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VIBRATION EVALUATION OF THE DRIVER'S SEAT OF MF 285 TRACTOR IN CONDUCTING THE TILLAGE OPERATIONS

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تقييم الاهتزاز لمقعد السائق للجرار MF 285 في إجراء عمليات الحرث

ملخص

كان الغرض من هذه الدراسة هو دراسة تأثير سرعة الجرار على اهتزاز مقعد الجرار وتقييم مستوى راحة السائق أثناء العملية باستخدام محاريث القرص والمحراث. أجريت تجارب على التربة الرملية الطميية في تجربة عامليّة تعتمد على تصميم بلوك كامل عشوائي بثلاثة مكررات. تأثير نوع معدات الحرث باستخدام المحاريث القرصية والمحاريث ، سرعة التقدم في أربعة مستويات هي 4.5 ، 6 و 8.8 كم/ ساعة وتم قياس الاهتزاز وتقييمه في ثلاثة اتجاهات طولية (x) ، جانبي (y) والعمودي (ض). أظهرت نتائج تحليل التباين أن التأثيرات الرئيسية لنوع جهاز الحراثة والسرعة والاتجاه الاهتزازي على قيم التسارع التي تم إدخالها في مقعد السائق كانت كبيرة عند مستوى احتمال 1٪. من أجل تقليل احتمال حدوث اهتزاز أقل يوميًا ، يُقترح استخدام محراث القوالب بسرعة 4.5 كم/ساعة وقرص مدفوع بسرعة 6 كم/ ساعة.

Abstract

The purpose of this study was to investigate the effect of the tractor speed on the tractors' seat vibration and to assess the level of comfort of the driver during the agricultural operation using moldboard and disc plows. Experiments were conducted on sandy loamy soil in a factorial experiment based on randomized complete block design with three replications. The effect of the type of tillage implement using the moldboard and disc plows, the velocity of advance in four levels of 4.5, 6 and 8.8 km/h and vibration was measured and evaluated at three directions of longitudinal (x), lateral (y) and vertical (z). The results of analysis of variance showed that the main effects of type of tillage implement, velocity and vibration direction on the acceleration values entered into the driver's seat were significant at 1% probability level. With increasing forward velocity of the tractor-implement system the vibration on driver's seat increased. In order to reduce the possibility of less daily vibration, it is suggested that a moldboard plow be used at a forward speed of 4.5 km/h and a disc driven at a speed of 6 km/h.

Keywords: Tractor, Vibration, Tillage

1. INTRODUCTION

The human body is subjected to various vibrations in everyday life conditions. When riding a bus, bike, and ... various vibrations from different parts of the body enter to the human body. Whole body vibration occur when the entire human body is in contact with a vibrational surface. For example, when a sitting person exposed to vibration through his bottom, this vibration is called vibration of the entire body. The increasing use of tractors around the world, especially in developing countries, is indicative of the increasing importance of power generating resources in modern and mechanized agriculture, and which are used in various operations. On the other hand, the safety of the tractor drivers should be increasingly taken into account. This issue is of great importance to the tractor drivers that are exposed to poor working conditions and high vibration of the tractor, especially through the seat. Unfortunately, in developing countries and low income countries, the safety and health of farmers are less important. Since this has been the basis of many researchers' work, this issue is of great importance. The effect of the whole body vibration on vibrational members will not be destructive in the short term and will only reduce the user's performance. For workers who spend a long time on a great value of vibration, there will be a lot of long-term adverse effects. The threshold of vibration-induced side effects in different individuals also varies depending on factors such as the amplitude and frequency of vibration, the physical characteristics of the person who is exposed to vibration (Abbaspour-Gilandeh and Rashidi-MohammadAbad, 2013). Therefore, it is not possible to define a specific point for the stimulus threshold for different individuals. Therefore, SAE and international standards (ISO) and British standard (BS) and ... have defined a range for the trigger threshold. Accelerations affecting humans are divided into linear and periodic acceleration groups. Linear vibrations can be transmitted in the three directions of the vertical, longitudinal, and lateral to the device and the human, with the longitudinal vibrations being more sensitive to vertical vibrations according to the tractor conditions. Experiments that evaluated the transmitted forces to loader and tractor drivers indicated that the body of these people was often placed at frequencies of 0.5-11 Hz. Many evidences suggest that the tractor drivers often suffer from diseases such as arthritis, rupture of the tissue, joint disks, back pain, abdominal pain and appetite loss. In conventional tractors, the vibration acceleration is about 0.5-1.5 g, the frequency range of the vibration is about 2 to 7 Hz (Patil and Palanichamy, 1985). In an experiment on a two-wheel drive tractor, it was observed that the vibrational acceleration in the three directions of longitudinal, lateral and vertical increases with increasing tractor speed. The experiments showed that the average root mean square (RMS) acceleration in the plowed land was 2 to 2.5 times more than in the asphalt and off roads. Also, the time of exposure for the tractor should not exceed 2.5 hours (Mehta et al., 2000). In the trials, the apparent mass of 15 men and 15 women were exposed to sinusoidal vibrations. The first vibrational mode was 0.7 Hz for both directions and the second vibration mode was 2 Hz in the lateral direction and 2.5 Hz for the longitudinal direction (Holmlund et al., 2000). Also, in another experiment, the acceleration values of 0.25, 0.5, 1 and 2 m/s^2 in the frequency range of 2-20 Hz were examined on eight persons. The results showed that the resonant frequency decreased by increasing the person's apparent mass from 6 to 4 Hz, and this trend was valid for the second resonance frequency (Fairley and Griffin, 1990).

