Produced Levels of Mehanical Vibration on Cabin of Agricultural Tractor by Different Agrotechnical Surfaces

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Summary

These research show results of produced level of tractors vibrations that affects on operator body measurement in relation to working hours of tractor in 2015 and 2016 year. It was done in accordance with the prescribed standards CRO ISO 2631-1 and CRO ISO 2631-4. Measurements were conducted in 2015 and 2016 on LANDINI POWERFARM 100 on access roads and production areas of Agricultural and veterinary school in Osijek. The measurements were performed with device MMF VM30. Results show that with increment of working tractor hours also increase the level of vibrations that affect on operator body on each measured surface (asphalt, grass and macadam).

Key words

agricultural tractor, whole body vibration, agrotechnical surface

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Introduction

Agricultural tractor has wide application both, on and off the road, or on agrotechnical surfaces. Operator is exposed to high level of vibration that affect operator's whole body. Vibrations in general represent oscillatory motion of whole body and depending on the shape of the path at which motions takes place, there are linear and angular oscillation. Vibrations can be high, medium and low frequency (vibrations under 16 Hz). Human body perceive and absorb vibrations from 1 to 1 000 Hz. Velocity of vibration is measured in peak units such as millimeters per second (mm/s) or meters per second (m/s). Another way of looking at velocity is distance per time or how much is the machine moving every second in three important directions at all main bearing points (axial, vertical, horizontal). Vibration acceleration is change of vibration velocity per second (m/s^2), Aranđelović and Jovanović (2009).

Brkić et al. (2005) has confirmed that vibrations on tractor occur as a result of the tractor motion, engine operation, transitive element work, and operation of the coupling machine. Because of the negative vibration effect on the whole operator's body there is a need to provide the best ergonomic conditions during work. Singh (2014) in his research states that the hip, neck, breech and spine injuries of the operator are consequence from exposure of vibration that is transfer on the operator body and because of unfavorable position during agrotechnical operations. Ahmadi and Altintas (2013) claim that measured vibrations, which affects on the whole operator's body during plowing with a spiral plough, are low level frequency vibrations (0-3 Hz). It means, in that case there are no danger on the health of the operator. Cvetanović and Zlatković (2013) in their research claims that when average age of the vehicle is higher than 15 years in generally have the negative effect on safety and health of the operator (ergonomically, old seats are the worst). They also emphasize the importance of regular maintenance of the tractor in purpose of preservation operators health. Scarlett et al. (2007) measured vibration that affect the operator's whole body on four different types of tractors and confirmed that due to acceleration increment there is also vibration increment, while the Deboli et al. (2008) also have measured vibration levels on four different types of tractors with four different types of pneumatics on different agrotechnical surfaces (asphalt, macadam and their combination) and established that the lowest level of mechanical vibrations are on asphalt. Crolla and Dale (2007) indicate that when the tractor pull loaded trailer in relation to the empty trailer, there is a significantly higher level of vibration in the direction of all three axes and it have negative influence on the operator health. Barač et al. (2016) explored mechanical vibrations that affects operator's whole body on different agrotechnical surfaces. The lowest measured vibrations was when tractor is moving on asphalt surface. The aim of this research is to establishe level of mechanical vibrations that affects operator's whole body when tractor is moving on different agrotechnical surfaces in relation to working hours of the tractor. The hypothesis is that the level of vibration which affects the body of the operator will increase with the increasing of tractor working hours.

Materials and methods

Research was conducted 2015 and 2016. The measurement was performed on tractor manufacturer LANDINI type POWERFARM 100 (year 2015 - 5800 working hours and year 2016 - 6800 working hours). The measurement was performed on production areas and access roads of Agricultural and Veterinary High School in Osijek. Produced values of mechanical vibration that affects on the operator's whole body (in direction x, y and z axis) were measured. Agrotechnical surfaces on which measurement took place are asphalt, macadam and grass. Each measurement lasted thirty minutes and has been repeated three times. Based on these measurements it was calculated the mean value which was used in further work. The measurement was performed in accordance with standards CRO ISO 2631-1 and CRO ISO 2631-4, which are applicable on the operators of agricultural tractor that are exposed to linear vibrations in the direction x, y and z axis. By the standard CRO ISO 2631-1 measurement was performed on the seat, i.e. while the operator is in the sitting position. Seat in this case represents a direct touch point between the vehicle structure and the operator. The research was performed with device for vibration measurement MMF VM 30 with the associated sensor. The measuring sensor was positioned on the part of the seat on which operator seated directly. Measuring range for each axis was set on 120 m/s^2. During measurement weight filters Wd (measurement of mechanical vibration in direction x and y axis) and Wk (measurement of mechanical vibration in direction z axis) was used, as it states in standard CRO ISO 2631-4. The measuring device was positioned on the seat and measured vibrations as follows (CRO ISO 2631-1): x axis: longitudinally, along the direction of movement – forward (positive) / backward (negative); y axis: sideways, under a 90° angle in regards to the motion's direction; z axis: vertically, upward (positive) / downward, perpendicular to the floor (negative). Climatic conditions during the measurement was identical so temperature were in range from 29°C to 31°C, relative air humidity in range from 63% to 64% and influence of the wind was negligible. Measured values was statistically processed using program package MS Office Excel 2013 and program IBM SPSS Statistics v.19.0.1. Descriptive statistics and analysis of variance were presented.

