Vibrations in Physical Systems 2020, 31, 2020312 https://doi.org/10.21008/j.0860-6897.2020.3.12

Vibroacoustic Analysis of the Polish Pharmacy Robot Fablox

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Abstract

This paper describes the vibroacoustic analysis of the Polish pharmacy robots Fablox 1 and 2, as a part of research and development work to build an automated, modular pharmacy robot that meets the requirements of the false directive 2011/62 / EU to counteract the illegal distribution of drugs in the European Union. There were undertaken acoustics and vibration measurements of a pharmacy robot under typical working conditions. Point measurements of a one-third octave spectra of a sound pressure levels and RMS values of acceleration were made at measuring points located in the room and at the pharmacy robot. The acoustic tests were divided according to the location of the measurement points into measurements inside room and noise measurements in the near field of the pharmacy robots. The vibration measurements were made directly on the devices. Based on the analysis of the one-third octave spectra of the noise of the Fablox pharmacy robots, the sound components were determined, which are responsible for achieving high noise levels in room. The acoustic measurements in the near field at a distance of 15 cm from the unloading / front side of the pharmacy robot Fablox 1 and Fablox 2 in room, showed that the arithmetically averaged A-sound level on the measuring surface with closed housing for the movement of the head through all three loading modules is higher for the pharmacy robot Fablox 2 (66.9 dB) by 1.7 dB than the equivalent A-sound level for the Fablox 1 (65.2 dB). Due to the fact that the pharmacy robot is mostly used in the working environment in the pharmacy, the noise it generates has a large impact on employees and customers.

Keywords: noise and vibration measurements, vibroacoustic analysis, pharmacy robot, Fablox.

1. Introduction

The vibraoacoustic analysis of the Polish pharmacy robots Fablox 1 and Fablox 2 (Fig. 1) is a part of research and development work to build an automated, modular pharmacy robot that meets the requirements of the false directive 2011/62 / EU [1] to counteract the illegal distribution of drugs in the European Union. First part of vibroacoustic measurements of Fablox robots were performed by Poznan University of Technology in the field of vertical and horizontal linear drives equipped with two types of servo drives and one selected type of stepper motors, one type of loading and unloading head [2].

The Fablox pharmacy robot is designed to dispense drugs indicated by the operator in company packagings. It is mainly used in pharmacies and due to its shallow depth (from 70 cm), it can be used to replace regular shelves. This allows this innovative device to be introduced even to pharmacies that do not have a lot of space. Expansion is possible due to the modularity of the device, which consists of a control module and storage modules. The Fablox pharmacy robots work in the drug loading and unloading mode. For Fablox 1 loading of drugs takes place separetly for every box of drugs via an opening located on the side of the robot. For Fablox 2 loading of drugs takes place multiply via a vertical drawer located on the side of the robot in the control module. Unloading is carried out

through openings in the storage modules for both robots, which are equipped with a movable loading and unloading head that changes its position in two directions, horizontally and vertically. These movements are realized thanks to servo drives and stepper motors. In the initial phase of the robot's use, a pharmacist has to load drugs, which are automatically registered in a special computer system by a system of barcode readers and cameras. Then the drugs are placed in storage modules, which can hold from 1,000 to 1,300 drugs each, depending on the type of device [4]. The working time of the pharmacy robot depends on the number of orders for drugs from warehouse modules and the time of customer service.

Fablox 1

Fablox 2

Figure 1. Visualisation of the Polish pharmacy robots Fablox 1 and Fablox 2 [4].

Vibroacoustic measurements included detailed measurements of one-third octave noise spectra (A-weighted sound pressure levels) and RMS values of vibration acceleration in a room with installed pharmacy robot.

2. Acoustic measurements

The acoustic measurements were undertaken to identify the noisy elements of the pharmacy robot in order to reduce the noise [3]. There was used SVAN 979 (Svantek) first class sound and vibration meter and analyzer equipped with amplifier SV17 (Svantek) and microphone 40AN (GRAS). Due to the location of the measurement points, the acoustic tests were divided into measurements in a room 1.5 m above the floor and noise measurements in the near field, 15 cm from the pharmacy robot.

