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VIBROACOUSTIC HELICOPTER IMPACT ON ELEVATED HELIPAD

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Abstract

A helicopter landing and taking off on an elevated helipad is a source of noise that affects the environment and causes vibrations of the landing pad or the building infrastructure. Vibrations are also excited by the air stream flowing through the main rotor and transferred to the landing pad by contact of the helicopter chassis. Vibrations are transferred to the building through the structure of the helipad. Depending on the damping properties of the structure and the vibro-isolating elements used, vibrations can be felt in rooms used by people and also transmitted to devices located in the building. The subject of the study described in this paper is the vibroacoustic effects of an EC-135 helicopter on an elevated landing pad during landing, standstill with the propulsion system engaged and take-off. Measurements of vibrations and noise were made at points located both on the landing pad and in the building. The paper presents selected results of measurements in various phases of flight and helicopter manoeuvres. The frequency analyses of the fragment of the measurement data for the flight phase, in which the highest levels of impact were recorded, were also performed and included. The results are presented as graphs and annotated.

Keywords: mechanical engineering; helipad; helicopter; noise; vibrations; impact
Type of the work: research article

1. INTRODUCTION

The impact of the helicopter on the environment is a complex issue which includes: vibration transmission through the chassis, the main rotor airflow and acoustic impact [1]. All these issues are interrelated and usually occur simultaneously. For example, the influence of the main rotor causes turbulent airflow [2] resulting in the helipad vibration [3] as well as the acoustic phenomena accompanying the main rotor operation. The Łukasiewicz Research Network – Institute of Aviation conducts research on the aerodynamic impact of the helicopter on the helipads [4] and vibrations excited by the helicopter, as well as acoustic measurements. This paper contains selected results of research on helicopter vibroacoustic impact on the elevated helipad located on the building roof.

The main sources of the helicopter's vibroacoustic impact on the environment are: the main rotor, engines and the tail rotor [5]. Each of them has different characteristics, and different noise and vibrations levels at particular helicopter manoeuvres [6]. The impact of these sources on the helipad elements, and building and hospital infrastructure, as well as on people in the vicinity of the helicopter and in buildings, is also different.

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Initial studies of sound sources were carried out for the helicopter operating on the ground helipad, and their results are presented in the study [7]. The main sound sources have been located and their characteristics are presented here. Those tests did not fully reflect the real conditions during the helicopter operation in urban areas over the buildings, because they were performed in the open airfield. In particular, the assessment of the amount of vibration generated by the helicopter on the helipad and the ability to meet the requirements for the construction of buildings [8,9] can be made by direct measurements in the building or by numerical analysis [10].

Other studies have already been carried out on elevated helipads with concrete and steel structures [11,12], where attention was focussed only on the properties of the landing pads. Further tests were performed during the landing and take-off, and during helicopter operation on the landing pad. They additionally included the impact of the helicopter on the helipad and the building [13], as well as measurements of noise emitted by the helicopter. Selected results of these studies are described in this paper.

2. TEST OBJECT

The tests were carried out on the hospital's elevated helipad situated on the building roof.

The helipad structure was built on the existing five-story building including the ground floor, three floors and an attic. Including the roof level, the helipad is situated on the sixth floor.

The landing pad was set on a steel truss structure supported above the roof on several dozen steel pillars attached to the load-bearing elements of the building. The landing pad is made of square-shaped aluminium panels. Each side of the plate has been extended with an openwork bridging grille, which enlarges the service area.

Figure 1 shows the helicopter operating over the tested helipad.

Figure 1. EC-135 helicopter over the tested helipad.

This landing area has one approach and departure direction for the helicopter. During tests, the approach was taken from the side of the building where the hallway windows are located, while the windows of the patient room are located on the perpendicular wall. On the opposite side are the windows of the treatment rooms, staff rooms and technical rooms.

This landing pad is designed for helicopters with a maximum take-off mass up to 5 tonnes [14]. Currently, the EC-135 helicopters are used in Polish Medical Air Rescue and in the coming years they will be mainly using the constructed landing field. This type of helicopter is the subject of the vibroacoustic impact tests on the helipad described in this paper.

