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Whole Body Vibration Exposure During Operation of Rice Combine Harvester under Egyptian Field Conditions

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ABSTRACT

The main target of this investigation is to study the effect of different working conditions during rice harvesting on the combine harvester operators WBV exposure under actual Egyptian field conditions. Data were measured and collected for four types of rice combine harvester and three methods of planting; manual transplanting, mechanical transplanting and direct sowing. Sixteen representative healthy rice combine harvester operators were selected for this study. Parameters of frequency-weighted vibration acceleration in root mean square (RMS), vibration dose value of weighted r.m.s acceleration, (VDV(8)kZ), heart pulses rate (HR), blood pressure (BP), work related body pain (WRBP), stand height and weight of operators were evaluated. Vibration measurements were performed according to (ISO 2631-1: 1997). Field experiments were conducted in a statistically designed layout (completely randomized design) and were conducted at the applied research farm of Rice Mechanization Center, Meet Eldeba, Kafr El-Sheikh governorate and other farms beside, in the 2016 grown seasons of rice crop. The obtained results indicated that the yanmer combine harvester used for the field planted by manual transplanting at soil moisture content of 20.38 % recorded the highest WBV data of the vibration dose value of weighted r.m.s acceleration, VDV(8)kZ magnitude, while the largest single orthogonal axis is in the axis (Z) which exceeded both of exposure action and exposure limit values. This causes a high risk on the operator body which increases the heart rate and blood pressure, followed by the Daedong combine harvester for the field planted by manual transplanting at soil moisture content of 20.42 %. On the other hand, the WBV parameters recorded the lowest values for Claas combine harvester used in the field planted by direct sowing at soil moisture content of 20.67 %., consequently there is no risk on the operator and also the heart rate and blood pressure. Using rubber spring during rice harvesting by yanmer combine harvester results in a decrement percentages in the WBV values and so heart rate and blood pressure. The maximum WRBP values were obtained during harvesting rice by yanmer combine harvester for the field planted by manual transplanting, followed by harvesting rice by Daedong combine harvester for the field planted by manual transplanting and harvesting rice by Class combine harvester for the field planted by direct sowing the recorded WRBP values were 13.1, 12.4 and 6.6 (Borg scale CR—10 scale.) respectively. Results showed that there are significant differences between the frequency-weighted RMS acceleration, vibration dose value of weighted r.m.s acceleration, VDV(8)kZ, heart rate and blood pressure during studied different farm operations.

Keywords: Rice combine harvester, whole body vibration (WBV), body mass index (BMI), heart pulses rate (HR), blood pressure (BP), work related body pain (WRBP), suspension seats, springs.

INTRODUCTION

Combine harvesters have been playing an important role in modern agricultural production in recent years, their working process divided into the cutting of the crop and recovering grains from the field; separating grains from the greater crop parts such as straw and separating grains from material-other-than-grain (MOG); then collecting cleaned grains in a tank for temporary storage or directly in a bags (Liang *et al*. 2015). WBV is the vibration a combine harvester driver feels when he sits on the driver seat during operating, the engine and other combine units for the daily check or travelling over rough ground or crop harvesting (Almosawi *et al*. 2016).Vibration produces a wide variety of different effects to the operators where farm equipment operators are usually exposed for two types of vibration: whole-body vibration transmitted via the seat or from the floor and feet, hand-arm vibration. Both forms of vibration have a detrimental effect on work performance and health. To assess the effect of vibration, the vibration intensity and frequency must be taken into account with exposure time (Dias and Phillips, 2002; HSE, 2005; and Hamed, 2011). Exposure to this vibration brings a driver problem, a machine problems and harvesting losses. Several studies recognized that the WBV as an influential source of discomfort for agricultural machinery drivers (Ahmadi, 2013).The directive 2oo2/44/EC assumed that the vertical axis vibration frequencies of some human bodies parts with appropriate approximation, for example: abdomen = 4 – 8Hz, eye socket = 80 Hz, chest = 60 Hz, head = 25 Hz, hips=50– 200 Hz, elbows = 16–30 Hz, *etc*., when these natural frequency (driver organ tissue frequency) match with forced vibration frequency of the machine lead to significant disorder in the internal organ of the driver body. For evaluating the degree of risk caused by the exposure to the whole body combine vibration two interval time values reported in the ISO 2631 –1:1997standard, these are the effective action value (EAV)and the effective limit value (ELV). The control of vibration at work Regulation 2005 (the vibration Regulation) set an EAV is equal to 0.5 $m.s^{-2}A(8)$ more than this value require to take action to reduce the exposure time. However; the ELV is equal to 1.15 $m.\ s^{-2}A(8)$ and must not be more.

Suspension seats are designed to isolate operators from potentially hazardous vertical whole-body vibration. Off-road vehicles are subjected to vibration that can be severe enough to cause seat suspensions exceed their range of travel, causing end-stop impacts that may increase the hazard for operators, the optimization of the isolation characteristics of a suspension seat take into account consideration of the dynamic responses of various components of the seat and its test standards require human subjects to be used for measuring the vibration isolation of vehicle seats (Lewis and Griffin 2002, Gunstona *et al*., 2004, Scarlett *et al*. 2005). Springs are resilient structures designed to endure large deflections within their elastic range. It follows that the materials used in springs should have an extensive elastic range. Some materials are well known as spring materials. The selection of material is a costbenefit decision. Some factors to be considered are costs, corrosion resistance, formability, fatigue strength, availability, stress relaxation, and electric conductivity. The right selection is usually a compromise among these factors (Joerres, 1986).The response of human body biodynamic seated without a back support and exposed to vertical whole-body vibration have been standardized in ISO 5982 and DIN 45676 in terms of driving point mechanical impedance and apparent mass. The occupation of driving agricultural machinery is closely linked to the occurrence of low back pain (LBP), drivers often encounter high excitation in low frequencies (1.5–5 Hz) when driving by road conditions, seats with horizontal suspensions help to minimize detrimental effects of whole-body vibration (WBV) on health, comfort and performance. (Hostens *et al*. 2004, Blüthner *et al*. 2006, Patra *et al*. 2008, Subashi *et al*. 2009). The optimal design of driver seats with suspension requires knowledge of human response to the perception of the vibration intensity and seat comfort or of the performance in motor tasks, the highest value of RMS occur in the vertical plane (Z) and followed by RMS of the longitudinal direction (X) and the RMS in transverse direction (Y). Harvesting is one of most important operation in production of paddy crop; it must be done at a short time, therefore the driver of harvester need to work along the day time in order to complete this operation at proper time (Schust *et al*. 2006, Solecki, 2007, Stein *et al*. 2008). The main target of this investigation is to study the effect of different working conditions during rice harvesting on the combine harvester operators WBV exposure under actual Egyptian field conditions

MATERIALS AND METHODS

Sixteen representative healthy rice combine harvester operators were chosen from the available operators in the applied research farm of Rice Mechanization Center, Meet Eldeba, Kafr El-Sheikh governorate and from other farms beside, during the 2016 rice crop season. They were healthy male operators without physical ailment. Two physical measurements were taken; stand height and weight using measuring tape and weighing balance as shown in Fig. (1). The measurements posture was such that the subject stands with his feet closed and his body vertically erected and two physiological measurements were taken; heart pulses rate (HR), blood pressure (BP) using heart pulses rate and blood pressure meter UA-651.

