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Analysis of vibration levels in agricultural tractor with and without cabin

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The use of tractors is indispensable and essential to the agriculture. However, despite being efficient machines, tractors may fail in their projects, leading to the appearance of vibrations in different parts of their structure. Many studies show that the daily exposure to high levels of vibration, these are a risk factor for the health of the whole human body. In view of that, the purpose of this study was to evaluate the vibration levels in two static tractors, with the following specifications: Tractor (1) without cab, 4×2 model TDA manufactured in 1997, 89 kW of nominal engine power; tractor (2) with cab 4×2 model TDA manufactured in 2014, 65 kW of nominal engine power. The rotations were determined by the manufacturer´s manual of both tractors. The vibrations were measured by the accelerometer, properly calibrated. Data were collected in the Test Center of Machines and Agroforestry tires - belonging to the Faculty of Agricultural Sciences, UNESP Botucatu - SP. The accelerometer was fixed at different points of the tractors, collecting their overall structural vibration. For the conditions that were conducted this study, it can be concluded that the tractor vibrations tend to increase according to the addition of the use of time of the tractors. The engine is a great source of vibration as noted in both tractors, as soon the vibration in steer wheel control system is a concern, due to the fact that is a place where the operator maintain constant contact, however the vibrations levels in tractor with cabin were lower than tractors without cabin. The cabin is an important equipment in machines protecting the operator from the vibrations, besides the weather roughness, dust and possible objects that could be launched during the operations.

Key words: Vibration, ergonomics, working environment, operator.

INTRODUCTION

The tractor's use is indispensable and essential for modern agriculture. Operations such as soil prepare, fertilizing, crop, pulverization among others have been developed with these machines help. The technology use

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in new tractors production is growing, since this gain in modernity is repassed to producers as low loss in production, as for example, enhanced fertilizing, pulverization and seeding activities, agricultural inputs saving, low spending with maintenance and fuel consumption by tractors, reflecting directly in productivity grow by the crops and rural producer profits. However, besides its efficiency related to field operations, the tractors can show project failures, which lead to vibration arising in, structure diverse parts (Lima et al., 2005).

The Brazilian Rule NBR 10082 Mechanical Vibration of machines with 600 to 1500 rpm operation speed Base for specification and pattern helps in evaluation of vibration of normal machines considering the trust, safety and human perception (ABNT, 2011).

Some studies have been done with the aim of evaluating the influence of vibration in operator's body, following the guidelines and rules established by the Ministry of Work and Employment. According to Jain et al. (2008) evaluating the vibration in operation post, they have conclude the use of dampers and springs in operator's seat have an important role in minimizing this vibration.

Debiasi et al. (2004) described that the efficiency which the men-machine system executes its functions depends in many issues and that the ergonomics acts over them searching to optimize them to raise the system efficiency in a way to benefit the man, enhancing its yield during working time and saving his health and the machines' components. Murrell (1965) exposes some of those issues where the environmental conditions (temperature, light, humidity) of operation post, noise, commands and operator seat stand out in agricultural tractors operation approach.

Most of the time, the tractors that are in operation show comfort and safety problems for the operators. In general, they produce vibrations in low frequency, which are conveyed to operator post, and all parts of tractors structure (Servadio et al., 2007). These vibrations can generate mechanical problems in tractor's components and generate damages to operator's healthy, in a more concerned way.

Many studies show that daily exposure to high levels of vibration, without necessary time control of this exposure, is a risk to health of all human body. They can be two types, whole-body vibration and extremities vibrations. The whole-body vibration exposes the worker to permanent physical damages or nervous system disturbs resulting damages in spine region what can also affect circulatory and urologic system, besides the central nervous system. Disturb symptoms usually appear during or after the exposure as fatigue, insomnia, headache or tremor. However, these symptoms usually disappear after a rest time. Yet, the extremities one entails problems in neurological and muscular order, besides the osteoarticular and vascular perturbations which is identified as the Raynaud disease, whose illness provokes the symptoms like pricking, numbness, pallor, burns, cyanosis and gangrene, sometimes can cause the sick member amputation.

In a practical way, the vibrations consist in a complex mix of diverse waves with different frequencies and directions. From the analysis of these components, it is possible to calculate the vibration average level (Santos Filho et al., 2003). According to Tewari and Dewangan (2009), the vibration reduction decreases the damages caused by the friction between machines' pieces and components, besides it decreases operator's stress and consequently improve his life quality.

Vibration reduction is linked with the reduction at source, for such it is necessary to know the reality of machines, equipment and mechanisms to mitigate the vibration levels on the tractor. Even in static mode vibrations can damage equipment and injure the operator since many agricultural operations are carried out with the tractor stopped using only the power transmission system as a source of labor power.

