Vibration characteristics of mini tractor (8.7 kW) on tar macadam

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Abstract: Mini tractor was operated on test tracks duly connected with vibration analyzer sensor at particular component and to prepare the database of vibration spectrum analysis on tar macadam road. Initially, the work was started on mini tractor vibration measurement on different components. The instrument for vibration analysis used SENDIG-911 portable vibration analyzer. The MCMe2.H software was used for data recording and analysis work. The experiment comprising three speed treatments i.e. low speed as 4.17 km h^{-1}, medium speed as 10.46 km h^{-1} and high speed as 14.13 km h^{-1}. Experimental statistical analysis was made from completely randomized design (CRD). The results on tar macadam road revealed that the maximum vibration (peak) with frequency of seat, foot rest, brake, clutch and steering was found as 2.97 m s^{-2} (85-102.5 Hz) to 4.14 m s^{-2} (77.5-80.5 Hz), 4.19 m s^{-2} (77.5-935 Hz) to 6.98 m s^{-2} (47.5-755 Hz), 3.15 m s^{-2} (110-497 Hz) to 6.26 m s^{-2} (95-820 Hz), 2.69 m s^{-2} (374.5-985 Hz) to 4.07 m s^{-2} (82.5-467.9 Hz) and 10.34 m s^{-2} (5-77.5 Hz) to 14.49 m s^{-2} (77.5-80 Hz), respectively under different operating speeds of mini tractor. The data, trend and percentage variation revealed that vibration on seat and clutch of mini tractor was found increased as forward speed of mini tractor increased and on foot rest, steering and brake, vibration was found decreased as forward speed of mini tractor increased. Data was compiled and database of vibration characteristics of mini tractor was prepared.

Keywords: vibration, portable vibration analyzer, mini tractor

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1 Introduction

Mini tractors are gaining popularity now days, because most of the agriculture operations can be performed with less expense, provides comparatively better remedy for labour problems and cost effective in general. The irony is that, still not sufficient data / literature on vibration measurement of mini tractor has been published / available. Therefore, this is an attempt to address this important research gap / missing link.

When a driver operates tractor / mini tractor's control points such as steering, brake, clutch etc. vibration affects hands and arms. Such an exposure is called hand-arm vibration exposure. When an operator sits on a seat, the vibration exposure affects the entire of the body and is called whole body vibration exposure.

Mini tractors are gaining popularity now days: due to division of farmer's family, the land holding becomes less and less day by day, even a small land holder is, willing to go for mechanization. As most of the agriculture operations can be performed with less expense. Mini tractor provides comparatively better remedy for the labour problems and is better option for saving the labour cost. It is a better substitute also for farming than a pair of bullock, with higher horse power multi cylinder tractors and power tiller. (Patel and Patel, 1994). It is surprising that still mini tractor vibration aspects has not been taken sincerely even at international / national / state level.

Postural discomfort of human body is stained much more during driving tractors. The different working

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postures could result in musculoskeletal aliments and taking sick leave by the tractor operators. The biomechanical disorders of tractor drivers are considered to be more prevalent in tropical agriculture, but the evidence to confirm this is very few. The position of the operator is directly above the rear wheels and hence the operator is subjected to vibration and is discomfort more easily in a tractor than in any other vehicle. The effect of tractor operation on the driver could be for either short term or long term. The short term effects are on blood circulation, speech trouble, head nodding movement, reduced speech and accuracy of reading, loss of constancy in foot pressure, etc. the long term effects are spinal and stomach disorders. (Manian, 2004). As the usefulness and importance of mini tractor in agriculture, transportation and the exposure of vibration on the operator, still not enough research work has been carried out on these aspects. This is the initial attempt to prepare the database of vibration characteristics of mini tractor components.

The specific objectives of this research were:

1) To work out vibration characteristics of selected components of mini tractor on tar macadam road condition.

2) To prepare the database of vibration spectrum analysis on tar macadam road condition for mini tractor components.

2 Materials and methods

Mini tractor (12 hp, 8.7 kW) is a standard tractor form with large rear wheels for traction and smaller front wheels for steering. This mini tractor has got 625 cc engine capacities. The seating position is above and forward of the rear axle. The driver has clear access from the seating position. Steering is by hand tiller and speed is controlled by foot pedal. The drive components are set above and between the rear wheels.

The experiment entitled “Vibration characteristics of mini tractor (8.7 kW) on tar macadam condition” was conducted during March-June, 2012. The details of experimental techniques followed, materials used, and criteria adopted for treatment evaluation and analysis during the course of investigation are presented in this chapter.

2.1 Experimental site

The field experiment was conducted on tar macadam behind the auditorium road and at the farm of Farm Machinery and Power Engineering department, College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh.

2.2 Climate and weather conditions

Geographically Junagadh is situated at 21.5°N latitude and 70.5°E longitudes with an altitude of 60 m above the mean sea level. Junagadh is situated in South Saurashtra Agro-climatic region of Gujarat state. Climate and weather data was recorded for the period from March-June, 2012.