2.1. Acoustic measurements in room 1,5 m above the floor

Measurements of the noise of the pharmacy robot in the room were made at two measuring points P1 - from the unloading side, P2 - from the control module side (see Fig.2) at a distance of 1 m for the typical three representative operating modes of the Fablox robots:

• Mode 1 - drug loading by a pharmacist,
• Mode 2 - the loading manipulator loads drugs on the shelves (at this time the pharmacist does not load drugs),
• Mode 3 - the loading manipulator loads drugs on the shelves, and the unloading manipulator dispenses drugs (at this time the pharmacist does not load drugs, as in mode 2).

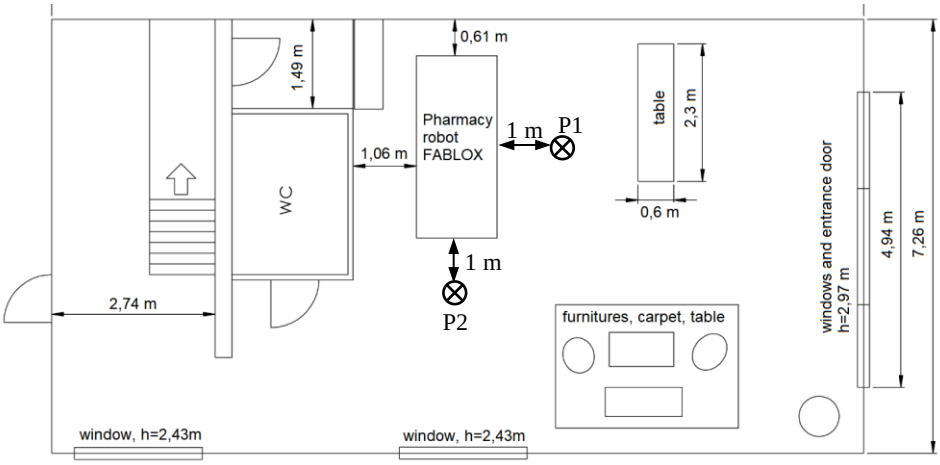


Figure 2. Location of measuring points around the Fablox pharmacy robots in research room of dimensions 13,6 m in length, 7,26 m in width and 3 m in height.

For Fablox 1 the mode 1 is a separate operation, which needs more time spent by the pharmacist to load drugs one by one. It was improved in Fablox 2 by installing vertical drawer, in which many drugs are placed at the same time, so the operating modes 1 and 2 became simultaneous. The measurement time was within a few work cycles (modes) of a pharmacy robot or in the range from 30 s to 5 minutes. The building, in which the research room was located with a wide window and entrance door, was located approximately 40 m from the expressway, hence the recorded measurement results may have distortions of the noise spectrum caused by higher background levels noise due to the moving of different types of vehicles. A test room was finished with gypsum plasters on the walls, a suspended plasterboard ceiling, ventilation grilles in the ceiling and ceiling lighting, concrete tiles imitating wood on the floor. There were elements of equipment and furniture in the room that increased the acoustic absorption of the room, however, significant reverberation in the room was noticeable.

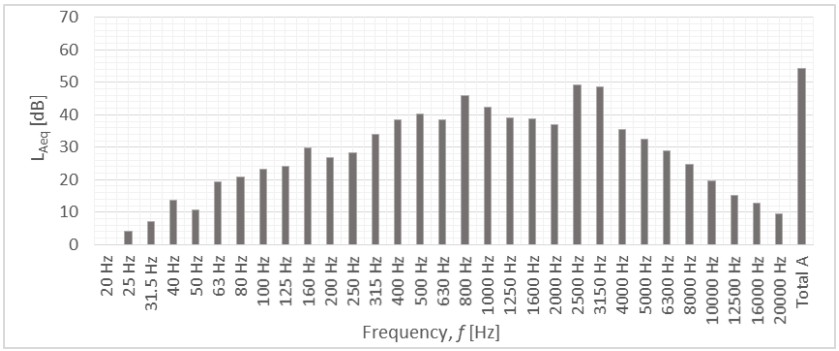
Table 1 presents the results of measurements of sound levels at individual measuring points around the pharmacy robot Fablox 1 and Fablox 2 in the room.

Table 1. Results of measurements of sound pressure levels at individual measuring points P1 nad P2 around the pharmacy robot Fablox 1 and Fablox 2 in the room.

