Acoustics'08 Paris
June 29-July 4, 2008
www.acoustics08-paris.org

Comparative helicopter noise analysis in static and in-flight conditions

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Abstract: Rotary wing aircraft, i.e. helicopter, is a source of intense noise, external and internal alike, in conclusion becoming serious environmental and health issue. The generated noise is in some aspects similar to propeller noise in fixed wing aircraft (airplane), while differing in main noise source alignment in respect to the relative airflow: in helicopters, both rotors, i.e. main and tail, that produce forces necessary for flight, are inline with the direction of flight, while in airplanes rotor(s) are perpendicular to it. Another distinctive noise in helicopters, well known as "slapping", comes from the rotor cutting its own wake/vortex air inflow, especially while descending. In this article main helicopter noise sources will be discussed and most significant results of various static and in-flight noise measurements on two different types of helicopters will be presented and analyzed.

1 Introduction

Rotary wing aircraft is a source of intense noise, external and internal alike, in conclusion becoming serious environmental and health issue. The generated noise is in some aspects similar to propeller noise in fixed wing aircraft (airplane), while differing in main noise source alignment in respect to the relative airflow: in helicopters, both rotors, i.e. main and tail, that produce forces necessary for flight, are inline with the direction of flight, while in airplanes rotor(s) are perpendicular to it. Another distinctive noise in helicopters, well known as "slapping", comes from the rotor cutting its own wake/vortex air inflow, especially while descending. In this article main helicopter noise sources will be discussed and most significant results of various static and in-flight noise measurements on two different types of helicopters will be presented and analyzed.

2 Helicopter noise etiology

Noise abatement procedures are the result of the principle of generating certain noise on helicopters depending on their characteristics and flight regimes. For instance, if the noise is recorded from the position which is immediately above the rotation axis of the electrically propelled rotor, only a dull sound of air "hissing" is heard from the rotor blades moving through the air. This noise is primarily generated by air molecules which accelerate in the boundary layer of air flowing around rotor blades, and then are discarded in irregular and chaotic motion over the trailing edge of the blade aerofoil **[1]**.

As the blade incidence angle increases, including lift, air vortices occur at their tips and they can change the characteristics of noise into a somewhat rougher sound. A part of this change is caused by the impacts of oncoming air volume which is created when the helicopter is hovering. The sound generated by the turbulent air and the sound generated by air vortices do not have the same frequency, and therefore such noise is called wide spectrum noise or "white" noise, similar to the white light that contains all the frequencies or colors of the spectrum. If the noise is recorded from the position which is in close vicinity to the rotor, the recorded sound will have different characteristics and noise generated by rotation will appear, containing every blade passage, i.e. higher harmonics and frequencies. The greater the number of rotor rotations and blade number, the higher the frequency of the passing blade. Since human ear is more sensitive to higher than to lower frequencies, it may happen that a small diameter tail rotor with four blades that rotate opposite to the main rotor, relatively quickly creates greater noise than the slower rotating main rotor with two blades, although lower air volume passes through the tail rotor. In helicopters in forward level flight, apart from the already mentioned noise generated by the rotation of the main rotor, another distinctive type of noise can be recorded, which is called "blade slap" or "impulsive noise" **[1]**. It can occur as consequence of two cases. In one case the tip of the advancing blade (blade which moves in the direction of the helicopter flight) moves at such a speed that it compresses the air in front to a great extent and very fast. This causes shock waves that are projected as large changes in pressure in front of the blade tip. At a small distance, the "crisp" sound of these impulses can be very discomforting. At a relatively large number of main rotor rotations, this noise turns into a series of "dull" impacts that can then be heard over great distances and is called High-Speed Impulsive Noise - HSI. Another case or type of impulsive noise is caused by interaction between the vortices when the blade enters the air vortex which is generated by the passage or the previous blade and it is called Blade Vortex Interaction - BVI. In the majority of helicopter flight regimes the tip vortices and blades do not come into contact, but in some maneuvers, such as slight rate of descent or entering the turn, there is still interaction. The airflow around the vortex creates sudden changes of the angle of attack and the speed of air flowing around the blade, which causes local stall and the possibility of shock waves generation. Here, the air pressure change rate comes to the fore, which consequently generates this type of noise which generally spreads in front and below the flight path, and to the untrained ear may sound like the noise generated by high speed of blade movement. All these types of noise result in "acoustic footprint" which is left by the helicopter on ground which includes areas of different noise intensities. This "footprint" is important for military helicopters in terms of identification distance, and in civil operations it has influence in determining and measuring the permitted noise intensity. For the designers who wish to reduce the external noise generated by helicopters, the optimum method is the selection of relatively low rotation speed of blade tips for the main and tail rotor **[2]**. This will reduce the noise generated by the rotor and minimize the noise caused by compressing air at high speeds, especially if blades have thin and/or curved tips. However, reduction in the speed of blade tips requires adequate increase of the blade area, and therefore also a heavier rotor, in order to achieve the same performances **[3]**. Because of the smaller number of rotations and higher torque, the weight of gear box and the size of the shaft increase. Thus, the final product of the design is always a compromise between high performances and low noise levels which best satisfy all the conditions for which the helicopter is intended. During tests which are meant to change the characteristics of the vortices generated by the blade tips, rotor blades are specially designed and shaped so that airflow is injected through them in order to either enlarge the vortex rings and make them less intensive **[1]**. That way vortices from the previous blade would not have influence on the next advancing blade. In this research certain positive results have been achieved, but they still do not have positive influence in the rotor production design.

