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Noise in the Cabin of Agricultural Tractors

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Abstract: This paper represents the results of the research of generated noise levels measured in three different years (2010, 2013, and 2015), in accordance with the proscribed norms HRN ISO 6394, HRN ISO 6396 and HRN ISO 5131. The research was conducted on test sites of Belje d.d. company. The measurement was carried out on three tractors of the FENDT model 410 with the aim of determining the increase of generated noise relative to the time the tractors spent in exploitation. The obtained results showed that none of the tractors produced a higher level of noise than the permitted 90 dB. The main hypothesis of this experiment is that, exploitation-wise, tractors with a greater number of work hours will produce more noise than the ones with a smaller number of work hours.

Keywords: agricultural tractor; ergonomics; noise; tractor cabin

1 INTRODUCTION

Based on their own research analysis it is stated that it is necessary to reduce the measured noise levels below the risk limit during agricultural activities [1]. It is recommended to use safety devices, especially when operating a cabinless tractor, which can reduce the equivalent level of sound pressure ranging from 10 to 45 dB.

A research of generated noise levels which affect a woodchipper handler according to [2] was conducted and the results showed that the measured noise levels did not exceed the permitted limit regulated by norms. The measurement was conducted on a VALTRA T 191 tractor combined with a BOBR 80 S and KESLA FORESTER C 4560 LF woodchippers. The highest measured level of noise with the BOBR 80S woodchipper was 77,70 dB, whilst the highest level of noise with the KESLA FORESTER C 4560 LF was 76,70 dB. [3] pointed out the differences in generated noise levels regarding the tractor construction, i.e. they conducted research on both tractors with and without a cabin. The results showed that the noise level in cabinless tractors was greater than the permitted limit, while tractors with a cabin produced lower noise levels. The research was conducted on a MASSEY FERGUSON 285 tractor at different speeds of motion during agricultural activities. During the measuring (at the height of the driver's right ear), it was confirmed that at 1000 min^{-1} the measured noise level was within the allowed range (78,8 dB) , however at 2000 min^{-1}, the noise level was over the permitted limit of 90dB. Furthermore, it was confirmed that the operator was exposed to danger in this kind of surrounding. Age, severity of previously undertaken work and insufficient tractor maintenance were specified as causes of higher noise levels [4].

Authors [5] state that the cultivator noise is a consequence of engine performance, which is very much the same reason why vibrations occur and have an effect on humans operating the machines. Furthermore, as a solution, they proposed changes on cultivator design – setting up an exhaust muffler that would create a pressure drop, friction decrease, create changes in the direction of fluid flow and distribute the total energy of the fluid and decrease the intensity of noise. Additionally, regarding the extent of use of these devices, they emphasize the importance of preventive and regular cultivator maintenance. According to [6] the level of emitted exterior noise during the motion of a tractor was higher with tractors that had less work hours, whilst the level of emitted interior noise on the operator's place was higher with tractors with a larger number of work hours. The measurement of the generated noise level was conducted on the operator's seat in both tractors with and without cabins during the motion over an agrotechnical surface. The research determined that there is a higher level of noise in a cabinless tractor (94 dB) as opposed to a tractor with a cabin (88 dB) [7].

Authors [8] have established through research that a Romanian tractor M 650 at 1700 min^{-1} produces a higher level of noise than at 850 min^{-1}. These same authors state that at 1700 and 850 min^{-1} a higher level of noise was measured on the right side (98,6 dB and 85,9 dB), in contrast with the measurement conducted on the left side (91,6 dB and 87,2 dB). This research was conducted in the interior of an agricultural tractor. The measurement of generated noise levels was done on tractors of the FENDT 410 model [9]. The reasarch was conducted on the operator's seat both on the inside and the outside of an agricultural tractor's cabin. It has been confirmed that not a single measured value exceeds the permitted limit of 90 dB. Authors [10] state that the difference in noise levels on the operator's workplace of the studied agricultural tractor during its motion over three different agrotechnical surfaces equals 4 dB. Furthermore, the highest level of noise was measured on an asphalt surface (72,5 dB) and the lowest on a grass surface (68,5 dB). It is clear that all the measured noise levels are below the permitted 90 dB.

The aim of this research was to determine the internal noise levels for same-model tractors relative to the number of their completed work hours and to determine the correlation between those elements. The hypothesis is that with the increase of completed work hours the noise levels of an agricultural tractor will also significantly increase.

