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Research Article

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Ergonomic Evaluation of Vibration in Tractor Operators

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Abstract Tractor users in forestry, as in other technological applications and professions, are faced with serious spinal disorders due to some negative features of vibration. In this study, vibration transmitted to the operator from tractors used in forestry in Turkey and the effects of this vibration on human health were evaluated. After giving general information about vibration and its effects, ergonomic measures to be taken for tractor users to work in a healthier, safer and more efficient way are presented. Tractor drivers are exposed to high levels of whole-body vibration. The most important of the tractor vibration components is the vertical vibration acceleration value, which has quantitatively larger values and has high human sensitivity. In vibration control, a risk assessment should be made first. Operator training, selection of suitable vehicles and seats, and work organization are the most important vibration control methods.

Keywords Ergonomics, vibration, seat type, WBV, forestry

Introduction

Millions of people around the world are exposed to mechanical vibrations throughout the day at work. Vibrations have an important place in terms of human-machine relations. Since the 1930s, many studies have been carried out to determine the sensitivity of the human body to vibrations [1]. Vibration is a well-known environmental factor with the proliferation of moving vehicles such as tractors, motor vehicles and airplanes.

The effect of vibration is important both in terms of human health and working comfort, as well as in terms of work efficiency, work quality and work safety. Vibration is a problem that affects not only the industrial sector but also rural workers [2]. Mechanical vibrations are an important environmental factor in mobile workplaces such as the driver's seat of a motor vehicle or manually operated machinery such as a chainsaw [3].

In this study, the vibration transmitted to the operator from the tractors used in forestry in Turkey and the effects of this vibration on human health were investigated. In this context, first of all, general information about mechanical vibrations is given. Then, vibration, its effects and protection methods in tractors were evaluated. Finally, necessary precautions to be taken in order to minimize the effects of whole body vibration caused by tractors used in forestry are presented.

The factors that determine the effect of vibration are its amplitude, frequency, duration of action, variation with time, direction of vibration and point of impact of vibration. One of the most important concepts related to vibration is frequency. The number of vibrations per second is called the frequency. Another important concept, the amplitude, refers to the highest wavelength of the oscillation [4]. Fundamental quantities in mechanical vibration are shown in Figure 1. The first integral of the measured general vibration acceleration (ms^{-2} or g-gravity acceleration) gives the velocity of the vibration and the second integral gives the amplitude.

The international standard ISO 2631-1 (1997) covers the evaluation of periodic, random and discontinuous vibration movements in relation to people's health, perception and comfort responses. The standard defines the vibration measurement location and directions, the equipment to be used, the duration and frequency weightings of the measurements, and the evaluation of the weighted rms (root mean square) acceleration results of the measurements.

