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Biotribology – biodynamic models

WHOLE BODY VIBRATIONS IN OLDER IMT TRACTOR MODELS

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ABSTRACT

During their work agricultural tractor drivers are exposed to various negative influences including vibrations. They are vibrations generated in engines, and which are transmitted to the driver body (whole body vibrations) through the seat, floor and controls of a vehicle. The exposure to these vibrations over a long period of time can lead to serious health problems. Therefore, it is important to estimate risk to the health that comes from whole body vibrations in order to develop mechanisms of protection. The measurements of vibration levels in older tractor models of the manufacturer Industry of machinery and tractors Belgrade –IMT showed that the work of more than one hour poses significant risk from daily exposure to vibrations, high above values legally permitted. In those cases, an employer must take organisational and technical measures in order to reduce the levels below permitted values.

Keywords: whole body vibration, daily vibration exposure, agricultural tractor.

AIMS AND BACKGROUND

During their everyday activities, agricultural machinery operators are exposed to many negative influences that have complex and harmful impact on the man. Beside the physical strains, precipitation, unfavourable microclimate, various pollutions (dust, crop protection chemicals), high or low temperatures, noise and ergonomically inappropriate controls, vibrations are also a significant harmful factor. They are vibrations generated in the interaction between the unevenness of the ground and the work of engine, as well as the work of implements and ag-

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gregates[1]. Whole vehicle is, in working conditions, exposed to complex oscillatory processes that are transmitted to the driver body, from the engine, through the transmission and the chassis, to the cab, its floor, seat and controls. The vibra-tions are spread throughout the whole body of the driver, therefore they are called whole body vibration.

The disorders that occur in human body depend on the physical characteristics of vibrations (frequency, amplitude, velocity, acceleration), on the direction of spreading (vertical, horizontal, rotational), on the place of direct contact and spreading through the tissue (local in general), on one hand and, on the other, on the individual characteristics of a body. Frequencies of vertical oscillations of some human body parts are low (e.g.: head≈25 Hz, shoulders≈ 4–5 Hz, chest ≈ 60 Hz, spine ≈ 10–12 Hz, abdomen ≈ 4–8 Hz, hips ≈ 50–200 Hz, elbows ≈ 16–30 Hz, etc.) while the frequency spectrum of the tractor is very diversified and ranges from low frequencies 1–50 Hz (vibrations of the cab and the steering wheel, longitudinal vibrations of the tractor, the resonance of the wheels etc.), medium frequencies 100–1000 Hz (vibrations of the transmissions, exhaust system, mechanical and gasodynamic flows in the intake or exhaust system etc) and high frequencies 1000–5000 Hz (vibrations of the engine that occur because of the combustion processes, mechanical noise, etc.)[2]. A detrimental factor to the drivers health is the resonance which occurs when the forced vibrations frequency of a tractor matches the natural frequency of some driver organ tissue. In those cases, even vibrations with a relatively small amplitude can lead to significant dislocations in internal organs in the body.

Because of the combination of vibrations and other occupational harmful effects it is impossible to correlate the negative influences from vibrations and drivers' health deterioration. However, many studies, biodynamic models and understanding of human body indicate the following effects of whole body vi¬bration to health: lower spinal column disorders, digestive system diseases and cardiovascular system disorders (hyperventilation, increased heart rate, etc.)[3,4,7].

Measurements of vibration levels have shown that the risk to the tractor drivers' health exists, even in case of drivers who are exposed to vibrations only one hour a day. The problem is a standard working day of professional drivers, which is 8 h and during the agricultural season it is often 12, even 16 hours.

The harmful effect of vibrations is obvious in older tractors especially, which do not have efficient vibration and impact absorption system because they have simple suspension system on the front drive and simple mechanical seats. Modern tractor models are better because they have improved suspension systems and seats, but in comparison to improvements related to power, velocity, electronic controls, the protection from vibrations could be significantly better. Currently, there are more than 25 million tractors in use worldwide which are more than 15 years old on average. Most of the tractors are in the USA, which is 4,2 million,

and with average life of 25 years[5]. According to 2012 Registry of agricultural resources, in Serbia there are 410 894 two-axle tractors, out of which even 95% are more than 10 years old.

This paper offers evaluation of exposure to vibrations levels of the whole body for drivers of some older tractor models of Serbian manufacturer IMT Belgrade.

EXPERIMENTAL

MEASUREMENT AND CALCULATION METHODS

The manufacture of IMT tractor series 533, 539, 558 and 560 (Fig. 1) began in the seventies in the last century in the production plant of IMT Belgrade. Regardless of the fact that 533 and 558 series are not a part of IMT offer any longer, and 560 and 539 are made in limited numbers, these models are most numerous in Serbia today[6]. The tractors are manufactured under the licence of Massey Ferguson. The 533 and 539 series have got three-cylinder M33/T engine with 35 and 39 HP, re-spectively, while the 558 and 560 series have got four-cylinder M34/T engine with 58 HP. The 533 and 558 series were manufactured either with or without the cab.