2 MATERIALS AND METHODS

The research was conducted on three occasions (in 2010, 2013, and 2015), on three FENDT 410 tractor models. The tractors did the same type of jobs before and during the research. These same tractors were marked as T1, T2 and T3 and they had an equal number of work hours in the year 2010 (5580, 6584 and 7574), 2013 (20158, 21017 and 21892) and 2015 (30273, 33589 and 33936). According to the data, it can be established that the tractors were operational for a similar number of work hours. Further in the text, the tractors with a fewer number of work hours will be marked as "1" or in Tab. 1, 2, 3 and 4, and the ones with a greater number of work hours will be marked with "2" in Tab. 1, 2, 3 and 4. The measurement of noise levels was carried out in accordance with the prescribed norms for measurement of an agricultural tractor generated noise [11], [12] and [13]. These same measurements were conducted on test sites of the Belje d.d. company. The procedure of the measurement of tractor generated noise levels was carried out in accordance with [11] which states that the research is done under both dynamic [12] and static conditions. In accordance with [11], there were three measurements carried out from both the left and the right side of the operator at 1100 min^{-1}, 1800 min^{-1} and 2200 min^{-1}. There were also three measurements conducted at both sides of the operator while the tractor moved forward along a 14-meter long line from point A to point B and moving back from point B to point A on that same line of the same length at 7,5 kmh^{-1}. [13] states that the position of the device is relative to the reference point of the operator's seat, which is the middle of the operator's head all the way to the seat level at the height of 790$^{\pm 20}$ mm and spaced from the middle of the head 200$^{\pm 20}$ mm both from the left and the right side. Every measuring point of the interior noise level was measured three times in 30 second intervals. Based on these measurings, an average equivalent of a constant noise level was founded. These measurements were conducted with the help of a METREL device, model Multinorm MI 6201 EU, which was equipped with a sound probe (microphone class B) produced by the same manufacturer, and were shown through the following values:

- L_{eq} - time average sound level or equivalent continuous sound level is measured on both channels. This is probably the most important and frequently used measurement. It measures the average of a sound level over the whole duration of measurement,
- L_{Fmin} - minimum time weighted sound level is measured on both channels. It is the minimum of L_F over the whole duration of measurement,
- L_{Fmax} - maximum time weighted sound level is measured on both channels. It is the maximum of L_F over the whole duration of measurement.

The measured values were statistically analysed using an application for statistical analysis in MS Office Excel 2013, and IBM SPSS Statistics v.19.0.1. The paper shows descriptive statistical values and analysis of variance (ANOVA). Correlations and regresion equation in this analysis were perfomed.

3 RESULTS AND DISCUSSION

3.1 A Parallel Representation of Internal Noise Mean Values

Partially confirmed suggested hypothesis was shown in Fig. 1 where in the year 2010, the highest equivalent continuous sound level (Leq) was produced by the T2 tractor during all tested operations (at 1100 min^{-1} it was 66,5 dB, at 1800 min^{-1} 71,7 dB and at 2200 min^{-1} 70,9 dB). The smallest equivalent continuous sound level (Leq) was also produced by the T2 tractor during all tested operations (at 1100 min^{-1} 57,2 dB, at 1800 min^{-1} 64,4 dB and at 2200 min^{-1} 67,2 dB). In 2013, the highest equivalent continuous sound level (Leq) was recorded on the T3 tractor at 1100 min^{-1} 66,9 dB and at 1800 min^{-1} 70,8 dB whilst the highest level of noise at 2200 min^{-1} was produced by the T2 tractor which was equal to 72,13 dB.

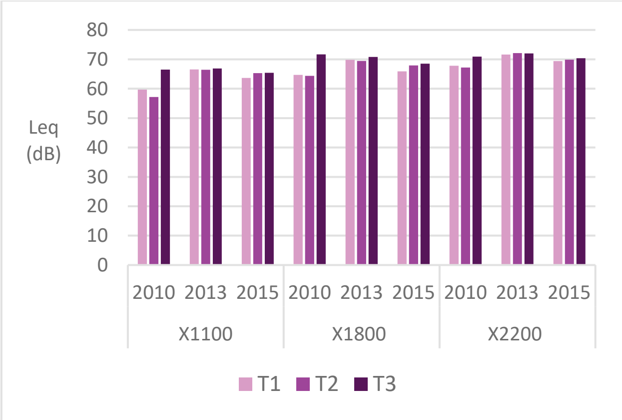

Figure 1 Comparative overview of the mean value of interior noise at a stationary position

