Noise and Vibration of Tractors: An Ergonomic Evaluation

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Abstract

The improvement and reliability of the agricultural machines provided a revolution in the human activities facilitating the production of commodities of agribusiness. Though, the efficiency of the tractor, well as the occurrence of accidents also depends on the level of fatigue to which the operator is submitted. Between the ergonomic factors that affect the operator machine, noise and vibration stand out among the principal. This study aims at evaluating the levels of vibration and noise emitted by agricultural tractors with different powers, comparing the results with existing regulations in Brazil. The tractors studied: MF 4292, MF 283, MF 297 and MF 680. As results, the structures of the seat were able to absorb the impact and creating a good working condition for the machine operator. The vibration levels, in general, were below the limits established for eight hours of work at frequencies 5-10 Hz, for the three directions for all tractors studied.

Keywords: agricultural tractors, ergonomics, noise, vibration, level

1. Introduction

The use of tractors in agriculture took place shortly after the Second World War and the beginning of 1950 were offered to the market wide variety of brands and models, but featuring configuration and rough appearance compared to what is observed today. In Brazil, 1960, was observed the beginning of concerning with ergonomic aspects, with emphasis on occupational safety and operator comfort, at which time the tractor industry in Brazil was installed. The evolution of the national fleet can be seen in Figure 1.

Recently, the projects of agricultural tractors centered on maximizing efficiency in detriment to the human factor. However, due to the increased rigor of safety standards at work, there has been a tendency to seek improvements in terms of ergonomics and operator safety, to improve working conditions (ALVES et al . 2011).

Agricultural tractors have evolved in recent years, highlighting the best distribution and organization of items related to ergonomics in the design of operating stations have contributed substantially to improve the comfort and safety of the operator, but there are few studies developed for the parameter assessment and occupational health implications (ANTONUCCI et al 2012; . CUNHA et al 2012.). The main ergonomic concerns is the human element, in order to satisfy the employee, it was understood that the increased production and improved quality of products are the result of an adequate interaction between man and the production system (FILIP & CANDALE 2012) .

Regarding the security items, security devices and systems under the regulatory norm, they must integrate the machines since its manufacturing and cannot be considered optional items for any purpose. However, it is known that there is no machine inspection obligation in Brazil on the occasion of their marketing, complicating the items standardization.

1.1. Model of Excellence in Management Commitments to Excellence: People – Ergonomics

Organizations are living systems, members of complex ecosystems with which they interact and on which they depend. Excellence in an organization depends fundamentally on its ability to pursue its purposes in complete harmony with its ecosystem (FNQ, 2008a). Among the foundations of excellence we have the "valorization of people", whose goal is to establish relationships with people, creating conditions for them to perform professionally and humanly, maximizing their performance through engagement, skills development and space to undertake.

The hazards related to occupational health, safety and ergonomic risks are identified and treated in order to inventory, prioritize and enable preventive treatment of the factors that may threaten the physical or psychological integrity of members of the workforce as a result of their activities (FNQ, 2008b). Factors related to ergonomics are related to man and machine, always seeking a condition of comfort and safety for staff, where it operates the machine. The treatment of risks to health, safety and ergonomics are actions or plans of actions that when implemented will eliminate or prevent the hazards identified.

1.2. Noise in Agricultural Machinery

Among the ergonomic factors that impair machine operators, noise is a major, but there are few studies developed for the evaluation of this parameter and its implications for occupational health. The changes caused by noise are not immediate and, yes, cumulative effects and will be deploying with time: hearing loss, mental imbalances and degenerative physical illnesses (Noronha et al 2005).

Vitória (2000) noted that in rural areas it is common the use of personal protective equipment (PPE) to prevent phytosanitary contamination. However, little attention is paid to prevention of noise effects.

Souza (2001) evaluated the levels of noise emitted by a tractor-harvester set of beans, concluding that in general, the noise levels obtained in threshing cylinder at 540 rpm rotation were higher than those obtained at 420 rpm. The noise level at the operator’s ear in his working day is one of the factors that must be evaluated in production systems that use machinery intensively.

Rinaldi et al. (2008) inspected 29 tractors, concluded that noise levels were issued above the maximum allowed by regulatory norms. They can cause hearing loss, irritability and loss of concentration, with the increased possibility of accidents.

