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VIBRATIONS ON DRIVER POSITION OF AGRICULTURAL TRACTOR DURING MEADOW MOWING USING HIGH EFFICIENT DISC MOWERS

Summary

The paper concerns the subject of vibrations influence on driver body, generated by high efficient disc mowers while mowing and during transport on public roads and dirt roads. Information about accelerations of the head and the seat of machine operator were collected. Then these data were converted to the characteristics, which were compared with the limit values specified in ISO 2631. Allowable exposure times of the human body to the vibrations were defined and assessment of the risk of loss of control over the machine by vibration was performed.
***Key words**: operation of machinery, agriculture, health, safety, mowing, disc mowers, mechanical vibrations, vibration, field tests, measurements of acceleration, filtering of signals*

DRGANIA NA STANOWISKU KIEROWCY CIĄGNIKA ROLNICZEGO PODCZAS KOSZENIA ŁĄKI Z ZASTOSOWANIEM WYSOKOWYDAJNYCH KOSIAREK DYSKOWYCH

Streszczenie

W artykule podjęto tematykę wpływu wibracji na organizm kierowcy, generowanych przez wysokowydajne kosiarki dyskowe, podczas realizacji procesu technologicznego koszenia oraz podczas przejazdów transportowych po drogach publicznych i polnych. Zgromadzono informacje o przebiegach przyspieszeń głowy oraz siedziska operatora agregatu. Dane te poddano następnie przekształceniom i uzyskano charakterystyki, które skonfrontowano z wartościami dopuszczalnymi określonymi w normie ISO 2631. Zdefiniowano dopuszczalne czasy ekspozycji na drgania dla organizmu człowieka i dokonano oceny narażenia na niebezpieczeństwo utraty kontroli nad prowadzonym zespołem w wyniku wibracji.
***Słowa kluczowe**: eksploatacja maszyn, rolnictwo, zdrowie, bezpieczeństwo, koszenie, kosiarki dyskowe, drgania mechaniczne, wibracje, badania polowe, pomiary przyspieszeń, filtrowanie sygnałów*

1. Introduction

Mechanical vibrations existing in nature accompany the man in various fields of activity. The continuous desire to improve the quality of life with the participation of modern machinery and equipment causes increasing number of the sources of vibration harmful to humans. This aspect is particularly important in agriculture, which uses highly advanced and efficient machines. In this case the speed of a moving unit, type of maneuver and the type of agrotechnical operation have the significant impact on the nature of vibration. In addition, the conditions under which the entire process is carried out causes large loads (working on the heterogeneous ground containing obstacles such as stones and branches). Emerging vibrations transmitted to the operator's seat can damage the human body not only biologically, but also in terms of deterioration of the functional capabilities [6] and depending on the level of vibration may exert different effects. However, in relation to the conducted considerations the most severe is impairment of perception, which may cause sudden unintended change in direction of movement. As a result, mowing becomes less efficient. In extreme cases, this can lead to situations that threaten the health and life of the operator.

In the Industrial Institute of Agricultural Engineering in Poznan there was conducted a research on the effects of mowing process on emerging vibration and the impact of vibration on the human body was assessed. For the experiments, a set consisting of three large disc mowers Pottinger brand and Deutz Fahr tractor was adopted.

2. Purpose of research

Direct aim of the study was to determine the vibration acceleration waveforms on the seat and on the head of an agricultural machine operator. Experiments with different speeds and for various maneuvers during operation and during transport were performed. The obtained data were compared with the limit values set out in the legal standards, which define the acceptable amplitude limits of accelerations of vibration acting on the human body.

3. Object of research

The farm tractor Deutz Fahr Agrotron X720 was the object of research. Tractor had a mass of approx. 10.5 t, and was aggregated with a set of high-performance disc mowers with a total weight of approx. 2.5 t (fig. 1). The kit consisted of the following elements:

- Two mowers NOVACAT 8600 ED, attached to the rear three-point hitch,
- One mower NOVACAT 301, attached to the front three-point hitch.

The vibrations were recorded with acceleration sensors [4, 5]. Two measuring points were chosen. One sensor was placed on the tractor operator seat. The second sensor was mounted on the head. The sensors, measured the acceleration in three mutually perpendicular directions: on the operator seat a_{x_s}, a_{y_s}, a_{z_s} and on the head a_{x_g}, a_{y_g}, a_{z_g}. In fig. 2 there are shown the directions in which the measurement of accelerations was performed.