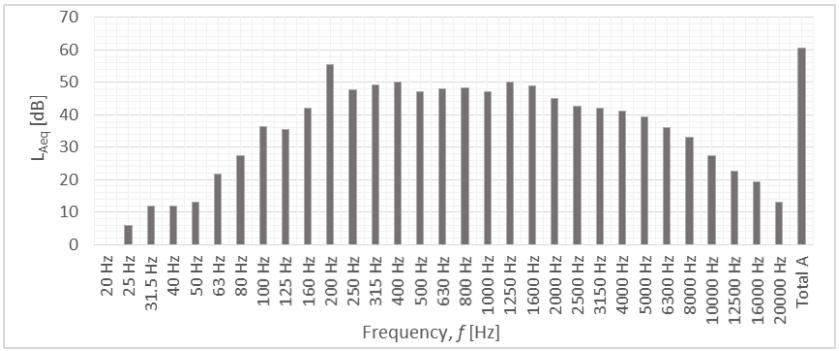
Point	Description	L_{Aeq} [dB]	L_{ASmax} [dB]	L_{Cpeak} [dB]
P1	**Fablox 1 - Mode 1**	54.3	63.7	78.2
	Fablox 1 - Mode 2	60.5	65.8	88.7
	Fablox 1 – Mode 3	62.3	72.3	97.9
	Fablox 2 - Mode 1 and 2	57.4	68.3	87.3
	Fablox 2 - Mode 3	57.0	66.9	86.9
	Background noise	39.3	46.7	70.8
P2	**Fablox 1 – Mode 1**	56.1	64.2	82.5
	Fablox 1 - Mode 2	60.6	66.0	89.4
	Fablox 1 - Mode 3	60.4	68.8	89.7
	Fablox 2 - Mode 1 and 2	56.3	66.3	87.2
	Fablox 2 - Mode 3	55.6	64.5	85.6
	Background noise	38.6	45.2	70.6

On the basis of the noise measurements contained in Table 1, it can be concluded that the loudest operating modes of the Fablox pharmacy robots are mode 2 and mode 3. In both cases we deal with the operation of a loading manipulator, which significantly increases the noise level in the room. The highest sound pressure levels were determined for Fablox 1 – Mode 3. Fablox 2 is much more quiet for this mode. The one-third octave noise spectrums for investigated operation modes for Fablox 1 and Fablox 2 were presented in Fig. 3 and Fig. 4, respectively.

Mode 1



Mode 2



Mode 3

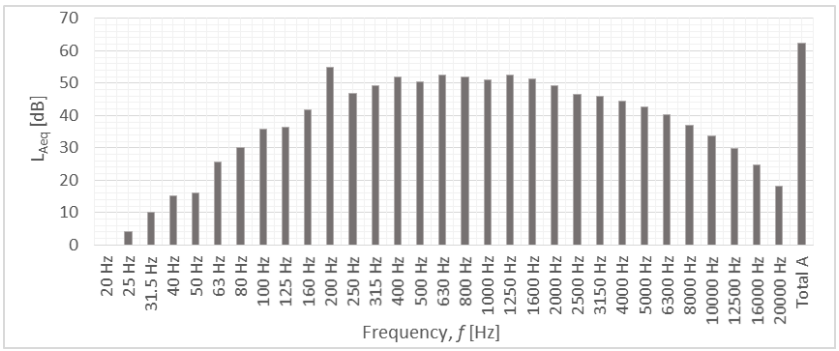
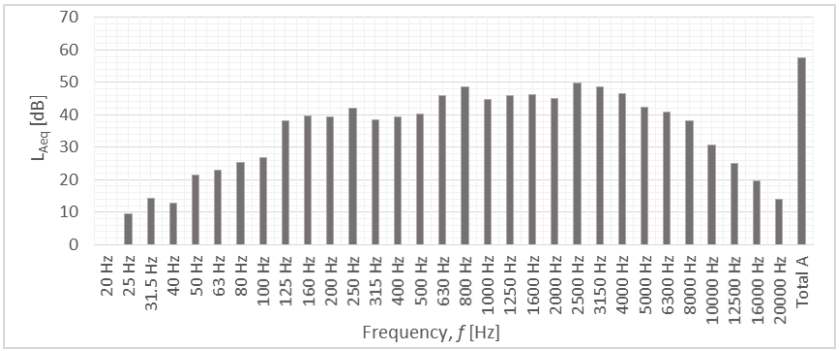


Figure 3. One-third octave noise spectrums measured in P1 for investigated operation modes for Fablox 1.