The value of apparent mass and vibration transferability from the seat to various parts of the body were examined in the frequency range of 0.2- 20 Hz. The results indicated a significant decrease in the resonance frequency with increasing vibration in the lower part of abdomen. Thus, with increasing acceleration from 0.25 to 2.5 m/s^2, the resonant frequency decreased from 5.4 to 4.2 Hz (Mansfield et al., 2000). The vibration tests conducted in the combine’s cabin and driver’s seat showed that in the combine cabin when driving at a speed of 20 km/h on the surface of the asphalt, a higher vibration frequency was obtained compared to a slower driving on off road and a seat with an air suspension reduces vibration at frequencies above 4 Hz better than mechanical suspension system and provides a more comfortable location for the driver (Hostens and Ramon, 2003). Investigating the effect of the front and rear wheel tire pressure on the MF 399 tractor on the vibration of the tractor's seat while driving in three modes of transporting a with moldboard plow in the field, on the road and plowing in the field at three levels of low pressure of 60 kPa, common pressure of 100 kPa and high pressure of 140 kPa showed that the most suitable pressure for the least vibration of the driver was100 kPa, which indicatedthat the vibration intensity increased by increasing and decreasing tire pressure (Abdollahpour et al., 2012).

In the vibration test of the MF 299 tractor in connection with the moldboard plow, the amount of acceleration transmitted on the tractor seat in a vertical direction at four engine speeds of 1000, 1250, 1500, and 1750 rpm in three modes of transporting the plow in the field, Plowing operations and moving on asphalt road were investigated. The results indicated that the RMS acceleration in the vertical direction increased with the increment of the engine speed in all three states, the maximum vibration acceleration of 2.7 m/s^2 was occurred at engine speed of 1750 rpm in plowing conditions and the least value of 0.9 m/s^2 was obtained at 1000 rpm moving on the asphalt road (Seifi and Yeganeh, 2013). In a study to evaluate the noise and vibration of different tractors, four types of tractors of MF 4292, 283, 297 and 680 were used. Measurement of vibration levels was done in three directions: longitudinal, vertical and lateral in all tractors. The results showed that in all tractors, in order to maintain the driver's health and safety, the tractor's operating time range should be less than 8 hours in the frequency range of 5-10 Hz, and it was concluded that improving the overall structure of the seat would be able to absorb the vibration and create a good working condition for the driver (Baesso et al., 2014).

