Analele Universităţii din Craiova, seria Agricultură – Montanologie – Cadastru (Annals of the University of Craiova - Agriculture, Montanology, Cadastre Series) Vol. 51/2/2021

COMPARATIVE STUDY OF VIBRATIONS IN APPARATUS COMBINATIONS TANGENTIAL THRESHING

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Keywords: vibration, human body, harvesters combine

ABSTRACT

Vibrations are dynamics phenomenon which appear in some environment as a result of an external force whose action consist on an oscillation. The effect of these oscillations harm to the environment where they appear and if this environment is the human body then the results are more harmful, hauling consequences, sometimes irreversible, on the health of the human body. In this respect, studying and knowing the effects of the vibrations on human body have become a necessity, the research taking place in order to find out the limit to which the men could work in an environment with vibrations such as the agricultural machinery (self-propelled combines for cereals crop in a way) without no effects on the health of human being.

INTRODUCTION

Vibration (WBV) refers to the oscillations of mechanical energy transferred to the entire human body, usually through a support system such as a chair, a platform, or machines that move in air, earth, and water. The most prone are agricultural machines that expose people to periodic, random and transient mechanical vibrations that can interfere with the comfort, activities and health shown in Figure 1. [1]

Regular exposure of the entire human body to vibration for several months or years can lead to damage and back pain. The longer the operator is exposed to vibration, the greater the risk of suffering a back injury. Once the back pain condition occurs and it is continuous, repeated exposure to vibration can aggravate the injury.

Prompt action to protect workers from vibration should prevent the damage from getting worse. Especially for operators working on forestry machines, who are usually exposed to vibrations a total of 8 hours a day, so protecting the whole body is a priority, to reduce long-term pain in the shoulder, neck and back. Whole body vibration usually contains many frequencies, occurs in several directions and varies over time. [2]

Whole body vibration is a reflection of the comfort limitations of agricultural machinery and is subjectively assessed by their drivers or passengers. The effects of mechanical vibration are determined by the frequency of vibrations, magnitude, directions and duration of time. Humans have different sensations of vibration and different parts of the human body resonate at different frequencies.

In general, a man sitting horizontally, the natural frequency of vibrations is about 1-2 Hz, while the natural frequency of vertical vibration is 4-8 Hz. During these frequency ranges, vibrations of the human body are caused by uneven ground and are transmitted to the operator through the tire, bogie, chassis, cab and seat. [3] Vibrations are dynamic phenomena that arise in elastic or quasi-elastic environments following a local excitation and which are manifested by the propagation of the excitation inside the environment in the form of elastic oscillations [4].

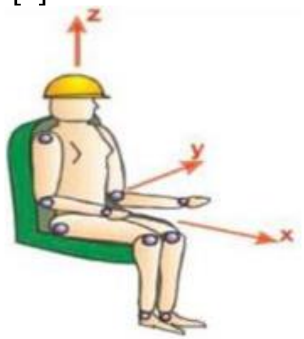

Fig.1. The ortogonal measuring directions that effect driver wbw [1]

In order to be able to discuss the excitation, propagation and radiation of an elastic wave, the condition must be imposed that at least one of the geometric dimensions of the medium be large enough, so that the initial excitation can be considered local.

The elements that condition the definition of the vibratory phenomenon allow a general classification of oscillations and elastic waves. Thus, depending on the dynamics of the phenomenon, there are vibrations with low variation frequencies, characteristic of mechanical structures, structures in constructions and seismic waves, as well as vibrations with high variation frequencies. The physical nature of the environment dictates how oscillations propagate: in a solid medium both transverse and longitudinal waves can propagate, while in fluid environments only longitudinal waves propagate. [5]

MATERIAL AND METHOD

Whole body vibration

The human body is a psychic and biological "system" of an extremely complex nature. Regarding a mechanical system it contains a linear number as well as a nonlinear number of "elements", and the mechanical properties are totally different from one person to another.

Biologically the situation is not very simple especially when the psychological effects are included in the human body. Given the human response to vibrations and shocks, it is also necessary to take into account both effects: mechanical and psychological [6].