Mode 1 and 2



Mode 3

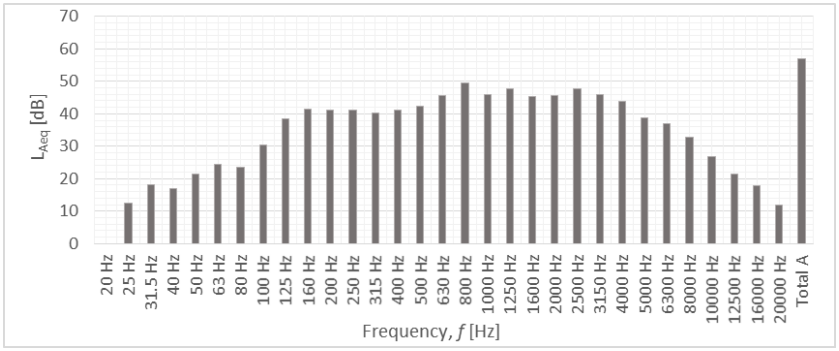


Figure 4. One-third octave noise spectrums measured in P1 for investigated operation modes for Fablox 2.

2.2. Acoustic measurements in the near field 15 cm from pharmacy robot

In Fig. 5 and Fig. 6 are presented the locations of measuring points and results of equivalent sound level A, L_{Aeq} [dB], in the near field at a distance of 15 cm form the unloading / front side of the pharmacy robot Fablox 1 and Fablox 2 in room. The manipulators work cycles were examined from the extreme left position to the extreme right position within a given module configuration including operation vertical drive with the closed housing.

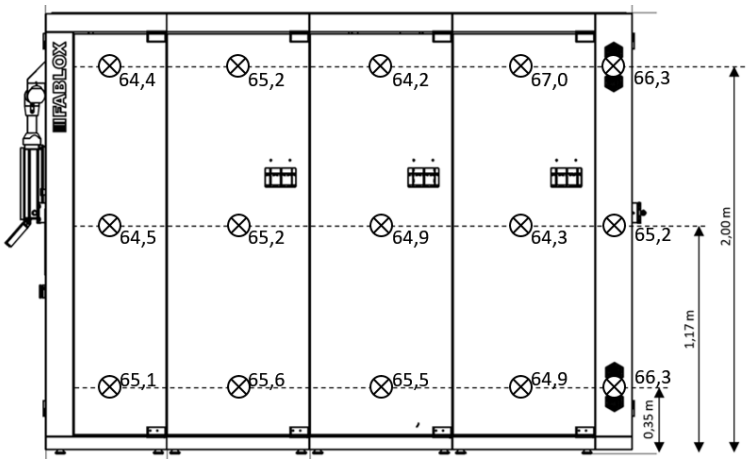


Figure 5. Equivalent sound level A, L_{Aeq} [dB], in the near field at a distance of 15 cm from the unloading / front side of the pharmacy robot Fablox 1.

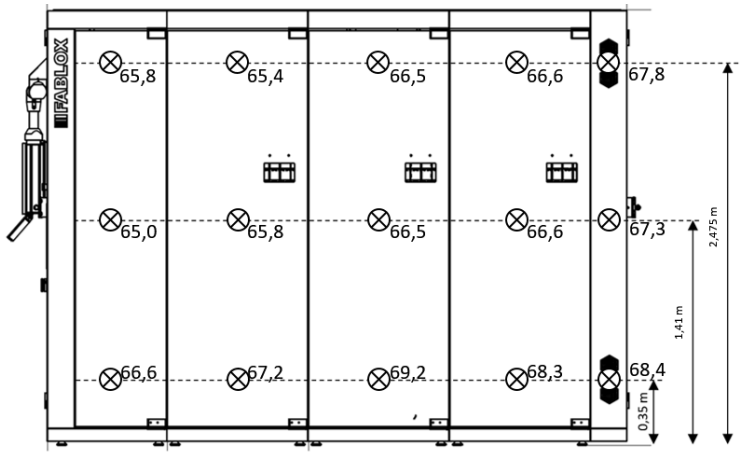


Figure 6. Equivalent sound level A, L_{Aeq} [dB], in the near field at a distance of 15 cm from the unloading / front side of the pharmacy robot Fablox 2.

