Investigation and Analysis of Driver Weight on His Health and Comfort in Three Commonly Used Tractors in Iran

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ABSTRACT

Occupational safety and health of agricultural workers has not yet received its due attention in developing countries. This is particularly true in the case of tractor drivers who operate tractors in unfavorable conditions and in a high level of seat and tractor vibrations. Therefore, an investigation of vibration sources and finding some methods for decreasing them are of considerable importance. In this research work, vibrations that the tractor operators of different weights, are exposed to, were examined during the operation of three commonly used tractors in Iran, which are plowing with moldboard plows, disk harrows or routine road travel, at different forward speeds. Acceleration data of tractor body and its driver, while riding the tractor, were measured and recorded. Following, Fast Fourier Analysis, root mean square of weighted accelerations for the case of driver health and comfort were analyzed and evaluated. Results revealed that levels of forward speed did not have any significant effect on vibrations introduced to drivers body, however, the average of acceleration vectors of different tractors and their drivers bodies revealed a significant influence($p<0.01$). Moreover, with increasing a driver's weight, the average of acceleration vectors on his body was decreased. In a comparison of permissible riding hours/day, JD3140 and U651 tractors scored maximum and minimum values, respectively. Also a comparison of acceleration vectors for different tractor operators, when compared with international standards, showed that the comfort level for these tractors was extremely low.

Keywords: Tractor, vibration, driver weight, health and comfort, Iran

1. INTRODUCTION

Recently, occupational health problems of agricultural workers have not received significant attention in developing countries. This is particularly important for tractor drivers who operate the tractor in unsuitable condition and high level of seat and tractor vibration. Tractors in high-income countries are very sophisticated and almost all have enclosed environment controlled suspended cabins and well design instrument and controls. These cabins are not likely to become common in countries like Iran, because of economic reasons.

Vehicle ride vibration is usually evaluated by acceleration value and its direction. In this regards, the acceleration which is effective on a human body can be divided into two groups, rotational and translational acceleration. Translational vibration is transmitted to a human body along three perpendicular axes, longitudinal, lateral and vertical direction. Most of the tractor vibration occurs in the vertical plane, which is transmitted from wheels to the seat, whereas tractor drivers have more sensitivity to this type of vibration. On the other hand, vertical vibration level during field operation is usually exceeded from ISO standards levels. Longitudinal and lateral vibrations occur due to tractor conditions. Vibration modes created

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by translational vibration on the human body caused discomfort, pain and injury. However rotational acceleration usually didn’t cause any pain and injury (Griffin *et al.* 1982).

The mechanical damages of body organs are mainly due to strains in the tissues produced by vibration. Moreover, physiological effects are not always compatible with frequency or any other aspects of vibration (Chaffin and Anderson 1990). The problems of tractor ride become more critical since the dominant natural frequency of the tractor (1-7 Hz) lies within most critical frequency range of human body (e.g. human trunk and lumbar vertebra have a natural frequency of 4-8 and 4-5 Hz, respectively) (Pop and Hansson 1992 , Troup 1978).

The vibration levels of tractors without cabins and suspensions have been extensively compared to the other road vehicles having suspension (Bovenzi and Betta 1994). Moreover, many studies have been conducted on tractor drivers in order to measure and compare the driver vibration with international health standards (ISO 2631-1) or concentrated on the effect of vibration on driver health (Futatuka *et al.*1998; Gerke and Hoag 1981; Sorainen *et al.*1998; Kumar *et al.* 2001).

Overall seating comfort is influenced by both static and dynamic characteristics of seat system. An overview of work related to comfort in seat-operator interface affected by static and dynamic pressure distribution, and other related parameters were conducted by Singh *et al.* (2003). This study revealed that seat-human interface pressure on the soft seat is more evenly distributed on a larger effective contact area than on a rigid seat. The pressure distribution at human seat interface of a rigid seat is affected by seat height, posture, type of cushion and frequency and vibration. The dynamic pressure at interface is nearly sinusoidal in the vibration range of 1-10 Hz. Under vibration excitation, increase in excitation magnitude causes increased maximum pressure and maximum effective contact area around resonant frequency of 4.5 to 5.0 Hz. Postural stress, whole body vibration and shocks are recognized as important factors, causing low back pain.