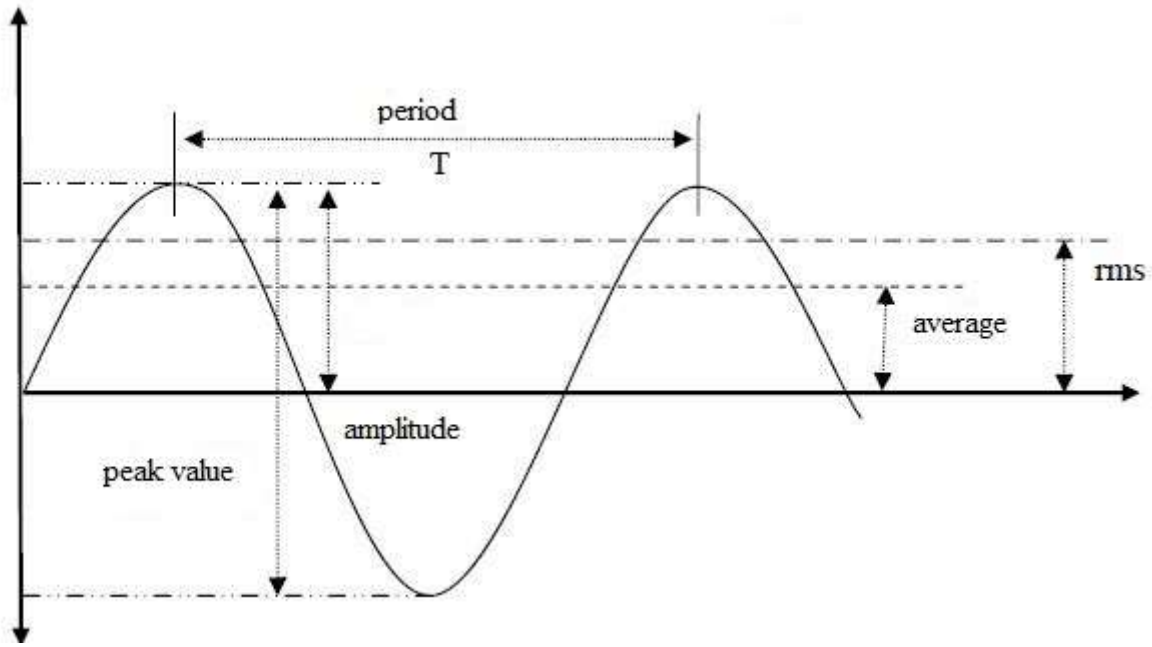

Figure 1: Fundamental quantities in mechanical vibrations

In vibration measurement, whole body vibration is made on the seat cushion of the driver's seat, from where the hand grips the handle of the vehicle. Whole body vibration is produced by various types of industrial machinery and by all means of transport [5]. Vibration measurement tool (accelerometer), tape recorder, frequency analyzer, frequency weighting network and display unit (printer or recorder) are required for vibration measurement [6].

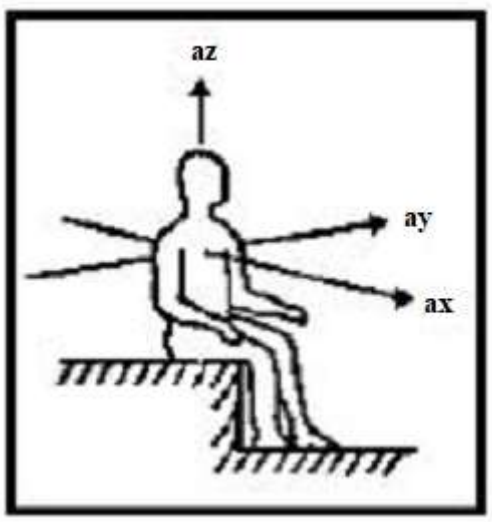

Figure 2: The x, y and z axes of vibrations affecting human

In the evaluation of vibration effects, acceleration is usually measured. This is because the biggest disturbing quantity is acceleration [7-8]. In order to better understand the relationship between vibration and comfort, systematic experimental studies have focused on determining which types of vibrations change people's judgment of describing their discomfort. The feeling of discomfort in humans increases with the energy level that the person is exposed to. The acceleration value of the vibration signals is an energy proportional to this energy and is used to measure the discomfort that occurs [9].

Method

Effects of Vibration

Tractor operators, as in other technological applications and professions, are faced with serious spine and stomach ailments due to some negative features of vibration. The work performance and concentration of operators who are exposed to high levels of vibration for a long time are adversely affected [10-11]. In general, the effects of whole body vibration on the body; It can be counted as a lack of perception, discomfort, decreased vision, disruption in the function of motor nerves, spinal column damage, digestive system and reproductive system damages [12]. In order to understand the effect of vibration, it is necessary to correctly understand five physical quantities consisting of the point of impact of the vibration on the body, its frequency, acceleration, duration of action, the specific frequency and resonance of the affected system. The harm of vibration to the human body depends on the duration of exposure to vibration, the frequency of vibration and the effect area of vibration on the human body [13]. Vibrations originating from the surface on which the machine moves are more important for human sensitivity. Because the vibration frequencies of human organs mostly have maximum values at 4 Hz. The most negative for humans are vibrations between 3-6 Hz. Human sensitivity to vibrations in this region is high, and vibration isolation possibilities are limited at these frequencies [14].

Depending on the type of machine used, it acts in two ways: whole body vibration (WBV) and hand-arm vibration (HAV). In whole body vibration, the resonance event occurs at 4-8 Hz in the z-vertical axis and 1-2 Hz in the y-horizontal axis. In hand-arm vibration, resonance is seen at 100-250 Hz [15]. When the effect of vertical vibrations is examined, the critical vibration resonances (resonance frequency) are around 4-6 Hz for the whole body, 15-20 Hz for the head, and around 60 Hz for the eyes and surroundings. Vibrations cause physiological changes in humans, as high frequencies also affect the hand-arm, foot-leg organs. These changes cause deterioration of body reflex, increase in breathing and energy use, increase in heart rate, muscle fatigue, decrease in hearing, affect the nervous system, pain and cramps in the body [16]. Reflex disorders seen in people exposed to mechanical vibration also cause work accidents.

The minimum health and safety requirements to which workers are exposed due to risks arising from physical factors (vibration) are also defined in the European parliament and council decree [17]. In this decree, the daily exposure limit value is rms = 1.15m/s^2 (an alternative vibration value VDV = 21 m/s$^{1.75}$), the daily exposure warning value is rms = 0.5 m/s^2 (an alternative vibration value is its value is VDV = 9.1 m/s$^{1.75}$). The variation of vibration acceleration values over time according to international standards is given in Figure 3 [18-19-20]. The effects of horizontal and lateral vibrations are the same as for vertical vibrations. However, at frequencies around 0.5 Hz, an additional load occurs in the form of balance disorders that affect the health status. If the frequency of horizontal vibrations is 20 Hz or more, cramp-like symptoms are observed in the feet [21].