Analyzing noise tractors, Cunha et al. (2012) stated that even with technological advances in the production of agricultural machinery, the noise level is still above permitted for a journey of 8 hours of work on tractors without cab protection, so it is necessary the use of hearing protection.

The decibel scale is used in most of evaluation, verification and quantification of noise, and the measurements of noise level should be made with an electronic compensation circuit of the type "A".

The maximum permissible daily exposures, according to Norm (NR 15) of the Ministry of Labor and Employment are shown in Table 1.

1.3. Vibrations in an Agricultural Tractor Seat

Besides noise, agricultural tractors in circulation mostly have problems with comfort and safety for operators. The tractors, in general, produce low frequency vibrations which are transmitted to the operator station (Servadio et al. 2007). These frequencies may cause vision problems, irritability, lumbar deformations and digestive problems.

The agricultural tractor operator is exposed to vibration problems that make it more susceptible to accidents. According to Araújo (2002), environmental risks are classified as physical, chemical and biological hazards, and are part of the physical risks: to recognize, evaluate and control the mechanical vibration.

In practice, vibrations consist of a complex mixture of several waves with different frequencies and directions. From the analysis of these components, it is possible to calculate the average level of vibrations. However, some work in this area will consider only the vertical vibration (Fernandes, 2003, Santos Filho et al. 2004), making it difficult to determine the impact of these waves on the human body and its mitigation. According to Tewari & Dewangan (2009), vibration reduction, and reduce operator stress, improves their quality of life.

The problem of vibration transmission from agricultural tractors to operators has been studied for years. However, there is still a clear need to develop systems for preventing (TIEMESSEN et al., 2007). In the absence of shock absorbers and springs, as in urban vehicles, the seat of the tractor has an important role in minimizing this vibration, thus being an important component (JAIN et al. 2008). According to Tewari and Dewangan (2009), vibration reduction, that reduces the operator stress, allows better quality of life and increase the workload without causing excessive fatigue. Blüthner et al. (2006) stated that the vibration can lead to serious damage to the backbone operators.

Thus, further research to understand how the three-dimensional vibration of agricultural machinery is transmitted to the human body is an issue (TIEMESSEN et al 2007; ANTONUCCI et al 2012.).

2. Objective

2.1. General Objective

This work has as general objective evaluate the vibration and noise level that came from different models of agricultural tractors (based on power) and work time, in comparison with the Brazilian legislation.

2.2. Specific Objectives

a) Determine the maximum daily exposure time to allowed noise level, according to Regulatory Standard (NR 15) of Brazilian Ministry of Labor and Employment;
b) Determine the vibration level on the operator seat;

3. Materials and Methods

The work has been realized at Faculty of Animal Sciences and Food Engineering (FZEA) from University of São Paulo located at Pirassununga County, in area conceded by the Prefecture of the Campus. The geographic location of the campus is 21º59’ south latitude and 47º26’ west longitude, and average height as 653 meters. The region weather is type Cwa in Köppen classification, and the average annual temperature is 20,8ºC, with average annual rainfall as 1298 mm.

3.1. Studied Tractors

The experiments were performed with four tractors, with different power and manufactory year, Massey Ferguson: MF 4292 (engine power of 110 cv at 2200 rpm manufactured in the year 2011, 907 hours worked), MF 283 (engine power of 86 cv at 2200 rpm, manufactured in the year 2005, 4050,5 hours worked), MF 297 (engine power of 120 cv at 2200 rpm, manufactured in the year 2005, 3800,0 hours worked), and MF 680 (engine power of 173 cv at 2200 rpm, manufactured in the year 1997, 7472,9 hours worked). All tractors are from the Prefecture of Pirassununga Campus.

3.2. Noise Level Evaluation

The noise levels have been determined by a digital decibel meter, ICEL brand, model DL-4020, in fast answer circuits and “A” equalization, expressed in dB(A). All measurements were made with wind protector.

The readings have been taken close to operator ear in each removal radius, 1 to 10 m, collected 1 in 1 meter, directed to right, left, rear and front parts of the tractor. Three readings were realized in each point and under each condition. During the test, the tractor was in rotation as 540 RPM in PTO (Power take-off).