The study selected subjects were well familiar with the rice combine harvester control levers and had sufficient experience of operating rice combine harvester under actual Egyptian field at different working conditions during rice harvesting namely, the harvesting after manual transplanting, mechanical transplanting and hand free planting to evaluate the whole body vibration (WBV) emitted by different units of the combine harvester to operators.

Fig. 1. Physical and physiological measurements for the subjects.

Field layout and experimental conditions

A randomized complete design of field layout design was taken. The subjects were taken as replications. The treatments were randomized in orders to minimize the effects of variation of rice combine harvester units due to different planting methods. Many types of rice combine harvesters which manufactured in Japan, Germany and Korea and commonly used by farmers were selected for the study (Claas, Kubota, Yanmer, Daedong). The main specifications of the rice combine harvester emitted WBV are given in Table (1).

Measuring instruments and Methodology

A portable human vibration analyzer type 4447 was used to measure vibration characteristics at the seat of different studied rice combine harvester during actual operation; The accelerometer was put on the seat and was fixed by the operator Fig. (2). There commendation of the International Standard ISO 2631-1:1997 was followed for orientation of the measurement axes as shown in Fig.(3). *X*-axis was the longitudinal axis which the operator directly move front and back; *Y*-axis was perpendicular to the *X*-axis which the operator directly move right and left and *Z*-axis was the vertical axis; the data stored in a personal computer at the end of experiment for analysis.

Human exposure to whole-body vibration should be evaluated using the method which defined in International Standard ISO 2631-1:1997. The root mean square, RMS vibration magnitude is expressed in terms of the frequency-weighted acceleration (m/s^2). Measurements should be made over periods of at least 20 minutes. The crest factor (maximum peak value divided by rms is below or equal to 9, the basic evaluation method is normally sufficient.

Table 1. The main specifications of rice combine harvester; Yanmer; under study.

Model			CA 48ex
size	Length(mm)		4615
	Width(mm)		2100
	Height(mm)		2385
weight(kg)			2900
engine	type		V3300-D1-T-ES06
	model		4 cycle water cooling turbo
	(L[cc])		3.318[3318]
	(ps[kw]/rpm)		80.8[59.4]/2400
	Burnt oil		0# fuel
	tank volume(L)		73
	Starting method		starter motor
	battery(V·Ah)		12·80
Travel unit	crawler belt	wideth × reach land length(mm)	450×1640
		middle distance (mm)	1155
		land pressure(kgf/cm2)	0.196
	change speed type		HST
	change qty(times)		front hst and rear hst
	speed (m/s)		lower:0~1.06.standard:0~1.50.travel:0~2.04
	turning way		Brake change
Harvest unit	harvest row		5
	harvestwidth(mm)		1720
	cut blade width(mm)		1690
	cut height range(mm)		35~150
	apply rice or wheat length(mm)		650~1300
Threshing unit	Threshing type		flow type threshing gear
	threshing pipe	dia × width (mm)	Φ 424×1000
		speed (rpm)	520
cereal discharge unit	discharge rice type		person work
	discharge volume(L)	tankvolume(L)	500
		discharge place (pcs)	3
Operational efficiency		A unit of area/ hour	4~8

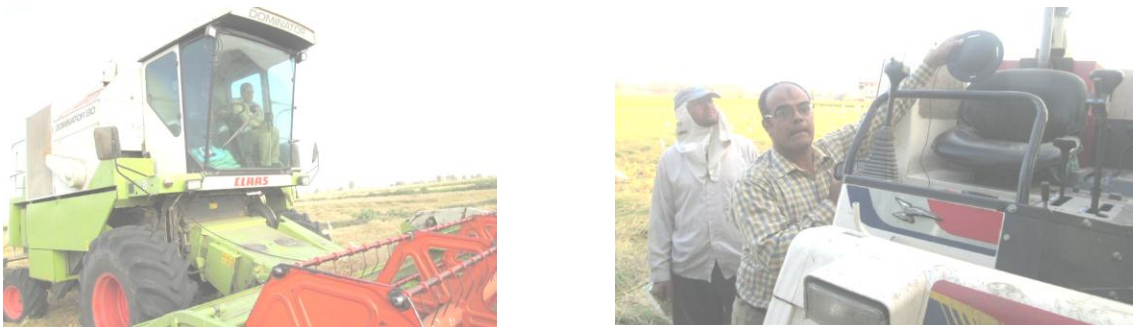

Fig. 2. The accelerometer position between the rice combine harvester seat and the operator.

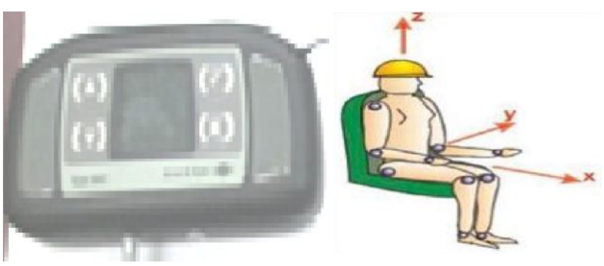

Fig. 3. Human vibration analyzer type 4447 and coordinate system for the WBV.

The vibration dose value (or VDV) provides an alternative measure of vibration exposure and was developed as a measure that gives a better indication of the risks from vibrations, ($m/s^{1,75}$), and unlike the RMS vibration magnitude, the measured VDV is cumulative value Griffin (1990),Scarlett *et al*. (2005), (ISO 2631-1, 1997).

They mentioned that WBV levels are evaluated in terms of frequency-weighted root-mean-square (r.m.s.) acceleration.

$$a_w = \left[\frac{1}{T} \int_0^T a_w^2(t) dt \right]^{1/2} \qquad (2)$$

where:-

$a_w(t)$ = frequency-weighted acceleration time history (m/s^2).

T= duration of measurement (seconds).

The (frequency-weighted) energy-equivalent acceleration (A_{eq}) corresponding to the total duration of exposure may be derived. This is effectively an overall average r.m.s. acceleration value for the total period in question (ΣTi)

$$A_{eq} = k\left[\frac{\sum a^2{}_{wi}.T_i}{\sum T_i}\right]^{1/2} \qquad (3)$$

where:-

A_{eq} = axis-weighted energy-equivalent continuous acceleration (r.m.s. acceleration (m/s^2))

a_{wi} = vibration magnitude (r.m.s. acceleration (m/s^2)) for exposure period *T*i

*ΣT*i = total duration of exposure / measurement

k= orthogonal (measurement) axis multiplying factor specified by ISO 2631-1:1997 (Table 2)

Table 2. Frequency weightings and multiplying factors for health aspects of whole body vibration (WBV) as specified by ISO 2631-1:1997 for seated persons.

Measurement axis	Frequency weighting	Multiplying factor (k)
Longitudinal (X) axis	Wd	1.4
Transverse (Y) axis	Wd	1.4
Vertical (Z) axis	Wk	1

For comfort evaluation ISO 2631-1:1997 recommends the following thresholds (Table 3).

Table 3. Vibration exposure values specified by ISO 2631-1:1997.