The smallest equivalent continuous sound level (Leq) was measured in the T2 tractor at 1100 min^{-1} 66,43 dB, at 1800 min^{-1} 69,45 dB, while the highest level was recorded in the T1 tractor at 2200 min^{-1} and was 71,66 dB. Furthermore, in 2015 the highest equivalent continuous sound level (Leq) was established in the T1 tractor at 1100 min^{-1} 65,4 dB, at 1800 min^{-1} 68,5 dB and at 2200 min^{-1} 70,4 dB. Then followed the T2 tractor at all engine min^{-1} [1100 (65,3 dB), 1800 (67,9 dB), 2200 (69,9 dB)] while the T1 tractor produced the lowest (Leq) [1100 (63,7 dB), 1800 (65,9 dB), 2200 (69,4 dB)]. Fig. 2 shows the highest equivalent continuous sound level (Leq) measured in 2010 and produced by the T3 tractor which amounted to 71,5 dB and the T1 tractor which produced a 68,55 dB noise level. The T2 tractor produced the lowest equivalent continuous sound level (Leq) of 64,5 dB.

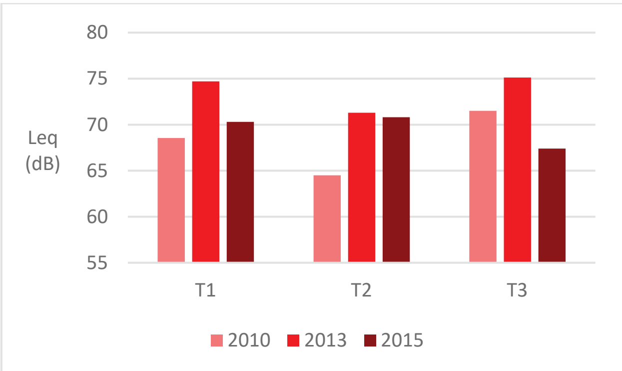

Figure 2 A comparison of mean internal noise values in movement

Furthermore, in 2013 with a repeated measurement, the highest equivalent continuous sound level (Leq) of 75,12 dB was noted in the T3 tractor followed by the T1 tractor that produced a 74,71 dB noise level. The smallest (Leq) was produced by the T2 tractor and that was 71,3 dB. In the year 2015 the highest equivalent continuous sound level (Leq) came from the T2 tractor (70,8 db). Then came the T1 tractor (70,3 dB) followed by the T3 tractor with the noise level of 67,4 dB.

3.3 A Parallel Statistical Representation of the Measured Noise Levels

Tab. 1 shows how at 1100 min^{-1}, 1800 min^{-1} and 2200 min^{-1} the standard error is the largest in tractors with the lowest number of work hours (1). Furthermore, it is visible from table 1 that the highest level of noise was produced by tractors with an average number of work hours (2), followed by tractors with the highest number of work hours (3) and tractors with the lowest number of work hours (1).

Through the analysis of the variance, Tab. 2, a statistically relevant difference in the amounts of mean values of measured levels of noise between the observed tractors was determined. It is shown that the level of emitted noise measured in a stationary position at 1100 min^{-1}, 1800 min^{-1} and 2200 min^{-1} is higher in the tractor (2) as opposed to the tractors (3, 1).

Table 1 Descriptive statistics of mean values of internal noise on standing

	N	Mean LA_{eq}, dB	Std. Deviation	Coef. of Variation	Std. Error	95% Confidence Interval for Mean		Min	Max
						Lower Bound	Upper Bound		
1100 min^{-1}									
1	18	61,177	4,1716	6,8189	0,9832	59,103	63,252	56,9	68,1
2	18	66,699	0,7817	1,1720	0,1842	66,311	67,088	65,6	68,2
3	18	64,8500	1,74971	2,69808	0,41241	63,9799	65,7201	63,0	67,9
∑	54	64,2425	3,48226	5,42049	0,47388	63,2921	65,1930	56,9	68,2
1800 min^{-1}									
1	18	66,988	3,6091	5,3876	0,8506	65,194	68,783	63,3	73,0
2	18	70,034	2,6161	3,7355	0,6166	68,733	71,335	65,9	74,3
3	18	68,8500	1,58458	2,30149	0,37349	68,0620	69,6380	66,0	71,3
∑	54	68,6245	2,96310	4,31784	0,40323	67,8157	69,4333	63,3	74,3
2200 min^{-1}									
1	18	68,672	1,8093	2,6348	0,4264	67,772	69,572	66,7	71,2
2	18	71,937	1,5172	2,1090	0,3576	71,183	72,692	69,7	74,3
3	18	71,2333	1,30789	1,83606	0,30827	70,5829	71,8837	69,5	73,4
∑	54	70,6145	2,08404	2,95129	0,28360	70,0456	71,1833	66,7	74,3

