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HELICOPTER NOISE AND NOISE ABATEMENT PROCEDURES

ABSTRACT

The helicopter generated noise at and around the airports is lower than the noise generated by aeroplanes, since their number of operations, i. e. the number of takeoffs and landings is much lower than the takeoffs and landings of the aeroplanes. Out of some hundred operations a day, helicopters participate with approximately 15%, but the very impact of noise is by no means negligible, since the number of helicopter flights above urban areas is constantly increasing.

This paper attempts to analyse this phenomenon and the type of helicopter generated noise, its negative impacts, to explain the flight procedures and the operative procedures during takeoff, landing and overflight of helicopters in operations in the vicinity and outside airports, as well as the methods of measuring and determining the limit of noise level, and the resulting problems.

KEY WORDS

noise sources, helicopters, noise abatement procedures

1. HELICOPTER NOISE SOURCES

Sound propagates through the air in the form of waves with their maxima and minima. Pressure variations between the maxima and the minima cause vibrations of the ear-drum and thus people hear the sound, and the number of these variations, i. e. waves per second represents the sound frequency. In studying the sound, calibrated microphones and special recording equipment are used, in order to measure at a certain point the variations in the air pressure caused by oscillating sound waves. The measuring unit for these pressure variations is the decibel or dB. Normal speech has a value of approximately 70 dB, whereas 140 dB is a value which causes physical pain. The loudness value scale is logarithmic, which means that for every 10 dB the loudness is doubled, so that the value of 140 dB is 130 times greater than the value of normal speech. It is precisely because of this specific characteristic of ear to recognise better the higher rather than the lower frequencies, that the techniques of compensation corrections of sound recording have been developed. Thus, the values obtained from the low frequency source are reduced, whereas those generated by the high frequency source are increased.

1.1. Rotor noise in hovering

In finding the solution for aircraft noise reduction, the aircraft designers play the most important role, but the pilots also have several possibilities available to reduce the noise. In order to be able to control the noise, first the source of the noise itself has to be understood. Not only are there several different noise sources in helicopters, but what the human ear hears depends on the place where the person is positioned.

For instance, if the noise is recorded from the position which is immediately above the rotation axis of the electrically propelled rotor, only uniform sound of air "hissing" as the rotor blades move through the air will be heard. This noise is primarily generated by the air molecules which accelerate in the border layer of airflow streaming around the rotor blades, and subsequently move in irregular and chaotic motion over the trailing edge off the blade airfoil. As the blade angle of attack increases, thus also increasing the lift, on their tips appear the airflow vortices which can change the sound characteristics into a somewhat "rougher" sound. Part of this change is caused by the impacts of the oncoming volume of air which is created when the helicopter is flying. The sound generated by the turbulent air and the sound generated by the airflow vortices have different frequencies. Therefore, such noise is called the wide spectrum noise or "white" noise according to the white light that contains all the frequencies or colours of the spectrum.

If the noise is now recorded at the position in close vicinity to the rotor, the recorded sound will have different characteristics. Here the noise will also appear which is caused by the rotation, hearing every passing of the blade, i. e. higher harmonics of this frequency.

The greater the number of rotor revolutions and the number of blades, the higher the frequency of the passing blade. Since the human ear is more sensitive to higher than to lower frequencies, it may happen that the low-diameter tail rotor with four blades rotating in the opposite direction from the main rotor, creates relatively fast greater noise than the slower rotating main rotor with two blades, although lower volume of air passes through the tail rotor.