Many studies showed that the daily exposure to high levels of vibration, these are a risk factor for the health of the whole human body and it can be reflecting directly on productivity and efficiency of the tractor. In view of that, the purpose of this study was to evaluate the vibration levels in two static tractors: Tractor (1) without cab, 4×2 model TDA manufactured in 1997, 89 kW of nominal engine power; tractor (2) with cab 4×2 model TDA manufactured in 2014, 65 kW of nominal engine power.

MATERIALS AND METHODS

The present work was done in Agroforestry tires and machines testing group – NEMPA, located in Agronomy Science College, FCA/UNEP in Botucatu, SP. It have been done structural vibration data samples in two distinct tractors which were static, with slow rotation engine, equivalent to 900 rpm, and with work rotation engine, 1700 rpm, as determined by the manufacturer manual of each tractor.

The used tractor (1) were a 4×2 TDA model without cabin manufactured in 1997 with engine nominal power of 89kW, front tires size was 23.1 to 30 and rear tires size of 14.9 to 26, and the other a 4×2 TDA model with cabin manufactured in 2014 with engine nominal power of 65 kW, front tire size was 14.9 to 24 and rear tire size of 18.4 to 34, both tractors were with their tires properly calibrated and ballasted with 75% of water. The moment of data sampling, the average temperature was 23.5°C, 76% of air humidity and atmospheric pressure was 701.75 mmHg, these data were obtained in the meteorological station of Soil and Environmental Resources Department from Agronomy Science College, Unesp Botucatu, SP. The vibration values were obtained by a measurer called accelerometer of Instrutherm brand, MV690, properly calibrated, according the Figure 1). The primary quantity used was the acceleration, expressed in m.s-2, based in ISO rule (2009).

The accelerometer was fixed in different parts in tractors, collecting the total structural vibration in them, the parts were operator seat base (OSP), engine linked frame (ELF), differential (DI), engine (EN), operator platform base (OPB), operator platform fixation (OPF), steer wheel control system (CS) and transmission system (TS) according the Figure 2. The sampling points were

Figure 1. (A) Accelerometer of Instrutherm brand - MV690; (B) 4×2 TDA model without cabin manufactured in 1997 with engine nominal power of 89kW; (C) 4×2 TDA model with cabin manufactured in 2014 with engine nominal power of 65 kW (A). Source: http://www.instrutherm.com.br.

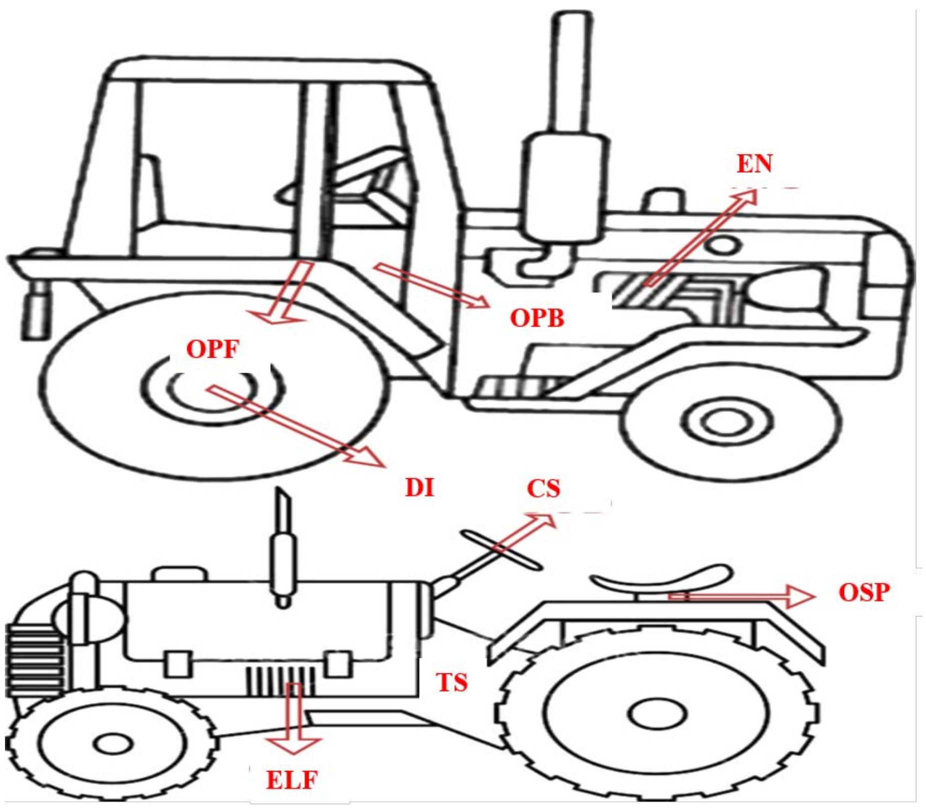

Figure 2. Tractors scheme indicating evaluating points. Source: http://pt.clipartlogo.com/premium/detail/tractor_57353851.html e http://www.midisegni.it/disegni/vari/tractor.gif adapted by author (2015).

previously cleaned with moistened cloth, so this way, the dirty would not interfere in data reading.