Regarding the common use MF 285 tractor and the moldboard plow as primary tillage tool and disc harrow as secondary tillage by farmers in Iran necessitate paying attention to the safety and health of this tractor driver when working with these implements. Then the study investigated the effect of tillage implements at different tractor speeds on the vibration of MF285 tractor's seat in three longitudinal, lateral and lateral directions.

MATERIALS AND METHODS

MF 285 tractor with 75 hp equipped with a precision measuring instrument was used to collect relevant data about the tractor speed and vibration of the tractor seat. The velocity measuring system was the fifth wheel type, the vibrating device with a one-way magnetic sensor and a data logger and laptop were used to collect data measured by sensors (Fig. 1).

Figure 1. MF285 tractor equipped with the fifth wheel and vibration meter and laptop

The fifth wheel which was used to measure the forward speed of the tractor, consists of an inflatable tire with 39 cm diameter that freely rotates on its own axis and moves in the tractor movement direction. A mechanical jack is used to lift and lower the fifth wheel manually. Also, this wheel is equipped with an induction proximity sensor (PR12-2DN) manufactured by the UNIX corporation of Korea. It senses the gear teeth fitted to the fifth wheel center and generates pulses. Pulse produced is displayed by the MP5W-44 pulse meter manufactured by the Autonix Corporation, Korea. Data logger DT800 (DataTaker) was used to collect data measured by pulse meter. Data logger and Pulse meter work with 220V AC electricity. A DC-to- AC converter of DXDRL1000H model manufactured by Doxin Corporation was used to provide the required AC current with a direct current of the tractor's battery.

VT-8204 vibration meter, manufactured by Lutron Company of Taiwan was used to measure the acceleration on the tractor's seat. Its precision was ± 0.05%, an acceleration measurement range of 0.5 to 199.5 m/s^2 and a working temperature range of 0 -50° C, and the acceleration measured by the device is displayed as RMS value. To get and record vibration data, the SW-U801-WIN Data logger application was used. In this research, two commonly used tillage machines, mainly used by farmers as primary and secondary tillage operations were used and their technical information is presented in Table 1.

Table 1. Technical information of tillage implements

Moldboard Plow		
	Bottom number	3
	Mounting type	Three point
	Working width	6 m
	Working depth	25 cm
	Tilling type	Primary tillage
Disc Harrow		
	Disc Number	2*14
	Disc diameter	46 cm
	Mounting type	Three point
	Working width	2.5 m
	Working depth	5-10 cm
	Tilling type	Secondary tillage

Field experiments were carried out in the April of 2019 at the Agricultural and Natural Resources Research Station of Ardabil province. Before the field experiment, the field was divided into 4×30 m plots. Tests were conducted as a factorial experiment based on randomized complete block design (RCBD) with 18 treatments and three replications. Tilling implements (Factor A) moldboard plow, disc plow, tractor speed (Factor B) of 4.5, 6 and 8.5 km/h, vibration direction (Factor C) at three directions of x, y, z were considered. The values of acceleration on the tractor seat, tractor speed and soil moisture content were measured. Table 2 presents the physical properties of the soil in which tests were conducted.

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Table 2. Some parameters of the soil of field

Soil parameters	Values
Sand	%47
Silt	%48
Clay	%5
Soil texture	Sandy loam
Plastic limit	%22.43
Liquid limit	%35.14
Plastic index	%12.71
Dry bulk density(0-30 cm)	1.75, gr/cm^3
Soil moisture, d. b.(0-30 cm)	18%

The accelerometer sensor and tractor seats are connected to each other directly without any mediation. The accelerometer sensor at each stage was attached to the driver seat in three directions of vertical (z), lateral (y) and the longitudinal (x) (Figure 2). Before starting any experimental plot, the tractor traveled 10 meters in order to reach the steady state, then data was recorded as the tractor traveled over the length of the plot.