Source: own work

Fig. 1. Tractor Deutz Fahr Agrotron X720 with a set of Pottinger mowers
Rys. 1. Ciągnik rolniczy Deutz Fahr Agrotron X720 z zestawem kosiarek dyskowych marki Pottinger

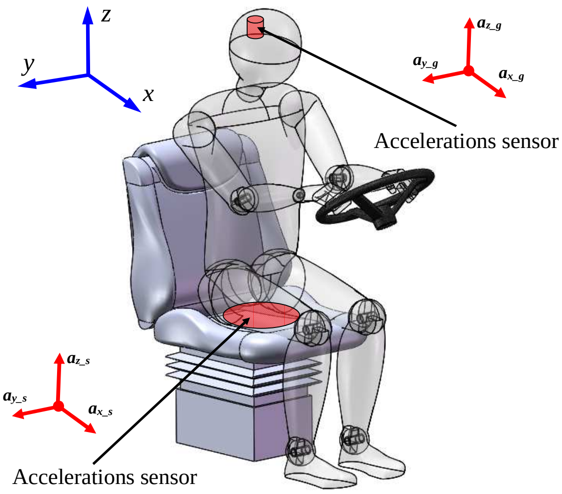

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Fig. 2. Directions of accelerations measurement
Rys. 2. Kierunki pomiarowe przyspieszeń drgań

The acceleration sensors (used during research) are three- direction piezoelectric sensors PCB Piezotronics, type 356A02. The mass of one sensor amounted to 10,5 g. Sensors to cards V8 LMS SCADAS Recorder V/ICP/TEDS 8-channel, 24-bit were connected. The sampling frequency amounted to 400 Hz. In fig. 3 computer with analyzer used during research is shown.

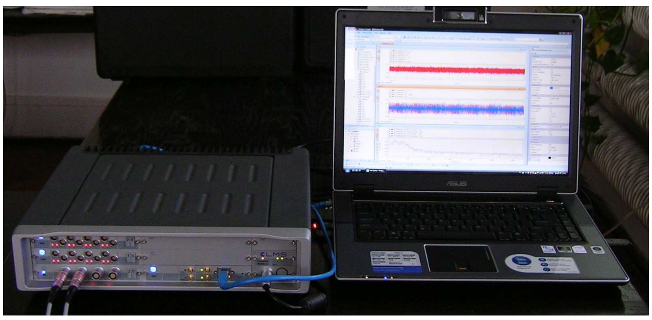

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Fig. 3. Computer cooperating with SCADAS Recorder analyzer
Rys. 3. Komputer współpracujący z analizatorem SCADAS Recorder

4. The test procedure and results

The assessment of human exposure to vibration having a general impact on the body was made by spectral method in accordance with ISO 2631 [2]. In fig 6 there is shown a procedure signal processing. Obtained RMS values of acceleration were referenced to the limit values of vibration acceleration [1], taking into account the time of their impact on the human body.

4.1. The research while mowing

The tests were carried out on the grassy ground at tractor speeds 5,0; 8,0 and 12,0 km·h^{-1}. The object of research is presented in fig. 4.

Source: own work

Fig. 4. The research object during mowing
Rys. 4. Obiekt badań podczas koszenia

Tests were carried out during straight driving and during turning at the end of the field. The duration of a single experiment was 5 minutes, to obtain stationary waveform [8]. In fig. 5 there is shown a vertical accelerations of driver's seat (in the z-direction) during mowing at the speed of 5 km · h^{-1}.