Vibration in Tractors

There have been many studies showing that farm tractor operators are exposed to high levels of whole-body vibration [5-22-23]. In the examinations carried out on tractor drivers, abnormal spinal disc discomfort, chronic arthrosis (wearing of the cartilage in the joints) and stomach and intestinal ulcers were found in these people. Vibrations in tractors are affected by the type of machine, surface roughness, forward speed, power transmission organs and seat insulation system features. It has been determined that 80% of the truck drivers, 71% of the tractor drivers and 44% of the bus drivers have spinal injuries due to the vibration effect [24].

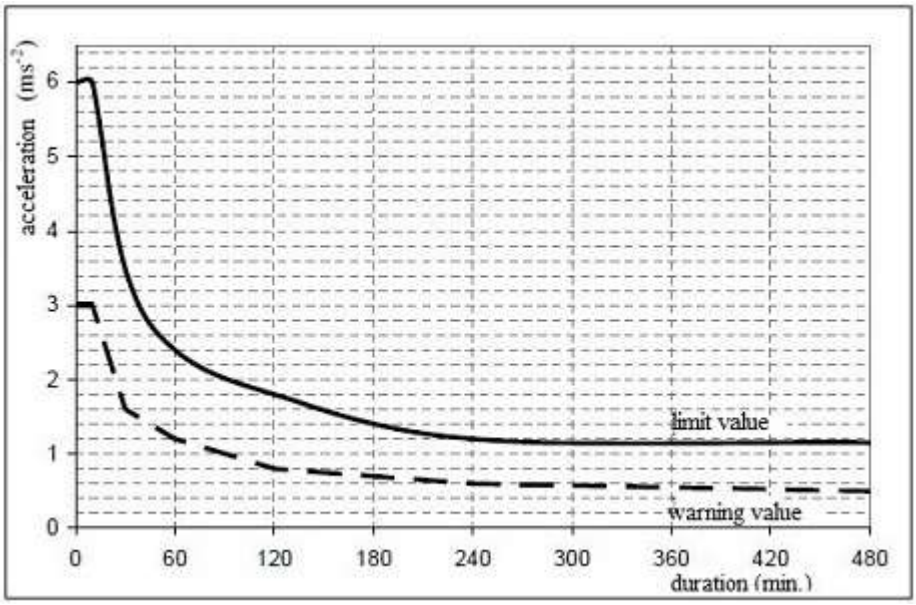

Figure 3: Vibration acceleration-exposure time warning and limit values

Vehicle accelerations measured for seated operators (ms^{-2}), forklift truck (0.8), bulldozer with standard seat (0.52-0.64), tractor on brick paved road (1.76-2.03), bulldozer with anti-vibration seat (0.43-0.80), tractor on asphalt (1.17), tractor on the road (1.1), tractor in the field (0.6), bucket loader (0.5-2.3) [2]. In a study by Oh et al. (2002) the vertical vibration acceleration value was found to be approximately 1.92 ms^{-2} at a speed of 1.7 km/h and 2.93 ms^{-2} at a speed of 5 km/h on a forest road. Under these conditions, it is possible to work for a maximum of 1 hour without exceeding the limit values according to international standards.

WBV measurements obtained from three different seat and tractor types were recorded and evaluated [25]. A statistical summary of the data regarding the skidding tractors obtained through the evaluation of the measurements is presented in Table 1. Average total WBV values (a_t) obtained from measurements with the old seats during the extraction practices were 1.51, 1.15, and 1.25 ms^{-2} for the skidding tractors international, fiat and ford tractor, respectively. The highest WBV values for all axes (a_x = 0.58 ms^{-2}, a_y = 0.65 ms^{-2}, a_z = 0.89 ms^{-2}, a_t = 1.51 ms^{-2}) were measured in the 30 year-old tractor with old without spring seat. When these vibration parameters is examined, the total value of vibration is above the warning limit of 0.5 ms^{-2} and the hazard limit value of 1.15 ms^{-2} specified in international standards.