Arithmetically averaged A-sound level on the measuring surface with the housing closed for the movement of the head through all three loading modules is higher for the pharmacy robot Fablox 2 (66.9 dB) by 1.7 dB than the equivalent A-sound level for the robot Fablox 1 (65.2 dB).

In Fig. 7 are presented example one-third octave noise spectrums measured in the near field at a distance of 15 cm from the unloading / front side of the pharmacy robot Fablox 1 and Fablox 2.

a)

b)

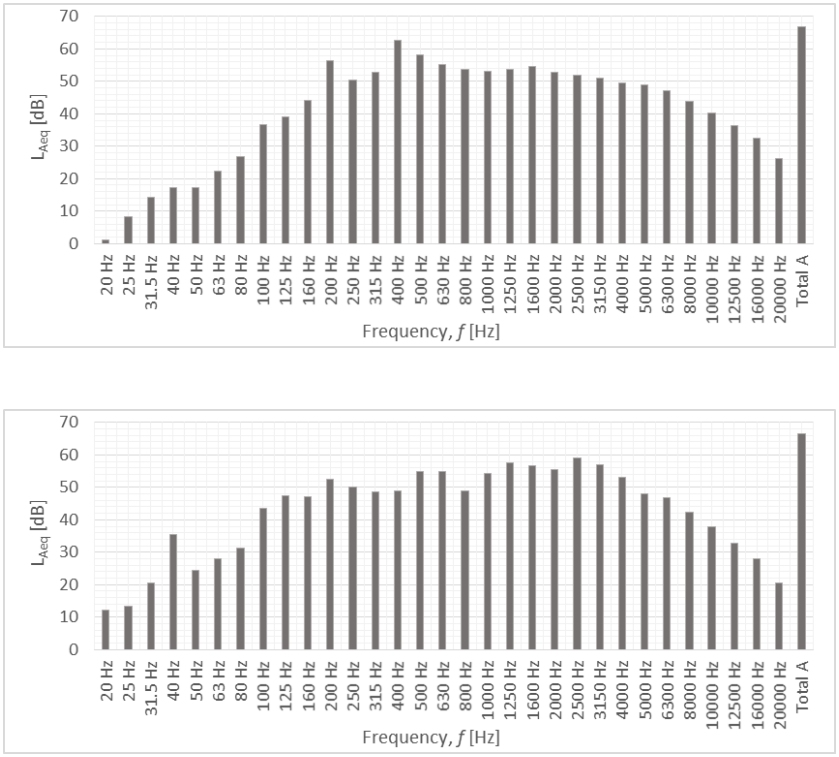


Figure 7. Example one-third octave noise spectrums measured in the near field at a distance of 15 cm from the unloading / front side of the pharmacy robots: a) Fablox 1, b) Fablox 2.

3. Vibrations measurements

Measurements of the one-third octave spectra of the RMS values of vibration acceleration at specific measurement points were performed by the use of SVAN 979 (Svantek) first class sound and vibration meter and analyzer equipped with accelerometer SV80 (Svantek). The measurement time was adapted to the measuring situation and, as a rule, was within a few work cycles (modes) of a pharmacy robot or in the range from 30 s to 5 minutes. The measurement directions were presented in Fig. 8.

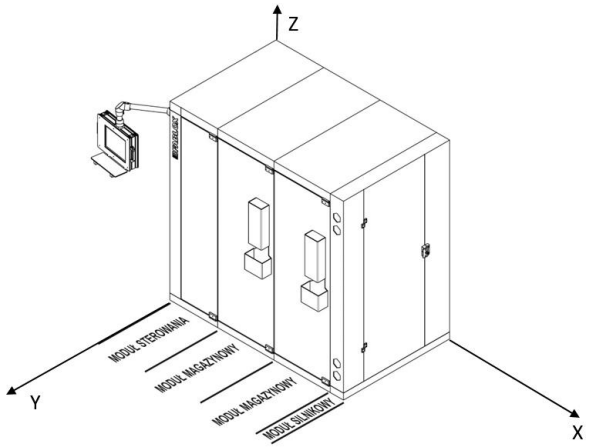


Figure 8. Vibration measurement directions of pharmacy robot Fablox.

The measurement points of vibrations for Fablox 1 are presented and described in Fig. 9.