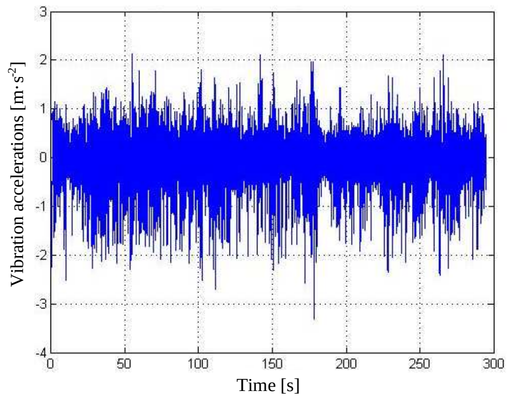

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Fig. 5. The signal recorded on operator' s seat corresponding to vertical vibrations (z-axis direction) during mowing at a speed of 5 km·h^{-1}
Rys. 5. Sygnał zarejestrowany na siedzisku operatora reprezentujący drgania pionowe (kierunek osi z) podczas koszenia z prędkością 5 km·h^{-1}

The data were then transformed (as shown in fig. 6), after that the RMS values of the acceleration were calculated and it was applied to the time charts (fig. 7). The limits did exceed neither the horizontal nor the vertical direction. Thus, it is possible to mow with this speed for 8 hours a day, without adverse effects of vibrations on the human body.

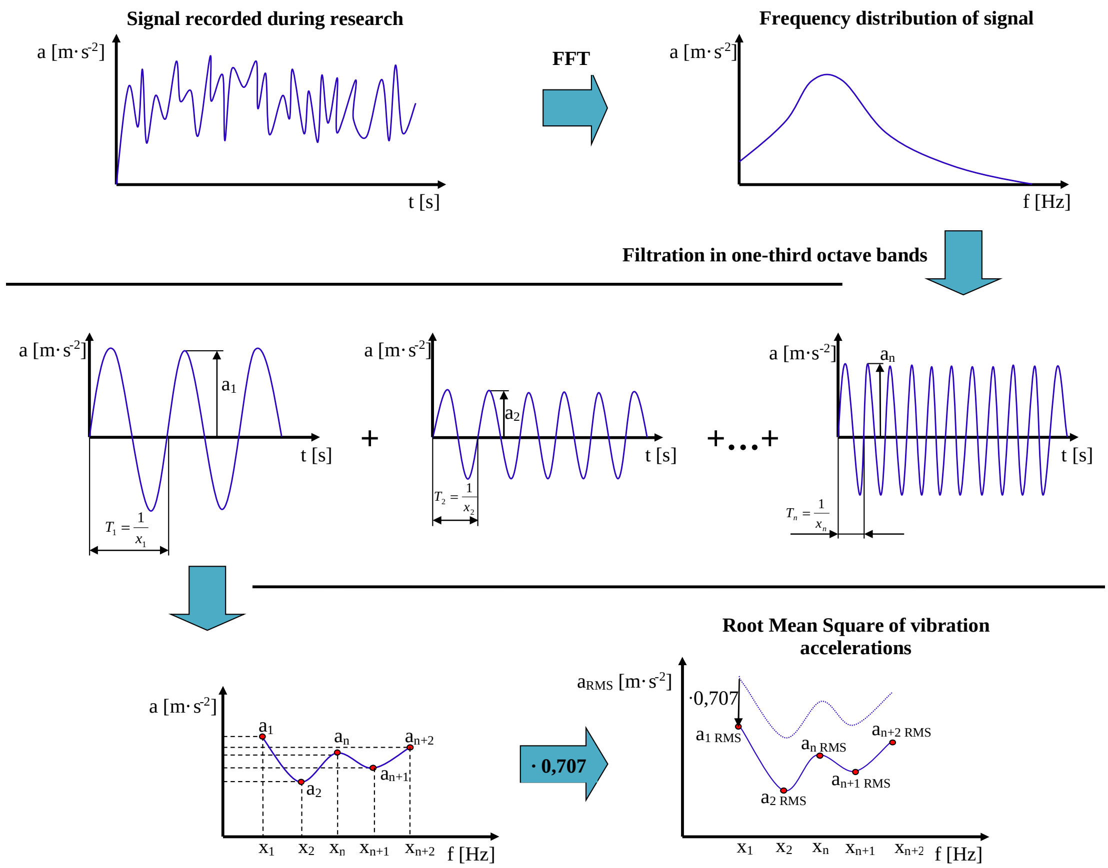

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Fig. 6. A diagram of signal processing to obtain Root Mean Square of vibration accelerations in frequency domain

Rys. 6. Schemat obróbki sygnału zastosowany w celu określenia wartości skutecznych przyspieszeń drgań w dziedzinie częstotliwości