3. TEST METHOD

The conducted tests included the measurement and recording of vibrations and sound emitted by the EC-135 helicopter during landing and take-off, as well as during operation of the helicopter on the landing pad.

Vibration acceleration and acoustic pressure were measured both outside (on the landing pad) and inside the building. The placement of vibration sensors and microphones is shown in Figure 2.

Accelerometers (the measurement results obtained from which are presented below) were placed in the following locations:

– 'Z:2' on the landing pad near its centre (on the lower surface of the panel), and
– 'Z:14' in the patient room, three levels below the landing pad (third floor of the building).

The microphones were placed in the following locations:

– 'mic1' at the helipad level from the departure side (under the openwork bridging grille that extends the landing pad),
– 'mic2' at the helipad level from the approach side (similar to the 'mic1' microphone, but on the opposite edge of the landing pad),
– 'mic3' in the patient room, three levels below the landing pad (third floor of the building, near 'Z:14' accelerometer), and
– 'mic4' in the hallway near the window from the approach side (third floor of the building, near the patient room).

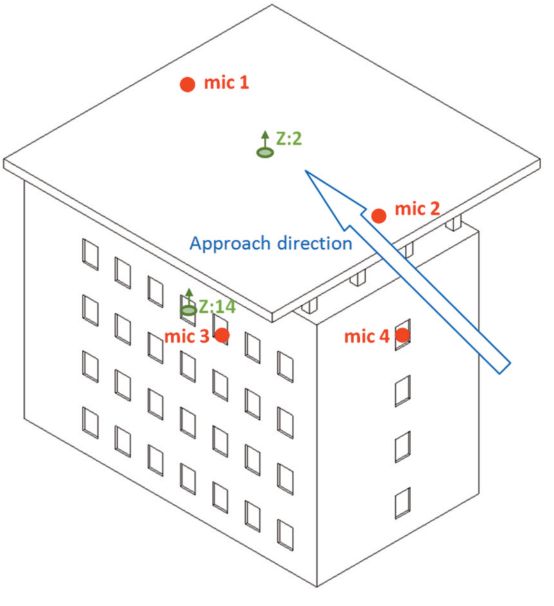

Figure 2. The building scheme and the location of measuring points.

During the measurements the hospital building was under renovation, which allowed access to all rooms.

Accelerometers and microphones located on the landing pad as well as in places used by people allow identification of the nature of the source of noise and vibration and assessment of their effects caused in the vicinity of the helicopter. Placing the microphones on both the approach and departure sides allows for the determination of flight phases where the acoustic impact is greatest.

The vibrations were measured with seismic acceleration sensors, and the noise was measured with 1/2² microphones. All sensors were connected to the multi-channel recorder, which was controlled by a computer equipped with LMS Test.XPress software for controlling the system and data recording. The system also recorded the current GPS time, which made it possible to synchronise the data with the helicopter position at selected times, flight parameters and manoeuvres.

The measurement and recording of vibrations and sound pressure started when the helicopter was on the approach path to the tested landing pad. The data were recorded continuously during landing and when the helicopter was standing on the helipad with the working powertrain, as well as during take-off and departure from the helipad. The measurement was completed when the helicopter left the landing zone. During normal operation of a helicopter transporting a patient to a hospital, the drive is shut down after landing. In the conducted experiment, for formal reasons and safety requirements, the engines were not completely switched off, and only a slight decrease in rotational speed occurred.

Commonly used research methods consist in determining the maximum or equivalent noise and vibration levels during the observed process. They are usually focussed on assessing the effects of impact on the environment, without a detailed analysis of the source of impact. The approach to experimental research described in the article includes the aspect of studying the source of vibroacoustic impact in specific helicopter flight stages and its impact on the environment, as well as the study of the vibration properties of the elevated helipad structure. In addition, unlike the methods used so far, a multi-channel recorder was used in the conducted tests, enabling the synchronous measurement of many physical quantities, even in several dozen points, which allows for a comprehensive analysis of the entire process.