Results and discussion

After all measurements it is evident that none of the measured values does not crossing recommended limit values for daily vibration exposure (1.15 m/s^2) (European Directive 2002/44/EC).

Figure 1 present mean values of measured vibrations in direction x, y and z axis calculated on the basic three measurements for each surface (asphalt, macadam and grass) in 2015 and 2016. It is evident that the highest level of mechanical vibrations were on macadam. Only in the direction x axis is measured the highest value on grass. Only in 2015 year all measured values in direction of all three axes was highest on grass. In general, 2015 and 2016 lowest mechanical vibrations that affects on the operator's whole body were measured on the asphalt surface in direction of all three axes. Considering the increase of tractor working hours in 2016 it's visible that the mechanical vibration level increased on each agrotechnical surface (asphalt, macadam and grass) in direction of all three axes.

In comparison with the highest measured values in 2015 and 2016 for all three agrotechnical surfaces in direction of all three axes it is visible that the none of the values does not exceed recommended limit value for daily exposure of vibrations (Figure 2), and does not exceed recommended limit value for vibration that affect on the operators whole body (not above 1.15 m/s^2).

Standard mistake is bigger in the second year of measurement in direction of all three axes (Table 1).

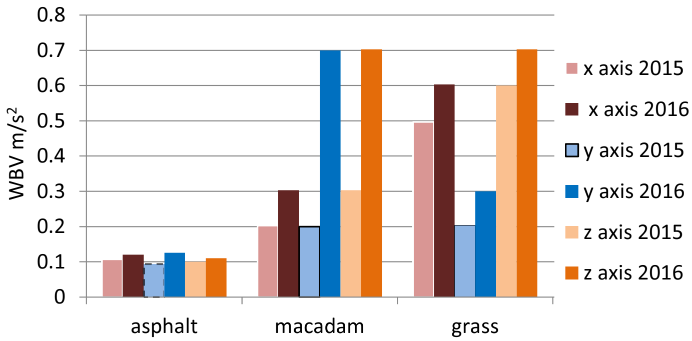

Figure 1. Measured mean values of vibrations in direction x, y and z axis for all three agrotechnical surfaces in year 2015 and 2016

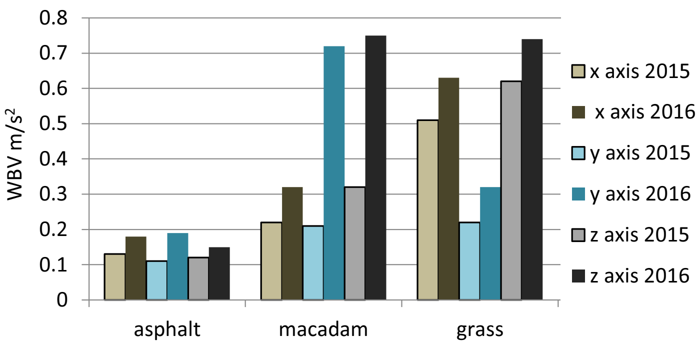

Figure 2. The highest measured values in direction x, y and z axis for all three agrotechnical surface in 2015 and 2016 year

Table 1. Descriptive statistics - mean values for measured vibrations in x, y and z axis direction - asphalt surface

	N	$\bar{x}$ (m/s²)	σ	C.V. (%)	Std. Error	95% Confidence Interval for Mean		Min	Max
						Lower bound	Upper bound		
					x axis				
1	3	0.10	0.020	19.56	0.012	0.054	0.158	0.09	0.13
2	3	0.12	0.052	44.09	0.030	-0.011	0.251	0.08	0.18
Σ	6	0.11	0.036	32.38	0.014	0,074	0.151	0.08	0.18
					y axis				
1	3	0.09	0.020	22.30	0.012	0.041	0.145	0.07	0.11
2	3	0.12	0.055	43.48	0.031	-0.010	0.263	0.09	0.19
Σ	6	0.11	0.041	37.70	0.016	0.066	0.153	0.07	0.19
					z axis				
1	3	0.10	0.020	20.00	0.011	0.050	0.149	0.08	0.12
2	3	0.11	0.036	32.78	0.020	0.020	0.199	0.08	0.15
Σ	6	0.10	0.026	25.38	0.010	0.077	0.132	0.08	0.15

Analysis of variance did not confirmed statistically significant difference between mean values of the measured mechanical vibrations 2015 and 2016 year in direction x, y and z axis (Table 2).

From Table 3 it's visible that the standard error is the same in first and second year of the measurement, while in the direction of y and z axis the standard error is higher in the second year of the measurement.