		8-hour energy-equivalent r.m.s. acceleration – A (8) (m/s^2)	Vibration Dose Value ($m/s^{1.75}$)
Whole-Body Vibration	Exposure Action Value (EAV)	0.5	9.1
	Exposure Limit Value (ELV)	1.15	21
Hand-Arm Vibration	Exposure Action Value (EAV)	2.5	-
	Exposure Limit Value (ELV)	5	-

The daily vibration dose value (VDV) (units: $m/s^{1.75}$) of a person may be derived from the formula:-

$$VDV = k\left[\int_0^T a_w^4(t)dt\right]^{1/4} \qquad (6)$$

where:-

$a_w(t)$ = frequency-weighted acceleration time history at the supporting surface (m/s^2)

T= total duration of exposure (seconds) within any period of 24 hours

k = orthogonal (measurement) axis multiplying factor specified by ISO 2631-1:1997.

The data were processed for frequencies procedure, and analysis of variance, (Snedecor and Cochran, 1980).

According to Hook's law of modulus of elasticity the materials were selected based on the large deflections within their elastic range and the mechanical properties according to its stiffness, a rubber spring by casting is a mix of granules and used rubber was used as an isolation to reduce the rice combine harvester vibration transmitted to the operator by the seat as shown in Fig. (4), other factors to be considered are costs, availability, formability, and stress relaxation. A universal testing machine was used to measure the stiffness of rubber springs as shown in Fig. (5).

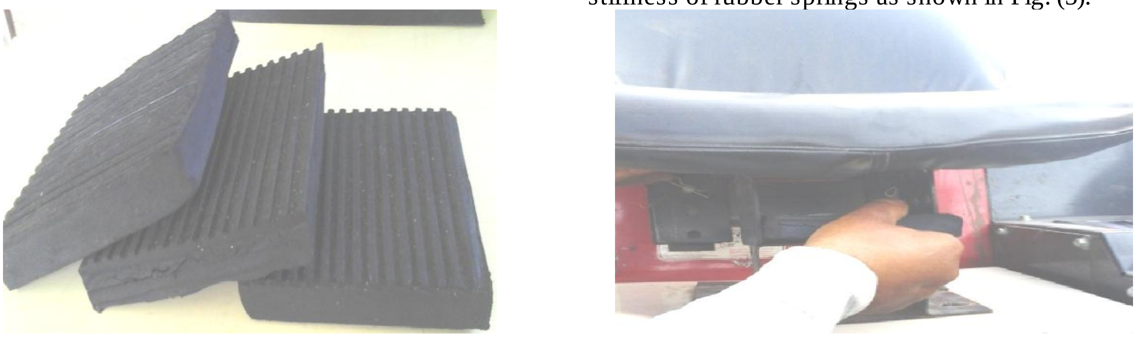

Fig. 4. Rubber spring used to reduce the rice combine harvester vibration transmitted to the operator.

Fig. 5. The universal testing machine with its control unit.

Soil moisture content

The moisture content of the soil was determined using an electric oven adjusted to (105° C) for24 hours. Soil samples were taken by screw auger immediately before using rice combine harvesters (three replicates for each sample). Determination of soil moisture contents were carried out at laboratory of Rice Mechanization Center on dry bases according to Black *et al*. (1965) method. The average values of soil moisture content were measured for different studied rice fields for all treatments (Table 4).

Table 4. The moisture content of soil for different studied treatments.

treatments	Soil moisture content, %			
	Sample 1	Sample 2	Sample 3	Av
Manual transplanting Daedong 65 hp	20.87	19.72	20.68	20.42
Manual transplanting Yammer 48 hp	20.87	19.72	20.54	20.38
Manual transplanting Kubota 55 hp	21.88	20.6	19.66	20.71
Manual transplanting Daedong 65 hp with cab	23.17	20.74	19.88	21.26
Manual transplanting Kubota 80 hp with cab	20.87	19.72	18.68	19.76
Mechanical transplanting Yammer 48 hp	22.87	18.72	16.38	19.32
Direct sowing Claas 130 hp with cab	21.86	20.16	19.72	20.58
Direct sowing Claas 130 hp with cab	22.66	20.24	19.12	20.67

RESULTS AND DISCUSSION

Subjects physical characteristics

The physical characteristics of the selected subjects for combine operation under different field conditions were measured, calculated and statically analyzed as shown in Table (5). Height and weight were used to calculate a participant's BMI according to the World Health Organization (WHO, 2000), which defines BMI as: the weight in kilograms divided by the square of the height in meters (kg/m^2).The rice combine harvester operator's data were classified according to age into five age categories. The obtained results showed that the highest number of rice combine harvester operator's was in the age group of (31-35) years (43.8%), followed by (41-45) years (31%), but the least number of operator's was in the age group of (46-50) years (12.6%), and followed by (51-55) years (6.3%) as shown in Fig (6).

Table 5. Physical characteristics of subjects for combine operation.

Body dimensions	minimum	Maximum	Mean	SD
Age, year	28	52	38.37	7.50
BMI	23.8	37.74	29.67	4.13
Height, cm	163	184	173.68	5.99
Weight, kg	64	125	90.18	17.60

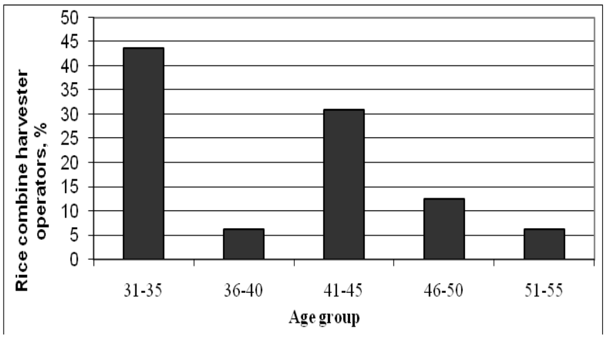

Fig. 6. Distribution of rice combine harvester operator's by age.

On the other side, the rice combine harvester operator's data were classified according to (BMI). It is worth to state that the body mass index divided into five categories; Less than 18 consider thin; 18-24 is ideal; 25-29 is overweight; 30-39 is obesity and more than 40 are over obesity. The obtained results from the samples under study showed that the highest percentage of body mass index was (44%) for both of overweight body and obesity body followed by (12%) for ideal body as shown in fig. (7).

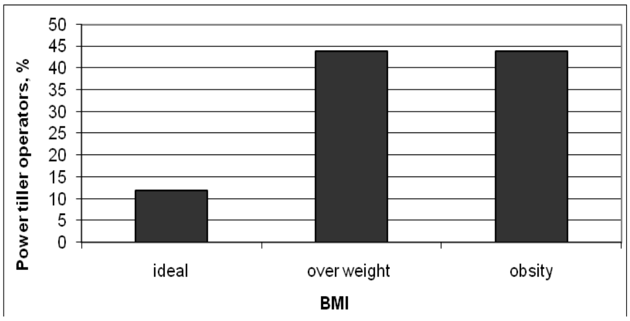

Fig. 7. Distribution of rice combine harvester operator's by body mass index.

