

ACOUSTIC CHARACTERISTICS OF THE CABIN OF THE RESEARCH PLATFORM ON THE AIRBAG IL-PRC-600M

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Abstract

Hovercrafts are a universal means of transport intended for use on flat surfaces such as water, ice, snow, swamp, or sand. They are used in rescue operations and patrolling difficult areas inaccessible to other means of transport. The Institute of Aviation conducted acoustic measurements inside the cabin of the hovercraft to determine the source of the noise and the sound pressure exerted on the pilot and passengers. Assessment of the sources of noise in the cabin is made using the acoustic beamforming method. Assessment of the level of noise to which a pilot is exposed during the operation was prepared on the basis of a standard specifying the requirements and methods of determining occupational noise exposure [1].

The test results indicate a significant penetration of noise from the drivetrain into the cabin. It is recommended that a hovercraft pilot and operators use hearing protection in some specified conditions and during testing. Thus it is pointed out in the summary that additional soundproofing of the cabin is needed. The points of the greatest penetration of noise into the interior have been indicated.

Keywords: noise, acoustics, acoustic, beamforming, hovercraft, cabin.

1. INTRODUCTION

Hovercrafts can have multiple applications and have been used for years. However, they have not been popular enough to be a subject of more extensive research with regard to the noise they generate. No standards or guidelines defining how to conduct research that would allow for unambiguous, reliable and verifiable determination of the level and nature of the noise generated and optimal operating conditions have been developed so far. The measurements were carried out so as to assess vibration and acoustic properties of a medium sized hovercraft with regard to their impact on the pilot and passengers and to develop the methodology of noise measurement inside a modern, newly designed means of transport. The ecology suggestions presented in the present paper [2], [3] were taken into account while developing ways of measuring the noise level inside the cabin. The measurements of

sound pressure level and the sound frequencies transmitted by the drive system into the inside of the cabin were performed during testing.

The analyses carried out included:

- the visualisation of sound sources in the form of acoustic pressure distribution maps displayed against the background of the object tested,
- the evaluation of the noise level to which the hovercraft pilot is exposed at work.

The sound source localization was assessed using an acoustic camera and acoustic beamforming method [4]. The pilot's exposure to noise was made by measuring the sound pressure level using a microphone placed in the cabin, and the result was evaluated against the standard PN-ISO 9612:2011 [1].



Fig. 1. Hovercraft PRC-600M during noise level tests. [W. Krzymień, 2016]

2. THE OBJECT OF TESTS AND MEASURING EQUIPMENT

The object of the study was the hovercraft PRC-600M owned by the Institute of Aviation and serving as a laboratory-platform placed on an airbag and intended to test the equipment and new construction technologies [5]. The hovercraft was placed on concrete and fastened with ropes. There was only a pilot and the measuring equipment (microphones) inside during the tests.

The tests were conducted at various engine speeds with the door either open or closed. Engine revolutions ca. 4000 rpm were assumed to be typical of a hovercraft in operation. This corresponds to the fundamental frequency of vibration: ca. 67 Hz (engine speed), ca. 19 Hz (fan speed) and ca. 153 Hz (fan speed multiplied by the number of blades).

The measurements were taken using a set of equipment consisting of: a microphones array, a ½" microphone, the LMS SCADAS recorder and a computer with LMS Test. Lab HD Acoustic Camera.



Fig. 2. Hovercraft PRC-600M while measuring a noise level in the cabin. [W. Krzymień, 2016]

3. TEST METHODS

Localization of sound source was defined using an acoustic beamforming method [4,6]. The method consists in simultaneous measuring of acoustic pressure by means of numerous microphones mounted in the circular array of an acoustic camera. A sound source localization is determined based on phase differences of sound waves reaching particular microphones and on sound pressure level measured by the microphones.

Measurements and an analysis of the results were performed using the LMS Test.Lab HD Acoustic Camera software. As a result of analysis, the amplitude-frequency characteristics of the sound pressure level were obtained as well as acoustic pressure distribution maps plotted against the background of the tested object.

The determination of the pilot's and crew's daily noise exposure in the cabin was made using the method based on the PN-EN ISO 9612:2011 standard [1]. Sound pressure measurement was carried out near the pilot's ear during various operating conditions of the hovercraft drivetrain. These states were assigned to particular stages of the hovercraft flight (see Section 5). Based on the measurement data, the daily noise exposure was determined.