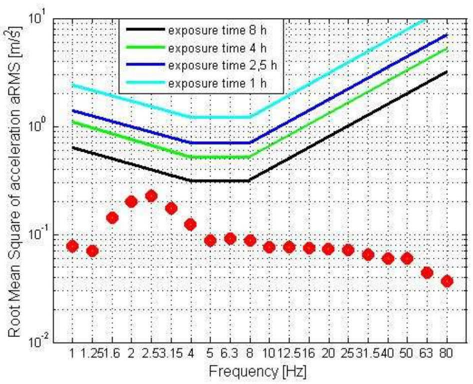

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Fig. 7. Root Mean Square of vertical accelerations (z-axis direction) in frequency domain on operator' s seat during mowing at a speed of 5 km·h^{-1}

Rys. 7. Wartości skuteczne przyspieszeń drgań pionowych (kierunek osi z) na siedzisku operatora podczas koszenia z prędkością 5 km·h^{-1}

However noticed, that for all cases the sensors recorded higher vibrations on the head, than on the operator's seat. Therefore, next results only for measurements on the head are presented (less favorable case). For the work at speed 8 km·h^{-1} admissible vibration amplitudes at 4 and 8 hours of exposure time was exceeded. Especially for frequencies 2 and 2,5 Hz, which is shown in fig. 8. For the test with speed of 12 km·h^{-1} acceptable maximum exposure time to vibrations amount to only 1 hour (fig. 9). Similarly as in previous case constituents of frequencies 2 and 2,5 Hz attained significantly higher amplitudes than the other.

4.2. Research while transport

First test was performed during driving in a circle. The maneuver was executed on a meadow. A method with a fixed radius of the track was used in the research. According to the recommendations of ISO 4138 [3, 7], path radius shall not be less than 30 m for non-standard research objects, i.e. for example such as high-efficiency system of disc mowers installed on the agricultural tractor. Hence, this radius 40 m was established. The tests for two speeds of driving were executed: for 8 km·h^{-1} and 12 km·h^{-1}. In fig. 10 there is shown Root Mean Square of accelerations in frequency domain during driving in a circle at a speed of 12 km·h^{-1}, determined for accelerations of vibration recorded on operator's head. For frequencies of 1,0; 1,25; 1,6; 2,0; 2,5 and 3,15 Hz exceedance of admissible values was noticed. The time limit for driving is 1 hour (head horizontal vibrations in y-axis direction were exceeded significantly).

Second test was performed on dirt track. The research with fixed speed of 8 km·h^{-1} was executed. For 4 hours and 8 hours of work time the exceedance of admissible accelerations was also noticed (fig. 11). Driving in comparable conditions maximum for 2,5 hours per day is acceptable. Exceeded Root Mean Square of vertical accelerations amounts to: for 1,6 Hz=0,566 m·s^{-2}, for 2 Hz=0,855 m·s^{-2}.

Research on asphalt road with movement speed of 30 km·h^{-1} also was executed. This is maximum speed for agricultural machines on public roads. Vibrations on operator's seat did not exceed admissible level, but vibrations of operator head were exceeded for 8 hours of work time (fig. 12).

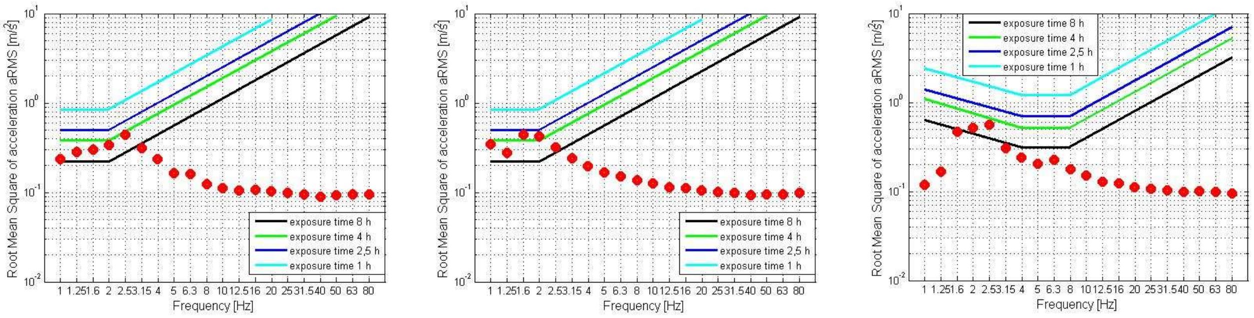

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Fig. 8. Root Mean Square of accelerations in frequency domain on operator head during mowing at a speed of 8 km·h^{-1} (consecutively in x, y, z direction)

