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ANALYSIS OF NOISE LEVEL GENERATED BY HELICOPTERS WITH VARIOUS NUMBERS OF BLADES IN THE MAIN ROTOR

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Abstract -*The possibility of landing and take-off from a small space and overflights at low altitudes makes horizontal propeller aircrafts (helicopters) significant sources of internal and external noise in the environment. Given the typical aircraft structure in relation to other aircraft, local sources of noise in helicopters are numerous: the main rotor, tail rotor, the propulsion system, transmission and others. Particular impact on the overall level of noise that is generated has the number of blades in the main rotor of a helicopter. This paper presents the results of measurements of noise generated by helicopter SA341H "Gazelle" at full throttle in the work on the land and take-off phase. The level of noise generated by helicopter type SA341H "Gazelle" was compared to the levels of noise generated by the helicopters Robinson R44 Clipper and Bell 206B.*

1. INTRODUCTION

One aspect of the project "urbaNoise" is a study of the noise impact of traffic on the urban environment. Sources of noise in urban traffic noise are road traffic, railway traffic noise, and aircraft noise. Influence of aviation noise on the population of the urban areas has different effects compared to the noise of the road transport.

As the term aviation noise, or aircraft noise, we consider "unpleasant" sound that comes from the aircrafts when they overfly populated places during various phases of flight. Aircrafts are bodies that are separated from the ground, and according to the way they move, they are divided into aerostats, which have the ability to hover, and aerodynes, which have the ability of progressive motion. From the standpoint of aircraft noise emission, they are divided to aircrafts with motor drive (airplanes, helicopters, gyrocopter, gyroplane, hang gliding, motor gliders, rockets ...) and the non-engine-powered aircrafts (gliders, kites, balloons, parachutes, paragliders ...).

2. CHARACTERISTICS OF AIRCRAFT NOISE

Aircraft noise is characterized by high levels of noise that arise during short periods. Its characteristics depend on the source of noise, ie. type of the aircraft that emitts the noise. In this regard, it is important to emphasize that aircraft noise arises as the result of movement of the aircraft through the air (aerodynamic noise) and because of work of the propulsion system - engine.

Aerodynamic noise occurs as a consequence of the specific flow (turbulence) around the aircraft structure, cavities, control holes and surfaces and landing gear of an aircraft.

The noise that is a result of the propulsion system is determined by the type of aircraft engines, which may be:

- internal combustion engines - piston engines and Wankel engines,
- reactive engines - jet engines, compressor reactive engines and rocket engines,
- without combustion engines - human powered and electric motors.

The piston engines have broadest application, in light motorized aircraft and jet engines in passenger, cargo and fighter aircrafta. Piston engines are used for subsonic flight speeds, while jet engines drives for supersonic aircrafts.

Influence of the aircraft noise on residents of urban areas depends on the distance of the area from the runway (airports, heliports, airports sports). Near the airport, the population is not exposed only to the impact of the aircraft noise, but also to the noise generated at the airport by the necessary devices and equipment for safe takeoff and landing of aircrafts, mobile and fixed resources for servicing the aircrafts, anti-fire, medical and other occupant protection, warked and the flight crew, etc... These sources of noise have rather constant level during time, regardless of time of day, weather conditions and air traffic density. The biggest noise influence still have the aircrafts, especially during the phases of landing, take-off and taxiing (movement along the taxiway), when the primary noise comes from the propulsion system.

Each airport has a precisely defined procedure for take off and landing on a runway, which consists in the determination of velocities, altitudes, and bank angles. Air traffic control has defined the procedures for each airport based on its category. Categorization of airports was based on the size of the runway, which determines the size of the aircrafts, i.e. number and type of the propulsion system, which directly affects the level of aircraft noise.

Specificity of the helipads is that they are regularly placed in densely populated urban areas, often on the roofs of residential, commercial and hospital facilities.

3. CHARACTERISTICS OF AIRCRAFT NOISE WITH HORIZONTAL PROPELLER

Aircrafts with a horizontal propeller (helicopters) are aircrafts characterized by takeoff and landing from limited area. This does not mean that helicopters only take-off vertically, by raising hull and hovering in progressive flight: they are able to, and depending on the load, and they have to be able to take-off from taxiing (aviation slang words – landing run-off). Of course, this refers to helicopters that have wheels as part of the landing gear.