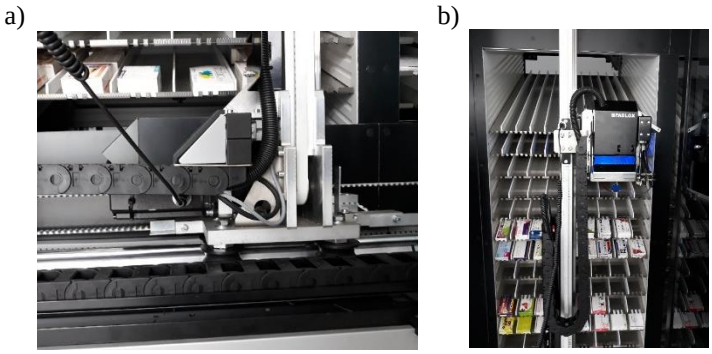


Figure 9. Vibration measurement points of the pharmacy robot Fablox 1:
a) on the horizontal drive motor, b) on the moving head.

The highest RMS values of the vibration acceleration of Fablox 1 were recorded on the horizontal drive motor during the operation of only the vertical drive (Fig. 10), which were 13.71 m/s^2 in the horizontal Y axis and 4.37 m/s^2 in the horizontal X axis. In the spectrum of RMS values of vibration accelerations in the horizontal Y axis the components in the one-third octave bands with the center frequencies of 2500 Hz and 3150 Hz are responsible for such a high value of vibrations. In the X axis, the highest RMS values of vibration acceleration were recorded in one-third octave bands with center frequencies of 1000 Hz and 1250 Hz.

A high RMS value of vibration acceleration for Fablox 1 was also recorded on the moving head during the operation of only the vertical drive, where a value of 7.65 m/s^2 was recorded in the horizontal Y axis. Movement of the head generates vibrations in one-third octave bands with center frequencies of 200 Hz and 400 Hz (Fig. 10). The vibrations are transferred to the floor for components in the same one-third octave bands with center frequencies of 200 Hz and 400 Hz, and for the higher harmonic frequency of 800 Hz.

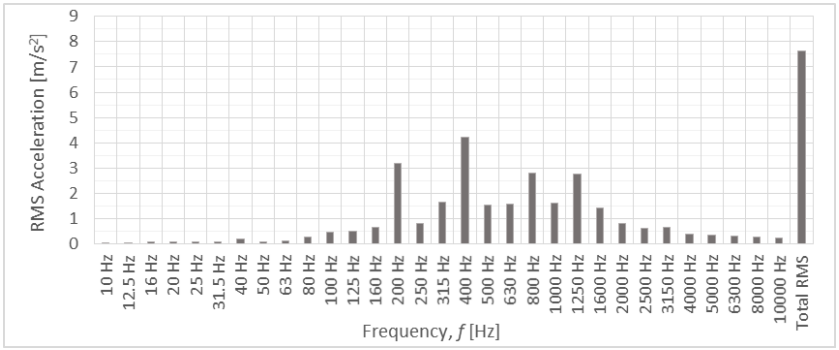


Figure 10. RMS values of vibration accelerations in the horizontal Y axis in one-third octave bands of Fablox 1 measured on the horizontal drive motor during operation of only the vertical drive.

For the Fablox 1 robot, the sound components in one-third octave bands with center frequencies of 200 Hz and 400 Hz dominate in the acoustic near-field and in the acoustic far-field in the room during the unloading head operation. Additionally, the vibration measurements show the presence of components in the same one-third octave bands on the floor in Z axis, as presented in Fig. 11.

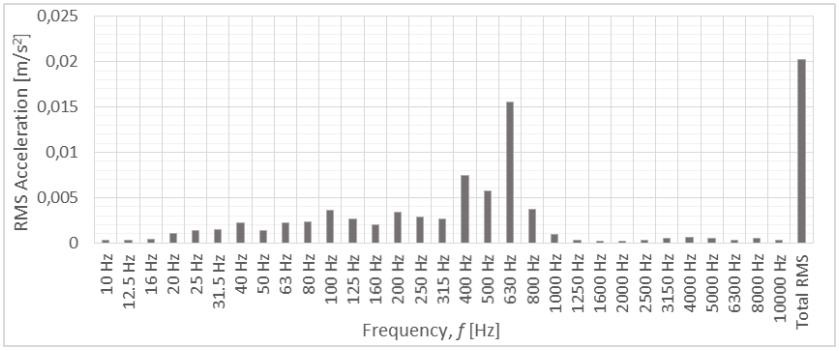


Figure 11. RMS values of vibration accelerations in the vertical Z axis in one-third octave bands of Fablox 1 measured on the floor during operation in the mode of maximum unloading and operation of vertical and horizontal drives.

