[1.]Anna YEHOROVA, [2.]Ervin LUMNITZER

ANALYSIS OF METHODOLOGIES IN THE FIELD OF OBJECTIVE EVALUATION OF ACOUSTIC DRONE DESCRIPTORS

[1.] Technical University of Košice, Faculty of Mechanical Engineering, Department of Environmental Engineering, Košice, SLOVAKIA

Abstract: Drones are currently used for various purposes. The ever-increasing number of professionally or amateurly used drones is causing an ever-increasing noise load in the area. Those sources of noise that occur historically in the environment (dor example railways) are currently perceived by people as less disturbing. On the contrary, new noise sources are perceived as significantly disturbing (various types of industrial noise) and people are not able to tolerate them. Drone is a completely new and so far not explored source of noise, which is characterized by a specific spectral composition of noise and often subjectively felt a high degree of interference. At present, there are no clear national or international methodologies for assessing the impact of drones on the population. For this reason, we have started research in this area in order to develop a methodology for assessing this specific noise source. We also consider it important that this period of drone growth in some countries is crucial for the accelerated implementation of methodological procedures for dealing with noise issues. The paper proposes a basic methodology for assessing the impact of drones on humans and performed noise measurements at different flight speeds for two types of drones.
Keywords: Drone, quadcopter, noise, human impact, field measurements

INTRODUCTION

In nowadays, the number of applications for small unmanned aerial vehicles (UAVs) is growing rapidly. Relatively new consumer markets for drones include forestry, agriculture and road management, energy and communications, oil and gas production and transportation, safety and environmental protection, and so on. The widespread use of drones, in addition to the undoubtedly positive aspects, has brought a number of noise problems. According to US scientists from NASA, the disturbing sound caused by drones hinders people more than the current noise of cars and trucks. The paper seeks to advance research in the field of drone acoustics and to improve the acoustic quality of the environment in which we live, work, and relax. It is necessary to realize that in the horizon of several years there will be a significant development of the user sector of drones (scanning of terrain, buildings, stands, delivery service, filming and, last but not least, amateur use as a hobby).

DRONE LAWS AND REGULATIONS

Flying with drones, most often in the form of a compact quadcopter with a camera, have in increasing popularity in both the recreational and professional spheres. According to Chapter 7 of the Aviation Act 143/1998 Coll. drones are distinguished between autonomous aircraft, remotely piloted aircraft and flight models.

The latest European Regulations, EU 2019/947 and 2019/945, provide a framework for the safe operation of civilian drones in the European sky (EU Member States and EASA). They consider the weight and technical parameters of the drone and the operation to be performed.

Implementing Regulation (EU) 2019/947 [1] regulates the operating rules for drones, divides the operation of drones by type and place of use, and evaluate their level of risk. Delegated Regulation (EU) 2019/945 [2] describes the building regulations and the characteristics of drones in different categories. It defines three categories "open", "specific" and "certified".

We consider the following to be the most important conclusions of the analysis of the legislative framework:

≡ based on the class (C0 - C4), the drones will be marked with a corresponding label,
≡ the drone operator will be required to register with the Civil Aviation Authority - thus obtaining a 12-digit personal identification number,
≡ the operator will have to mark all his drones with a personal identification number,
≡ the minimum age of the drone pilot is set at 16 years,
≡ the maximum drone flight is reduced to 120 meters above the ground, even outside operating areas and controlled areas.

All these measures concern pilots, operators and the drones themselves. But still there is no detailed specification of the effects of drones on inhabited areas and human-inhabitants. As mentioned, Delegated Regulation (EU) 2019/945 includes a standard assessment of drone noise. This is an indication of the guaranteed sound power level. This level should be determined according to STN EN ISO 3744: 2010 Acoustics.

The operation of the drone as a source of noise in accordance with Decree MzSR 549/2006 Coll., which lays down details on permissible values of noise, infrasound and vibration and requirements for objectification of noise, infrasound and vibration in the environment, corresponds to the category "Noise from other sources" according to tab. 1 of the said Decree. For this reason, the basic quantity for assessing compliance with the legislation is the equivalent A-weighted sound level for the relevant time interval $L_{Aeq,R}$, which is binding in the external environment for the relevant categories of territory.