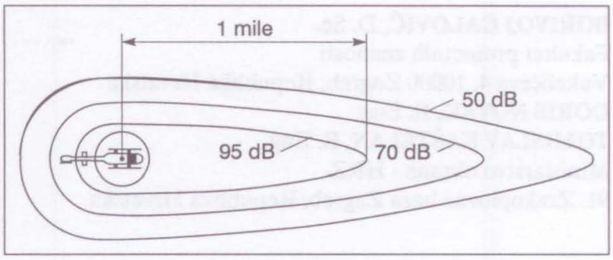

Figure 1

1.2. Helicopter noise in level flight

In case of helicopters in progressive flight, along with the already mentioned noise generated by the rotation of the main rotor, it is possible to record another characteristic type of noise which is called "blade slap" or "pulse blade noise of the main rotor". It can occur as the consequence of two cases. In one case the tip of the advancing blade (blade rotating in the direction of the flight) moves at such a speed that it significantly and very fast compresses the air in front of it. This causes impact waves which are projected as great changes in pressure in front of the blade tip. At a short distance the sound of "cracking" of these pulses can be very uncomfortable. At a relatively great number of main rotor revolutions, this noise is converted into a series of "dull" impacts which can then be heard at great distances (*HSI – High-Speed Impulsive Noise*). Another case or type of pulse noise results from the interaction between the vortex air-stream when the blades enter the vortex air flow which is created by the passing of the previous blade (*BVI – Blade-Vortex Interaction*). In the majority of helicopter flight regimes the vortex air flows and the blades do not come into contact, but in some manoeuvres, such as slight descent or entering the turn, the interaction occurs after all. The air flow around the vortex results in sudden changes of the angle of attack and the speed of air flowing around the blades, causing local separation of airflows ("*stall*") and the possibility of impact wave occurrence. Here, the air pressure change rate occurs which creates therefore another type of noise which generally spreads in front of and below the flight path, and to an untrained ear this may sound the same as the noise caused by high-speed blade rotation.

All these types of noise result in the "sound footprint" which is left on the ground by the helicopter and it contains fields of different noise intensity (Figure1). This "footprint" is important for the military helicopters regarding detection distance, and in civil operations it has influence in determining and measuring the allowed noise intensity

For the designers who wish to reduce the external noise generated by the helicopter, the optimal method is to choose relatively low speeds of blade tip revolutions for the main and the tail rotor. This will reduce the noise generated by the rotation of the rotor and minimise the noise generated by air compression at high speeds, especially if the blades have thin and/or curved tips. However, the reduction in the speed of blade tips requires adequate increase in the blade area, resulting in heavier rotors, in order to obtain the same performances. The smaller number of revolutions and the higher torque force result in the increase in the weight of the transmission and size of the shaft. Thus, the end product in the design is always a compromise between high performance and low level of noise which best meets all the helicopter requirements. Testing is underway with the objective of changing the characteristics of vortex airflow generated by the blade tips, so that they are specially designed now or the air flow is injected through them in order to either increase the vortex rings or to reduce their intensity, so as to reduce their influence on the blades entering their stream. Certain positive results have been obtained in the research, but they still do not have any impact on the manufacturing rotor design.

To a certain extent the pilot also has control over the external helicopter noise, especially in case of noise generated by the blade entering the vortex air flow of the previous blade (blade slap). Figure 2 shows the results of the testing program on the helicopter of the Bell 212 type with the aim of measuring precisely this type of noise depending on the flight regime and conditions. Since the measuring equipment was installed on the helicopter fuselage, the measured values of noise cannot be the same as those that would have been obtained if the measurements had been

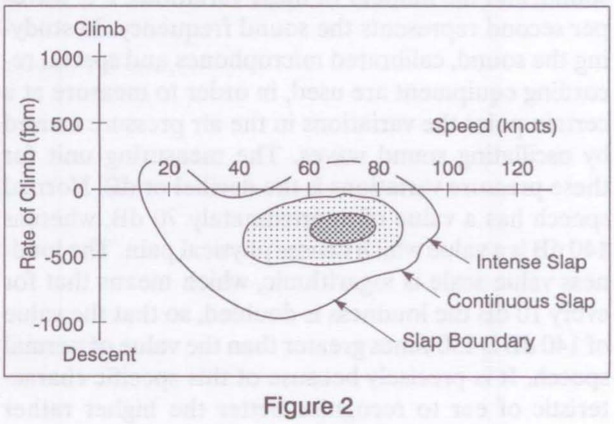

Figure 2

taken from the ground, but they can be used as example. The diagram shows that the flight conditions that generate the greatest noise are at the flying speed of 75 KTS and at the descending speed of 300 FPM. Avoiding these values in approach to landing will reduce the level of noise reaching the ground, but also the noise within the helicopter itself.

2. PROCEDURES OF MEASURING AND REDUCING NOISE

In order to control noise generated by aircraft, certain procedures have been developed and these have to be complied with by the aircraft in certain phases of flight. The noise measurement systems and standards have been also established at the most critical points of the flight, depending on the type and maximum takeoff weight of the aircraft. Thus, JAR-36 Aircraft Noise (*Joint Aviation Requirements*) defines the reference points for noise measurements for helicopters of different takeoff masses in certain flight regimes, as well as the highest allowed noise intensity above these points. The flight procedures given for takeoff, overflight and landing, and defining the flight path have to meet all the safety requirements (obstacle clearance altitude), and have to be approved by the aviation authorities of the State of Registry or the aircraft operator.