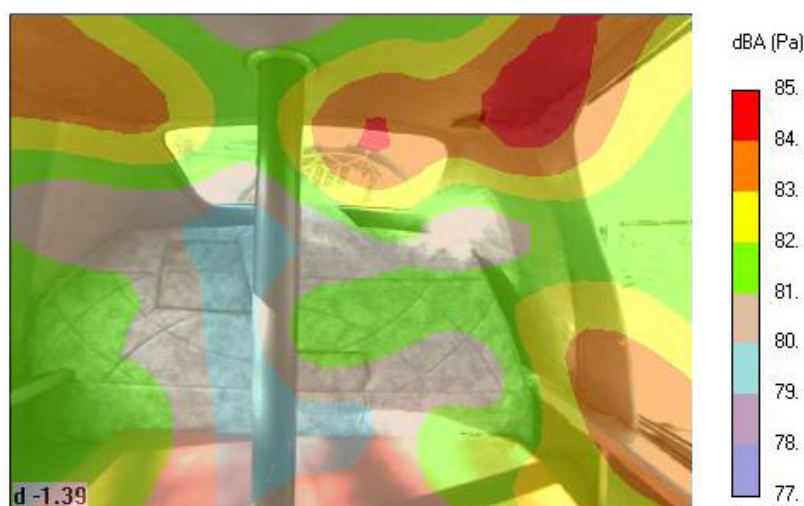
4. SOURCES OF NOISE IN THE CABIN

In order to determine the sources of noise in the cabin, a microphone array integrated with the HD camera was placed facing the left and right doors (Fig. 2) and the fan. The analysis also included sound recordings ranging from several to tens of seconds.

The following figures show the distribution of noise at engine speed of ca. 4000 rpm on the surface of the rear wall of the cabin: for the full range of frequencies tested (Fig. 3) and for the narrow range of 2150 to 2550 Hz (Fig. 4), for which an increase in the acoustic pressure level perceptible on the amplitude-frequency characteristic was recorded.



Fig. 3. The distribution of the noise sources in the hovercraft cabin in a broad frequency range, engine speed 4000 rpm, the door opened [S. Cieślak, 2016]



Rys. 4. The distribution of the noise sources in the hovercraft cabin. Frequency range: 2150-2550 Hz, engine speed 4000 rpm, the door opened [S. Cieślak, 2016]

Based on Fig. 4 it can be concluded that vibrations of the monocoque construction of the cabin have a great share of higher frequencies.

Measurement of noise from the side doors were taken in order to get information about the muffling effect of the door and the impact of the open door on the noise level in the cabin. The results of the measurements indicate quite little muffling ability of the doors, i.e. closing of the door reduces the sound level by mere 2-3 dB (A).



Fig. 5. The distribution of the noise sources on the left wall of the cabin – the door closed.
[S. Cieślak, 2016]



Fig. 6. The distribution of the noise sources on the left wall of the cabin – the door opened.
[S. Cieślak, 2016]

The figures also point to the fact that the drive system is also a source of noise.

Diagrams in Fig. 7 show a correlation between the acoustic pressure and engine speed for different sources of noise in the cabin. The sound pressure values were recorded by reading the individual sound source maps.

The curves and values confirm a marginal muffling effect of the door and proportionally increasing correlation between a noise level and engine speed.

Opening or closing the door does not influence the noise inside the cabin. At the same time the sound source maps for three test matrix settings indicate that the maximum noise level is generated by the rear wall and to a lesser extent by the side walls.

It is also noticeable that the noise emitted by the right door is greater by 1-2 dB than that of the left door. This is due to the location of the exhaust pipe on the right side and the asymmetrical noise emission produced by the fan – deviation of the jet stream to the right.

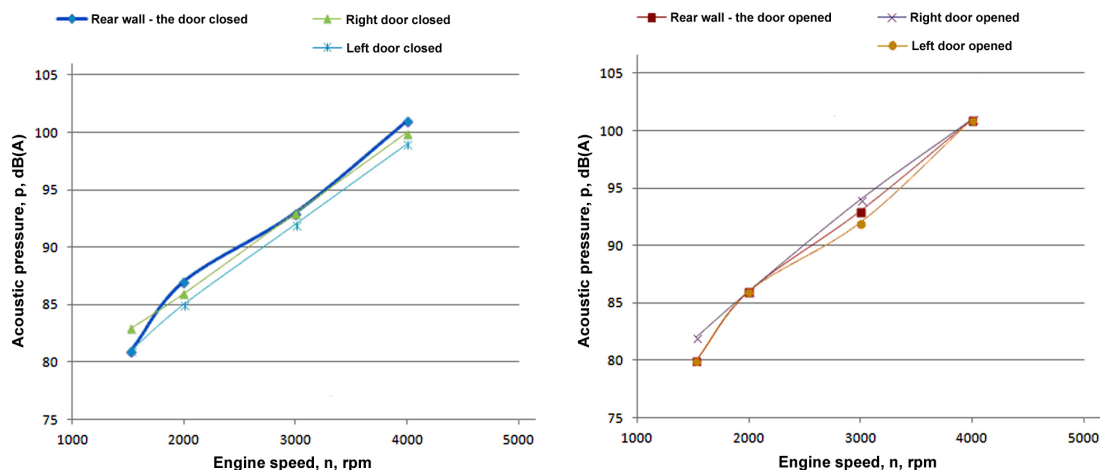


Fig. 7. A correlation between the acoustic pressure and engine speed for different sources of noise in the cabin for both the open and closed doors. [S. Cieřlak, 2016]

5. PILOT'S NOISE EXPOSURE MEASUREMENT

The noise affecting the crew was measured using a microphone placed on a tripod near the pilot's right ear (Fig. 2). A sound pressure level was measured during a slow increase of the engine speed. As a result of the FFT analysis of the measured signal the amplitude-frequency diagram of the sound pressure level was obtained. The graph in a 1/3 octave format is shown in Figure 8.