3 The experiment

3.1 The objects of investigation

Two rotary wing aircraft were subjected to thorough external noise measurements:

1) Robinson R44 Clipper, single piston engine powered helicopter, 205 HP, (153 kW), 113 kn max speed (Fig. 1), and
2) Bell 206B, single turbine engine powered helicopter, 420 SHP (313 kW), 122 kn max speed (Fig. 2).

Fig. 1 Robinson R44 helicopter

Fig. 2 Bell 206B helicopter

3.2 Measurement layout

A-weighted and octave-band noise measurements were conducted in free-field conditions on a partially cloudy, light-wind day with no significant background noise, by means of B&K 2230 Sound Level Meter with octave filters at approximately 3 meters away from the aircraft. Three typical power settings/flight regimes with no progressive speed were used as the most convenient for the experiment: idle, full correction and take-off power (hovering).

3.3 The results

The collected data are presented in the following graphs: Fig. 3 shows external octave-band noise measurement results in the idle power setting, while Fig. 4 and Fig. 5 show the results under full correction and take-off settings respectively.

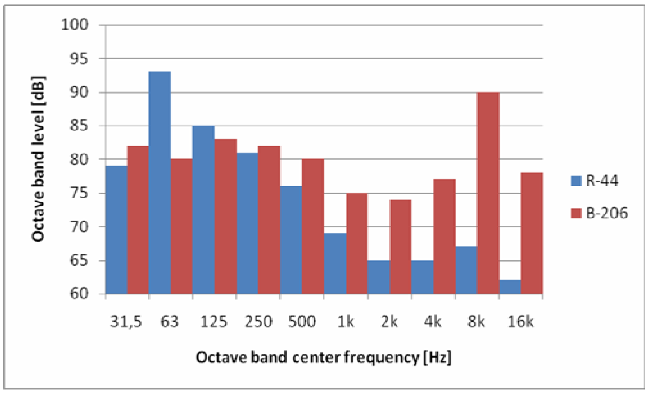

Fig. 3 Octave-band noise in idle power settings

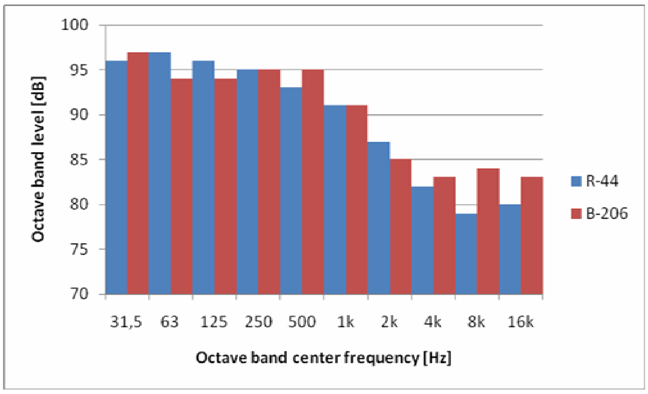

Fig. 4 Octave-band noise in full correction power settings

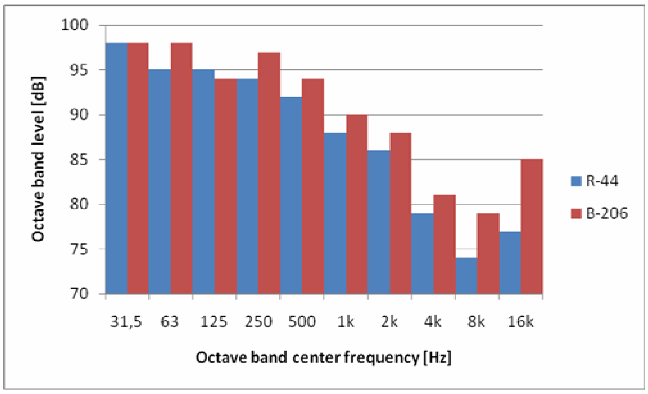

Fig. 5 Octave-band noise in take-off (hover) power settings

Fig. 6 depicts A-weighted spatial noise image taken around the aircraft under idle power settings. The 0-180 line follows the main longitudinal aircraft axis, while 90-270 line represents the main lateral axis.