The evaluations have been based in the method described in NBR-9999 (ABNT, 1987). At the position and time for noise level measurement, the temperature was between -5 and 30ºC and wind velocity was under 5,0 $m.s^{-1}$, being satisfactory at the evaluation time according to this standard.

For the study of noise level variation in function of the removal radius, regression equations have been adjusted for the tested group. By this mean, it was possible to determine the noise level that operators, and workers close to the machinery also, were exposed.

3.3. Vibration Evaluation

Concerning to vibration evaluation, the quantity used was acceleration, expressed in $m\ s^{-2}$, based in ISO 2631 norm (ISO, 1985). It was employed a human vibration measurer, model HD-2070HA-WB with band pass filter, that allowed evaluation of vibration transmitted for the whole body. The device for data acquisition has been adjusted for acceleration readings in the whole body with storage in each second.

The total acquisition time was 10 minutes, with the tractor operating in equivalent conditions, whereas the signals were acquired at a frequency of 4096 Hz. For the weighted effective acceleration have been utilized digital filters. The signals have been transformed to the frequency domain, utilizing the FFT function (amplitude and phase), being digitally filtered in 1/3 octave bands to obtain the effective acceleration. The maximum values obtained, in each band, have been multiplied by weighting factors, generating the weighted accelerations. For the effective overall weighted effective acceleration, the range between 1 and 80 Hz was used.

The operator seat was the factory original for all tractors and, before the test beginning, it was adjusted for the weight and height of the operator. It is worth mentioning that a study was done in accordance with standard ISO 4253 (1999). The study has been done in two types of trajectory: asphalt and firm ground.

4. Results and Discussion

4.1. Noise Level

Table 2 shows the average values of the noise levels obtained close to the operator's ear and every ray of distance from 1 to 10 meters, taken each one meter, targeted for the right and left side, rear and front parts of each tractor.

The noise levels obtained close to the operator's right ear were 90,0; 90.3; 89.0 and 88.0 dB (A) respectively for the MF 4292, MF 297, MF 283 and MF 680 tractors. Noise level above the maximum allowed for the work day of 8 hours was observed in all tractors studied, according to the regulatory standards of the Brazilian Ministry of Labor and Employment (NR 15). The use of hearing protection is required. Similar results were observed by Alves et al.

(2011), where the level of noise in static condition and dynamic of a Valtra Model 785 TDA (75 hp) tractor was evaluated, and concluded that the levels of noise near the operator in terms of field were higher than those established by the rules for maximum daily 8-hour exposure, without the use of hearing protection.

In relation to the ray of distance the highest values generally occur up to 4 m away, for people who are in a distance of up to 4 m of the tractor during his workday the use personal protective equipment is required.

Pimenta Junior et al. (2012) determined in 5 meters the compulsory use of protective equipment in routine operations with tractors, both for operators and other employees working in its proximity.

Applying linear regression of the mean values of noise on the right side of the tractor in function of the ray of distance, the following equations were found: -1,6718D + 92,232 (R^2 = 0,9254); -1,6509D + 91,255 (R^2 = 0,9375); -1,7418D + 88,127 (R^2 = 0,9705); e -1,5882D + 92,209 (R^2 = 0,8595), respectively for the MF 4292, MF 297, MF 283 and MF 680 tractors.

Applying the same principle of the left side of the tractor to the following equations are found: -1,5873D + 92,318 (R^2 = 0,9137); -1,4818D + 90,282 (R^2 = 0,9648); -1,5500D + 90,423 (R^2 = 0,9574 e -1,5109D + 91,636 (R^2 = 0,8990), respectively for the MF 4292, MF 297, MF 283 and MF 680 tractors.

The results in the left side of the operator are similar to those on the right. Therefore the use of protective equipment for people in a shorter distance than 4 meters is required for all tractors.

4.2. Vibration Evaluation

The vibration values (1/3rd octave band) measured for the three directions (az- axis, ax- axis and ay- axis) with tractors on firm ground are illustrated in Figures 2, 3 and 4.

For comparison purposes, we used the values recommended by the ISO2631 standard (ISO 1978) for exposure limit (LE), reduced comfort level (NCR) and reduced efficiency level (NER) (8 hours daily work).