Fig. 1. IMT tractors

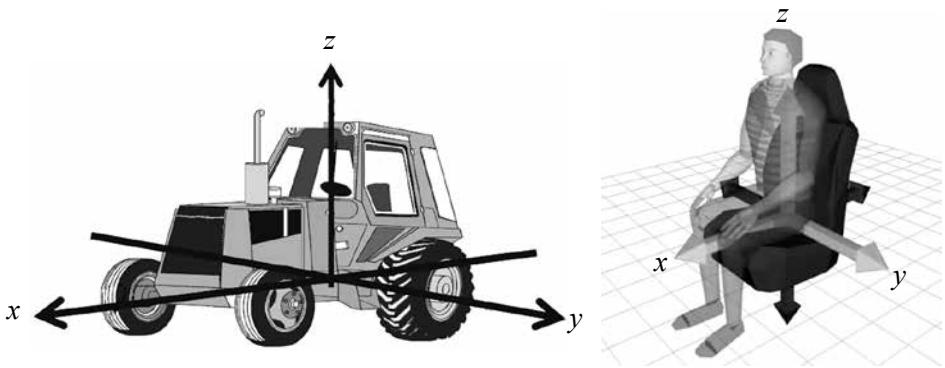

Fig. 2. Defining of orthogonal measuring directions on the tractor and the operator

As a measuring device a Brüel & Kjær type 4447 human vibration analyser was used, with a type 4524-B acceleratometer built in a Seat Pad type 4515-B-002.

The vibration levels were measured in three orthogonal measuring directions: *z*-direction (vertical), *x*-direction (afterward) and *y*-direction (sideward) (Fig. 2).

The tractors performed their everyday activities whose lengths were different, but the drivers level of daily exposure to vibrations A(8) was measured for a referent 8-hour period[9]. Only for the model IMT 560 the measurement was performed twice.

The obtained values were compared to maximum permitted values that are, in EU, regulated with the Directive 2002/44/EC[8]. Republic of Serbia incorpo-rated the Directive 2002/44/EC into its legal framework. In case of daily exposure to whole body vibrations it specifies exposure limit value (ELV) of 1.15 m/s^2 which must not be exceeded in professional working conditions and exposure action val-ue (EAV) of 0.5 m/s^2, in case of which employers must control the risks coming from vibrations.

RESULTS AND DISCUSSION

After obtained values of vibration levels (Table 1), levels of drivers exposure (Table 2) were calculated by means of HSE whole body vibration calculator[9].

Table 1. Values of vibration levels

Tractor model	Average r.m.s. acceleration [m/s^2]			
	x	*y*	*z*	highest axis
IMT 533	0.55	0.79	1.12	*z*
IMT 539	3.04	2.34	4.42	*z*
IMT 558	3.44	2.42	4.85	*z*
IMT 560 (1)	1.78	1.93	2.74	*z*
IMT 560 (2)	1.95	1.58	4.00	*z*

Table 2. Daily exposure levels

Tractor model	Partial daily vibration exposures (m/s²)			Daily vibration exposure A(8) (m/s²)	Time to EAV (h:min)	Time to ELV (h:min)
	A(8) *x* axis	A(8) *y* axis	A(8) *z* axis			
IMT 533	0.77	1.11	1.12	1.12	1:35	8:26
IMT 539	4.26	3.28	4.42	4.42	0:06	0:32
IMT 558	4.82	3.39	4.85	4.85	0:05	0:26
IMT 560 (1)	2.49	2.70	2.74	2.74	0:15	1:24
IMT 560 (2)	2.73	2.21	4.00	3.74	0:07	0:39

The obtained results of daily exposure show that, during everyday activities, there is a risk to IMT tractor drivers from whole body vibrations. Except for IMT 533, all other models exceeded even ELV.

In case of 539, 558 and 560, the results of the drivers daily exposure indicated unacceptable risk from vibrations to health. In case of such high levels the activities had to be canceled until vibration levels were reduced below legaly permitted values. In these cases some organisational measures, such as changing the drivers, would not help because permitted length of work (time to ELV or EAV) was too short in comparison to working day during an agricultural season (8, 12 and, even, 16 h).

The obtained values indicated critical levels of exposure along all axes, whereby the highes values axe is the *z*-axe. It is obvious that the suspension, which is basically vital for vibrations and impact absorption along *z*-axe, during the activities in the field was not efficient. When tractors are moving on the road, it is the opposite – the suspension is efficient because it reduces vibrations along the *z*-axe[10,11].

As the best solution, in case of these IMT tractors, for vibration level reduction and possible impact absorption one can consider building-in of modern seats. These seats meet strict ergonomic requirements, and according to their manufacturers, they can reduce vibration levels up to 75%. The other technical measures, the change of suspension for example, is non-cost effective with respect to the life of the machines.

CONCLUSIONS

The measurements of vibration levels and the evaluations of drivers daily exposure levels indicate that the older IMT models are risk from the aspect of harmness of whole body vibrations. It seems that it is a logical consequence of their life and their design and manufacture from even 40 years ago when meeting ergonomic requirements was not prime objective. Old suspension systems and seats

cannot absorb vibrations generated during the work of, now, old diesel engines built-in in these tractors.

It should be kept in mind that the vibration level, and their spreading in particular, can be also affected by the driver himself. A skilled and expirienced driver that is familiar with the capacities of his vehicle, and is also well-acquainted with the negative impacts of vibrations, will be able to reduce the vibration level, at least by a minimum extent.

In case of measured IMT tractors, from the aspect of ergonomics an analysis of seat quality should be carried out as a measure for vibration level reduction, as well as their consequent purchase and building-in. Mandatory procedure assumes that after a seat is built-in vibration levels are measured and evaluated so as to verify the effects of the measure taken.

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