Figure 2. The position of vibration sensor in different directions of x, y and z

In global standards, the effects of vibration on the driver have been expressed as criteria for maintaining the efficiency (reducing the skill level due to fatigue), maintaining the safety limit and comfort range. The ISO-2631 standard is accepted by the ministry of health and medical education and American Conference of governmental industrial hygienists (ACGIH) is used for general body vibrations evaluation. ISO-2631 describes the method for measuring acceleration, root mean square (RMS), or vibration dosing value of VDV, and states that when the crest factor (CF) is greater than 9 the vibration dose rate provides a more reliable assessment of the exposure, since the high CF indicates vibration shocks and repetitive shocks. Crest Factor is a dimensionless dimension that is defined as the ratio of peak acceleration to effective acceleration which was calculated using Eq. (1).

$$CF = \frac{a_{max}}{a_{rms}} \quad (1)$$

Crest factor value was measured for all working conditions and because of the average CF value was less than 9, the RMS acceleration was used. With comparison of the results of the RMS acceleration values with the standards in Table 3, and the description of the human reaction to the inserted vibrations the range of driver comfort was determined accordance with the ISO 2631 standard.

Table 3. A description of the human reaction to vibration (ISO 2631)

Measured vibration, m/s^2	Level of comfort
Less than o.315	comfortable
0.315-063	A little uncomfortable
0.5-1	Fairly uncomfortable
0.8-1.6	Uncomfortable
1.5-2.25	Very uncomfortable
More than 2	Extremely uncomfortable

Also, the vibration of the human body when working with tools and machines was measured by the daily vibration exposure criterion using the Eq. (2) with considering 8 hours operation in each day.

$$A(8) = a\sqrt{\frac{T_{exp}}{T_0}} \quad (2)$$

a, Acceleration value (RMS), T_{exp}, Daily vibration exposure time, T_0: Reference time 8 hours per day (ECDE, 2006).

3. RESULTS AND DISCUSSION

The results of variance analysis of tractor seat vibration are presented in Table 4. According to the variance analysis, the main effects of implement type, velocity, and vibrational direction, as well as all binary and triple interaction effects, were significant at 1% probability level. In order to compare the mean of main factors effects, the Duncan's multiple range test at the 5% probability level was used.

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Table 4. Results of analysis of variance for data on acceleration measured on tractor seats

Factor	Degree of Freedom	Mean of Squares	F value
Blocks	2	0.641	7.5915^{ns}
Tillage Implement(TI)	1	3.426	40.5943**
Tractor velocity(TV)	2	13.695	162.309**
Vibration direction(VD)	2	56.039	664.157**
TI×TV	2	5.961	70.644**
TI×VD	2	34.086	403.977**
TV×VD	4	2.734	32.408**
TI×TV×VD	4	9.54	113.067**
Error	34	0.085	
Titoal	53		

**Highly significant, * significant

3.1. The effect of the type of tillage device on vibration of the tractor's seat

Fig. 3 shows the effect of each tillage implement on the vibration of the tractor's seat. As illustrated in the diagram, vibration on the seat is on the seat as using of a moldboard plow and disc plow was 5.077and 4.573 m/s^2, respectively. This indicates that the tillage equipment attached to the tractor and how it interacts with the soil has a significant effect on the vibration of the seat, so the vibration of the tractor seat was as it was used together with the disc.

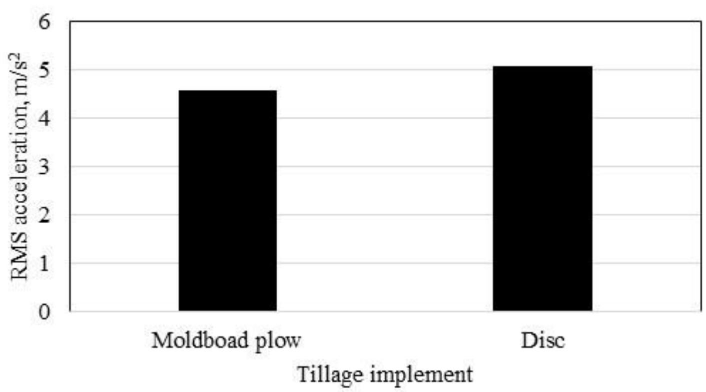

Figure 3. Effect of Type of tillage equipment on vibration of tractor seats

3-2. The effect of the tractor velocity on the tractor's seat vibration

Fig. 4 shows that increasing the forward speed with increasing engine speed increased the vibration of the tractor’s seat. The result is consistent with the results of Taghizadeh-Alisaraei et al. (2007). Maximum acceleration of 5.78 m/s^2 was obtained at velocity of 8.5 km/h.