Because experiments on the human body are difficult, time consuming and extremely unsightly processes, most of the data found were obtained through animal experiments. It is, of course, not always possible to compare the results obtained from animal experiments with the reactions expected from humans, but nevertheless such experiments frequently result in valuable information.

Considering the human body as a mechanical system, at low frequencies and vibration levels, can be roughly approximated by a linear system of grouped parameters (figure 2). One of the most important parts of this system with respect to the effects of vibrations and shocks seems to be the part called the "chest-abdomen system" [7]

This is due to a distinct resonant effect occurring in the 3-6 Hz range (Figures 3 and 4) and which makes effective isolation of vibration when sitting or standing very difficult. In addition, the resonance effect is found in the region of 20 to 30 Hz and is caused by the "head-neck-shoulder" system, figure 2. [8]

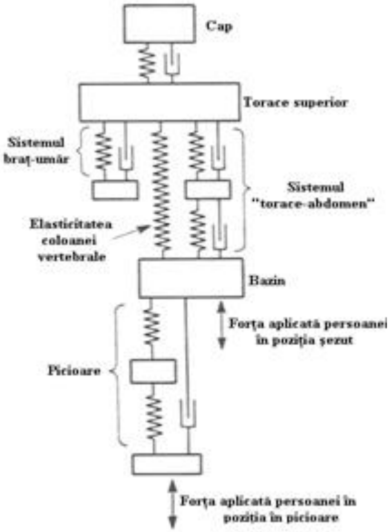

Fig.2. Simplified mechanical system representing the human body standing on a vertical vibrating platform [17]

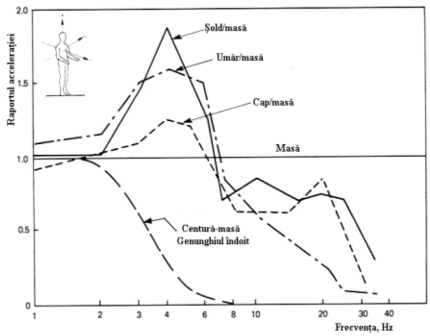

Fig. 3. Transmission of vertical vibrations from the platform to the variant parts of the human body in the standing position [17]

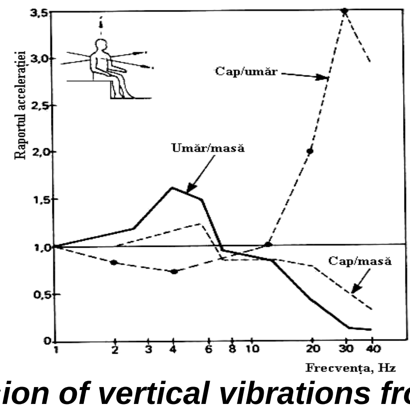

Fig. 4. Transmission of vertical vibrations from the platform to the variant parts of the body in the sitting position [16]

Also, in the region of 60 to 90 Hz the disorders are ambiguous suggesting a resonance of the eyeball, and between 100 and 200 Hz a low resonance effect was found in the jaw-skull system.

The vibrations of agricultural machinery and equipment are mainly generated by: working process, working conditions, operating mode, transmission of motion from the motor to other working parts, unbalanced masses in rotational or alternating motion, mechanical collisions, friction between parts in movement, unforeseen forces caused by the movement of the wheels on uneven surfaces of the road, etc.

Thus, the manufacturers of agricultural machines and especially those of grain harvesters are concerned with finding ways to reduce these vibrations in order to improve working parameters and especially the working conditions of the operator, knowing that mechanical parts can be repaired or however, the effects on the operator's health are sometimes irreversible. [9]

In order to achieve the best possible protection of the operator on the combine against vibrations and shocks, it is necessary that the seat on which it is placed during work is as ergonomic as possible and to ensure elasticity and damping conditions necessary for optimal comfort.

Solutions for reducing whole-body vibration for operators of agricultural machinery can be obtained in the following three ways: 1) Isolation of vibration sources by improving the terrain, proper selection of machines or equipment, proper loading and proper maintenance; 2) Improving the suspension systems between the operator and the vibration source; 3) Improving cab and seat structures or optimizing ergonomic posture In the last few years, much research has been studied to reduce vibrations on uneven terrain and improve driving comfort. [10]

Given that most of the vibrations are transmitted to the operator through the seat, numerous studies have been performed on different combines, to highlight the vibrations transmitted to it by the combine at stationary, during work and during transport.