Using as a criterion the exposure limit, the vibration levels, in general, were below the limits established for eight hours of work at frequencies 5-10 Hz, for the three directions (az- axis, ax- axis and ay- axis) for all tractors studied. For the reduced comfort level, we note that for some frequencies there are situations where vibration exceeds the limit for eight hours of work. The vibration values (1/3rd octave band) measured for the three directions (az-axle, ax-axle and ay-axle) with tractors on asphalt are illustrated in Figures 5, 6 and 7.

Using as a criterion the exposure limit, reduced comfort level (NCR) and reduced efficiency level (NER), the vibration levels, in general, were below the limits established for eight hours of work at frequencies 5-10 Hz, for the three directions (az- axis, ax- axis and ay- axis) for all tractors studied. This demonstrates that the structures of the seat were able to absorb the impact and creating a good working condition for the machine operator.

5. Conclusion

- The structures of the seat were able to absorb the impact and creating a good working condition for the machine operator.
- The vibration levels, in general, were below the limits established for eight hours of work at frequencies 5-10 Hz, for the three directions (az-axle, ax-axle and ay-axle) for all tractors studied in the asphalt and firm ground .

6. Acknowledgements

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7. Figures

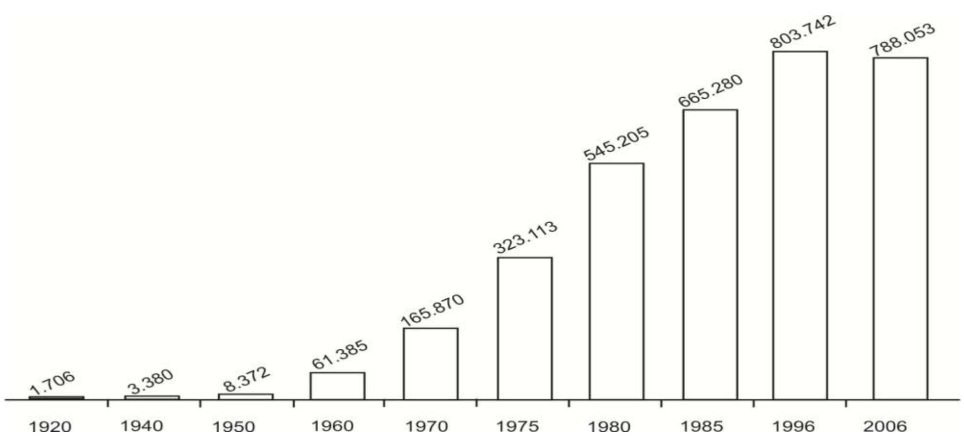

Figure 1: Evolution of the National Tractor Fleet. Source: IBGE (2010)

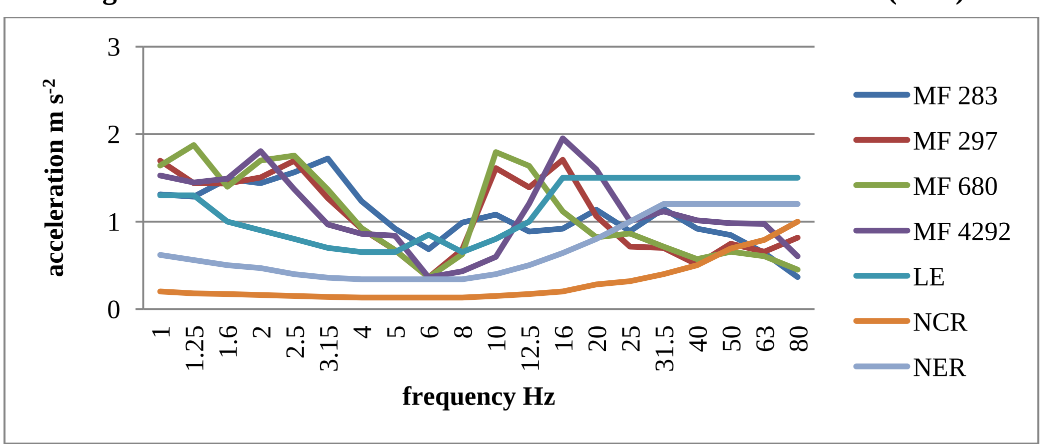

Figure 2: RMS Acceleration (Az- Axis) At 1/3rd Octave Band, for Tractors MF 283, MF 297, MF 680, MF 4292 Operation in Firm Ground, According to the Level Permitted by the ISO 2631 Standard (8 Hours Daily Work) for Exposure Limit (LE), Reduced Comfort Level (NCR) and Reduced Efficiency Level (NER)