Measurements and control of noise in helicopters are performed at certain points in the characteristic regimes and helicopter flight paths:

- during takeoff;
- during overflight, and
- during the approach phase.

2.1. Points and procedures during takeoff

The measurement point is on the ground vertically below the flight path, and horizontally 500m away (in the direction of flight) from the point at which the conversion to the climb regime begins. In line with this point there are two more measurement points, symmetrically arranged at the lateral horizontal distance of 150m away from the defined path (trail) of the flight.

In developing the procedure for the take-off phase, the helicopter engine operation regime is considered to have stabilised at the maximum take-off power which corresponds to the minimal available specific engine power for the surrounding conditions or maximum power on the reducer transmission (whichever is less) along the path which starts 500m before the reference point of the flight path at an altitude of 20m (*66 ft*) above ground. During the take-off procedure, and depending on whichever is greater, it is necessary to maintain the speed of the best climb or minimal allowed climbing speed, and the stable climbing regime has to be maintained by maximum allowed number of revolutions of the main rotor. The helicopter flight path in the take-off phase has been determined within the straight segment, and it starts as an inclined path from the point which is 500m before the central microphone at an altitude of 20 m above ground (*N*), and the angle is determined by the best rate of climb for the specific type of helicopter.

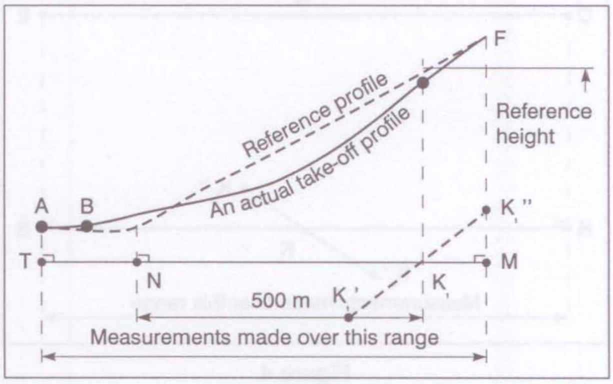

Figure 3

A – starting point of the helicopter flight path in the take-off phase;

B – start of conversion into the climb regime (the position of this point may vary within certain limits);

F – end point of the helicopter flight path in the take-off phase;

K_1 – reference measurement point of the flight path in the take-off phase;

K_1, K_1 – assigned measurement points;

M – end of trail of the take-off phase;

N – point on the trail where the conversion into the climb regime starts;

T – starting point of trail in the take-off phase;

NK_1 – distance from the beginning of the conversion into the climb regime up to the reference point of the flight path in the take-off phase (measuring distance in the take-off phase);

TM – distance at which the helicopter position is measured (trail length in the take-off phase).

2.2. Points and procedures in fyover phase

The measurement point is on the ground at a vertical distance of 150m below the flight path. In line with this point there are two more measurement points symmetrically arranged at the lateral horizontal distance of 150m from the defined flight path. The noise measuring procedures in overflight (*Overflight reference procedures*) are established in such a way that the helicopter is stabilised in the horizontal flight regime on the path above the reference point at an altitude of 150m, and during this procedure the velocity is maintained at $0.9\ V_h$, $0.9\ V_{ne}$, $0.45 V_h$ + 120 km/h ($0.45\ V_h$ + 65 kt), $0.45\ V_{ne}$ + 120 km/h ($0.45\ V_{ne}$ + 65 kt), whichever is reached later. The helicopter has to be in the cruising speed configuration (in case of retractable undercarriage which has to be retracted), and with the maximum number of revolutions of the main rotor in the horizontal flight.

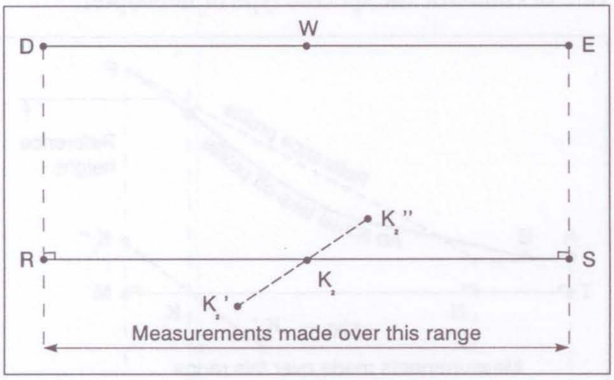

Figure 4

D – starting point of the helicopter flight path in overflight phase;

E – end point of the helicopter flight path in overflight phase;

K_2 – reference measurement point in overflight phase;