Vibration measurements

The expression of root mean square, RMS vibration magnitude (m/s^2) was used to determine the human whole body vibration in terms of frequency-weighted acceleration according to the method defined in International Standard ISO 2631-2(1997). The RMS vibration magnitude represents the average acceleration over a measurement period. It is the highest of three orthogonal axes values (1,4awx, 1,4awy or 1.0awz) that are used for the risk assessment. Measurements should be made over periods of at least 20 minutes.

Fig. (8) showed that the basic vibration measurement parameters in the yanmer combine harvester for the field planted by manual transplanting at soil moisture content of 20.38 % were for the x, y, z-direction and vector sum, the maximum frequency weighted RMS (root mean square) acceleration of (0.591 m/s^2) was in vertical (Z) axis, crest factor (CF) is more than the threshold limit and above the critical ratios, it was (71.805) in vertical (Z) axis, MTVV (maximum transient vibration value) of (6.589 m/s^2) was in vertical (Z) axis, VDV (vibration dose value) of (15.415 $m/s^{1.75}$) was in vertical (Z) axis, this in considerably in excess of the WBV exposure action value (EAV) and also exposure limit value (ELV) proposed by ISO 2631-1-1997.

Fig. (9) showed that the daily vibration exposure level (A (8)) (units: m/s^2), expressed as eight-hour energy equivalent continuous, frequency-weighted RMS acceleration of (0.285 m/s^2), (0.303 m/s^2), and (0.591 m/s^2), were for the x, y, z-direction respectively. The daily vibration dose value (VDV(8)kZ) of (13.35 $m/s^{1.75}$), (13.48 $m/s^{1.75}$), and (32.75 $m/s^{1.75}$), were for the x, y, z-direction respectively, for yanmer combine harvester at the field planted by manual transplanting with soil moisture content of 20.38 %, it was clear that the values are exceeded both of exposure action value and exposure limit value proposed by ISO 2631-1-1997, especially in vertical (Z) axis. So there is a need to provide good suspension for the seat (which get the final transmitted force then to the operator) to ensure operating in safe conditions.

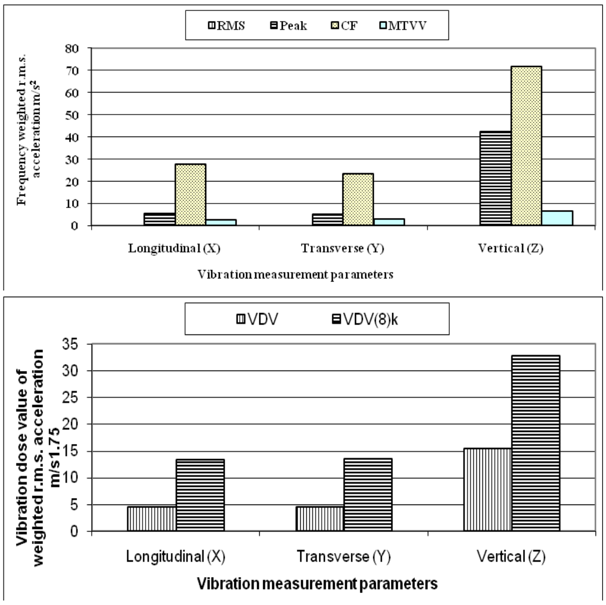

Fig. 8. Vibration measurement parameters for Yanmer combine during measuring time of rice harvesting.

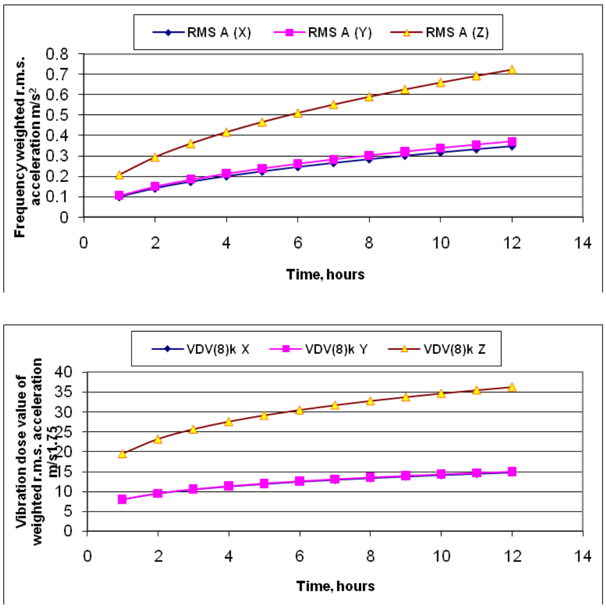

Fig. 9. Vibration measurement parameters for Yanmer combine during measuring time of rice harvesting.

Fig. (10) showed that the basic vibration measurement parameters in the claas combine harvester for the field planted by direct sowing at soil moisture content of 20.67 % were for the x, y, z-direction and vector sum, the maximum frequency weighted RMS acceleration of (0.314 m/s^2) was in vertical (Z) axis, (CF) is more than the threshold limit and above the critical ratios, it was (15.02) in vertical (Z) axis, MTVV of (1.05 m/s^2) was in vertical (Z) axis, VDV of (2.036 $m/s^{1.75}$) was in vertical (Z) axis, this in considerably is not excess of the WBV exposure action value (EAV) and also exposure limit value (ELV) proposed by ISO 2631-1-1997.

Fig. (11) showed that the frequency-weighted RMS acceleration of (0.216 m/s^2), (0.301 m/s^2), and (0.314 m/s^2), were for the x, y, z-direction respectively. The (VDV(8)kZ) of (6.46 $m/s^{1.75}$), (10.17 $m/s^{1.75}$), and (11.74 $m/s^{1.75}$), were for the x, y, z-direction respectively. In the claas combine harvester for the field planted by direct sowing at soil moisture content of 20.67 %. It is clear that the values are not exceeded both of exposure action value and exposure limit value proposed by ISO 2631-1-1997, especially in vertical (Z) axis. Because there is a good suspension for the seat (which get the final transmitted force then to the operator) and ensure operating in safe conditions.

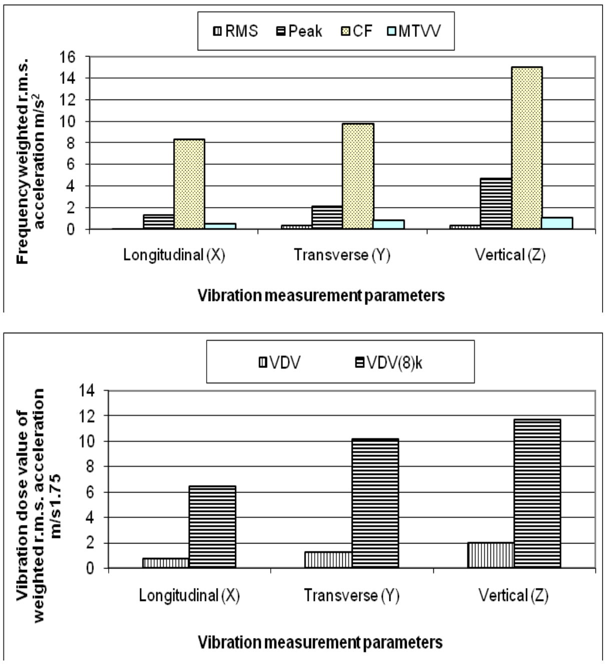

Fig. 10. Vibration measurement parameters for claas combine during measuring time of rice harvesting.

