards the rear, the footprint shape of the Fenestron™-equipped EC145T2 is extending slightly further on the blowing side of the Fenestron™ but is significantly smaller in all other directions. The resulting iso-noise contour area is considerably reduced to 56%.

In other words, the area on the ground impacted by a certain noise level is now almost divided by two for this type of operation. This result is a major benefit in terms of environmental assessment for new and existing heliports and the associated land use planning considerations.

6 CONCLUSION AND OUTLOOK

The Franco-German collaboration in acoustic design and testing has led to substantial achievements that are demonstrated by the highly competitive noise certification levels of the EC175B and particularly the EC145T2. The experience gained during these latest test campaigns shows that:

- The common noise certification test procedure applied in France and Germany ensures a very efficient use of resources.
- The on-board visualization and validation of key parameters during the certification tests provides excellent trajectory guidance and a high level of repeatability.
- The fully automated analysis chain significantly speeds up the noise certification report generation and eliminates any kind of manually induced errors during data analysis. The French-German process and documentation harmonization also improves document traceability and validation work.
- A newly standardized acoustic data format provides easy usage of noise certification data in generating noise footprints, feeding semi-empirical prediction codes or simply in

comparing acoustic measurement data from different helicopters and/or test campaigns.

- The EC175B noise levels are among the best in its category. The advanced automatic RPM schedule is the main contributor to EC175B's low noise levels.

- The EC145T2 is one of the most silent helicopters in the worldwide fleet, fulfilling even the very stringent operational noise limit for Grand Canyon National Park. The main reason for the drastic reduction in certification noise levels compared to the EC145 (which is already one of the quietest aircraft in its class) is the replacement of the tail rotor by a Fenestron™.

- The aural detectability radius of the EC145T2 Fenestron™ is significantly reduced compared to classical tail rotors.

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