The standard error was the biggest in tractors with the smallest number of work hours (1) in relation to other tested tractors (3 and 2), Tab. 3. It is noticeable (and shown in Tab. 3) that the highest level of noise was produced by tractors with an average number of completed work hours (2) followed by tractors with the highest number of work hours (3) and tractors with the lowest number of work hours (1).

Tab. 4 determines a statistically significant difference between the tested tractors. In addition, the level of emitted noise during motion is higher in tractors (2) as opposed to tractors (3 and 1).

Table 2 Analysis of variance (ANOVA)

	Sum of Squares	df	Mean Square	F	Sig.
1100 min^{-1}					
Between Groups	284,399	2	142,200	20,241	0,000
Within Groups	358,286	51	7,025		
∑	642,685	53			
1800 min^{-1}					
Between Groups	84,862	2	42,431	5,688	0,006
Within Groups	380,476	51	7,460		
∑	465,338	53			
2200 min^{-1}					
Between Groups	106,320	2	53,160	21,887	0,000
Within Groups	123,870	51	2,429		
∑	230,190	53			

Table 3 Descriptive statistics of mean values of internal noise in movement

	N	Mean LA_{eq}, dB	Std. Deviation	Coef. of Variation	Std. Error	95% Confidence Interval for Mean		Min	Max
						Lower Bound	Upper Bound		
1	12	68,216	3,5748	5,2404	1,0319	65,945	70,488	62,3	75,0
2	12	73,739	2,0788	2,8191	0,6001	72,418	75,060	70,9	77,2
3	12	69,5667	2,08167	2,99233	0,6009	68,2440	70,8893	66,8	73,1
∑	36	70,4972	3,51003	4,97896	0,58500	69,3096	71,6848	62,3	77,2

Table 4 Analysis of variance (ANOVA)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	196,537	2	98,269	13,819	0,000
Within Groups	234,672	33	7,111		
∑	431,210	35			

The correlation of the generated noise levels at a stationary position (1100 min^{-1}) and the age of tractors is shown with a correlation coefficient and its belonging equation of regression. This correlation shows a statistical significance of the relations of the aforementioned variables, and this relation is described with a square regression equation, Fig. 3.

Fig. 4 represents the connection between the generated noise levels at a stationary position (1800 min^{-1}) and tractor age, which is shown with a correlation coefficient and a belonging polynomial regression equation. Furthermore, there is a noticeable statistical significance of the previously mentioned variables.

The correlation coefficient and its belonging polynomial regression equation show the relation between the generated noise levels during motion (2200 min^{-1}) and the tractor age. Fig. 5 shows a high statistical significance of the aforementioned variables.

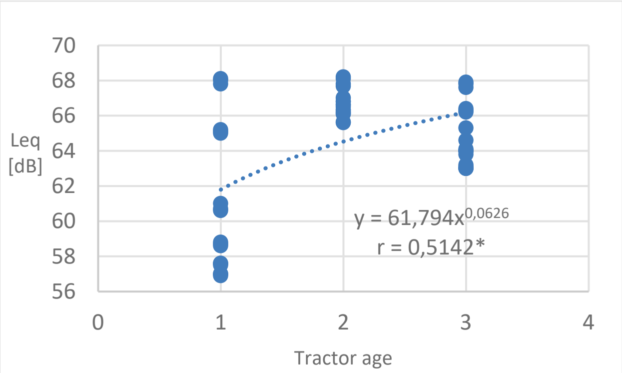

Figure 3 Correlation between tractor age and generated levels of internal noise at a stationary position (1100 min^{-1})