4. TEST RESULTS

The measured vibration acceleration and the acoustic pressure were recorded in the time domain. In further processing of the results, frequency analyses and correction (for the acoustic signal only) of the amplitude-frequency characteristics were performed according to the A-weighting curve, which represents the audibility of sound by the human ear.

Figure 3 shows the time graphs of the acoustic pressure measured by microphones on the landing pad. The graph shows the flight phases and manoeuvres of the helicopter. Figure 4 shows the acoustic pressure measured indoors. Figure 5 shows the graphs of vibration acceleration at the same time.

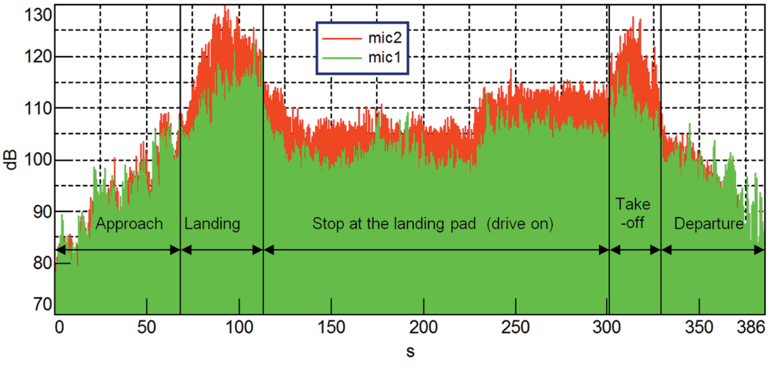

Figure 3. Sound pressure level recorded during helicopter manoeuvres on the landing pad.

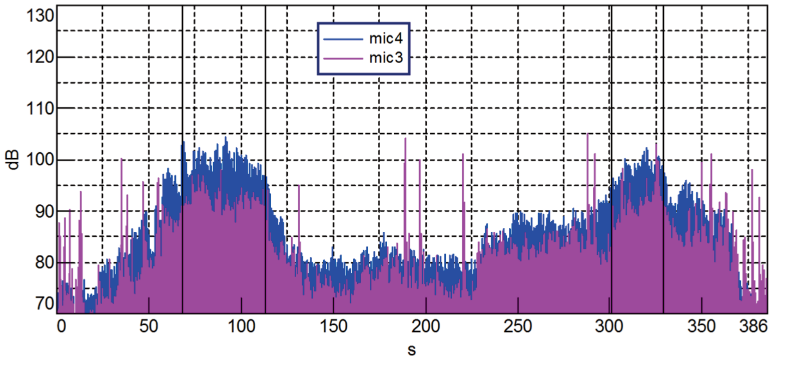

Figure 4. Sound pressure level recorded during helicopter manoeuvres indoors.

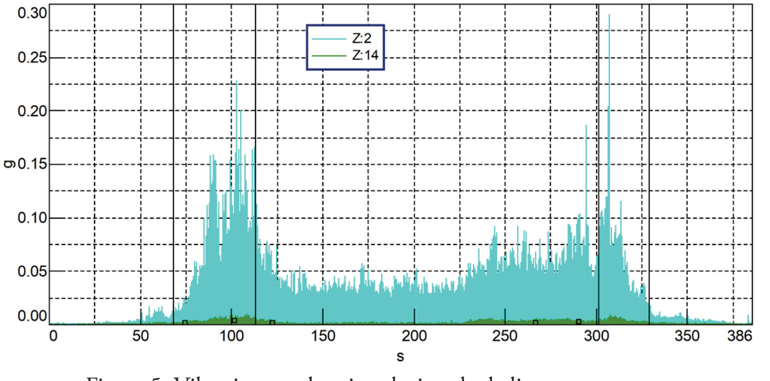

Figure 5. Vibration acceleration during the helicopter manoeuvres:
on the landing pad (blue curve); and indoors (green curve).