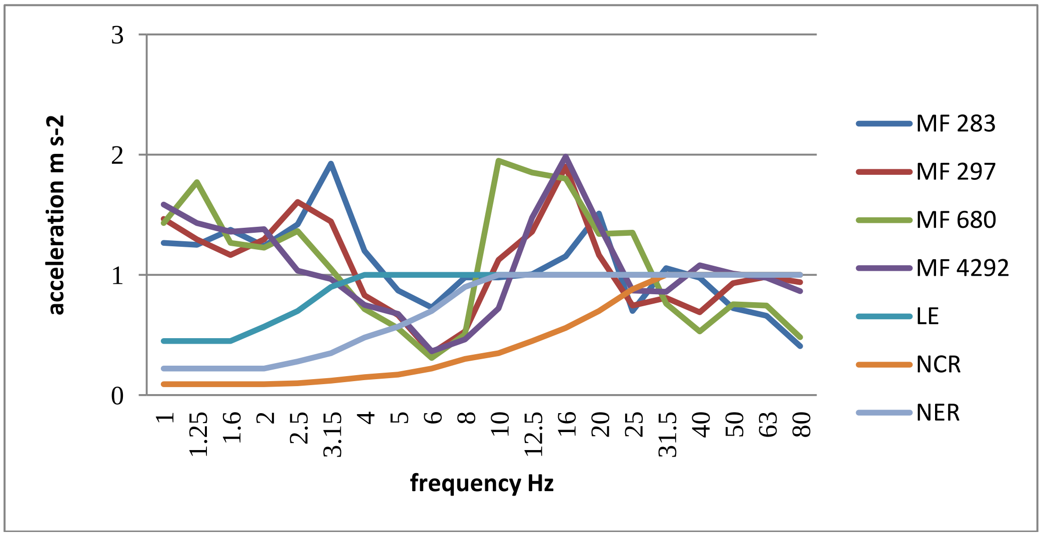

Figure 3: RMS Acceleration (Ax- Axis) At 1/3rd Octave Band, for Tractors MF 283, MF 297, MF 680, MF 4292 Operation in Firm Ground, According to the Level Permitted by the ISO 2631 Standard (8 Hours Daily Work) for Exposure Limit (LE), Reduced Comfort Level (NCR) and Reduced Efficiency Level (NER)

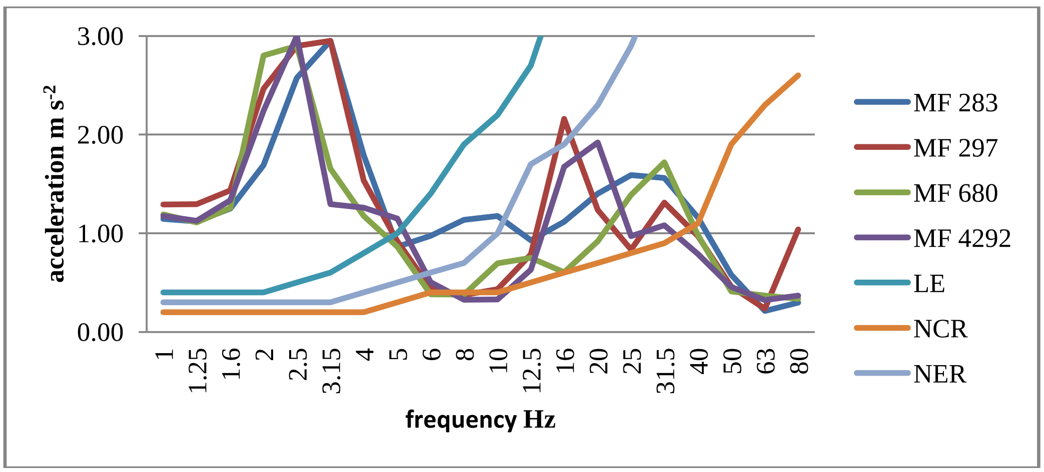

Figure 4: RMS acceleration (ay- axis) at 1/3rd octave band, for tractors MF 283, MF 297, MF 680, MF 4292 operation in firm ground, according to the level permitted by the ISO 2631 Standard (8 hours daily work) for exposure limit (LE), reduced comfort level (NCR) and reduced efficiency level (NER).