It is important to highlight that it had been done three following measurements in each of the points cited above, characterizing three repetitions of vibration levels and extracting an average between these levels.

The experimental design used was full randomized and after, the values were submitted to the average comparison by Tukey test, in

Table 1. Averages of vibrations by Tukey test collected from different places in tractors with engines in 900 rpm.

Tractor	Collected place								Unit
	OSB	ELF	DI	EN	OPB	OPF	CS	TS	
Without cabin	1.83[a]	2.43[a]	0.00[a]	7.90[a]	1.30[a]	1.50[a]	1.60[a]	0.10[a]	m/s²
With cabin	1.23[a]	2.93[a]	0.27[b]	17.03[b]	7.13[b]	1.40[a]	2.20[b]	0.13[a]	m/s²
C.V.	8.45	2.08	3.62	9.86	8.27	8.45	3.72	4.99	%

#Averages with same letters in column does not differ among them by Tukey test at probability 5%.

Table 2. Averages of vibrations by Tukey test collected from different places in tractors with engines in 1700 rpm.

Tractor	Collected Place								Unit
	OSB	ELF	DI	EN	OPB	OPF	CS	TS	
Without cabin	3.50[a]	6.73[a]	1.23[a]	33.86[a]	16.26[a]	4.10[a]	10.20[a]	0.54[a]	m/s²
With cabin	1.67[b]	7.90[a]	0.90[b]	21.03[a]	0.60[b]	0.87[b]	3.17[b]	3.34[b]	m/s²
C.V.	6.69	8.22	3.83	2.70	2.89	3.02	1.62	2.36	%

#Averages with same letters in column does not differ among them by Tukey test at probability 5%.

SISVAR 5.3 software, probability level of 5%.

RESULTS AND DISCUSSION

Table 1 contains the results obtained of engine vibrations in idling for both tractors; they were submitted to an average comparison. Analyzing data, it is verifiable that happened a statistical difference only in values on btained in differential (DI), engine (EN), operator platform base (OPB) and steer wheel control system (CS). It was observed that only in one sampling point, the tractor with cabin showed lower vibration than the one without cabin, the operator seat base (OSB), because this one have a cabin and less use time, since it was manufacturer in 2014. Possibly, the isolation of cabin interior is higher, so, the vibrations are lower in the work post.

Table 2 shows the results obtained by the vibration of both tractors with engine in 1700 rpm to an average comparison. The engine with a higher rotation, it is observed a raise in vibration in all places where the accelerometer was fixed, outstanding the engine (EN) and steer wheel control system (CS) showing more raises in vibration. It is observed that the steer wheel control system (CS) of the tractor with cabin vibrated less than the one without cabin, and according to Schlosser (2001) the cabins collaborates for the reduction of vibration levels which could reach the operation post. For the tractor without cabin, the vibrations in the operator seat base (OSB), in the operator platform base (OPB) and in the operator platform fixation (OPF) were higher than the ones obtained in the tractor with cabin, these results corroborate with Servadio et al. (2007), where the higher levels of vibration could be transmitted to operator post because the non-using of the cabin. It can be affirmed that the cabin presence in tractor was efficient, absorbing the vibration waves that could reach the operator, preserving this way, his health according to Tewari and Dewagan (2009).

It is good to point that the vibration analysis were done in the machine structure in different points, then, not all vibration could reach the machine operator, due to the fact that part of it is absorbed by the ground and also it can be beam in a noise form. According to Magalhães et al. (2013) the noise level increased in high rotation and decrease with the distance from the operator's seat. The speed rotation and type of floor interfere with the noise level. That conversion of vibration to noise is an important fact when the static vibration is being studied because the noise is a health risk to the driver as well as the vibration.

Conclusions

From the conditions that the work was done, it is concluded:

1. The vibration in tractors tends to rise according to using time growth being better observed in the tractor without cabin.
2. The engine is a great source of vibration as noted in both tractors, as soon the vibration in steer wheel control system is a concern, due to the fact that is a place where the operator maintain constant contact.
3. The cabin is an important equipment in machines protecting the operator from the vibrations, besides the weather roughness, dust and possible objects that could

be launched during the operations.

Conflict of Interests

The authors have not declared any conflict of interests.

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