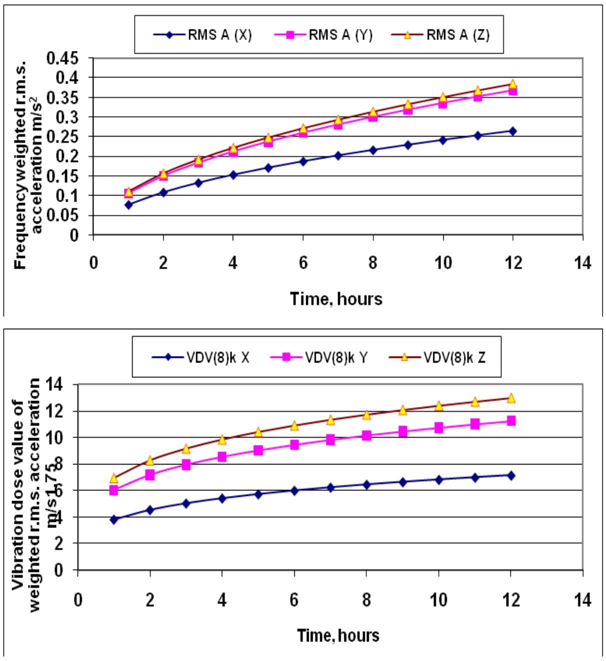

Fig. 11. Vibration measurement parameters for claas combine during measuring time of rice harvesting.

Table (6), (7) present the results of the statistical analysis of ANOVA for the all treatments conducted by different types of combine harvesters. Data analysis showed that there was highly significant difference on the mean of RMSZ, VDVX, VDVY and VDVZ for different types of combine harvesters; on the other hand, there was insignificant difference on the mean of RMSX, RMSY. So it was clear that the vibration measurement parameters for yammer combine harvester during measuring time and during twelve hours of rice harvesting at soil moisture content of 20.38 %; the mean of RMSZ, which cause body pain were between (0.68 and 1.36) m/s^2 and the mean of VDVZ, which cause body pain were between (31.49 and 34.02) $m/s^{1.75}$ is more than the threshold limit. However, the values exceeded both of exposure action value and exposure limit value proposed by ISO 2631-1-1997, especially in vertical (Z) axis. So there is a need to provide good suspension for the seat (which get the final transmitted force then to the operator) to ensure operating in safe conditions.

Table 6. Analysis of variance for the effect of different types of rice combine harvester on frequency-weighted vibration acceleration (RMS) for the x, y and z-direction on operators.

Vibr Ation axis	Rice combine harvester	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	F	Sig.
RMSX	Yammer 48 hp	0.3268	0.1109	3.92E-02	0.234	0.4195	1.774	0.102
	Daedong 65 hp	0.4101	0.1244	4.40E-02	0.3061	0.514		
	Yammer 48 hp	0.3296	5.47E-02	1.93E-02	0.2839	0.3753		
	Kubota 55 hp	0.359	0.1609	5.69E-02	0.2244	0.4935		
	Daedong 65 hp cab	0.275	0.1837	6.50E-02	0.1214	0.4286		
	Kubota 80 hp cab	0.2607	0.1313	4.64E-02	0.1509	0.3705		
	Claas 130 hp cab	0.2509	9.57E-02	3.39E-02	0.1709	0.331		
	Claas 130 hp cab	0.2322	9.91E-02	3.75E-02	0.1405	0.3239		
RMSY	Yammer 48 hp	0.3614	0.1425	5.04E-02	0.2423	0.4805	1.904	0.078
	Daedong 65 hp	0.3917	9.65E-02	3.41E-02	0.311	0.4724		
	Yammer 48 hp	0.3862	9.90E-02	3.50E-02	0.3034	0.469		
	Kubota 55 hp	0.3821	0.176	6.22E-02	0.2349	0.5292		
	Daedong 65 hp cab	0.2952	0.1743	6.16E-02	0.1496	0.4409		
	Kubota 80 hp cab	0.3267	0.1445	5.11E-02	0.2059	0.4476		
	Claas 130 hp cab	0.2386	7.77E-02	2.75E-02	0.1737	0.3035		
	Claas 130 hp cab	0.2251	4.58E-02	1.73E-02	0.1827	0.2674		
RMSZ	Yammer 48 hp	1.0255	0.4069	0.1439	0.6853	1.3658	2.556	0.019
	Daedong 65 hp	0.8197	0.2809	9.93E-02	0.5848	1.0545		
	Yammer 48 hp	1.0063	0.3169	0.1121	0.7413	1.2712		
	Kubota 55 hp	0.7868	0.2759	9.76E-02	0.5561	1.0175		
	Daedong 65 hp cab	0.6486	0.2885	0.102	0.4074	0.8898		
	Kubota 80 hp cab	0.6895	0.2904	0.1027	0.4468	0.9322		
	Claas 130 hp cab	0.6324	0.2273	8.04E-02	0.4424	0.8224		
	Claas 130 hp cab	0.6094	0.1227	4.64E-02	0.4959	0.7229		

Table 7. Analysis of variance for the effect of different types of rice combine harvester on vibration dose value of weighted r.m.s acceleration, VDV(8)kZ for the x, y and z-direction on operators.

Vibration axis	Rice combine harvester	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	F	Sig.
VDVX	Yammer 48 hp	14.8555	3.9582	1.3994	11.5463	18.1647	6.126	0
	Daedong 65 hp	17.5887	4.8712	1.7222	13.5163	21.6612		
	Yammer 48 hp	12.0904	1.77	0.6258	10.6106	13.5702		
	Kubota 55 hp	13.6208	4.6874	1.6572	9.702	17.5395		
	Daedong 65 hp cab	10.5024	4.2805	1.5134	6.9238	14.081		
	Kubota 80 hp cab	9.7751	4.2087	1.488	6.2566	13.2937		
	Claas 130 hp cab	8.3536	2.576	0.9108	6.2	10.5072		
	Claas 130 hp cab	6.7813	2.9611	1.1192	4.0427	9.5199		
VDVY	Yammer 48 hp	15.8299	5.4578	1.9296	11.267	20.3927	6.111	0
	Daedong 65 hp	16.6871	3.9257	1.3879	13.4051	19.9691		
	Yammer 48 hp	13.8888	1.9751	0.6983	12.2375	15.54		
	Kubota 55 hp	13.7748	4.7096	1.6651	9.8374	17.7121		
	Daedong 65 hp cab	11.5869	4.8123	1.7014	7.5637	15.61		
	Kubota 80 hp cab	12.0754	3.1869	1.1267	9.411	14.7397		
	Claas 130 hp cab	7.9756	1.2001	0.4243	6.9723	8.979		
	Claas 130 hp cab	6.7846	0.7108	0.2687	6.1272	7.442		
VDVZ	Yammer 48 hp	32.7613	1.5102	0.5339	31.4987	34.0238	264	0
	Daedong 65 hp	28.2406	1.3722	0.4852	27.0934	29.3878		
	Yammer 48 hp	24.701	1.154	0.408	23.7362	25.6658		
	Kubota 55 hp	21.836	0.9161	0.3239	21.0701	22.6019		
	Daedong 65 hp cab	20.0657	0.3511	0.1241	19.7722	20.3593		
	Kubota 80 hp cab	18.1736	0.5453	0.1928	17.7178	18.6295		
	Claas 130 hp cab	15.2526	1.6373	0.5789	13.8838	16.6214		
	Claas 130 hp cab	11.8397	0.6032	0.228	11.2819	12.3976		