Mehta *et al.* (1996) installed a seat on a 7.5 kW rotary power tiller and investigate the effects of vibration transmissibility from seat to the driver. It was observed that, equivalent acceleration levels increases as forward speed of travel increased. Also acceleration levels in lateral axis were insignificant. Moreover, there was no conclusive difference between measured acceleration levels on untilled and tilled fields during transportation and rotatilling. Finally they concluded that exposure time for power tiller operator should not been exceeded 2.5h during rotatilling and 4h during rotapuddling.

Griffin (1990) presented acceleration data regarding to vibration exposures in a variety of vehicles showing that some vehicles such as tractors and military tanks showed more weighted acceleration in horizontal direction than vertical direction. Despite of the relative importance of horizontal vibrations comparing to the vertical vibration, most of previous researches concerning to the effects of vibration on the human body have been restricted to the vertical vibration.

The objective of this research is investigation of vibration levels of three common used tractors in Iran and effects of driver weight on the vibration transmissibility from tractor seat to the human body.

2. MATERIALS AND METHODS

Experiments were conducted on three tractors (Massey Ferguson 165, John Deer 3140 and Universal 651) at 4.1 and 7.6 Km/h forward speeds by six tractor drivers having 550, 650, 700, 750, 850 and 1000 N weights on the concrete road carrying moldboard plow and disk harrow due to ISO standard. A field experiment was conducted during plowing with moldboard plow and disk harrow at the same forward speed as a control treatment.

Sensors were attached to upper and lower part of driver's lumbar and rid vibration was measured and recorded by a vibrometer, type TM100 and the data was saved on a PC computer after each experiment. Root mean square and vibration dose value of weighted accelerations were calculated based on international standards (ISO 2631-1) in each direction and also acceleration vector of each point were calculated.

Experiments were done at randomized completed design with 2*3*2*6 factors. Forward speed, tractor model, tillage implement and driver weight were experiment factors in different levels. Root mean square and vibration dose value of weighted acceleration of tractor body in the three mutually perpendicular axes, longitudinal, lateral and vertical directions and lower and upper part of the driver body in two directions were measured and analyzed by Duncan compare mean test ($P<0.05$).

3. RESULTS AND DISCUSSION

Table1 show mean square of main and interaction effects of different levels of forward speed, tractor model, tillage implement and driver weight in case of driver health and comfort. Result of root mean square analysis of weighted accelerations was investigated at two conditions of health and comfort using ISO standard. In both conditions, the tractor forward speed and type of tillage implement did not have any significant influences on vibration exposed to drivers. However, due to Mehta *et al.*(1996) research, forward speed had significant effect on the vibration exposed to the driver. It seems that in this research, smooth track test and high weight of tractors in comparison to lower weight of power tillage did not cause any significant effects on vibration exposed to the tractor drivers.

Table1. Mean squares of main and interaction effects of different levels of forward speed, tractor model, tillage implement and driver weight and their significant level.

Sources of Vibration	**Degrees of freedom**	**Mean squares**	
		Health	**Comfort**
Tractor(T)	2	631748.6^{**}	484904.4^{**}
Tillage implement(I)	1	17692.5^{ns}	11645.9^{ns}
Forward speed(S)	1	15563.1^{ns}	14927.1^{ns}
Driver weight(M)	5	407753.7^{**}	299937.9^{**}
T×I	2	68207.1^{*}	468829^{*}
T×S	2	1390.8^{ns}	670.3^{ns}
T×M	10	103650.1^{**}	79099.1^{**}
I×S	1	1583.5^{ns}	453.8^{ns}
I×M	5	21093.5^{ns}	15492.3^{ns}
S×M	5	652.9^{ns}	704.7^{ns}
Error	347	22412.6	12770.5

*, ** and ns showed significant level at 5%, 1% and not significant, respectively.

Analysis of root mean square of tractor accelerations showed that mean acceleration vector of tractors' bodies had significant influence ($p<0.01$); JD3140 tractor had minimum acceleration vector value both on the driver body and tractor body. Analysis showed that mean acceleration vector of JD3140 tractor body was about 75% of U651 tractor body. However, this amount on driver body was about 50% of the same value on U651 tractor(table 2). Because tractor engine produces high frequency vibration that dose not damage body organs (Pop and Hansson 1992), therefore ratio of suspended to unsuspended mass of JD3140 tractor can be the main result of these differences.