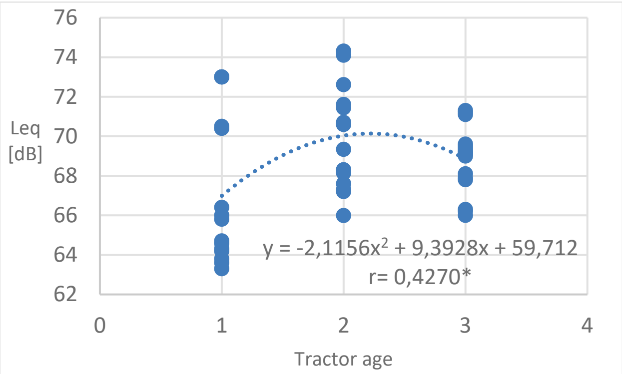

Figure 4 Correlation between the tractor age and generated levels of internal noise at a stationary position (1800 min^{-1})

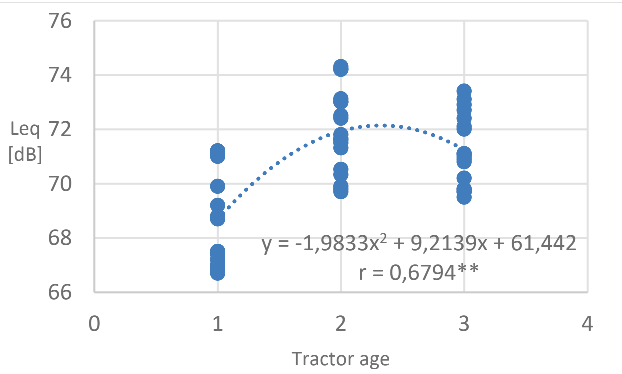

Figure 5 Correlation between tractor age and generated levels of internal noise of the tractor during motion (2200 min^{-1})

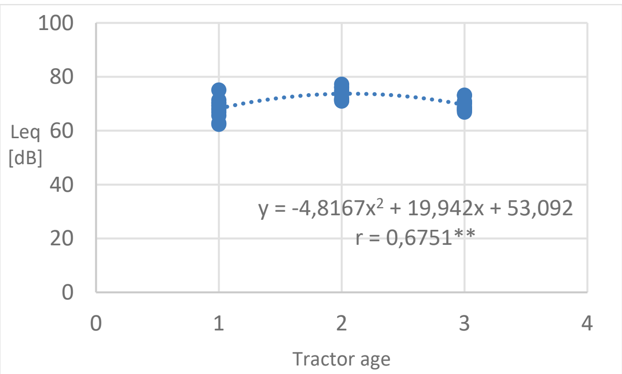

Figure 6 Correlation between tractor age and generated internal noise levels during motion

The correlation between generated noise levels during motion and tractor age is displayed with a correlation coefficient and its belonging regression equation, Fig. 6. In addition, a statistical significance of these variables was confirmed and their mutual correlation is described by a polynomial regression equation.

4 CONCLUSION

Tab. 1 shows how at 1100 min^{-1}, 1800 min^{-1} i 2200 min^{-1} the standard error is the largest in tractors with the smallest number of completed work hours (1). Furthermore, it can be seen from table 1 that the highest level of noise was produced by tractors with an average number of completed work hours (2) followed by tractors with the largest number of work hours (3) and tractors with the smallest number of work hours (1).

Analysing the variance Tab. 2 a statistically significant difference in the amount of mean values of measured noise levels among tested tractors was determined. It is shown that the level of emitted noise measured in a stationary position at 1100 min^{-1}, 1800 min^{-1} and 2200 min^{-1} is higher in tractors (2) as opposed to tractors (3 and 1). The standard error is the largest in tractors with the smallest number of completed work hours (1) in contrast with other tested tractors (3 and 2). It is evident, and shown in Tab. 3, that the highest level of noise was produced by tractors with an average number of completed work hours (2), followed by tractors with the highest number of work hours (3) and tractors with the smallest number of work hours (1). It is apparent from Tab. 4 that there is a statistically significant difference between these tested tractors. In addition the level of emitted noise during motion is higher in tractors (2) as opposed to tractors (3 and 1).

The correlation between tractor age and generated noise levels during stationary position and motion was interpreted with correlation coefficients and their belonging regression analyses which describe the already mentioned variables. The most prominent value of the correlation coefficient or the highly significant is evident in Fig. 5 and 6, therefore at a stationary position with the highest number of revolutions (2200 min^{-1}) and during motion. From these measurements, it is evident that, with regard to the equivalent continuous sound level (Leq), not a single tractor at any measuring point, whether at determining the internal noise in a stationary position or during motion, crossed the permitted limit of 90 dB.

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