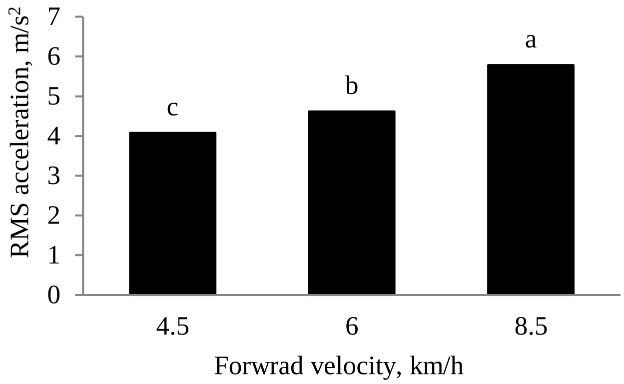

Figure 4. The effect of the tractor velocity on driver's vibration

3.3. The effect of vibration direction on the acceleration on the tractor's seat

Fig. 5 shows the measured acceleration at three longitudinal (x), lateral (y) and vertical (z) directions. As the diagram shows, the magnitude of acceleration on the transverse direction (y) is 6.745 m/s^2, in vertical direction (z) is 4.453 m/s^2 and in longitudinal direction (x) is 3.277 m/s^2. Therefore, the tractor seat is vibrated more in the transverse direction. High acceleration in transverse direction is due to inadequate seat design and it structure. Because the seat is in the middle of the cabin and does not have any reliance on the sides. Considering the draft force of the tillage tool and its natural frequency, then the maximum vibration occurs in the longitudinal direction. In the case of a tractor without a tilling machine, based on the nature of the seat, the roughness of the ground and tires lugs affect the tractor's vibration should be high in the vertical direction. In developed and new tractors, the seat produced by the KAB Company for the Messy Ferguson tractors are in contact with the cabin in back and sides of seat, and this arrangement optimized the driver seat leveling. Therefore, it is better to observe all standards in producing the tractor's to reduce driver acceleration.

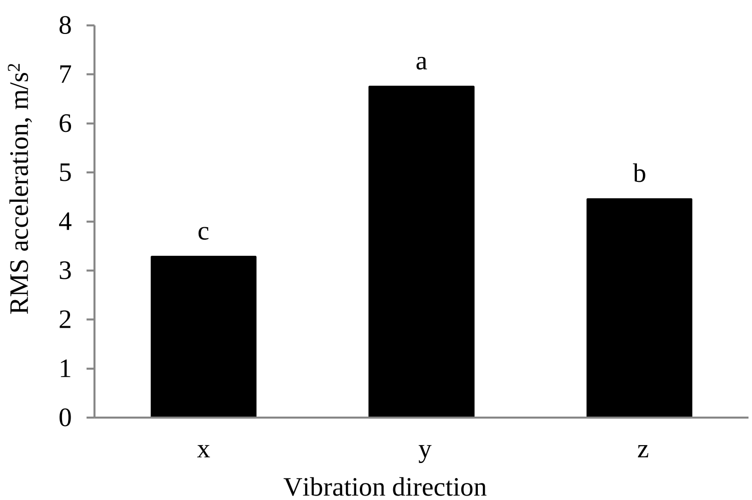

Figure 5- Seat vibration in different main coordinate directions

3.4. The binary effect of the type of tillage implement and the tractor forward speed on the vibration of the tractor's seat

According to Fig. 6, on both tested tilling implements, with increasing forward speed, the vibration increased on the seat. Fig. 7 shows that there is a linear relationship between the velocity and measured acceleration, which is consistent with the results of the research by Seifi and Yeganeh (2013).