Table 2. Analysis of variance (ANOVA) for x, y and z axis - asphalt surface

	Sum of Squares	df	Mean Square	F	Sig.
		x axis			
Between groups	0.000	1	0.000	0.165	0.705
Within groups	0.006	4	0.002		
Total	0.007	5			
		y axis			
Between groups	0.002	1	0.002	0.962	0.382
Within groups	0.007	4	0.002		
Total	0.009	5			
		z axis			
Between groups	0.000	1	0.000	0.176	0.696
Within groups	0.003	4	0.001		
Total	0.004	5			

Table 3. Descriptive statistics - mean values for measured vibrations in x, y and z axis direction - macadam

	N	$\bar{x}$ (m/s²)	σ	C.V. (%)	Std. Error	95% Confidence Interval for Mean		Min	Max
						Lower bound	Upper bound		
					x axis				
1	3	0.20	0.015	7.51	0.008	0.165	0.241	0.19	0.22
2	3	0.30	0.015	5.03	0.008	0.265	0.341	0.29	0.32
Σ	6	0.25	0.056	22.28	0.023	0.194	0.312	0.19	0.32
					y axis				
1	3	0.20	0.010	5.00	0.005	0.175	0.224	0.19	0.21
2	3	0.70	0.020	2.86	0.011	0.650	0.749	0.68	0.72
Σ	6	0.45	0.274	60.94	0.111	0.162	0.737	0.19	0.72
					z axis				
1	3	0.30	0.015	5.03	0.008	0.265	0.341	0.29	0.32
2	3	0.70	0.045	6.41	0.026	0.591	0.815	0.66	0.75
Σ	6	0.50	0.221	43.94	0.090	0.271	0.735	0.29	0.75

Table 4. Analysis of variance (ANOVA) for x, y and z axis - macadam

	Sum of Squares	df	Mean Square	F	Sig.
		x axis			
Between groups	0.015	1	0.15	64.586	0.001
Within groups	0.001	4	0.000		
Total	0.016	5			
		y axis			
Between groups	0.375	1	0.375	1500.000	0.000
Within groups	0.001	4	0.000		
Total	0.376	5			
		z axis			
Between groups	0.240	1	0.240	211.765	0.000
Within groups	0.005	4	0.001		
Total	0.245	5			

For the mean value of the measured mechanical vibrations in direction x, y and z axis it was established statistically significant difference (Table 4).

Standard error is bigger in the second year of the measurement in x, y and z axis direction (Table 5).

Table 5. Descriptive statistics - mean values for measured vibrations in x, y and z axis direction - grass

	N	$\overline{x}$ (m/s^2)	σ	C.V. (%)	Std. Error	95% Confidence Interval for Mean Lower bound	95% Confidence Interval for Mean Upper bound	Min	Max
					x axis				
1	3	0.49	0.015	3.07	0.008	0.458	0.534	0.48	0.51
2	3	0.60	0.025	4.17	0.014	0.540	0.665	0.58	0.63
Σ	6	0.55	0.061	11.14	0.025	0.485	0.614	0.48	0.63
					y axis				
1	3	0.20	0.015	7.51	0.008	0.165	0.241	0.19	0.22
2	3	0.30	0.020	6.66	0.011	0.250	0.349	0.28	0.32
Σ	6	0.25	0.055	21.96	0.225	0.193	0.309	0.19	0.32
					z axis				
1	3	0.60	0.020	3.33	0.011	0.550	0.649	0.58	0.62
2	3	0.70	0.035	4.99	0.020	0.616	0.790	0.67	0.74
Σ	6	0.65	0.062	9.53	0.253	0.586	0.716	0.58	0.74

Table 6. Analysis of variance (ANOVA) for x, y and z axis - grass

	Sum of Squares	df	Mean Square	F	Sig.
		x axis			
Between groups	0.017	1	0.017	39.385	0.003
Within groups	0.002	4	0.000		
Total	0.019	5			
		y axis			
Between groups	0.014	1	0.014	44.263	0.003
Within groups	0.001	4	0.000		
Total	0.015	5			
		z axis			
Between groups	0.016	1	0.016	19.612	0.011
Within groups	0.003	4	0.001		
Total	0.019	5			

Analysis of variance did confirm statistically significant difference in the amount of mean value of mechanical vibrations in of x, y and z axis direction (Table 6).

Conclusion

As statistical tables of the mean values vibration levels show, the higher vibration levels were measured 2016 in all three axis and at all agrotechnical surfaces on which the agricultural tractor was moving, what is in accordance with the hypothesis of the research. Further, in 2016 were measured highest levels of mechanical vibrations on macadam, while only in the direction of the x axis was measured the highest value on the grass, as opposed to 2015, when the measured values in direction of all three axes were higher on the grass. It is visible that 2015 and 2016 lowest mechanical vibrations that affect on the operator's whole body on the asphalt surface in direction of all three axes were measured. Even though on different agrotechnical surfaces (asphalt, macadam and grass) by increasing working hours of the tractor occurs higher intensity of vibrations that affects on the operator's whole body in 2016 in relation to 2015, the assumption is that they will not affect operators health because they are not exceed limit value of vibrations which is 1.15 m/s^2.

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