K_2, K_2 – assigned measurement points;

R – starting point of the trail in overflight phase;

S – end point of the trail in overflight phase;

K_2W – actual altitude of the helicopter above the reference measurement point in overflight phase;

RS – the trail length in overflight phase (distance at which the helicopter position is marked)

2.3. Points and procedures during approach phase

The measurement point is located on the ground at vertical distance of 120m below the flight path. On the flat terrain this corresponds to the distance of the point of contact (landing) of 1140 m, i. e. to the point where the approach path plane of 6° intersects the ground plane. In line with this point there are two more measurement points symmetrically arranged at the lateral horizontal distance of 150 m from the defined flight path.

The landing procedures require the helicopter to maintain constant approach path at an angle of 6°, at a speed which is equivalent to the speed of the optimal climb or which corresponds to the minimum allowed approach speed, whichever of the two is greater, at stabilised power during the approach phase which is maintained all the way to the contact itself. The helicopters, where applicable, will have their undercarriage extended during the entire approach phase.

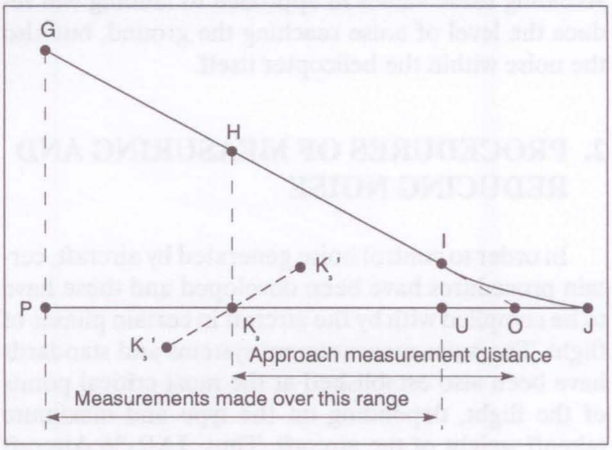

Figure 5

G – starting point of the helicopter flight path during approach phase;

H – position on the approach path vertically above the reference measurement point;

I – end point of the approach path;

J – point of contact;

K_3 – reference measurement point in approach;

K_3, K_3 – assigned measurement points;

O – intersection point of approach path and earth plane;

P – starting point of trail in the approach phase;

U – point on the ground vertically below the end approach point and point of levelling;

K_3H – altitude of helicopter above the reference measurement point in the approach phase;

OK_3 – measured distance in the approach phase;

PU – length of trail in the approach phase (distance at which the position of the helicopter is marked during approach)

During the take-off phase the allowed level of noise for helicopters ranges maximally from 109 EPNdB (*Effective Perceived Noise Level*) for the maximum take-off mass (80,000kg and more), and decreases then linearly along with the decrease in mass to the value of 89 EPNdB. By further decrease in mass, the level of maximally allowed noise is constant and amounts to 89 EPNdB (*Table 1*). In measuring the noise in overflight the maximum allowed level of noise is 108 EPNdB for helicopters with the maximum take-off mass (MTOW) of 80,000 kg and more, and it is also decreases linearly to the value of 88 EPNdB, which is constant for all the other lower masses, and in approach procedures for landing these values amount to 110 EPNdB and 90 EPNdB. The exception are Austria and Switzerland with the maximum allowed noise levels in those phases reduced by 3 EPNdB.

Table 1

	0 – 78,800 kg takeoff mass (M)	78801 – 80,000 kg takeoff mass (M)	80,000 kg and more takeoff mass (M)
Level of noise during takeoff (EPNdB)	89	90.03+9.97 log M	109
Level of noise during approach phase (EPNdB)	90	91.3+9.97 log M	110
Level of noise during overflight (EPNdB)	88	89.03+9.97 log M	108

Effective perceived noise level (EPNL) measured in decibels represents the overall noise generated by aircraft regardless of the scale of human reaction to inconvenience. The EPNL value is calculated by means of PNL (*Perceived Noise Level*) and PNLT (*Tone Corrected Perceived Noise Level*), and it includes corrections for a certain period of measuring the noise during aircraft overflight and the occurrence of high secondary frequencies and tones generated by the jet engines.

In determining the limits of noise levels the research has been taken into consideration which was carried out on a population living in the vicinity of airports, as well as the aerodynamic possibilities of aircraft and their performances. Diagram No. 1 shows the results of the study on the impact of the noise level on the population living in the residential areas in the vicinity of airports.