Analysis of MF165 tractor acceleration vector in this case showed that mean acceleration vector on the tractor body was almost equal to U651 tractor; but, this value for driver body was about 50% of the same amount for U651 tractor. Kind of suspension systems of these tractors (wheels and seat spring) and their weights are the main reasons of differences. Narrow wheels and less flexibility (high stiffness) of U651 tractor wheels as compared with other tractors transmitted more vibrations to the tractor body and thus produced a mean acceleration vector about twice of the other tractors vibration vector. By reducing tire pressure corresponding to the standards, the wheel flexibility increases and thus the mean acceleration vector of this tractor become decreased.

Table2. Mean acceleration vector of different levels of tractor, driver weight and their interactions effects and also mean acceleration vector of tractor body.

Tractor	**Driver Weight(N)**						**Mean Acceleration Vector(ms^{-2})**	
	1000	**850**	**750**	**700**	**650**	**550**	**Tractor**	**Driver Body**
Massey Ferguson 165	2.8[&] 2.4	6.1 5.2	4.9 4.2	4 3.4	10.2 8.6	3.9 3.3	5.3[a*] 5.4	11.7[b]
John Deer 3140	3.4 2.9	7.3 6.2	4.9 4.2	3.9 3.3	5.7 4.8	3.3 2.8	4.8[a] 4.0	6.8[a]
Universal 651	3.8 3.3	16.1 13.9	8.7 7.6	7.9 6.7	15.8 13.8	4.9 4.2	9.5[a] 8.3	11.6[b]
Means	3.3[A#] 2.9	9.8[D] 8.4	6.2[C] 5.3	5.3[BC] 4.5	10.6[D] 9.1	4[AB] 3.4		

&.Upper and lower numbers of each cell show mean acceleration vector in health and comfort respectively.
#. Numbers with common capital letters in driver mean acceleration vector row with different masses have no significant influence ($p<0.05$)
*. Numbers with common letters in driver mean acceleration vector and tractor mean acceleration vector columns have no significant influence ($p<0.05$).

Difference of mean acceleration vector of MF165 tractor as compared with U651 tractor should be due to their suspension systems. Good seat suspension of MF165 tractor damped transmitted vibration to the driver body parts and reduced mean acceleration vector on the driver body parts. Low acceleration vector of JD3140 tractor both on driver's body parts and tractor body, is due to its good suspension and high weight of this tractor as compared to other tractors. However all acceleration vector were higher than international standards levels (ISO 2631-1).

Analysis of mean acceleration vectors of driver body parts showed that there was a significant influence ($p<0.01$) due to driver weight, such that by increasing the driver weights, this value on the body parts was decreased. For example for driver with 1000 N weight, the magnitude of mean acceleration vector was 3.3 m/s^2, meanwhile for driver with 550 N weigh, the magnitude of mean acceleration vector was 9.8 m/s^2(table 2). Muscular volume and suspension weight of each driver were the main reason of this difference. High flexibility and low stiffness of fat people due to their high volume in muscular tissue and fat around their body especially around the buttock and abdominal wall as compared to the slim people damped vibration in these parts and thus decreased the acceleration vectors (Mansfield and Griffin, 2000).

Acceleration mean vector of 750 N weight driver showed that he had maximum value than other drivers. In this study, all of the drivers had only a test on concrete road; but this driver not only had a test on concrete road but also had a test on a farm during plowing and disk harrow as a control treatment. Uneven farm track test during plowing and disk harrowing, related to smooth and even surface of concrete track test, caused higher mean acceleration vector of his body compare to other drivers.

Vector of root mean square on upper and lower part of driver lumbar were measured and analyzed. Result showed that there was a significant influence ($p<0.05$) at both conditions of health and comfort. Because of interior organs of driver body and damping vibration in these organs, Mean acceleration vector on upper part of lumbar was less than the same value on lower part, such that mean acceleration vector on upper part of body became half of the same value on lower part of body.