The presented graphs show that the highest noise level occurred during landing, but a comparable noise level is also observed during take-off. A similar relationship is observed on the vibration diagram of the landing pad and in the building. Higher noise levels for both landing and take-off were recorded from the approach side ('mic 2') than from the departure side ('mic 1'). This is due to the take-off procedure which, in the case of elevated helipads, takes place in the first phase 'backwards', i.e. along a path close to the approach path. Inside the building, more noise was recorded in the hallway than in the patient room, because the hallway window was on the side of the helicopter approach.

While the helicopter rests standstill on the helipad but with the propulsion system engaged, an increase in vibrations and the noise level is discernible (~228 s of the graphs), which is a result of the increase in engine speed before take-off.

The noise level recorded in the rooms is about 25–30 dB lower than level on the landing pad, near the source. This is due to the decrease in sound intensity with distance, and noise absorption by walls, ceilings and windows, as well as sound dispersion and reflection from the landing pad. The level of vibrations in the building is much lower than on the landing pad. This indicates the effectiveness of vibration isolation and good damping properties of the entire structure.

The perception of noise by the human ear depends not only on the sound pressure level but also on the sound frequency. The analysis graphs resulting in the A-curve corrected frequency domain characteristics are given in Figs 6 and 7. The graphs are presented in third octave frequency bands. For the analyses, a fragment of time signal with the highest amplitudes recorded during the helicopter landing was used.

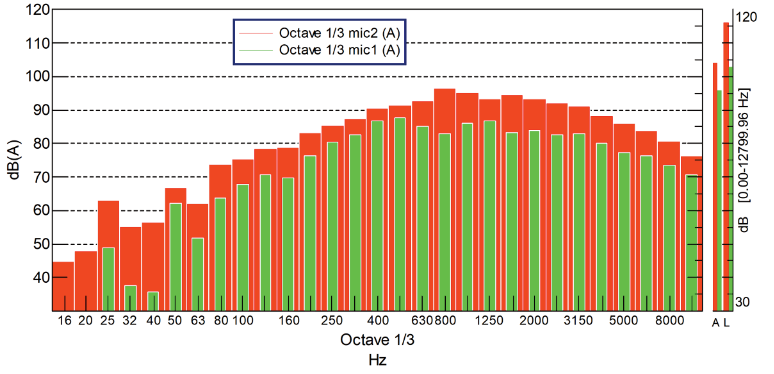

Figure 6. Amplitude-frequency characteristics of noise measured on the landing pad, corrected according to curve A.

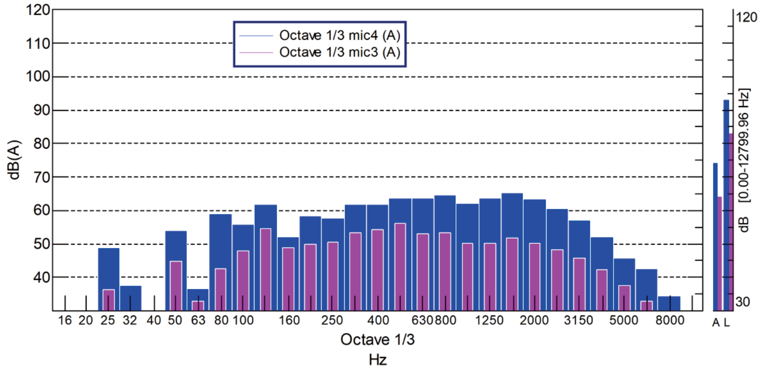

Figure 7. Amplitude-frequency characteristics of noise measured indoors, corrected according to curve A.

The additional axis of the graphs (on the right) shows the equivalent sound pressure level (Leq) determined in the full band of analysed frequency (up to 12.8 kHz). In the case of rooms used by people, this level is up to 75 dB (A) (in the hallway), while near the source of noise it reaches up to about 105 dB (A) (from the approach side). However, this noise level occurs for a short time, i.e. for several seconds only during take-off and landing. In addition, flights at a given location are rare, on average no more than one flight a day.