From the standpoint of noise, what separates helicopters from the aircraft is the specificity of propulsion system, the existence of horizontally mounted rotor, the existence of tail rotor and the existence of the transmission system.

Propulsion systems that are installed on the helicopters are gas turbine engines and, rarely, piston and jet engines. Gas turbine engine is structurally very similar to the propeller-turbine engine. For propeller-turbine engine, a lift is created by the vertical propeller that is directly related to the turbine shaft (propeller engines on many passenger and cargo aircrafts). Gas-turbine engine transmits its power to the shaft, and then through the transmission system reduces the required horizontal rotor speed. In both of these types of engines the emphasis is on the transmission moment, and not at the speed of exhaust gases - thrust. In the construction, it is achieved by a small number of degrees of air compressor, and by large number of degrees of turbine engines.

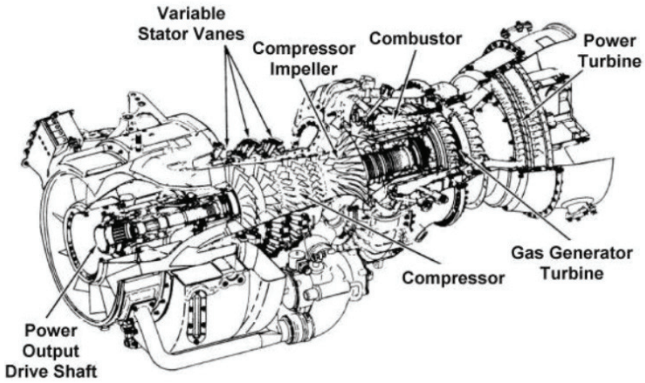

Fig.1 *Turboshaft engine [4]*

The advantages of this the propulsion systems are: high power, long life, small size and weight, easy maintenance, low complexity of construction, low vibration, while the main disadvantages are higher fuel consumption and higher prices of the development because of the specific materials for fabrication. Helicopters may have one or two engines and/or a start-engine.

The helicopter has six degrees of freedom, and five of them are regulated by main rotor, i.e. horizontally mounted propeller. The main rotor is made of a number of blades and the supporting head. The system is installed on the main gear that drives the motor shaft. Number of main rotor blades is in range from two to seven, and usually it is two, three or five. The construction of a blade is very similar to that of an airplane wing, only with a smaller surface area.

Steering of the sixth degree of freedom, rotation around a vertical axis, is achieved by rotating the tail rotor blades. It is important to emphasize that this is not the only solution. There are helicopters without tail rotors, but with two main rotors that turn in the opposite direction.

Transmission moment from the engine is transferred to the main rotor and tail rotor through the system transmission and shaft. The system consists of a toothed power transmission and rpm regulator.

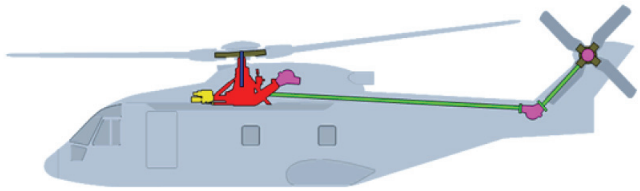

Fig.2 *Helicopter transmission [4]*

As it can be seen from the presented structural analysis of the helicopter, the helicopter noise sources are:

- propulsion system - engines,
- the main rotor,
- tail rotor (if applicable),
- transmission,
- air flow around the aircraft.

Fig.3 *Helicopter noise sources [5]*

4. OBJECT OF MEASUREMENT

Object of measurement noise is the helicopter SA341H French company "Aérospetiale" which was produced under license in the airplane factory "SOKO" in Mostar. It is a light multipurpose helicopter for use in civil and military aviation. The test helicopter is attack helicopter used for anti-armor rockets and firing low-speed targets in the air within of the Air Force of the Serbian Army.

Fig.4 *Helicopter SA341H "Gazelle-gamma" AFAS*

The helicopter has engine of type Astazou IIIB produced at the plant "May 21st" in Rakovica. It is a gas-turbine jet engine with fixed engine turbine, composed of the stator and rotor parts of axial and centrifugal compressors and turbines three-steps.