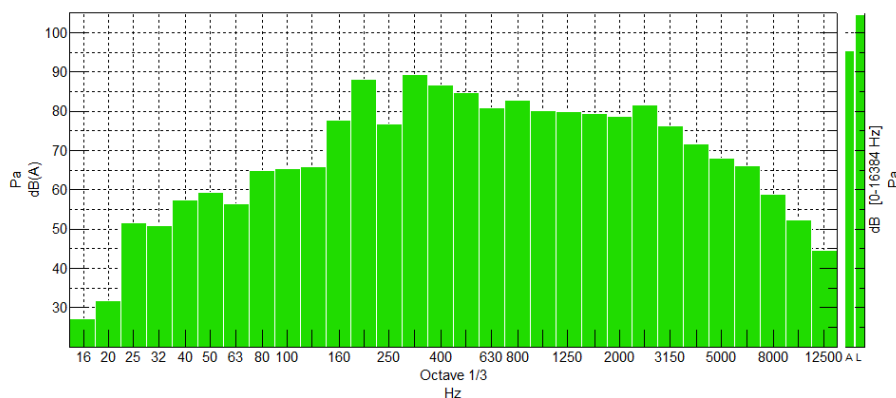


Fig. 8. Amplitude-frequency diagram of the acoustic pressure in the cabin. [S. Cieřlak, 2016]

In order to assess the pilot's exposure to noise and schedule the measurements, the working day including 10 patrol flights each ca. 30 mins. long was taken into account. Each flight involves: working at idle engine speed (warming up, cooling), accelerating and braking, flying (ca. 4000 rpm), flying at top speed and reducing the flight speed (in appropriate proportions). Such a division into separate types of activities served as a basis for measuring a sound pressure level according to correction A.

The results of individual measurements of the equivalent sound pressure level $L_{p,A,eqT,m,i}$ for activities investigated were inserted into a spreadsheet of the already mentioned standard. Furthermore, $L_{p,A,eqT}$ values were obtained for each activity. This was the basis for determining the daily value of the PRC-600M hovercraft pilot's exposure and a confidence level:

$$L_{EX,8h} = 88 \text{ dB at } U = 1.6 \text{ dB}$$

The measurements taken during tests show that the permissible noise level is exceeded by ca. 3 dB, which means (at the operation time assumed) that it is necessary to use hearing protection devices as indicated in the PN-N-01307:1994 standard [7]. These recommendations are introduced in the training program for students of technical universities [8].

Noise level tests conducted inside the cabin are one of the fields in which the Institute of Aviation specialises [9]. The measurement methodology developed can be applied to other flying objects [5].

6. CONCLUSIONS

1. The high level of noise in the cabin stems from vibrations which are transmitted through the structure.
2. The top sound pressure values determined for the cabin interior are similar at three different directions (rear wall, right door, left door) to which the microphone array is set. The highest difference between the values determined does not exceed 2 dB.
3. For a hypothetically assumed workday of a PRC-600M hovercraft pilot, which day covers all the activities investigated, the exceeding of the permissible noise exposure level with reference to eight-hour workday have been recorded:

$$L_{EX,8h} = 88,0 \pm 1,6 \text{ dB } (L_{EX,8h} > 85 \text{ dB}).$$

The employer, in accordance with the standard for such conditions, is obliged to provide hearing protection devices for the pilot and staff in the hovercraft when they perform their operational tasks.

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WŁAŚCIWOŚCI AKUSTYCZNE KABINY PLATFORMY BADAWCZEJ NA PODUSZCE POWIETRZNEJ IL-PRC-600M

Streszczenie

Poduszkowce stanowią uniwersalny środek transportu przeznaczony do poruszania się po płaskich powierzchniach takich jak woda, lód, śnieg, bagna, piach. Znajdują zastosowanie w ratownictwie i patrolowaniu trudnych terenów trudno dostępnych dla innych środków transportu. W Instytucie Lotnictwa przeprowadzono pomiary akustyczne wewnątrz kabiny poduszkowca w celu określenia źródeł hałasu oraz ciśnienia akustycznego działającego na pilota i pasażerów. Ocenę źródeł hałasu w kabinie wykonano przy pomocy tzw. holografii akustycznej 3D. Ocenę poziomu hałasu, na jaki narażony jest pilot w czasie pracy przygotowano na podstawie normy określającej wymagania i sposoby wyznaczania zawodowej ekspozycji na hałas [1].

Wyniki badań wskazują na znaczne przenikanie do kabiny hałasu, którego źródłem jest układ napędowy. Przy pewnych warunkach eksploatacji oraz podczas badań zalecane jest stosowanie ochronników słuchu na stanowisku pracy pilota poduszkowca i operatorów. W podsumowaniu pracy zalecono dodatkowe wytłumienie tylnej ściany kabiny. Wyznaczono miejsca największej intensywności przenikania hałasu do wnętrza.

Słowa kluczowe: hałas, akustyka, holografia akustyczna, poduszkowiec, kabina,