Hence, in order to reduce both noise and vibrations of a pharmacy robot Fablox 1, one should start with vibration isolation and silencing the mechanisms responsible for the operation of the head. Next, the drive motors that introduce large vibrations into the system should be dealt with.
The measurement points of vibrations for Fablox 2 are presented and described in Fig. 12.

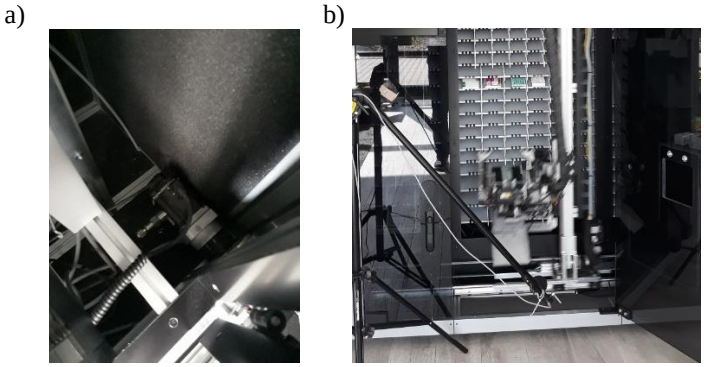
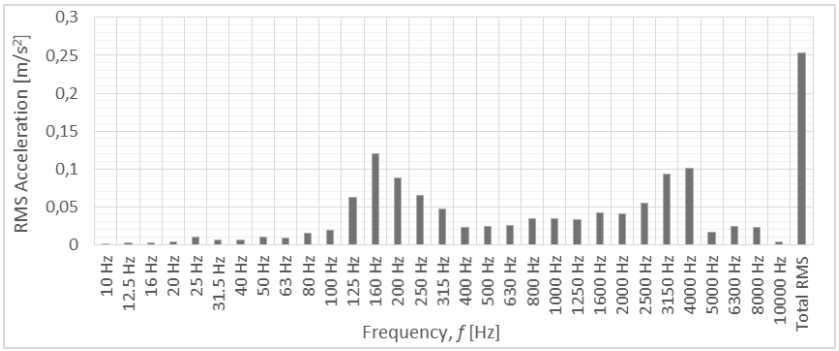


Figure 12. Vibration measurement points of the pharmacy robot Fablox 2: a) on the vertical drive motor, b) on the moving head.

The highest RMS values of vibration acceleration of Fablox 2 were recorded on the vertical drive motor during operation of this drive only, which were 45.0 m/s^2 in the horizontal Y axis and 43.3 m/s^2 in the horizontal X axis (Fig. 13). In the spectrum of RMS values of vibration accelerations in the horizontal Y axis the components in the one-third octave bands with the center frequencies of 2500 Hz and 3150 Hz are responsible for a high value of vibrations. In the X axis, the highest RMS values of vibration acceleration were recorded in one-third octave bands with center frequencies of 2000 Hz and 2500 Hz.

As in the case of the Fablox 1 robot, a high RMS value of vibration acceleration were also recorded on the moving head during the operation of only the vertical drive, where a value of 26.1 m/s^2 was recorded in the horizontal Y axis. Movement of the head generates vibrations in one-third octave bands with center frequencies 800 Hz and 1000 Hz. However, the RMS values of vibrations accelerations measured on the supporting structure of the Fablox 2 robot during operation in the maximum unloading mode and operation of vertical and horizontal drives reach the highest values in one-third octave bands with center frequencies of 630 Hz and 1250 Hz. They are transferred to the floor for the vibration components in one-third octave bands with center frequencies of 500 Hz, 630 Hz and 1250 Hz. For the pharmacy robot Fablox 2 the sound components in one-third octave bands with center frequencies of 800 Hz, 1250 Hz and 2500 Hz dominate in the acoustic near-field (Fig. 7b) and in the acoustic far-field (Fig. 4) in the room during the unloading head operation. The measurements of vibrations carried out during operation in the maximum unloading mode and operation of vertical and horizontal drives indicate that vibrations are transmitted to the floor in one-third octave bands with central frequencies of 500 Hz and 630 Hz, as presented in Fig. 14.

a)



b)