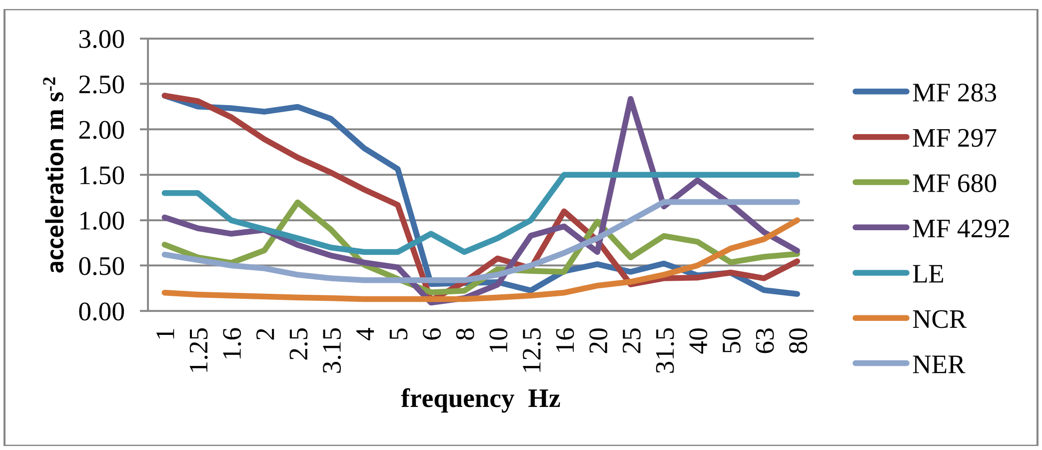

Figure 5. RMS acceleration (az- axis) at 1/3rd octave band, for tractors MF 283, MF 297, MF 680, MF 4292 operation in asphalt according to the level permitted by the ISO 2631 Standard (8 hours daily work) for exposure limit (LE), reduced comfort level (NCR) and reduced efficiency level (NER)

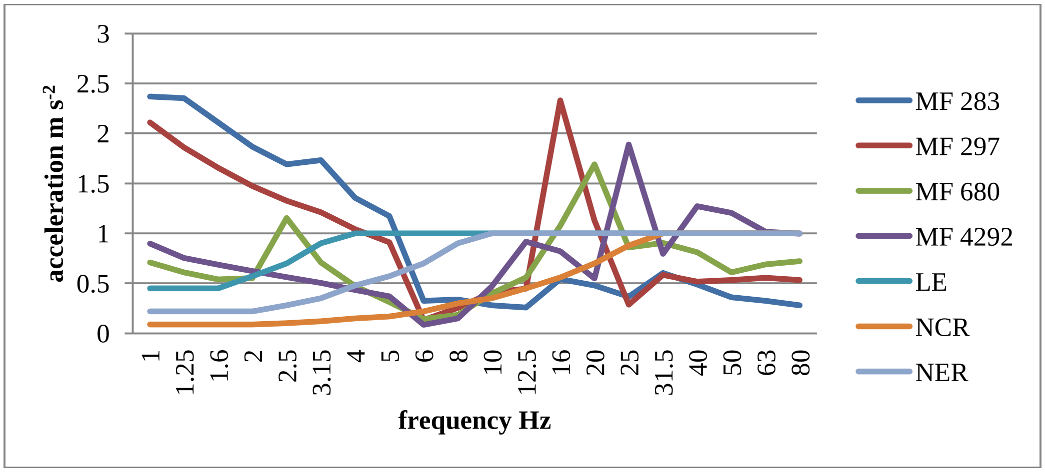

Figure 6: RMS acceleration (ax- axis) at 1/3rd octave band, for tractors MF 283, MF 297, MF 680, MF 4292 operation in asphalt according to the level permitted by the ISO 2631 Standard (8 hours daily work) for exposure limit (LE), reduced comfort level (NCR) and reduced efficiency level (NER).