Table 1: Statistical data regarding the WBV values (ms^{-2}) of the skidding tractors[a]

Tractor type	Seat type	a_x	a_y	a_z	a_t
Ford 6610	Without spring	0.58 (0.10)	0.65 (0.19)	0.89 (0.19)	1.51 (0.33)
	Couple springs	0.41 (0.10)	0.49 (0.23)	0.51 (0.12)	1.04 (0.36)
	Four springs	0.25 (0.05)	0.33 (0.30)	0.46 (0.10)	0.76 (0.08)
International 444	Without spring	0.35 (0.05)	0.43 (0.11)	0.82 (0.21)	1.15 (0.21)
	Couple springs	0.42 (0.14)	0.44 (0.14)	0.57 (0.16)	1.02 (0.31)
	Four springs	0.30 (0.08)	0.30 (0.45)	0.48 (0.03)	0.77 (0.09)
Leyland 154	Without spring	0.46 (0.05)	0.54 (0.09)	0.75 (0.07)	1.25 (0.08)
	Couple springs	0.29 (0.07)	0.37 (0.06)	0.50 (0,16)	0.83 (0.20)
	Four springs	0.24 (0.11)	0.36 (0.52)	0.44 (0.05)	0.76 (0.12)

[a] Values are means, and standards deviations are in brackets

Vertical vibrations are the most ergonomically important of the tractor vibration components. Because vertical vibrations have higher values than others, both quantitatively, and human sensitivity to these vibrations is high. For this reason, vertical vibrations have been investigated in most studies by neglecting other vibration components [26]. The difference in vibration transmission between the suspension seat and the normal seats is shown in figure 4 comparatively.

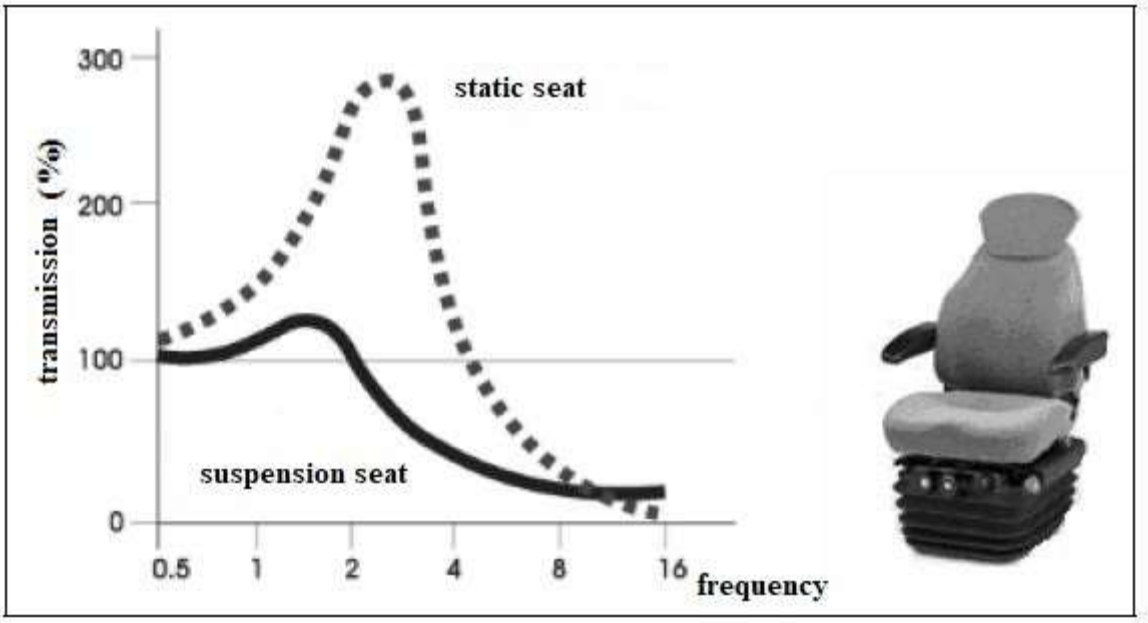

Figure 4: Vibration transmission in suspension and normal seats

In studies on tractor drivers, it has been determined that operators suffer from stomach ailments due to gastritis due to working [24-27-28]. The vibration caused by the road is generally at the resonance limits of the body, affecting the whole body and causing the movement of all the muscles. As a result, the neck and shoulder muscles get tired more easily and the support of these muscles decreases. Well-designed driver's seats can reduce these discomforts by 70%.

Conclusion

Tractor users face serious inconveniences due to mechanical vibrations. Vertical vibrations in tractors exceed the limit values specified in international standards. Vibrations in tractors are under the influence of features such as the type of machine, ground roughness, forward speed, seat insulation system. In order to prevent the negative effects on the health and work performance of the operators in the tractors, a risk assessment should be made, especially by measuring the vertical vibration values.

Vibration permeability in vehicle operators is tried to be prevented by various suspension systems. Vibration permeability in tractor operators can be prevented by the tractor tire and operator seat. Tractor vibration accelerations also increase with the increase in tire pressure.

Tractor front and rear tire pressures should be kept at appropriately low levels. Tractor operator seats with damaged static and dynamic structure should be renewed. Seats with automatic mass adjustment and high suspension system should be preferred instead of seats whose suspension system does not work. Since the tractors work in rough terrain with different equipment, they generate more vibration than the vehicles moving on the normal road. Appropriate working posture, work performance and physical environmental conditions are created by choosing an ergonomic seat.

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