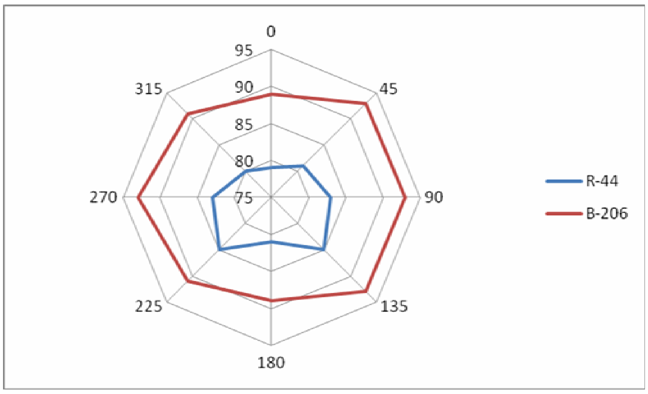

Fig. 6 A-weighted spatial noise image

4 Conclusion

Two different types of rotary wing aircraft by means of powerplant section were subjected to external noise investigation: piston and turbine powered. Both helicopters are the sources of intense and almost omnidirectional community noise, value of each exceeding 75 dBA @ 3m distance from the main rotor center. A-weighted values are especially pronounced in B-206 case, balancing around recommended daily dosage (8-hour noise exposure by OSHA), which is of utmost importance for ground staff (aircraft mechanics and airport personnel) as they are widely susceptible to noise-related disorders..

The graphs also reveal the main noise spectrum differences between powerplants. While in piston powered engine first five octaves of audio spectrum obviously dominate over the higher spectrum components by more than 15 dB due to combustion process in the cylinders, turbine powered engine, mostly due to the strong contribution of broadband compressor/turbine/core noise, has the spectrum somewhat flattened, with distinctively pronounced higher octaves ("hissing" sound). More detailed spectrum investigation to isolate particular harmonics and differentiate powerplant from propeller/rotor noise is planned to continue.

Acknowledgments

This study is a part of the project No. 135-1352339-2349 supported by the Ministry of Science, Education and Sports of the Republic of Croatia.

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