Fig 1 shows root mean square of acceleration of upper and lower part of driver bodies in different directions. This results show that root mean square of acceleration in longitudinal, lateral direction both on drivers' body parts and tractors' bodies become higher than vertical direction. Lateral unbalance of tractors and tractor vibrations of power transmission system can be the main result of this state (Griffin, 1990; Mansfield and Lundstrom, 1999). Fig 2 also shows average of allowable driving time per day due to ISO standards for all subjects. It shows that 1000 N driver had maximum allowable time (9.3 h/day) with MF165 tractor, While 550 N driver had minimum allowable time (0.01 h/day) with U651 tractor. Generally, JD3140 tractor had higher allowable time for all subjects.

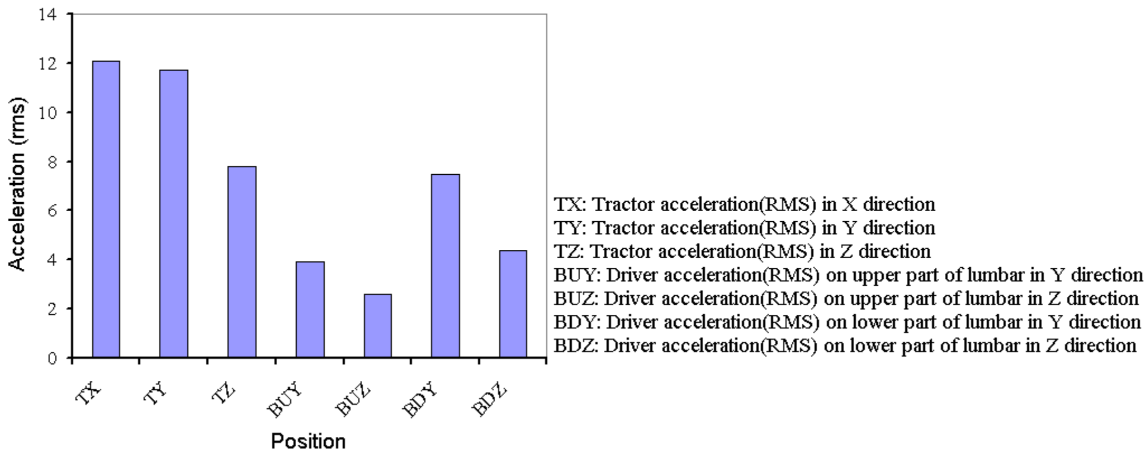

Figure 1. Acceleration root mean square of upper and lower part of driver lumbar and tractor in different directions.

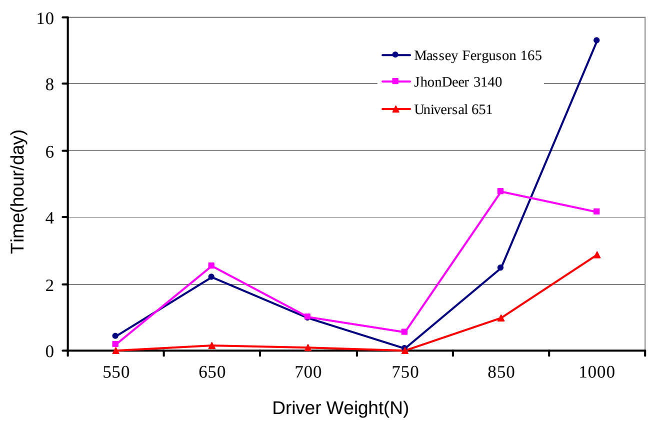

Figure 2. Average of allowable driving time per day due to ISO standards

4. CONCLUSIONS

Mean acceleration vector of drivers were compared to ISO standards. This comparison showed that level of comfort in these tractors was extremely uncomfortable. Due to the acceleration vector of drivers' body in this research, it is recommended that suspension system of these tractors (especially seat and seat foam) should be improved. Because of wide range of driver weight, seat suspension system should be redesigned in a manner that is useful for all drivers' weights and also an intelligent suspension system controls the vibration exposure based on driver weight and roads' levels. If it is possible, wheels with higher stiffness, lower pressure or double wheels use for tractors to reduce the vibration exposure levels.

5. ACKNOWLEDUGEMENT

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