Table (8) concludes the results of the statistical analysis of ANOVA for the effect of vibration dose value of weighted r.m.s acceleration, VDV(8)kZ magnitude on operator's blood pressure 120 mmHg using different types of combine harvesters on vibration exposure. Data analysis showed that there was highly significant difference on the mean of yammer combine harvester and other treatments. It was clear that the operator's blood pressure (high level 120 mmHg) increased due to the increase in vibration dose value of weighted r.m.s acceleration, VDV(8)kZ magnitude. However, the values exceeded both of the threshold limit, exposure action value and exposure limit value proposed by ISO 2631-1: 1997. So there is a need to provide good isolation for the seat of yammer combine harvester (which get the final transmitted force then to the operator) to ensure operating in safe conditions.

Table (9) concludes the results of the statistical analysis of ANOVA for the effect of vibration dose value of weighted r.m.s acceleration, VDV(8)kZ magnitude on operator's blood pressure 80 mmHg for all treatments conducted by different types of combine harvesters on vibration exposure. Data analysis showed that there was highly significant difference on the mean of yammer combine harvester and other treatments It was clear that the operator's blood pressure (high level 80 mmHg) increased due to the increase in vibration dose value of weighted r.m.s acceleration, VDV(8)kZ magnitude. However, the values exceeded both of the threshold limit, exposure action value and exposure limit value proposed by ISO ISO 2631-1: 1997. So there is a need to provide good isolation for the seat of yammer combine harvester (which get the final transmitted force then to the operator) to ensure operating in safe conditions.

Table 8. Analysis of variance for the effect of frequency-weighted vibration acceleration (RMS)on operator's blood pressure 120 mmHg.

Rice combine harvester	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		F	Sig.
				Lower Bound	Upper Bound		
Yammer 48 hp	152.25	4.6522	1.6448	148.3607	156.1393	26.43	0
Daedong 65 hp	142.75	3.9911	1.4111	139.4134	146.0866		
Yammer 48 hp	134.375	1.3025	0.4605	133.2861	135.4639		
Kubota 55 hp	124.25	6.1586	2.1774	119.1013	129.3987		
Daedong 65 hp cab	132.75	0.7071	0.25	132.1588	133.3412		
Kubota 80 hp cab	135	4.567	1.6147	131.1819	138.8181		
Claas 130 hp cab	137.75	3.5355	1.25	134.7942	140.7058		
Claas 130 hp cab	133.1429	5.7859	2.1869	127.7918	138.4939		

Table 9. Analysis of variance for the effect of frequency-weighted vibration acceleration (r.m.s)on operator's blood pressure 80 mmHg.

Rice combine harvester	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		F	Sig.
				Lower Bound	Upper Bound		
Yammer 48 hp	97.125	2.031	0.7181	95.427	98.823	29.41	0
Daedong 65 hp	89.5	2.4495	0.866	87.4522	91.5478		
Yammer 48 hp	87.375	4.2741	1.5111	83.8018	90.9482		
Kubota 55 hp	85.5	2.4495	0.866	83.4522	87.5478		
Daedong 65 hp cab	77.5	2.4495	0.866	75.4522	79.5478		
Kubota 80 hp cab	90.5	2.4495	0.866	88.4522	92.5478		
Claas 130 hp cab	84	3.4641	1.2247	81.1039	86.8961		
Claas 130 hp cab	89.5714	1.6183	0.6117	88.0747	91.0682		

Table (10) presents the results of the statistical analysis of ANOVA for the effect of vibration dose value of weighted r.m.s acceleration, VDV(8)kZ magnitude on operator's heart rate (bpm) for all treatments conducted by different types of combine harvesters on vibration exposure. Data analysis showed that there was highly significant difference on the mean of yammer combine harvester and other treatments, it was clear that the operator's heart rate (bpm) increased due to the increase in vibration dose value of weighted r.m.s acceleration, VDV(8)kZ magnitude. However, the values exceeded the threshold limit, exposure action value and exposure limit value proposed by ISO ISO 2631-1: 1997. So there is a need to provide good isolation for the seat of yammer combine harvester (which get the final transmitted force then to the operator) to ensure operating in safe conditions.

Table 10. Analysis of variance for the effect of frequency-weighted vibration acceleration (RMS)on operator's heart rate (bpm).

Rice combine harvester	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		F	Sig.
				Lower Bound	Upper Bound		
Yammer 48 hp	128	2	0.7071	126.328	129.672	14.95	0
Daedong 65 hp	120.5	2.4495	0.866	118.4522	122.5478		
Yammer 48 hp	101.75	9.7797	3.4577	93.574	109.926		
Kubota 55 hp	87.875	13.4317	4.7488	76.6458	99.1042		
Daedong 65 hp cab	88.75	13.667	4.832	77.3241	100.1759		
Kubota 80 hp cab	92.5	14.442	5.106	80.4262	104.5738		
Claas 130 hp cab	96.625	7.0089	2.478	90.7654	102.4846		
Claas 130 hp cab	86.857	16.6776	6.3035	71.4329	102.2814		

In general, exposure of a high level of whole body vibration has detrimental effect on health. Exposure of the whole body vibration produces low back pain and at least causes work-related body pain (WRBP). This is due to physical characteristic of the vibration exposure and differences between tools and occupations. The Borg rating of perceived exertion (RPE) scale measures perceived exertion, the original scale introduced by Gunnar Borg rated exertion on a scale of 6-20. Borg then constructed a category (C) ratio (R) scale, the Borg CR10 Scale. The CR-10 scale is best suited when there is an overriding sensation arising either from a specific area of the body, the seemingly odd range of 6-20 is to follow the general heart rate of a healthy adult by multiplying by 10. For instance, a perceived exertion of 12 would be expected to coincide with a heart rate of roughly 120 beats per minute. It ranges from 6 to 20where 6 means "no exertion at all" and 20 mean "maximal exertion. The maximum WRBP values were obtained during harvesting rice by yanmer combine harvester for the field planted by manual transplanting, followed by harvesting rice by Daedong combine harvester for the field planted by manual transplanting and harvesting rice by Class combine harvester for the field planted by direct sowing which were 13.1, 12.4 and 6.6 (Borg scale CR—10 scale.) respectively.

Increase safety considerations

In rice combine harvester, the seat is the part where the operator comes in deep contact danger. It is more safe to get the operator spine apart enough of the whole body vibration resulted from the unsuspended seat during operation. A suspended seat by a rubber spring conducted seriesly was used depending on the maximum value of operator weight (125 kg), also the seat weight itself (20 kg). According to the distance vertically under the seat (10 cm), the thickness of the three pieces overlapping springs made a safe deflection as an elastic deformation according to the maximum stiffness of the three pieces overlapping springs (222, 266 N/mm), this value will provide safely and suspended distance between the seat and the rice combine harvester block during operating Fig. (12).