Various parameters are used in measuring vibrations such as: movement, speed and acceleration, but the most used is the acceleration that can be determined very easily today using piezoelectric transducers. In general, the rules existing today on the permissible limits of exposure to vibration are given as a function of acceleration, for which there is the standard SR ISO 2631-78 which gives the limits of vertical vibration exposure curves - a_z (figure 5), and longitudinal - a_x and transversal - a_y (figure 6). This standard applies to vibrations transmitted to the person's torso in a sitting or standing position on the axis of the indicated system. [16]

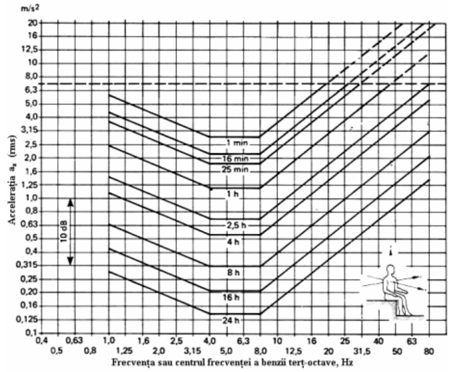

Fig.5. Limit of vertical vibration exposure curves [16]

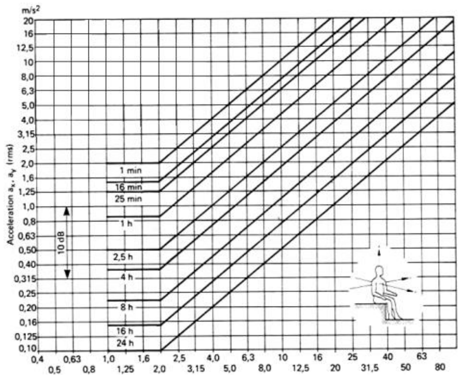

Fig.6. Longitudinal and transverse vibration exposure limit [16]

The effects of shocks and vibrations

Attempts to highlight the effects of vibration on the operator were performed on 9 combines, namely: New Holland TC 57, New Holland TC 56, Bizon Z085 Record, Laverda L626 I, New Holland TX 66, Sema 110, Sema 140, Deutz- Fahr Toplliner 4065 and Deuz-Fahr Toplliner 4075.

Vibration measurement was performed for three conditions in which the combine is: stationary, during work and in transport (at maximum speed, the most unfavorable). Among the accelerations measured for these conditions the highest or recorded during transport (without header). [12]

The maximum accelerations measured on the three directions, for each of the 9 combines are presented in table no. 1 [16].