Due to the nature of the sound of drones, which very often contains a significant tonal component, it is also possible to apply a correction for specific noise according to tab. 2 of the said Decree. We currently classify drones as "noise from other sources". According to a study of the available literature and analyzes of the perception of drone noise by the population, this classification often does not correspond to its operational character (random, aeronautical). It is clear that further legislation will be needed in this area.

DESIGN OF DRON NOISE MEASUREMENT METHODOLOGY

The process of elaboration of the methodology suitable for solving the problem of drone noise consists of the following steps:

≡ analysis of the requirements and objectives of the methodology,
≡ draft methodology,
≡ analysis and selection of appropriate technical equipment,
≡ selection of measuring objects - drones,
≡ verification of the methodology by trial measurement.

Among the basic recommended measuring principles that can be used to assess the acoustic quality of drones we advise:

≡ sound visualization by acoustic camera,
≡ acoustic compass,
≡ sound level meter system,
≡ sound intensity measuring device,
≡ 3D visualization.

— Sound level meter measurements

For testing the principles of measurement as well as verification of the proposed methodology, classical measurements were performed with a system of sound level meters. The measurement of acoustic properties using a system of sound level meters was performed on the area of the Faculty of Aviation of the Technical University in Košice. The measuring points were located in an isolated zone, which eliminated interfering effects on the measurement.

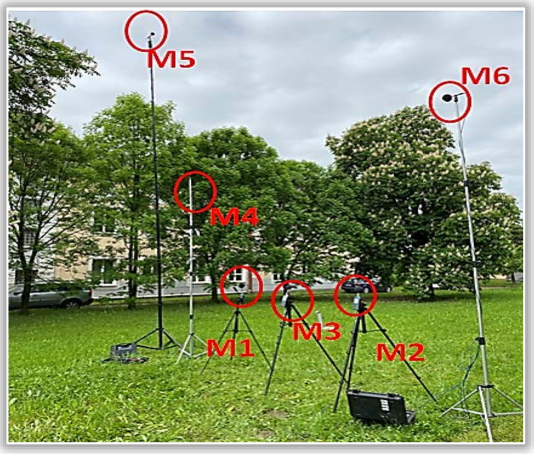

Figure 1. Scene of the measuring points

Figure 1 shows a scene of the measuring points and the arrangement of the measuring devices. The location of the measuring points was chosen so that it was possible to characterize the acoustic properties of individual typical drone operations. The measuring microphones were arranged in a way, that we could assess the effect of a flying drone on a person who is at ground level (1.5 m above ground level) and at several heights (the effect of drones on protected objects at level 2 to 3 above ground). The task of the placement and setting of the instruments was to analyze the individual acoustic events in terms of time domain (time record) and frequency domain (frequency spectrum).

Drones have a wide range of different noise characteristics. The main components of noise are the noise of the flow when the propeller moves and the noise from the engine. The nature of the noise is very closely related to the drone flight mode and flight speed. For the initial testing of the methodology, we decided to focus on the individual flights of two different quadcopters at different speeds. Said quadcopters and their characteristics are shown in Figure 2. The nature of drone noise is also affected by the current air flow rate, load and acceleration.

For the needs of the initial analysis, which we present in this work, 2 types of drones were selected.

≡ Quadcopter No.1

The manufacturer of this quadcopter operates at the Faculty of Aviation of the Technical University in Košice, it is his own design and construction, printed on a 3D printer. Look at this quadcopter and its characteristics are shown in Figure 2 and in tab. 1.

Figure 2. Quadcopter no.1 and no.2

Table 1. Characteristics of the quadcopter no.1 and no.2

Quadcopter number	No.1	No. 2
Power supply:	3S LiPo, 4500 mAh	2S Li-ion, 2400 mAh
Propellers:	GWS EP 9050x3	4,7x2,6x2
Weight:	1350 g	249 g
Shoulder length **	225 mm	107 mm

≡ Quadcopter No.2 DJI Mavic Mini

This quadcopter is a Professional one that excels in its compactness and performance. It is a popular model for those who want to operate a professional drone at a relatively low price. Look at the quadcopter no. 2 and its characteristics are shown in Figure 2 and in table 1.