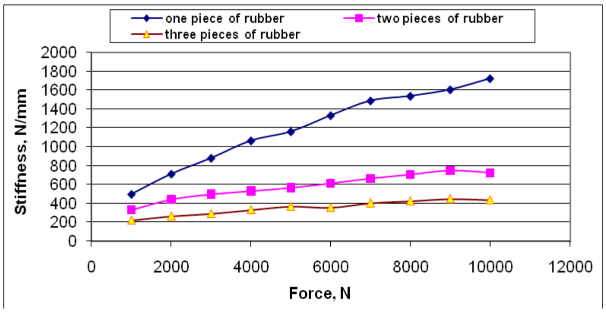

Fig. 12. Stiffness of rubber springs.

]According to ISO 2631-1, (1997) the operator in the safe conditions works 8 hours per a day. In case of injury by body pain he will work less than the 8 hours per day, in addition to surgery of low back pain, so there will be loss in the return. The seat with its suspension unit save all these losses where the labor may works 8 hours per day or more than that.

Data of vibration measurement parameters in the yanmer combine harvester for the field planted by manual transplanting at soil moisture content of 19.5 % with a suspended seat by rubber spring illustrated graphically in fig. (13). The figure revealed that the RMS of (0.349 m/s^2), (0.172 m/s^2), and (0.424 m/s^2), were for the x, y, z-direction respectively, it is clear that the RMS is not more than the threshold limit, it was (0.424 m/s^2) in vertical (Z) axis. CF of (4.18), (5.15), and (3.01), were for the x, y, z-direction respectively. It also clear that CF is not more than the threshold limit, it was (3.01) in vertical (Z) axis. MTVV of (0.396 m/s^2), (0.217 m/s^2), and (1.02 m/s^2), were for the x, y, z-direction respectively. The MTVV is not more than the threshold limit, it was (1.02 m/s^2) in vertical (Z) axis. VDV of (0.661 m/s$^{1.75}$), (0.351 m/s$^{1.75}$), and (1.524 m/s$^{1.75}$), were for the x, y, z-direction respectively. Also VDV is not more than the threshold limit, it was (1.524 m/s$^{1.75}$) in vertical (Z) axis, this in considerably not excess of the WBV exposure action and limit values (EAV), (ELV) proposed by ISO 2631-1-1997.

Fig. (14). shows that the A (8) RMS of (0.349 m/s^2), (0.172 m/s^2), and (0.424 m/s^2), were for the x, y, z-direction respectively. The VDV(8)kZ of (6.629 m/s$^{1.75}$), (3.521 m/s$^{1.75}$), and (10.908 m/s$^{1.75}$), were for the x, y, z-direction respectively. In general the values not exceeded both of exposure action value and exposure limit value proposed by ISO 2631-1-1997, especially in vertical (Z) axis. Rubber spring of three pieces conducted seriesly is better than others so it is recommended to use it as a suspension spring under the seat.

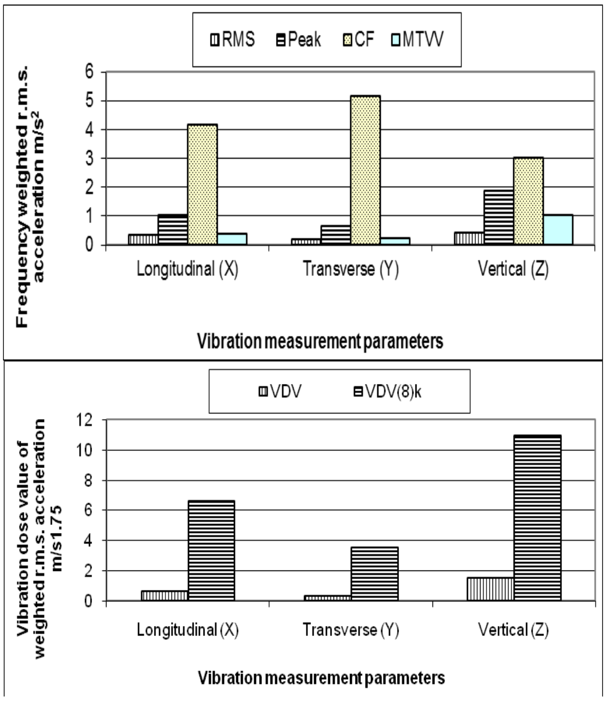

Fig. 13. Vibration measurement parameters for Yanmer combine during measuring time of rice harvesting by using rubber spring.

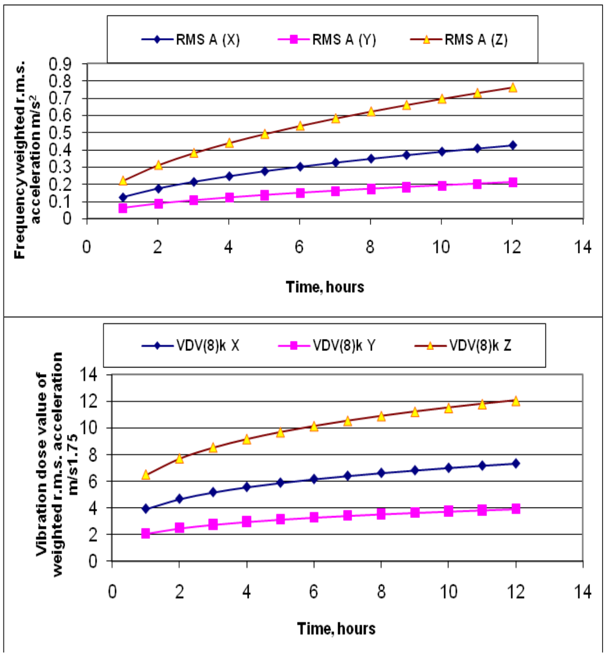

Fig. 14. Vibration measurement parameters for Yanmer combine during measuring time of rice harvesting by using rubber spring.

CONCLUSSION

The obtained results concluded that:-

1- The maximum vibration dose values of weighted r.m.s acceleration, VDV(8)kZ during harvesting rice by yanmer combine harvester for the field planted by manual transplanting were 13.35, 13.48 and 32.75 $m/s^{1.75}$ compared with 6.62, 3.52 and 10.9 $m/s^{1.75}$ after using the rubber spring at the X, Y and Z axes respectively for soil moisture content of 20.38 %.
2- The peak vibration acceleration values during harvesting rice by yanmer combine harvester for the field planted by manual transplanting were 5.67, 5.04 and 42.45 m/s^2 compared with 1.04, 0.63 and 1.87 m/s^2 after using the rubber spring at the X, Y and Z axes respectively for soil moisture content of 20.38 %.
3- The MTVV values (maximum transient vibration value) during harvesting rice by yanmer combine harvester for the field planted by manual transplanting were 2.63, 2.70 and 6.58 m/s^2 compared with 0.39, 0.21 and 1.02 m/s^2 after using the rubber spring at the X, Y and Z axes respectively for soil moisture content of 20.38 %.
4- The CF values (crest factor) during harvesting rice by yanmer combine harvester for the field planted by manual transplanting were 27.83, 23.30 and 71.80 compared with 4.18, 5.15 and 3.01 after using the rubber spring at the X, Y and Z axes respectively for soil moisture content of 20.38 %.
5- The heart rate and blood pressure (high and low level 120, 80 mmHg) increased due to harvesting rice by yanmer combine harvester for the field planted by manual transplanting compared with other treatments and decreased by using rubber spring.
6- The stiffness of rubber spring decreased due to use three pieces of rubber compared with one piece of rubber and cause more elasticity which ensures less vibration dose value of weighted r.m.s acceleration and operating in safe conditions.
7- The maximum WRBP values were obtained during harvesting rice by yanmer combine harvester for the field planted by manual transplanting, followed by harvesting by Daedong combine harvester, for the field planted by manual transplanting and harvesting by Class combine harvester and for the field planted by direct sowing were 13.1, 12.4 and 6.6 (Borg scale CR—10 scale.) respectively.