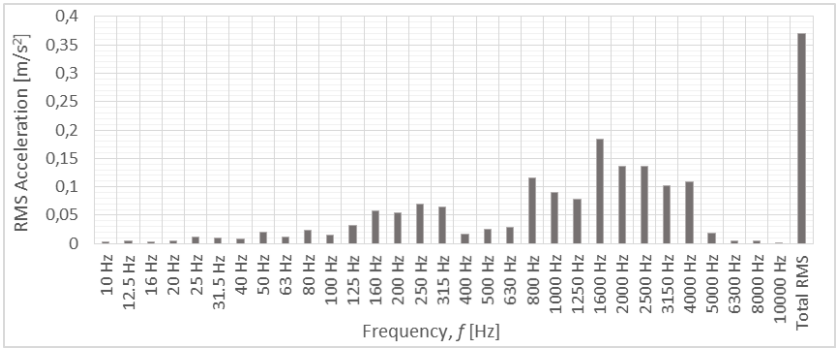


Figure 13. RMS values of vibration accelerations in the horizontal X (a) and Y (b) axis in one-third octave bands of Fablox 1 measured on the vertical drive motor during operation of this drive only.

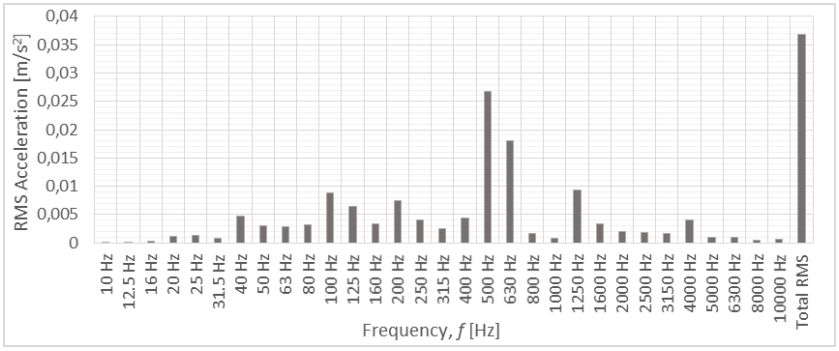


Figure 14. RMS values of vibration accelerations in the vertical Z axis in one-third octave bands of Fablox 2 measured on the floor during operation in the maximum unloading mode and operation of vertical and horizontal drives.

Hence, in order to reduce both noise and vibrations of the pharmacy robots, start with vibration isolation and silencing of the mechanisms responsible for the operation of the vertical drives and the heads.

4. Conclusions

The quiet operation of the pharmacy robot is very important for the work comfort of pharmacists and pharmacy customers. There were undertaken acoustics and vibration measurements of a pharmacy robot Fablox 1 and Fablox 2 under typical working conditions. On the basis of the acoustic measurements contained in the distance of 1 m and 1,5 m above the floor in room, it can be concluded that the loudest operating modes of the Fablox pharmacy robot are mode 2 and mode 3. In both cases we deal with the operation of a loading manipulator, which significantly increases the noise level in the room. The highest sound pressure levels were determined for Fablox 1 – Mode 3.

The acoustic measurements in the near field at a distance of 15 cm form the unloading front side of the pharmacy robot Fablox 1 and Fablox 2 in room, showed that the arithmetically averaged A-sound level on the measuring surface with closed housing for the movement of the head through all three loading modules is higher for the pharmacy robot Fablox 2 (66.9 dB) by 1.7 dB than the equivalent A-sound level for the Fablox 1 (65.2 dB).

To reduce both noise and vibrations of a pharmacy robot Fablox 1, one should start with vibration isolation and silencing the mechanisms responsible for the operation of the head. Next, the drive motors that introduce large vibrations into the system should be dealt with. In order to reduce noise and vibrations of the pharmacy robot Fablox 2, one should start with vibration isolation and silencing of the mechanisms responsible for the operation of the vertical drive and the head.

Acknowledgments

Author gratefully acknowledges that the study concerns to the contract No. 0612/2020/3 between Poznań University of Technology and Alutec K&K Polska sp. j. for the implementation of industrial research under the Wielkopolska Regional Operational Programme for 2014-2020. Project co-financed by the European Regional Development Fund. This work was also partially financed by the Polish Ministry of Science and Higher Education as a project No. 0612/SBAD/3558 and 0612/SBAD/3567.

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