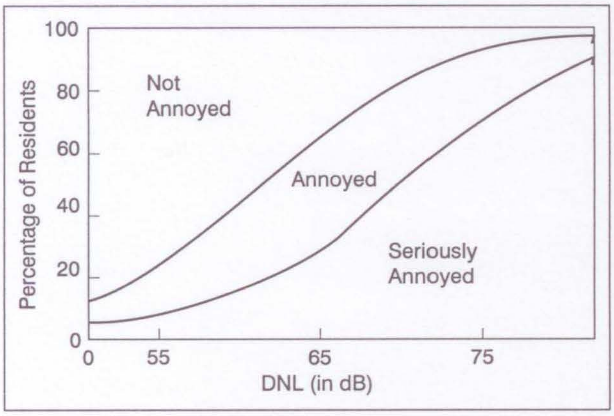

Diagram 1

The problem of noise is also present mainly because helicopters fly at much lower altitudes than the aeroplanes (Diagram No. 2). The results of research carried out by the Department of Transport of the Federal State Hawaii in the period from 1991 to 1994 showed that 25% of the population in the region considered the noise generated by helicopters as a very disturbing one, 65% were ready to tolerate 4-5 overflights a day, and all agreed that the government should stipulate rules regulating the helicopter operations in that area.

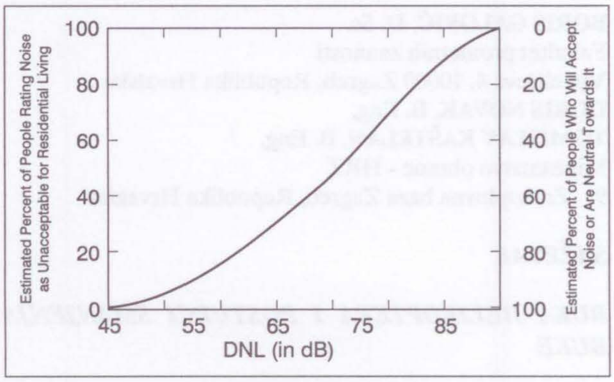

Diagram 2

This leads to the conclusion that there is a certain gap between the possibilities of noise reduction on helicopters depending on their performances and technical solutions, and the level of noise that the inhabitants of the surrounding area can and accept to tolerate. This is the reason why a lot of understanding is needed from both parties in order to reach acceptable compromises.

3. CONCLUSION

While flying, helicopters generate noise which is caused by the engine operation, airflow at different flying speeds of the main rotor, tail rotor, their interaction, etc. However, the greatest noise is generated by the interaction of the vortex airflow and the blades of the main rotor in certain flight phases and under certain conditions. In order to reduce this noise, it is first of all necessary to understand how and when it occurs and what causes it. Therefore, this type of noise has been the subject of many testing and research going on worldwide. Also, numerical methods are being developed for the simulation and forecasting of noise. These would help to a great extent in the design of the helicopter rotors, but also in determining the procedures during takeoff and landing. The development and standardisation of these procedures has been the topic of many discussions, since the noise reduction requirements need to be harmonised with the type and performance of the aircraft. This is precisely the reason why cooperation and understanding among air operators, airports, engine and aircraft designers and local community are necessary. Regarding the interconnection between sound, noise, and their impact on the humans and the environment, many more and intensive researches have to be undertaken, in order to establish the concrete cause-effect relationships, since little has been known scientifically about the interconnection between the actual intensity of the measured noise generated by the aircraft and the noise intensity causing discomfort and various difficulties in humans.

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SAŽETAK

BUKA HELIKOPTERA I POSTUPCI SMANJENJA BUKE

Buka helikoptera na, i oko zračnih luka manja je od one koju stvaraju avioni, jer je njihov broj operacija, odnosno broj uzlijetanja i slijetanja mnogo manji od uzlijetanja i slijetanja aviona. Od stotinjak operacija na dan na helikoptere se odnosi približno 15%, no sam utjecaj buke nikako nije zanemariv, jer je broj letova helikoptera iznad urbanih područja u znatnom porastu.

Ovaj članak nastoji analizirati pojavu i vrste buke kod helikoptera, njene negativne utjecaje, objasniti procedure leta i operativne postupke kod uzlijetanja, slijetanja i nadlijetanja helikoptera u operacijama u blizini i izvan zračnih luka, kao i načine mjerenja i određivanja ograničenja nivoa buke, te probleme koji se pri tome javljaju.

KLJUČNE RIJEČI

izvori buke, helikopteri, postupci smanjenja buke

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