The aim of the study was to compare the level of noise emitted by the helicopter to the noise emitted by engines of similar power, design, and performance, but with a different number of main rotor blades, which are used in aviation in the Republic of Serbia.

Some characteristics of the engine, which can affect the production of noise, are:

RPM of tail rotor ....5774 rev / min

RPM of starter generator ....7808 rev / min

RPM of alternator.......................11 968 rev / min

Flow within compressor .... 2.6 kg / s

From the comparative table, it can be seen that the helicopter SA341H has similar characteristics as the helicopters B-206B and Robinson R44 Clipper.

Table 1 *Technical characteristic of helicopters*

	SA 341H	B-206B	R44
Length [m]	9.53	12.11	9.00
Width [m]	2.04	2.33	1.28
Height [m]	2.20	2.83	3.30
Kerb weight [kg]	850	777	658
Diameter MR [m]	10.50	10.16	10.06
No. blades MR [which]	3	2	2
Rpm MR [rev/min]	378	395	
Diameter TR [m]	0.69	1.65	1.50
No. blades TR [which]	13	2	2
Engine	Astazou IIIB	Rolls-Royce 250-c20J	Lycoming Io-540-AE1A5
Type of engine	gas turbine	gas turbine	piston
Type turbine engine	fiksna	slobodna	/
Engine power [kW]	440	313	183
Rpm engine [rev/min]	43500	53519	2718

From the standpoint of the analysis of noise generated by the helicopter as a source it is important to note that there are some structural differences between the two types of helicopters. Engine types are different, but with similar forces. However, Astazou engine has two modes - with relant and full throttle. Rolls-Royce Motors and Lycoming have a third mode called full correction, which corresponds to Astazou mode with full throttle. Full throttle mode in the two engines corresponds to rotor rpm when the engine load is approximately 93%.

In the transmission system of the helicopter SA341H there is centrifugal clutch, which is not the case with the other two helicopters. The result of such a design solution is that during engine work inn a relant mode of SA341H there is no turning of the rotor, which is not the case the other two helicopters.

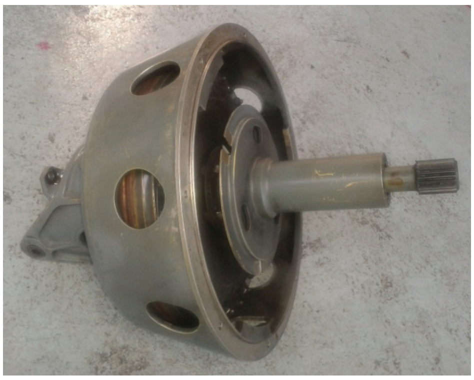

Fig. 5 *The appearance of the centrifugal clutch SA341H*

The tail rotor on the helicopter SA341H belongs to turbine type, i.e. it is built into the wing structure of vertical tail stabilizer, while the other two helicopters have free style tail rotor. For that reason SA341H helicopter has a smaller diameter of the tail rotor and has more blades, even though the function is the same.

It is also important to note that the helicopter is fully functional from technical and flying stadpoints, which was confirmed by examining the service documentation of the helicopters. The functional correctness comprises also resource status of each part of helicopters, engines and equipment.

5. METHODOLOGY

The measurement was performed at the central helicopter landing field on Ladjevci airport near Kraljevo. The helicopter was placed on a concrete base with no slope and oriented in the East-West directon. The closest barriers were located at a distance larger than 150 m. Weather conditions were established by instrument Testo 410-2, and the parameters of the time were clear sky, ambient temperature of 28°C, humidity of 31%, and the wind velocity of 3 m/s from East-Southeast.