Recommendation

1- Use a rubber spring as a vibration isolator reduces whole body vibration parameters: VDV, MTVV and cause more elasticity which ensures less vibration dose value of weighted r.m.s acceleration, heart rate and blood pressure (high and low level 120, 80 mmHg) which ensures operating in safe conditions.
2- It is highly recommended to perform studies related the ergonomics, human factors engineering, and human body vibration for the numerous benefits and impact on the safety of workers in order to increase the productivity of agricultural mechanization units.

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التعرض لإهتزاز كامل الجسم أثناء تشغيل آلة حصاد الأرز الجامعة تحت ظروف الحقل المصرية

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انتشر الحصاد الآلى لمحصول الأرز في مصر باستخدام آلات الحصاد الجامعة (الكومباين) في الآونة الأخيرة بشكل سريع وذلك لان هذه الطريقة تعتبر من أفضل الطرق لحصاد الأرز حيث يتم الضم والدراس والتعبئة فى خطوة واحدة مما يؤدى إلى زيادة درجة النظافة مع تقليل الزمن اللازم لإجراء هذه العمليات. وما ترتب على ذلك من زيادة الطلب على استخدام الكومباين في حصاد الأرز وظهور العديد من الموديلات المختلفة للكومباين والتى تتباين فيما بينها في أحجامها ونظرية الدراس والتذرية المتبعة بها وتطبيقات الصحة والسلامة المهنية لكل منها وعلاقتها بمشغلى الكومباين الذين يتعرضون أثناء التشغيل إلى اهتزازات للجسم كله والتى تتوقف شدتها على حالة ونوع وسرعة الكومباين المستخدم لذا تهدف هذه الدراسة لدراسة تأثير استخدام آلات حصاد الأرز الجامعة على تعرض المشغل لاهتزاز كامل الجسم تحت ظروف الحقل المصرية حيث تمت القياسات و تجميع البيانات من خلال حصاد محصول الأرز الذى تم زراعته بثلاث طرق هى: شتل يدوى ، شتل آلى و زراعة بدار باستخدام أربعة أنواع من آلات الحصاد الجامعة (يانمار ، كوبوتا ، ديادونج ، كلاس) عند مستوى رطوبة أرضية يتراوح فيما بين ١٩,٣٦% وحتى ٢١,٢٦%. تم اختيار ستة عشر مشغل لآلات حصاد الأرز الجامعة بحالة صحية جيدة للدراسة حيث تم تقييم الدراسة بقياس المؤشرات التالية: الجذر التربيعى RMS لمتوسط اهتزازات الجسم كله أثناء زمن القياس الكلى ، قيمة جرعة الاهتزاز VDV ، معدل نبضات القلب ، ضغط الدم ، طول الإنسان ووزنه ودليل كتلة الجسم موضوع الدراسة .هذا وقد تم قياس مؤشر الاهتزازات الميكانيكية وفقا لمنظمة التوحيد والقياس العالمية (ISO) وتم تصميم التجربة الحقلية وفقا للتصميم التام العشوائية حيث أجريت التجارب العملية وأخذت القياسات بالمزرعة التطبيقية لمركز ميكنة الأرز بميت الديبة - محافظة كفر الشيخ وبعض المزارع المجاورة خلال موسم زراعة محصول الأرز عام ٢٠١٦م . وقد أوضحت النتائج المتحصل عليها أن أقصى قيمة لجرعة الاهتزاز VDV أثناء زمن القياس الكلى كانت فى اتجاه المحور Z لعملية حصاد محصول الأرز بواسطة الكومباين اليانمار عند مستوى رطوبة أرضية ٢٠,٣٨% لأرض تم زراعتها شتل يدوى حيث تتجاوز قيم الحدود الموصى بها من قبل منظمة التوحيد والقياس العالمية مما يشكل خطر على كامل جسم المشغل والذى أدى بدوره إلى الزيادة فى معدل نبضات القلب وضغط الدم عن المستوى الطبيعى تلاها عملية حصاد محصول الأرز بواسطة الكومباين الديادونج عند مستوى رطوبة أرضية ٢٠,٤٢% لأرض تم زراعتها شتل يدوى ، من ناحية أخرى سجلت قيمة جرعة الاهتزاز VDV أثناء زمن القياس الكلى اقل قيمة عن قيم الحدود العتبية الموصى بها فى عملية حصاد محصول الأرز بواسطة الكومباين الكلاس عند مستوى رطوبة أرضية ٢٠,٦٧% لأرض تم زراعتها بدار مما يوضح ان ظروف التشغيل آمنة وان معدل نبضات القلب وضغط الدم فى حدود المستوى الطبيعى .أثبتت التجارب أن استخدم نابض مطاطى (ثلاث قطع مطاط متصلة على التوالى) أدى إلى تقليل قيمة جرعة الاهتزاز VDV وكذا قيمة اقصى اهتزاز منقول MTVV أثناء زمن القياس الكلى وبالتالى معدل نبضات القلب وضغط الدم للحصول على ظروف تشغيل آمنة مهما كانت قيمة VDV فى لعمليات الحصاد الزراعية تحت التجربة . وقد أظهرت النتائج أيضا أن مؤشر ألم الجسم نتيجة العمل سجل أكبر قيمة فى عملية حصاد محصول الأرز بواسطة الكومباين اليانمار تلاها حصاد محصول الأرز بواسطة الكومباين الديادونج ثم حصاد محصول الأرز بواسطة الكومباين الكلس وكانت قيمته ١٣.١ ، ١٢.٤ ، ٦.٦ على الترتيب . كما تبين أن هناك علاقات معنوية بين عوامل الدراسة : قيمة جرعة الاهتزاز VDV ، الجذر التربيعى لمتوسط اهتزازات ذراع الإنسان أثناء زمن القياس الكلى ، معدل نبضات القلب ، ضغط الدم . هذا وتوصى الدراسة بضرورة استخدام نابض مطاطى وتجنب العمل فى الأراضى شديدة الصلابة والجفاف لتقليل قيمة جرعة الاهتزاز VDV أثناء زمن القياس الكلى وبالتالى معدل نبضات القلب وضغط الدم للحصول على ظروف تشغيل آمنة فى مثل هذه العمليات الزراعية.