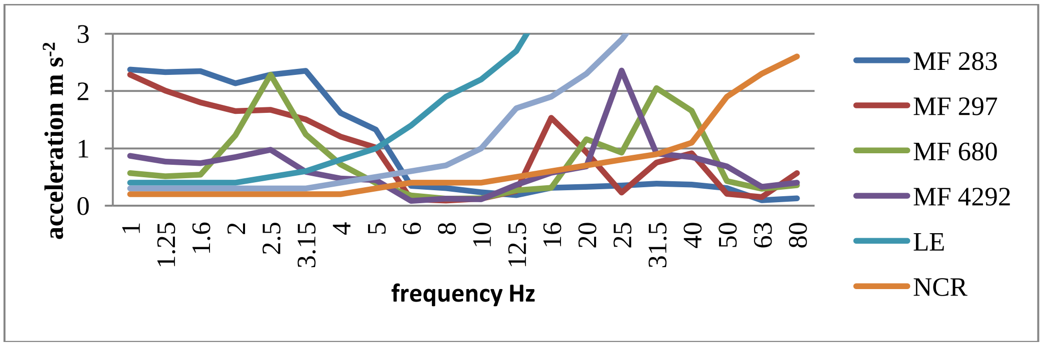

Figure 7: RMS acceleration (ay- axis) at 1/3rd octave band, for tractors MF 283, MF 297, MF 680, MF 4292 operation in asphalt according to the level permitted by the ISO 2631 Standard (8 hours daily work) for exposure limit (LE), reduced comfort level (NCR) and reduced efficiency level (NER).

8. Tables

Table 1: Maximum Permissible Daily Exposure and Noise Level

Noise level dB(A)	Maximum permissible daily exposure
85	8 h
86	7 h
87	6 h
88	5 h
90	4 h
92	3 h
95	2 h
100	1 h
105	30 min
110	15 min
115	7 min

Source: Norm (NR 15) of the Ministry of Labor and Employment.

Table 2: Average Values of the Noise Levels Obtained Close to the Operator's Ear and Every Ray of Distance of 1 to 10 Meters Taken from a One per One Meter, Targeted for the Right and Left Side, Rear and Front Parts of Each Tractor

Ray of distance (m)											
Position	0	1	2	3	4	5	6	7	8	9	10
MF 4292											
Front	-	92,7	87,0	85,0	83,1	81,7	81,0	79,7	79,2	78,5	77,1
Right	90,0	93,9	90,6	86,7	84,5	82,5	81,2	80,1	78,8	77,9	76,4
Left	89,3	94,1	90,7	87,5	85,6	83,7	81,8	80,4	79,3	78,5	77,3
Rear	-	86,3	84,4	81,3	78,5	76,6	75,1	74,2	72,5	71,8	70,8
MF 297											
Front	-	90,8	87,8	84,8	82,6	81,4	79,6	78,6	77,6	76,5	75,6
Right	90,3	92,8	88,6	85,6	83,5	81,7	80,1	79,2	78,2	76,5	76,4
Left	89,8	90,5	87,8	85,5	83,6	81,5	80,2	79,3	78,5	77,3	76,5
Rear	-	83,4	80,6	78,6	77,3	75,7	73,6	72,8	72,7	71,4	71,2
MF 283											
Front	-	91,6	88,4	84,4	81,6	79,8	78,4	77,1	76,4	74,6	74,0
Right	89,0	87,9	84,7	82,1	79,9	78,5	76,6	75,6	74,1	72,9	72,3
Left	92,7	89,4	86,8	84,5	83,0	82,0	80,2	79,3	78,1	77,1	76,3
Rear	-	84,6	82,8	79,4	77,9	76,6	75,6	74,4	73,4	72,4	71,3
MF 680											
Front	-	94,7	89,4	86,9	85,1	83,8	82,9	81,2	80,8	79,9	78,8
Right	88,0	95,1	90,4	88,2	85,8	84,0	82,3	80,8	79,7	78,7	77,8
Left	88,9	93,8	89,9	87,3	84,6	82,9	81,7	80,6	79,1	78,3	77,8
Rear	-	83,8	81,8	80,5	78,6	77,1	76,1	75,7	74,0	73,5	72,4

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