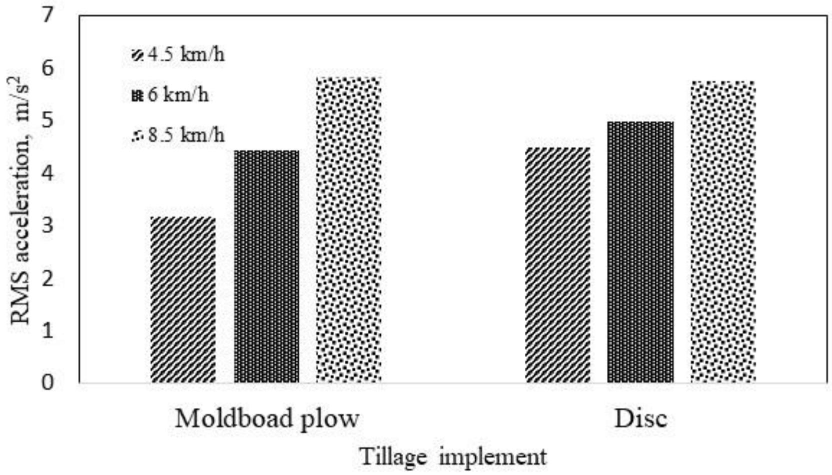

Figure 6. Binary effect of tilling implement and the tractor velocity

3. 5. Binary effect of the tractor velocity and vibration direction on the vibration of the tractor's seat

Fig. 7 shows that at all forward speeds, the acceleration values measured in the transverse direction (y) was higher than the vertical (z) and horizontal (x) directions. At a forward speed of 4.5 km/h acceleration in three directions of longitudinal, lateral and vertical was 2.34, 6.43 and 3.43 m/s^2, respectively. At maximum velocity of 8.5 km / h acceleration in three directions was 4.43, 6.85 and 6.07 m/s^2, respectively.

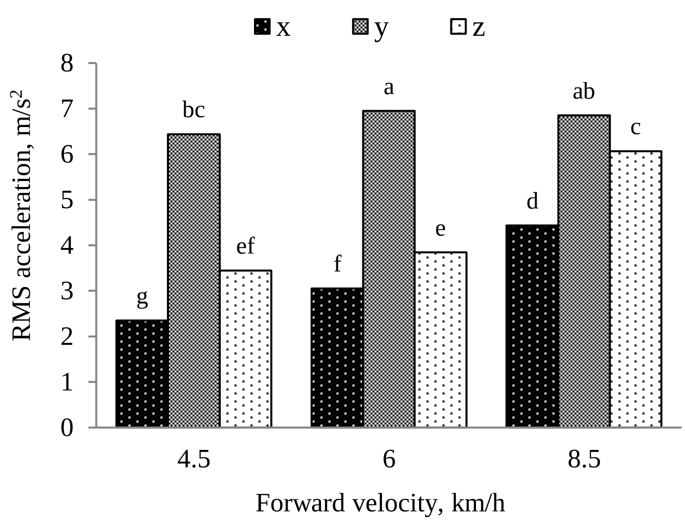

Figure 7. Interaction of the forward speed with the vibration direction on the tractor's seat vibration

In a research by Shahgholi et al., (2010) using Massey Ferguson 390 tractor with subsoiler operation, it was found that the lateral acceleration was much less than the measured values in other direction on the tractor seat. The tractor seat used in tests was KAB 303 which is a universal standard seat, the effective accelerations measured at a speed of 3 km/h were less than those measured in this trials. This shows that the Ferguson 285 seat is not suitable for driver and the tractor's seat should include universal standards with proper suspension.

3.6. Driver comfort

By comparing the obtained acceleration RMS values with the standards levels in Table 3 (ISO 2631), at different speeds, it was found that the comfort level of the driver was extremely uncomfortable. In a similar study (Maleki et al., 2008) reported the level of comfort of drivers of the three commonly used tractors in Iran (Massey Ferguson 165, John Deere 3140 and Universal 651) was highly uncomfortable.