The highest perceived noise levels in the vicinity of the helicopter, observed in the presented characteristics, occur in the frequency band from about 250 Hz to 5 kHz. This noise is also heard indoors, but it is well-damped. Low-frequency noise in the range 25–125 Hz is less damped indoors than noise in the higher frequency bands. Good noise reduction in the building is observed for bands above 5 kHz. In the study [7], the source of the sound was located mainly as the noise from the exhaust of helicopter engines.

Figure 8 shows the 1–3 amplitude-frequency graphs of the vibrations measured during the helicopter landing for the same part of the time recording.

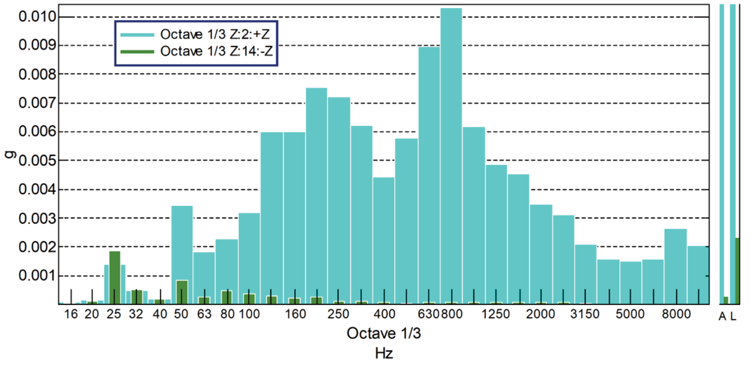

Figure 8. Amplitude-frequency graphs of the vibrations measured: on the landing pad (blue diagram); and indoors (green diagram).

The increase in vibration levels on the landing pad occurs near the 800 Hz, 200 Hz, 50 Hz and 25 Hz frequency bands. The maximum amplitude of vibrations occurs in the 800 Hz and 200 Hz third octave bands and in the adjacent bands. These are probably local resonances of the panels from which the landing plate is made. These vibrations are not transmitted to the building, i.e. no increase in the vibration levels is observed for the sensor located in the patient room.

As in the case of the sound level graphs, there are increases in the vibration level for the frequencies of 25 Hz and 50 Hz. These vibrations are transmitted to the building structure and they are also visible on the indications of the accelerometer located in the patient room.

Increased levels of noise and vibration in low-frequency third octave bands are related to the rotational frequency of the main rotor multiplied by the number of blades and to the frequency of next harmonics. The phenomenon is clearly visible on the characteristics presented in uncorrected line graphs. Such charts, for the frequency range up to 300 Hz, are presented in Figure 9 (landing pad) and Figure 10 (indoors) for the noise, and in Figure 11 for the vibrations.

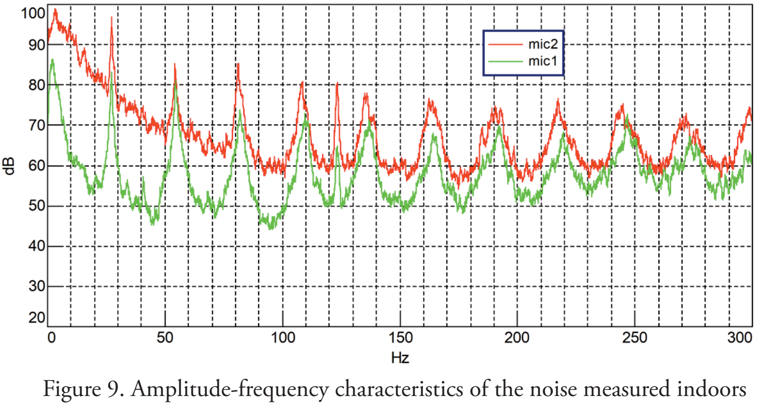

Figure 9. Amplitude-frequency characteristics of the noise measured indoors (uncorrected).