Rys. 8. Wartości skuteczne przyspieszeń drgań na głowie operatora podczas koszenia z prędkością 8 km·h-1 (kolejno w kierunku x, y, z)

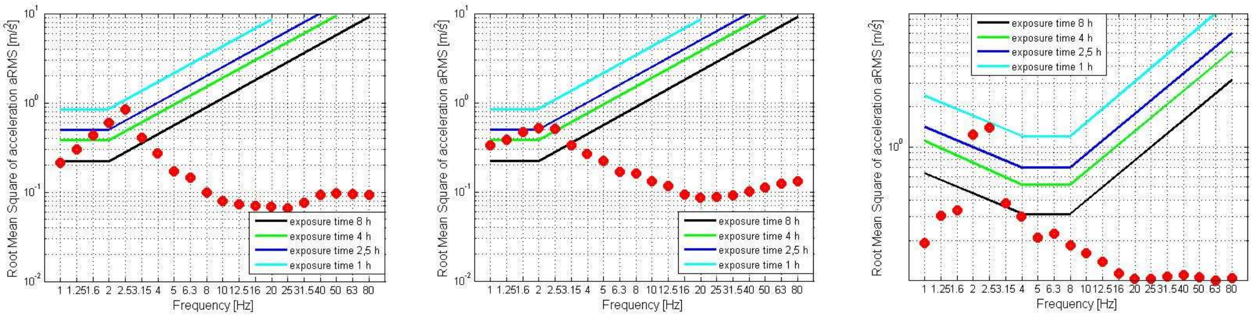

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Fig. 9. Root Mean Square of accelerations in frequency domain on operator head during mowing at a speed of 12 km·h^{-1} (consecutively in x, y, z direction)

Rys. 9. Wartości skuteczne przyspieszeń drgań na głowie operatora podczas koszenia z prędkością 12 km·h^{-1} (kolejno w kierunku x, y, z)

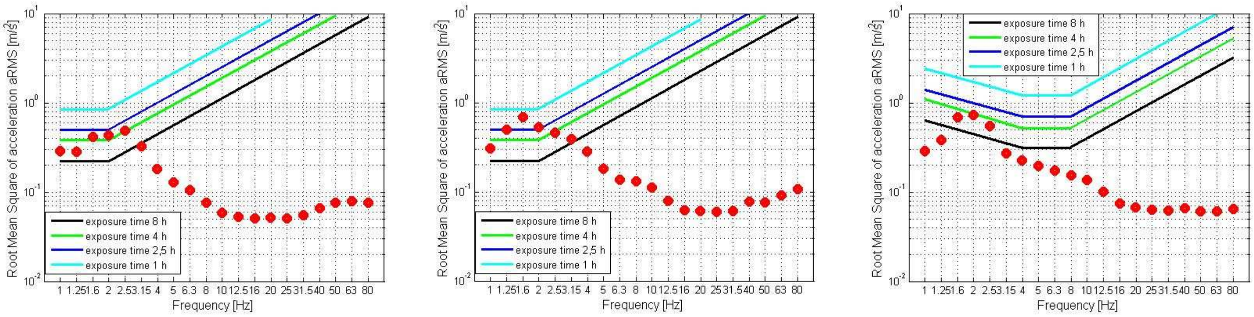

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Fig. 10. Root Mean Square of accelerations in frequency domain on operator head during driving in a circle with speed of 12 km·h^{-1} (consecutively in x, y, z direction)

Rys. 10. Wartości skuteczne przyspieszeń drgań na głowie operatora podczas jazdy po okręgu z prędkością 12 km·h^{-1} (kolejno w kierunku x, y, z)