Table no. 1

Nr. crt.	Working cond.	STAŢIONARY			IN WORK			TRANSPORT		
	Combine / accel.	a_x	a_y	a_z	a_x	a_y	a_z	a_x	a_y	a_z
1.	TC 56	0,44/ 40Hz	0,023/ 4Hz	0,072/ 3,15	0,41/ 63Hz	0,12/ 8Hz	0,077/ 3,15Hz	0,11/ 1,25Hz	0,16/ 1,25Hz	0,54/ 5Hz
2.	TC 57	0,07/ 2Hz	0,014/ 2Hz	0,066/ 10Hz	0,1/ 1,25Hz	0,07/ 1,25Hz	0,06/ 4Hz	0,086/ 2Hz	0,13/ 1,25Hz	0,18/ 8Hz
3.	Bizon Z085	0,019/ 1,25Hz	0,013/ 1,25Hz	0,13/ 6,3	0,24/ 1,25Hz	0,13/ 1,25Hz	0,09/ 6,3Hz	0,3/ 1,25Hz	0,26/ 1,25Hz	0,25/ 2,5Hz
4.	Laverda L626I	0,005/ 1,6Hz	0,006/ 1,6Hz	0,015/ 10Hz	0,09/ 1,25Hz	0,13/ 2Hz	0,12/ 10Hz	1,34/ 20Hz	0,74/ 2Hz	1,44/ 20Hz
5.	TX 66	0,003/ 2Hz	0	0	0,068/ 1,25Hz	0,16/ 1,25Hz	0,1/ 8Hz	0,4/ 31,5Hz	0,23/ 1,25Hz	0,4/ 16,3Hz
6.	Sema 110	0	0	0	0,13/ 1,25Hz	0,24/ 1,25Hz	0,27/ 5Hz	0,38/ 2,5Hz	0,34/ 1,25Hz	1,52/ 2,5Hz
7.	Sema 140	0	0,007/ 1,25Hz	0	0,15/ 1,25Hz	0,14/ 1,25Hz	1,11/ 50Hz	0,29/ 3,15Hz	0,14/ 2Hz	1,05/ 3,15Hz
8.	Deutz-Fahr 4065	0,005/ 2Hz	0,01/ 1,25Hz	0,01/ 8Hz	0,07/ 1,25Hz	0,34/ 1,25Hz	0,17/ 8Hz	0,75/ 25Hz	0,34/ 1,25Hz	1,02/ 2,5Hz
9.	Deutz-Fahr 4075	0,004/ 2Hz	0,002/ 2Hz	0,013/ 25Hz	0,12/ 1,25Hz	0,13/ 1,25Hz	0,11/ 10Hz	0,35/ 40Hz	0,39/ 1,25Hz	0,64/ 2,5Hz

where: $a_{x,y,z}$ – [m/s^2].

In the case of longitudinal and transverse accelerations, the range in which their effect is very strong is between 1 and 2.5 Hz, and in the case of vertical accelerations it is between 4 and 10 Hz. [16]

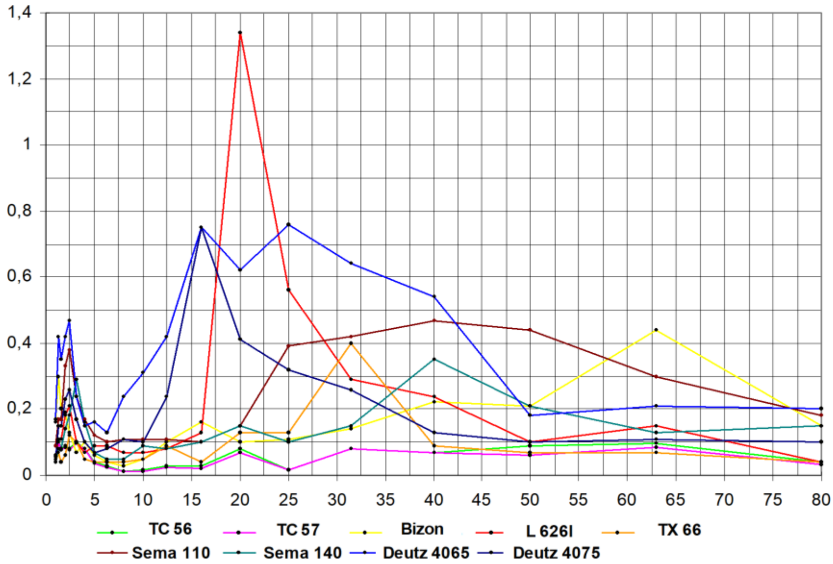

Fig.7. Maximum acceleration diagram a_x [17]

Based on the values of the accelerations measured at different frequencies and in the three possible conditions of operation of the combine (stationary, transport and work), the nomograms were drawn representing the maximum values of the accelerations a_x (figure 7), a_y (figure 8) and a_z (figure 9) in transport, this being the most unfavorable condition in which there is a danger to the operator's health.

At stationary and in work the accelerations appeared were very small and from the nomograms with the admissible limits given by ISO 2631-78 it results that the operator can work without danger over 24 hours, with small exceptions.

In transport, vertical accelerations were the most dangerous, resulting in a danger to the health of the operator when driving with the combine uninterrupted for more than: 1h (Sema 110, Sema 140, Deutz-Fahr 4065); 2.5h (Laverda L626I, New Holland TC 56); 4h (Deutz-Fahr 4075) and 16h (New Holland TC 57, Tx 66 and Bizon Record Z085). [16].