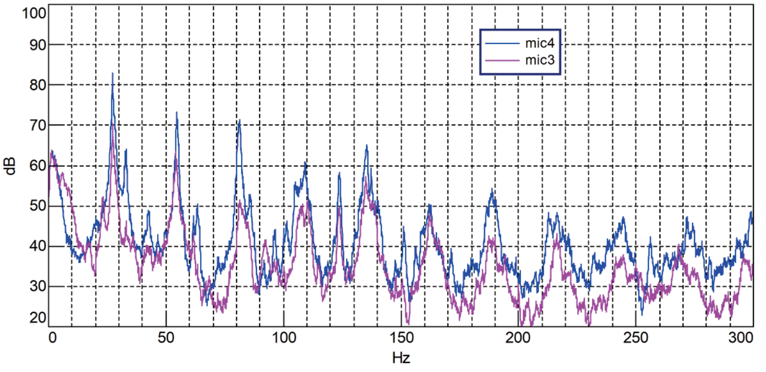

Figure 10. Amplitude-frequency characteristics of the noise measured on the landing pad (uncorrected).

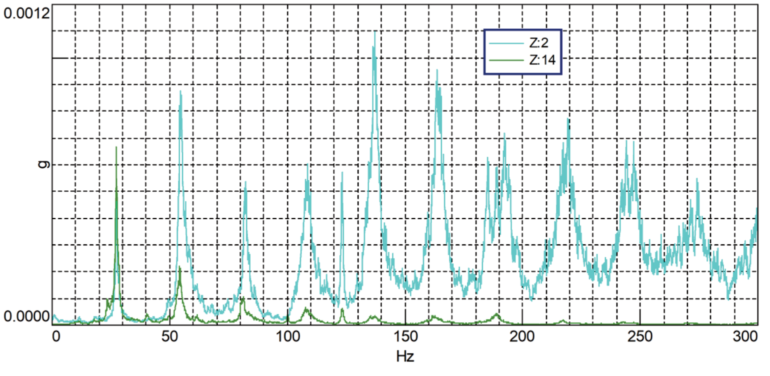

Figure 11. Amplitude-frequency graphs of the measured vibrations (uncorrected).

The characteristics presented in Figs 9 and 10 show the frequency distribution of the noise generated by the helicopter and the noise reaching the inside of the building. The graphs facilitate the assessment of the possibility of acoustic excitation of vibrations of structural elements and infrastructure [15], such as windows, doors, cabinets, equipment housings, etc. Such excitation may occur when the natural frequency of the elements is similar to the frequency of the generated noise components.

In the characteristics of the sound level (Figs 9 and 10) and the vibration amplitude (Fig. 11), the basic frequency is about 27.2 Hz (being the product of the rotational speed of the main rotor and the number of blades) and its harmonics. Thus, it can be seen that the main source of the low-frequency vibroacoustic interaction is the main rotor.

The obtained test results confirm the effectiveness of the used research method. The recording of signals in the time domain allowed for the subsequent analysis of the results, including the tracing of the entire landing and take-off process of the helicopter on the hospital helipad. Time synchronisation using GPS made it easier to compare the signals measured on the helipad with the helicopter flight parameters recorded by the on-board system and to accurately identify individual manoeuvres. The software used made it possible to select and analyse fragments of signals corresponding to individual flight phases.

5. CONCLUSIONS

A greater acoustic impact of a helicopter on an elevated helipad occurs from the approach side, both during landing and take-off, which is related to the safer rear take-off procedure (along a track close to the approach path). This information is quite important for planning the purpose and location of utility rooms in a building, e.g. hospital rooms and operating rooms or offices.

The landing pad also acts as an acoustic screen separating the sound source from the building.

The greatest vibroacoustic impact occurs just before landing and after take-off when the helicopter is located just above the landing pad, which indicates that vibrations are more induced by non-contact impact (air flow, acoustics) than by direct contact of the helicopter chassis with the landing field.

Especially during take-off and landing, the movement of helicopters in the vicinity of the hospital building causes noise and vibrations to occur in the building. However, the impact is short-lived and occasional. It should not pose a risk to patients or hospital staff.

The noise emission into the building during the measurements was influenced by window gaps (the building was under renovation) and open windows (due to the cables being led through them). In an air-conditioned building, helicopter noise can be low.

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