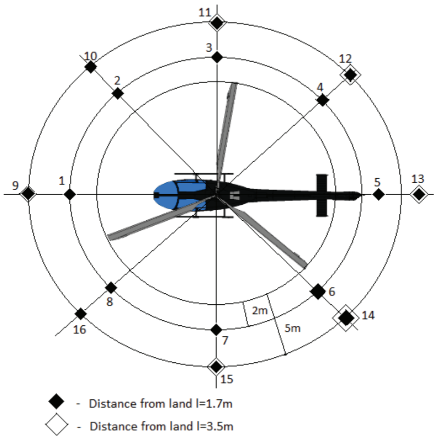

Fig.6 *Measuring points around the helicopter*

Sixteen measurement positions were selected, as it is shown in Figure 6. Th points were uniformly distributed with angular spacing of 45° relative to the helicopter centerline, starting from the axis of the helicopter in front of the cabine. They had distances 2 m and 5 m from the extreme edge of blade of the main rotor and vertical tail stabilizer in the direction of the helicopter centerline. At a distance of 2 m, measurements were carried out at a height of 1.7 m, and at a distance of 5 m, measurements were conducted at two heights: 1.7 m and 3.5 m. The duration of the measurement was 60 seconds, except for height of 3.5 m, where the measurement time was 30 seconds.

The measurement was made in pauses between the flights, and measurements of noise of during the take off phase were not performed.

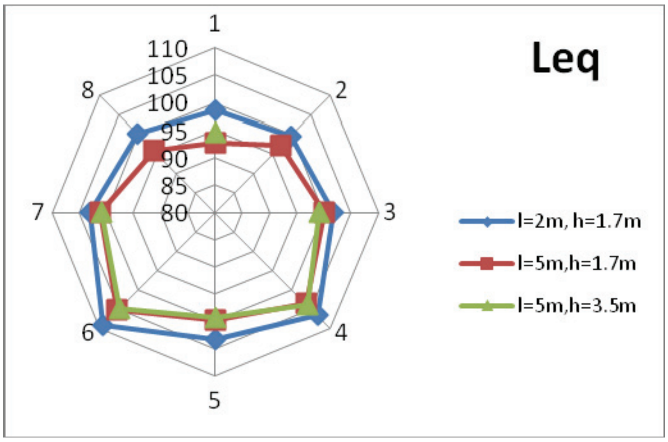

Fig. 7 *The equivalent noise levels at the measurement points*

Measurement equipment consisted of:

- Microphone unit Brüel & Kjær type 4188-A-021
- Acquisition card Brüel & Kjær Type 3560-B-120
- Notebook Acer Aspire 5732Z,
- Software Brüel & Kjær type Data Recorder.

6. RESULTS AND DISSCUSION

For data processing was used the software package Matlab. The analysis was performed in two ways:

- Analysis of time variation,
- Frequency analysis.

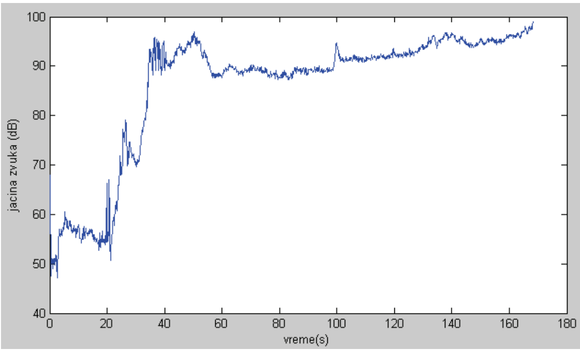

Fig. 8 *The level of noise taken at measuring point 3 during start of engine and rotor*

When the analysis of time variation was performed, averaging was done every 0.125 s, with a sampling frequency of 8192 Hz. This choice was made because the research is primarily intended for the purposes of protection from urban noise, and the rules of construction acoustics were applied. It is shown that in this way the noise spectrum covered spectra of all important noise sources on the investigated helicopter.

The measurement results are presented by a spatial equivalent noise level diagram shown in Figure 7.

The results of measurements during engine start from zero to full throttle are shown in Figures 8 and 9:

Because of the variety of design and operating principles of engines and rotors at relant, it is not possible to compare the noise levels emitted SA341H helicopter helicopters with B-206B and R44 in that regime.

