

Evaluation of Whole-body-vibration Among Tractor (41 kW) Drawn Subsoilers

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ABSTRACT

Whole-body-vibration can be say to that part of vibration which received by a person's body, from the machine. Subsoiling is heavy draft farm operation so to know the effect of subsoiling on vibration, it needs documentation which helps to decide safe exposure limits in sense of duration of safe subsoiling hours. For study, three subsoilers as single tine straight shank subsoiler (S_1), double tine straight shank subsoiler (S_2), and double tine curved shank subsoiler (S_3) at three different depths (20-25, 25-30, and 30-35 cm) performed subsoiling and evaluated the effect of subsoiling on different parameters as vibration, fuel consumption, wheel slip, draft, and soil disturbance area were observed and analyzed. The vibration was increased as operating depth was increased. It was recorded maximum at depth of 30-35 cm (d_3) for "X" direction as 0.296 m/s^2 , for "Y" direction as 0.284 m/s^2 , for "Z" direction as 0.431 m/s^2 , and for total acceleration (A_{nv}) as 0.451 m/s^2 . The vibration in "X" direction was increased 5.86 % and 11.64 %, in "Y" direction was increased 6.52 % and 12.42 %, in "Z" direction was increased 3.68 % and 8.11 %, and A_{nv} was increased 10.23 % and 13.59 %, for d_2 and d_3 depths compared to d_1 depth. On the other hand, the fuel consumption, wheel slip, and draft were found maximum for S_2 subsoiler and minimum for S_1 subsoiler. Soil disturbance area was observed maximum for S_2 subsoiler and minimum for S_1 subsoiler. Also same effect as vibration, the increased subsoiling depth resulted increased in these parameters. The safe exposure working hours were calculated as work with S_1 subsoiler at the depths of d_1 , d_2 , and d_3 were 8 h, 6 h, and 4 h respectively. Same as for S_2 subsoiler were 4 hours at all depths and for S_3 subsoiler it was calculated 4 to 6 hours. In conclusion, single tine subsoiler can be a better option for subsoiling. Only the soil disturbance area and field capacity becomes half as compared to double tine subsoilers.

Keywords: *whole-body-vibration, subsoiling, vibration database, safe exposure period.*

INTRODUCTION

With invention of internal combustion engines and further advances in engine technology, the problem of un-necessary sound and vibration are arisen. Vibration enters the human body from the organs in contact with vibrating surface. When a worker sits or stands on a vibrating surface, the contact among both is called whole-body-vibration

exposure. Many people are exposed to vibration (WBV) in their occupational lives. The biodynamic responses of the human body in sitting conditions have been widely measured under whole-body vibration (WBV)⁴. Working with agricultural machine in farm operation, the important thing in man-machine interference is ergonomic as human health. Obviously exposing high level vibration and more than allowable time of operation affect the health as

damaging different part of body and consequently decreasing efficiency and quality of work⁸.

Vibration is the mechanical oscillation of an object about an equilibrium point. Normally, the agricultural tractor produces low-frequency vibrations and it affects severe to human body. These vibrations are depended on various parameters such as soil type, field operations, tractor mass distribution, engine speed and forward speed^{5,7,9}. In view of the deterioration in health and working efficiency base on vibration, it is necessary to study the effect of vibration transmission to the vehicle seat⁶. Most of the past work on vibration align with tractor is only done as riding tractor and study the vibrating effect on running tractor. But the use of tractor is mostly with implement working in field and trailer working¹.

Based on the feedback from the tractor drivers operating subsoilers complained about severe fatigue after working few hours. This needs a documentation /database. Neither the effect of implements on tractor ride vibration is well understood, nor is the effect of tractor ride vibration on operator's effectiveness and health. To know this effect of vibration characteristics of implement as different subsoilers, working depths, and particular safe working period, this present study was undertaken. The human vibration data collection for subsoilers working at different depths and to analyze the effect of the experiment on the transmissions of human vibration to operator helps to work-out the schedule of safe / harmful exposure limits can be determined. It can be find out by comparing the vibrations values with the limits of tri-axial acceleration set by the International Standards ISO:2631-5(2004)³ and total exposure acceleration by the EU Directive 2002/44/EC. 2002². By comparing these data with standards, one can

Table 1: Fatigue decreased proficiency limits for whole-body-vibration

Exposure time, normal h work day,	Acceleration, m/s ² r.m.s.	
	Vertical "Z" axis	Horizontal "X" and "Y" axis
8	0.315	0.224
6	0.400	0.285
4	0.530	0.355

decide the safe working hours of subsoiling operation for individual three subsoilers at respective depths.