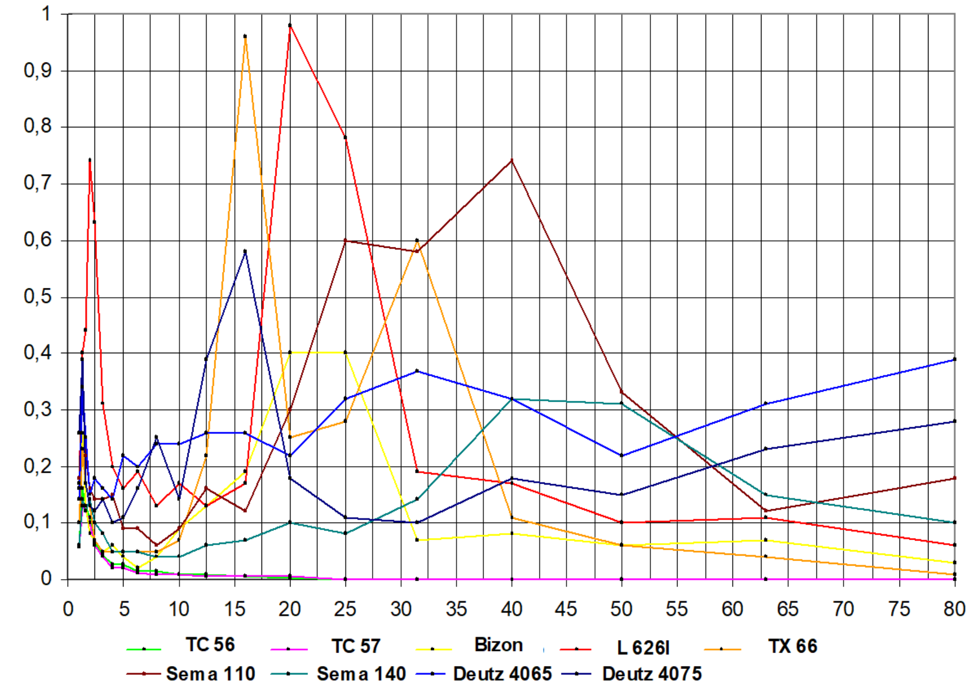

Fig. 8. Maximum acceleration diagram a_y [16]

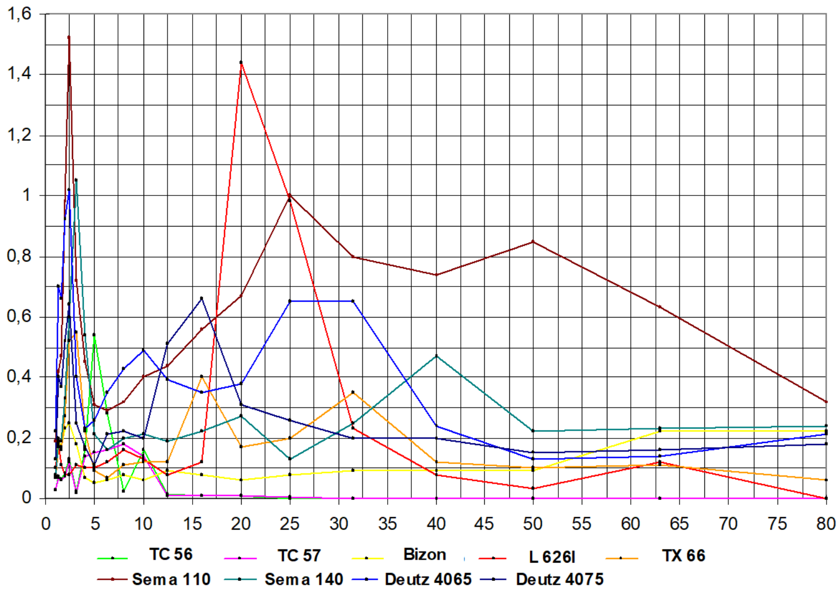

Fig. 9. Maximum acceleration diagram a_z [16]

RESULTS AND DISCUSSIONS

Scientists are trying to identify the main sources of vibration that occur inside agricultural machinery and want to find solutions to improve or repair sources of vibration. By conducting research studies on seat vibration in the John Deere 1055I combine (fig.10) and finding a suitable solution to prevent damage to users, a step forward can be taken to ensure the health and safety of operators and to increase the degree of use of this type of combine.