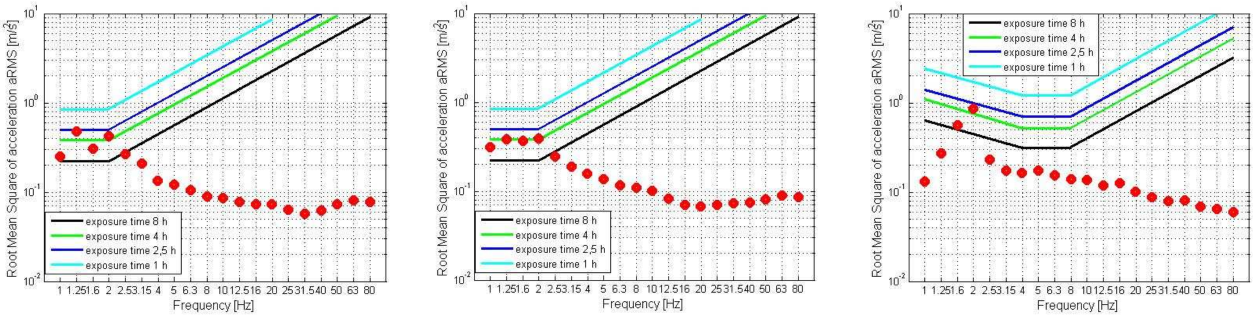

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Fig. 11. Root Mean Square of accelerations in frequency domain on operator head during driving on the field track at a speed of 8 km·h^{-1} (consecutively in x, y, z direction)

Rys. 11. Wartości skuteczne przyspieszeń drgań na głowie operatora podczas jazdy drogą polną z prędkością 8 km·h^{-1} (kolejno w kierunku x, y, z)

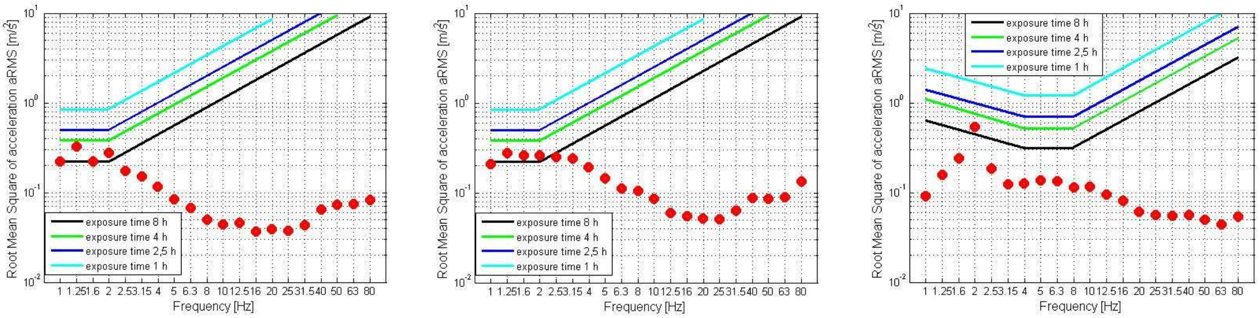

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Fig. 12. Root Mean Square of accelerations in frequency domain on operator head during driving on the road at a speed of 30 km·h^{-1} (consecutively in x, y, z direction)
Rys. 12. Wartości skuteczne przyspieszeń drgań na głowie operatora podczas jazdy drogą asfaltową z prędkością 30 km·h^{-1} (kolejno w kierunku x, y, z)

5. Summary

For achieving the research aim, tests while mowing and during transport at various speeds were made. The values of acceleration acting on the seat of agricultural machines and the operator's head were determined. Data obtained from measurements (after treatment) were related to the law standards defining acceptable acceleration action thresholds. However, the considerations were restricted to maximum 8 hours of work time.

The most important conclusion which was achieved is: Impact on the vertical vibration is not only motion of the object of research, but also the rotation of mowing units. This conclusion was arrived after comparing the distributions of vibrations generated while riding on a circle, and when the mower worked. Both of tests on the same substrate were performed. The vibration amplitudes during mowing were significantly higher, than during driving with disabled mowers. Undoubtedly, mowing realized during driving causes adverse influences on human body.

Additionaly it was detected, that Root Mean Square of accelerations are higher on operator's head, than on seat, hence operator's head is exposed to higher dynamic loads.

6. References

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