MATERIALS AND METHODS

For this experimentation mature, the performance was evaluated with 41 kW tractor John Deere – 5310 and three subsoilers. To measure the parameters like whole-body-vibration, fuel consumption, wheel slip, draft, and soil disturbance area, the used instruments are human vibration meter VM-30H, fuel consumption measuring device, length measuring tape, digital dynamometer and soil profile meter respectively.

Experimental Site

To perform the experiment, the field of Instructional Farm, Department of Soil and Water Engineering, College of Agricultural Engineering and Technology, JAU, Junagadh was selected.

Experimental Design

The experiment was carried out with two factors and nine combinations as three subsoilers working at three different depths with three replications to study the effect of subsoiling on whole-body-vibration and other parameters.

Table 2: Effect of subsoiling on Vibration Acceleration r.m.s. and safe working period

Sr. No.	Treatment combination	Avg. Vibration acceleration r.m.s.,(m/s ²)			Max. safe working period, h
		"X"	"Y"	"Z"	
1	S1d1	0.220	0.207	0.315	8
2	S1d2	0.235	0.222	0.328	6
3	S1d3	0.249	0.235	0.351	6
4	S2d1	0.301	0.290	0.502	4
5	S2d2	0.321	0.310	0.521	4
6	S2d3	0.340	0.330	0.534	4
7	S3d1	0.276	0.261	0.377	6
8	S3d2	0.287	0.274	0.392	6
9	S3d3	0.300	0.285	0.409	4

r.m.s. = root mean square; Avg. = Average; Max. = Maximum

Table 3: Effect of subsoiling on Total Acceleration (Ahv) and safe working period

Sr. No.	Treatment combination	Avg. Total Acceleration (Ahv)	Calculated exposure acceleration, (m/s ²)			Limiting values, (m/s ²)	Max. safe working period, h
			8 h	6 h	4 h		
1	S1d1	0.328	1.102	0.954	0.779	1.15	8
2	S1d2	0.369	1.237	1.071	0.874	1.15	6
3	S1d3	0.389	1.300	1.126	0.919	1.15	6
4	S2d1	0.470	1.579	1.367	1.116	1.15	4
5	S2d2	0.476	1.598	1.384	1.130	1.15	4
6	S2d3	0.485	1.622	1.405	1.147	1.15	4
7	S3d1	0.392	1.311	1.136	0.927	1.15	6
8	S3d2	0.468	1.570	1.360	1.110	1.15	4
9	S3d3	0.479	1.612	1.396	1.140	1.15	4

Table 4: Performance of subsoilers with respect to Whole-body-vibration

Subsoilers	Whole-body-vibration, m/s ²			Total Acceleration (Ahv)
	Vibration acceleration r.m.s. in "X" axis	Vibration acceleration r.m.s. in "Y" axis	Vibration acceleration r.m.s. in "Z" axis	
S1	0.234	0.221	0.332	0.362
S2	0.321	0.31	0.519	0.477
	-36.79%	-40.11%	-56.22%	-31.73%
S3	0.288	0.273	0.392	0.446
	-22.71%	-23.49%	-18.13%	-23.28%

() indicates % higher vibration acceleration compared to the S1 subsoiler.

Independent parameter: 3

Working/subsoiling depths

1. 20 – 25cm (d₁)
2. 25 – 30cm (d₂)
3. 30– 35 cm (d₃)

Dependant parameters: 5

1. Vibration (m/s²)
2. Fuel consumption (l/h)
3. Wheel slip (%)
4. Draft (kgf)
5. Soil disturbance area (cm²)

Vibration Measurement

Vibration (X, Y, and Z direction) acceleration r.m.s. values (Whole-body-vibration) were collected in first run in the plot and the data were saved in

vibration meter. It was also collected total vibration (Ahv) values of Whole-body-vibration for same plot in second run and data were saved in vibration meter. Total Vibration Value (Ahv) was determined from vibration in three orthogonal directions and for particular exposure period, it was calculated via instrument software as ;

$$A_{ws} = A_{hv} = \sqrt{k_x^2 a_{hwx}^2 + k_y^2 a_{hwy}^2 + k_z^2 a_{hwz}^2}$$

Where,

$\alpha_{hwx}, \alpha_{hwy}, \alpha_{hwz}$ are the acceleration interval r.m.s. values for X/Y/Z axes, and

k_x, k_y, k_z are multiplying factors as 1.4, 1.4 and 1 respectively.