A comprehensive analysis of previous studies in this regard shows that, unfortunately, no efforts have been made to take into account the issue of the health of combine users, and now attempts are being made to address this issue.

Fig.10. Harvester Combine John Deere 1055[20]

Scientists performed tests on a Harvester John Deere combine on engine speed (at two levels of 1800 rpm and 2500 rpm) and the transmission ratio (1, 2 and 3 gears) with three repetitions. The tests were performed taking into account the factorial experiment based on a completely randomized design. A farm with an orderly and regular topography was selected to operate the combine. Because drivers of agricultural machinery are more sensitive to vertical vibrations, the vibrations of the combine transmitted to the driver through the seat were measured in the perpendicular direction (Z direction) [16, 17].

Because the driver's body mass influences the results of vibration tests, the combine was operated by a single driver weighing 78 kg at a distance of 100 m to measure and record the vibration signals of the machine seats [18, 19]. For measuring vibrations, the Lurton-VB 8203 vibration meter was used with a vibration acceleration range of 0.5-199 m / s2, accuracy of 0.1 m / s2 and a frequency range of 10-1000 Hz. [13]

The vibration meter was unidirectional, and its sensor magnetically offers the possibility of a fast and stable connection with a metal surface object. The sensor must not be under pressure and would be damaged if the driver is sitting on it. Therefore, in order to prevent damage and obtain accurate results, a hole was made in the seat of the combine with a larger diameter than the vibration meter. A metal plate with an area equal to the seat surface and a constant thickness was constructed, without any change when the driver sat on it shown in Figure 11. [15]

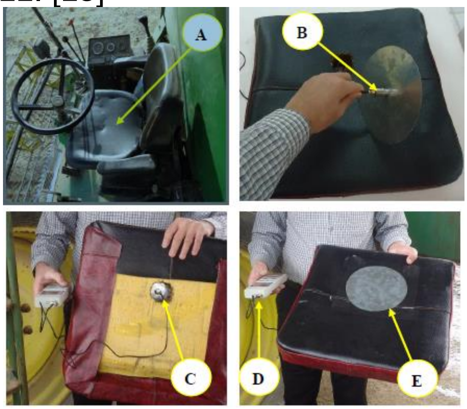

Fig. 11. The combine harvester' seat and connecting vibration measurement equipment:
A) Driver's seat, B) Vibration sensor, C) Location of vibration sensor to driver's seat, D) Vibration meter, and E) Vibration sensor holder plate [10]

Through the detailed vibration analysis, it was observed that the effect of two key variables, namely engine speed and transmission ratio on the vibrations transmitted from the driver's seat of the John Deere combine, is significant at a probability level of 1%. Increasing the engine speed from 1800 to 2500 rpm and changing gears from 1-3, would increase the average RMS value of vibrations. The effect of changing the engine speed on reducing the vibration of the combine seat was greater than that of changing gears. Therefore, the user is advised to use a lower engine speed (1800 rpm speed) when using the combine. Based on the findings of this study, drivers can drive the John Deere combine at 1800 rpm engine speed using gears 1 and 2 and 2500 rpm engine speed using stage 1 for 8 hours a day without any problems [14].

CONCLUSIONS

The vibration in the three orthogonal axes of the harvester is usually affected by the forces resulting from their directions (X, Y, Z). These forces are caused by the improper operation of the various agricultural units and by the rugged surface of the soil on which the combine is to be harvested. The nature of the soil surface that the combine always faces has shown a very large impact on the overall vibration results.

Therefore, most of the time, the operator is exposed to vibrations harmful to the human body due to difficult working conditions that can lead over time to major health problems. The diversity of the working conditions of the combine to be harvested. significantly affects the global and independent values of vibration at the three orthogonal axes (X, Y, Z).

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