3.7. Checking daily vibration values on the driver's body

The driver's daily exposure to the vibration was considered four hours and exposure values for daily vibration were calculated for plowing with moldboard and disc plow in different test modes. The average values of daily vibration exposure in Fig. 8 shows that the minimum of exposure of daily vibration was obtained at a speed of 4.5 km/h for moldboard plow. Also, according to Fig. 9, the use of a disc at a speed of 6 km/h resulted in less exposure to vibration per day. The longitudinal and lateral vibrations are created according to the conditions of the tractor, but most of the vibrations of the tractor are in the vertical direction that is transmitted through the wheel (Abbdollahpour et al., 2012). Therefore, the use of the tractor-tilling implement at the proposed speeds will result in less vibration in the lateral direction to the driver.

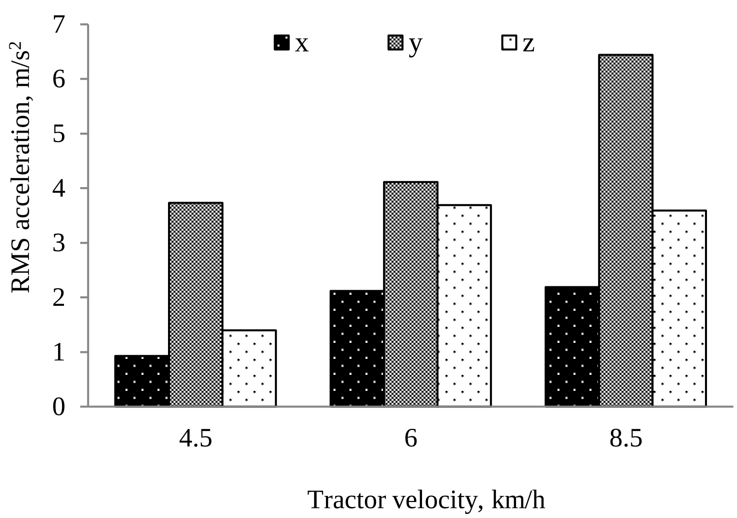

Figure 8- Exposure values for daily vibration when plowed with moldboard plow

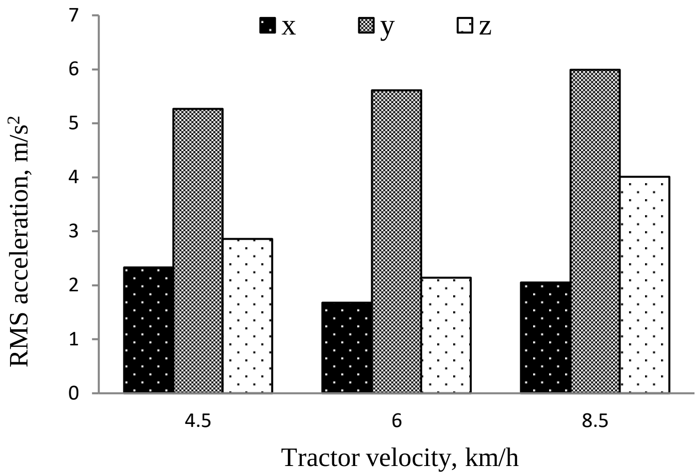

Figure 9- Exposure values for daily vibration when using a disc

CONCLUSION

In this research, the effect of tractor speed in different engine periods on the vibration of the driver's seat when using moldboard plow and disc plow in agricultural operations was investigated.

1-The results of analysis of variance showed that the vibration on the seat in all three directions of longitudinal, lateral and vertical were higher in use of the disc compared with moldboard plow. It was also observed that in all of the test modes, in the lateral direction more vibration is inserted into the driver's seat relative to the vertical and longitudinal directions.

2-In order to evaluate the level of driver comfort, the acceleration assessment was assessed based on the global standard (ISO 2631). The results of the assessment of the comfort and convenience of the driver of the Ferguson 285 Tractor, when using the moldboard and disc plow, showed that the driver was in an extremely uncomfortable condition.

3-Considering the possibility of less daily vibration exposure and attention to driver safety and health, it is suggested that the moldboard plow should be used at velocity of 4.5 km/h (engine speed of 1000 rpm) and using disc plow velocity of 6 km/h was recommended (engine speed of 1500 rpm). In order to reduce the damage to the driver of the tractor, its seat should be designed and fabricated according with international standards.

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