Data Analysis

Vibration data were analyzed in the Microsoft Excel software in computer and compared with the standards. Vibration acceleration values were compared with ISO:2631-5(2004)^[3] as Table 1 and the Total vibration (Ahv) values were compared with standard "EU Directive 2002/44/EC (2002)"^[2] given permissible acceleration value as 1.15 m/s².

RESULTS AND DISCUSSION

Results and Discussion describes the experimental testing and functional performance in the field. It also includes the effect of subsoiling on whole-body-vibration, fuel consumption, wheel slip, draft and soil disturbance area. Aimed to vibration, the safe exposure period for operator for subsoiling operation discussed and presented accordingly.

Vibration Parameters

Vibration acceleration r.m.s. (root mean square) and Total acceleration (Ahv) data were obtained for three subsoilers operating at three different depths

Vibration acceleration r.m.s

For analysis, the average value of three replications of Vibration acceleration r.m.s. is presented in Table 2 for individual direction. Limiting acceleration values of whole-body-vibration for particular directions given by ISO:2631-5(2004)³ are as Table 1. Obtained acceleration data were compared with standard and results showed that how much hours of subsoiling in particular condition was beyond the safe working period.

Total Acceleration (Ahv)

For analysis, the average value of three replications of total acceleration (Ahv) was analysed as finding of calculated exposure hours for 8 h, 6 h, and 4 h in Microsoft Excel software. This calculated acceleration is presented in Table 3. European standard "EU Directive 2002/44/EC. 2002"^[2] gives the maximum permissible safe limiting value as 1.15 m/s². Obtained Total acceleration (Ahv) data gives the calculated exposure acceleration and these data were compared with European Standard, whose results showed that how much hours of subsoiling in particular condition was beyond the safe working period. Both of the Vibration acceleration r.m.s. and Total acceleration (Ahv) compared with standards and gives same results of safe working hours for particular subsoiling operations.

Operating Parameters

The parameters as fuel consumption, wheel slip, draft, and soil disturbance area were also measured during subsoiling in three replications. The average result is given in Table 5.

The major conclusions drawn from this experiment were;

1. The vibration was increased as operating depth was increased. It was recorded maximum at depth of 30-35 cm (d_3).
2. The vibration acceleration r.m.s. value in "X" axis was found minimum with single tine straight shank subsoiler (S_1). It was increased by 36.79 % and 22.71 % for S_2 and S_3 , respectively than S_1 for maximum depth d_3 .

Table 5: Result of various operating parameters

Sr. No.	Treatment combination	Fuel consumption (l/h)	Wheel slip (%)	Draft (kgf)	Soil disturbance area (cm ²)
1	S1d1	2.46	8.35	986.67	719.17
2	S1d2	2.63	8.93	1095.00	920.83
3	S1d3	2.89	10.81	1266.00	1034.17
4	S2d1	3.23	10.57	1157.33	1328.33
5	S2d2	3.33	12.29	1254.33	1813.33
6	S2d3	3.59	14.66	1515.67	1975.00
7	S3d1	3.07	9.17	1071.33	1270.00
8	S3d2	3.18	11.06	1194.67	1773.33
9	S3d3	3.38	12.78	1404.33	1855.00

3. The vibration acceleration r.m.s. value in "Y" axis was found minimum with single tine straight shank subsoiler (S_1). It was increased by 40.11 % and 23.49 % for S_2 and S_3 , respectively than S_1 for maximum depth d_3 .
4. The vibration acceleration r.m.s. value in "Z" axis was found minimum with single tine straight shank subsoiler (S_1). It was increased by 56.22 % and 18.13 % for S_2 and S_3 , respectively than S_1 for maximum depth d_3 .
5. The total acceleration (A_{nv}) vibration was found minimum with single tine straight shank subsoiler (S_1). It was increased by 31.73 % and 23.28 % for S_2 and S_3 , respectively than S_1 for maximum depth d_3 .
6. The fuel consumption, wheel slip, draft, and soil disturbance area were also increased as operating depth was increased.
7. Comparison of safe exposure working period for the operator for subsoiling operation at d_3 depth, safe exposure period of S_1 subsoiler is 6 h, for S_2 subsoiler is 4 h, and for S_3 subsoiler is 4 to 6 h.

Future scope of the work regarding this study is work on whole-body-vibration attenuation may be undertaken and also study of hand arm vibration can be conducted for analysis and finding of safe limiting hours of working.

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