— Measurement results

During our research, 4 sets of measurements were made. Each quadcopter flew back and forth at low and high speeds. Figure 3 shows the time record of the equivalent A-weighted sound level when flying at a low speed by the quadcopter no. 1 through the vertical microphone system.

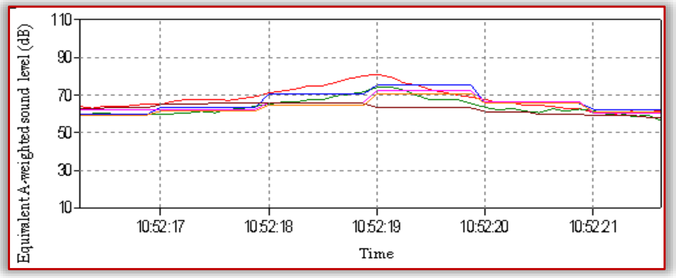

Figure 3. Time record from all measuring points, low speed flight of the quadcopter no. 1

Legend: measuring point M1 – red colour, M2 – green, M3 – blue, M4 – pink, M5 – burgundy, M6 – orange colour.

From the time course it is clear:

≡ changes in the equivalent A-weighted sound level as the drone approaches and departs from the measuring system,

≡ scattering of equivalent A-weighted sound level for individual measuring microphones, which depend on the height above ground level and the distance from the flying drone.

This analysis also shows the scatter of the equivalent A-weighted sound level of the individual measuring microphones during the flight.

Figure 4 shows the frequency spectrum of the low speed flight of the quadcopter no.1 at the measuring point M1.

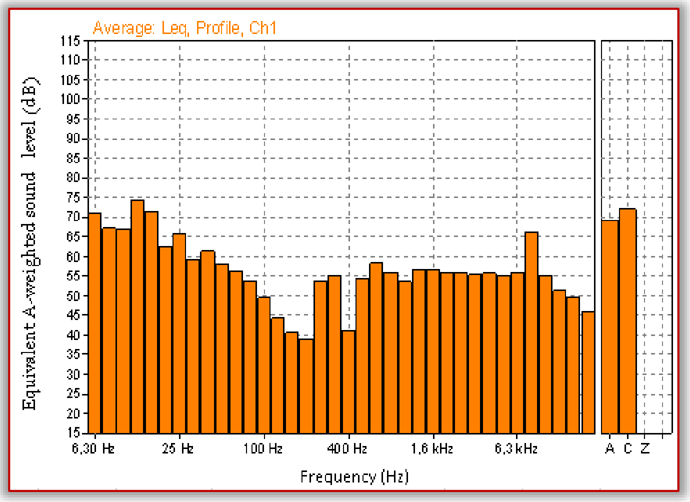

Figure 4. Frequency spectrum from measuring point M1, low speed flight of the quadcopter no. 1

Figure 5 shows the time record of the equivalent A-weighted sound level when flying at a high speed by the quadcopter no. 1 through the vertical microphone system.

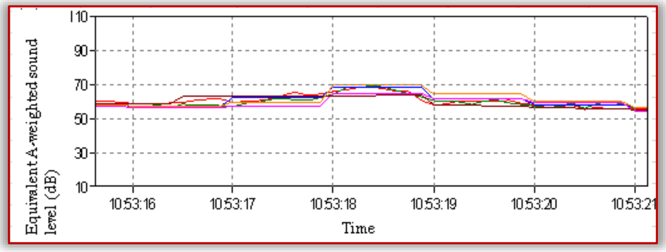

Figure 5. Time record from all measuring points, high speed flight of the quadcopter no. 1

Figure 6 shows the frequency spectrum of the high speed flight of the quadcopter no.1 at the measuring point M1.