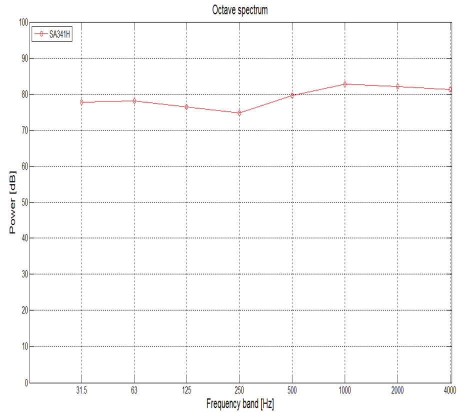

Fig. 9 *Octave-band analysis of noise measurements taken at measuring point 3 during engine and rotor start*

SA341H helicopter noise level at full throttle, measured from a distance of 2 m from the edge of the blade of the main rotor taken at measuring point 6, is comparable to the noise levels of helicopters B-206B and R44 at full correction, as shown in Figure 10 [3]:

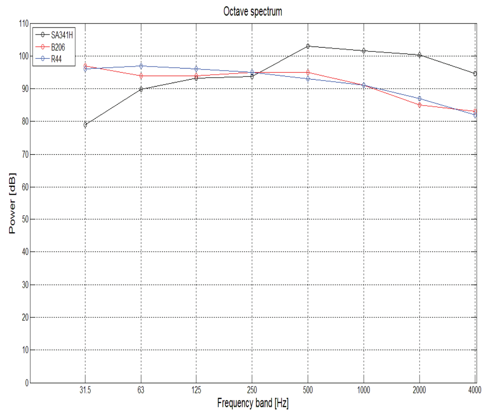

Fig.10 *Octave-band noise in full throttle for helicopters SA341H, B-206B and R44*

The noises levels emitted by helicopters B-206B and R44, shown in Figure 10, were obtained by measuring at the distance of 3 m from the edge of blade of the main rotor [3]. Figure 9 shows octave-band noise during starting of the engine and rotor, taken at measurment point 3. High frequency noise is emitted by the compressor and turbine rotary engine parts, and the low frequencies noise is consequence of rotation of the main and tail rotors.

From the Figures 8 and 9 the following may be concluded:

- During the period 0-22 s variations of the level of noise are caused by operation of the engine ingnition and combustion of the mixture in the combustion chamber during ingnition;
- During the period from 22-45 s starts turning of the motor shaft and turning of compressor and turbine startup engine parts, causing a sudden jump of the noise level;
- During the period 45-48 s the engine is running at relant;
- During the period 48-57 s arises hitching i.e. transmission of torque from the engine to the main rotor through the centrifugal clutch,

- During the period 60-170 s engine and rotor comes to the full throttle regime.

From the Figure 10 it can be concluded that the high noise levels (over 100 dB) occur arund the frequency of 40 Hz and in the frequency range of 400-2000 Hz, which indicates that the rotor and the engine produce similar levels of the noise. This spectrum is characteristic for the measurement points exposed to the higher influence of engine noise, because the exhaust pipe is slightly angled to the left, relative to the helicopter centre line, looking in the direction of the helicopter flight.

7. CONCLUSIONS

The measurements of noise levels of helicopter SA341H by the selected methodology showed that the noise levels at the measuring points have similar values for both distances from the edge of the main rotor blade, and that they can be compared to the values shown in Figure 10, which were measured at distance of 3 m. This paper used the noise levels at a distance of 2 m from the edge of blade of the main rotor.

By performing an analysis of the octave-band noise with SA341H, B-206B and R44 helicopters, the following conclusions can be drawn:

- Helicopter SA341H creates a higher level of noise at the frequencies close to 40 Hz, which corresponds to noise from the main rotor, but at other frequencies in the frequency range of 31.5-125 Hz, that also show the influence of main rotor noise levels, the helicopter SA341H has lower noise levels than the helicopters B-206B and R44.
- Helicopter SA341H has approximately the same level of noise as helicopters B-206B and R44 in the frequency range of 150-300 Hz, which corresponds to the impact of the tail rotor;
- Helicopter SA341H has higher noise levels than helicopters B-206B and R44 in the frequency range of 400-2000 Hz, corresponding to the impact of the engine.

In order to determine more reliable values of noise levels emitted by the main rotor, it is necessary to peform measurements with fixed flight controls, to reduce the impact of a sense of the pilot to maintain of the main rotor rotation in one plane. However, it can be concluded that helicopter with three blades in the main rotor emits less noise in low frequency range than helicopters with two blades in the main rotor. Higher noise levels in the high frequency spectrum of of the helicopter SA341H, compared to B-206B and R44, is expected because of the the engine that the helicopter SA341H uses.

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