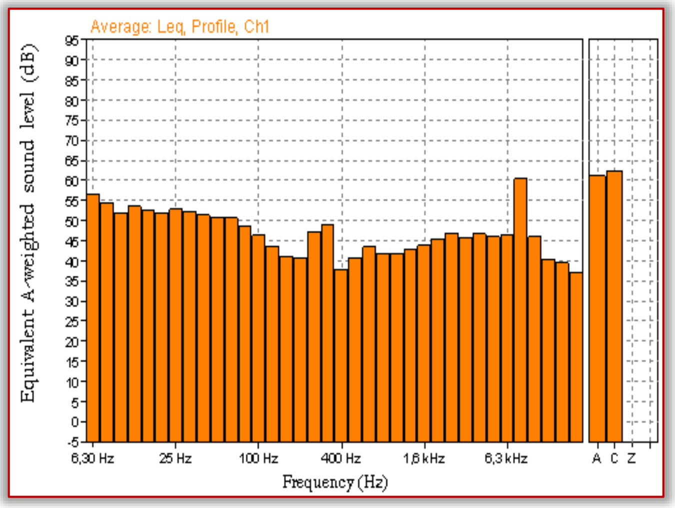

Figure 6. Frequency spectrum from measuring point M1, high speed flight of the quadcopter no. 1

A comparison of the frequency spectra of high and low speed flights shows that significant tonal components appeared at different frequencies at low flight speed, but at 250 and 315 Hz they disappear at high speed, on the contrary, at 8.0 kHz the tone component is still more pronounced.

It should be noted that in the case of a low speed flight, higher noise levels were measured, as is evident from the above records. This is due to the smaller drone flight distance, as the operator did not dare fly at close distances from the microphones at higher speeds. This is another of the problems that need to be addressed in the further processing of the topic.

Figure 7 shows a time record of the equivalent A-weighted sound level when flying low speed of quadcopter no. 2 through a vertical microphone system.

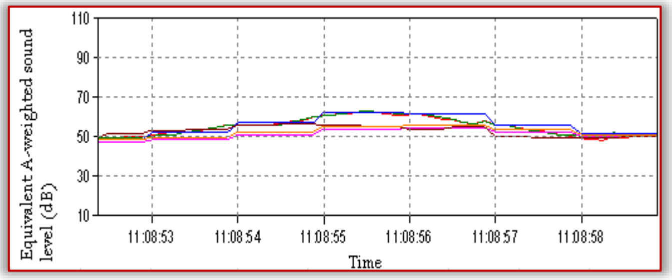

Figure 7. Time record from all measuring points, low speed flight of the quadcopter no. 2

Figure 8 shows the frequency spectrum of the low speed flight of the quadcopter no.2 at the measuring point M1.

It is clear from the frequency spectrum that the emitted noise does not have a significant tonal character. In this case, it is a professional product of one of the renowned manufacturers (DJI Mavic Mini). It is clear that the manufacturer dealt with acoustic optimization, which results in the frequency spectrum. In further proposals, it would be appropriate to address the situation in the range of 250-315 Hz, as there are more significant anomalies (deviations from the smooth frequency spectrum).

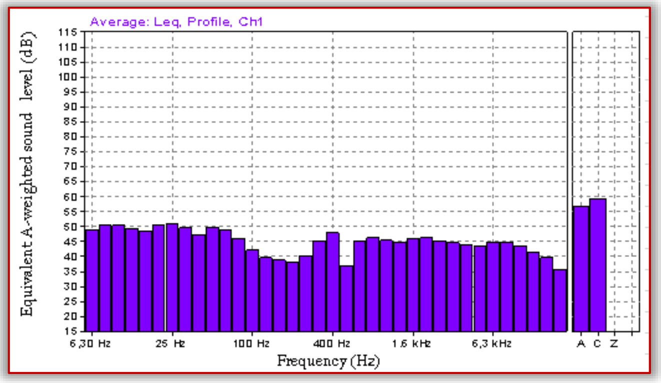

Figure 8. Frequency spectrum from measuring point M1, low speed flight of the quadcopter no. 2

Figure 9 shows the time record of the equivalent A-weighted sound level when flying at a high speed of the quadcopter no. 2 through the vertical microphone system.

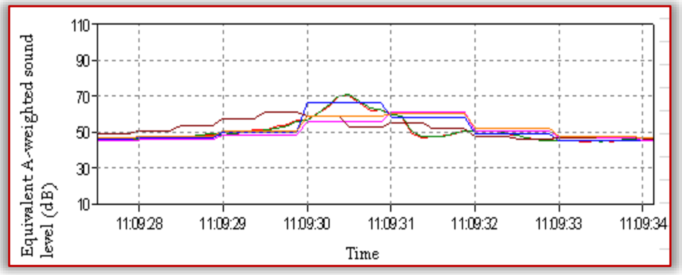

Figure 9. Time record from all measuring points, high speed flight of the quadcopter no. 2

Figure 10 shows the frequency spectrum of the high speed flight of the quadcopter no.2 at the measuring point M1.

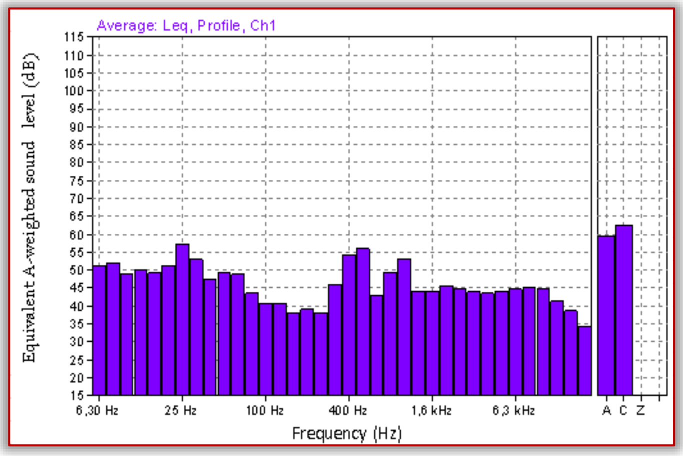

Figure 10. Frequency spectrum from measuring point M1, high speed flight of the quadcopter no. 2

A comparison of the frequency spectra of high and low speed flights for quadcopter no. 2 shows that when flying at a higher speed, there are more tonal components at different frequencies, namely at 25 Hz, 400 Hz, 500 Hz, 800 Hz and 1000 Hz, with which is associated with a significant increase in the disruption of the population. In this case, the pilot was able to follow the same drone flight paths at both speeds, as evidenced by the achieved noise values.

CONCLUSION

The measurements that were performed and described in this paper were the first step in the design of a methodology for measuring drone noise and its effects on humans. In addition to the described measurements when flying through the vertical system of microphones, other measurements were performed, measurements with the horizontal system of microphones, measurements with an acoustic camera, which will be gradually incorporated into the new methodology.

Acknowledgments

This paper was created within the project KEGA 011TUKE-4/2021.

References

[1] Commission Implementing Regulation (EÚ) 2019/947 of 24 May 2019 on the rules and procedures for the operation of unmanned aircraft.
[2] Commission Delegated Regulation (EU) 2019/945 of 12 March 2019 on unmanned aircraft systems and on third-country operators of unmanned aircraft systems.
[3] Lumnitzer, E. et al.: Evaluation of the effects of physical factors on human health. TU, 2014.159
[4] Yehorova, A. et al.: Methodology for increasing the quality of technical equipment In: Acta Technica Corviniensis : Bulletin of Engineering. Roč. 13, č. 4 (2020), s. 13-18
[5] Lumnitzer, E; Yehorova, A: Acoustic properties of washing machines in terms of customer expectations. In: Fyzikálne faktory prostredia = FFP. - Košice (Slovakia): IbSolve Roč. 10, č. 1 (2020), s. 16-21
[6] Lumnitzer, E; Badida, M; Polačeková, J. Akustika. Základy psychoakustiky, 2012, Košice – ISBN 978-80-8086-182-8, str.51-73
[7] Abagnali, V; Fabbri, G. Sound Waves: Propagation, Frequencies and Effects. Hauppauge: Nova Science Publishers, 2012. ISBN 9781614701699.
[8] Kloet, N. Drone on: a preliminary investigation of the acoustic impact of unmanned aircraft systems (UAS). 24th International cobgress of sound and vibration, 2017.
[9] Perron, S. Review of the effect of aircraft noise on sleep disturbance in adults. Noise and Health, 2012.
[10] Yongcho, T. Characterizing sources of small DC motor noise and vibration. Micromachines 2018;84(9):1–16.
[11] Sinibaldi, G. Experimental analysis on the noise of propellers for small UAV. Applied Acoustics 74 (2013).

ISSN: 2067-3809