The weather parameters such as temperature, relative humidity, ambient temperature, wind velocity and evaporation were more or less congenial for operator and measurement of vibration during summer season of 2012. The mean minimum and mean maximum temperature 23.7 and 39.2˚C. The range of average relative humidity and wind speed was 26%-76% and 7.2-8.4 km h^{-1} respectively.

2.3 Soil parameters

The following soil parameters were observed during the experiment.

2.3.1 Moisture content of soil

The soil moisture was determined on the dry basis. Five samples of the soil were collected randomly from the site. The samples were determined on the dry basis by hot air oven dry method. The samples were analyzed for determination of moisture content, as per the standard procedure. The observation and results of average moisture content was 5.9%.

$$\text{Moisture content (\% d.b.)} = \times 100\% \quad (1)$$

2.3.2 Physical properties of the soil

Soil type was taken before commencement of the experiment. The soil of the experimental plot was clayey in texture and slightly alkaline. The mechanical composition of sand, silt and clay of the soil were observed 22.58%, 13.37% and 64.05%, respectively value at 0-30 cm depth. (International Pipette method, Piper, 1950).

2.4 Selection of mini tractor and operator

The mini tractor (8.7 kW) was selected for this study and the operator was kept same throughout the experiment. A specification of mini tractor is given in Table 1.

Table 1 Specifications of mini tractor

S.N.	Specifications-Mini tractor	
1.	Date of purchase:	31/12/08
2.	Dimensions	
	Length:	2430 mm
	Width:	1220 mm
	Ground Clearance:	260 mm
	Exhaust height:	1850 mm
	Wheel Base:	1700 mm
	Track Width (driving wheel):	975 mm
	Track Width (steering wheel):	953 mm
3.	Engine	
	Type:	Four stroke direct injection
	Horse Power:	11.5 HP
	Bore / Stroke:	85/110 mm
	No. of cylinders:	One
	Capacity:	625 cc
	Cooling System:	Air Cooled
	Air cleaner:	Oil Bath air cleaner with pre cleaner
	Diesel consumption:	1.5 L h^{-1} (approx)
4.	Transmission	
	Clutch:	Dry. friction plate
	Gear box :	Four forward, one reverse
	Foot brakes :	Internal expanding shoe type mechanical brakes
	Steering:	Mechanical worm and peg type
5.	Tires	
	Front	5.20 x 14 (6 Ply Rating)
	Rear	8.00 x 18 (4 Ply Rating)
6.	Tire pressure	
	Front	20-30 psi
	Rear	15-20 psi

2.5 Details of experiment

1) Design: Completely Randomized Design

2) Number of replications: Six

3) Total number of treatments: Three

2.6 Components of mini tractor under study

The vibration of mini tractor at different points on seat, foot rest, brake, clutch and steering were measured on tar macadam road condition at selected forward speeds of mini tractor. Portable vibration analyzer was connected with the accelerometer / magnetic sensor through its cable.

2.7 Determination of speed levels of mini tractor on tar macadam road condition

Mini tractor was operated on tar macadam road condition with available gears for the transmission. Distance between two points was kept 100 m and time required to cover this distance by mini tractor was recorded. Thus, the speed levels were determined as per standard procedure.

2.7.1 Test track of tar macadam

Tar macadam is a type off road surface. The term is also used, with varying degrees of correctness, for a variety of other materials, including tar grouted macadam, bituminous surface treatments and even modern asphalt concrete as per ISO: 2631 (Part-1) – 1997. The experimental field has an even topography.

2.8 Vibrations measurement of mini tractor on tar macadam road condition

2.8.1 Seat vibration

Vibration of mini tractor was recorded on seat with different speed levels. While measuring the vibration of seat, a galvanized iron sheet was placed below the operator and magnetic sensor was connected with portable vibration analyzer, as shown in Figure 1.

Figure 1 Vibration measurement of seat at different speed on tar macadam

2.8.2 Foot rest, brake, clutch & steering vibration

Vibrations of mini tractor were recorded on foot rest, brake, clutch and steering with different speeds levels. Portable vibration analyzer was attached with sensor on them.

2.9 Statistical analysis

The statistical analysis for the various characters studied in the investigation was carried out as per the Completely Randomized Design. Significance of variance was tested by ‘F’ test (Panse and Sukhatme, 1985). Summary tables for the treatment effects were prepared with standard error of mean (S.E.M.) and critical differences (C.D.) at five per cent probability level were given for the treatments whose effects were found significant. Co-efficient of variance (C.V. %) was calculated.

3 Results and discussion

This chapter described the observations and analysis of experimental results conducted during March-June, 2012. Data pertaining to the vibration characteristics of seat, foot rest, brake, clutch and steering of mini tractor on tar macadam condition were presented and statistically analyzed.

3.1 Seat vibration of mini tractor on tar macadam road

Mini tractor seat vibration was observed on tar macadam road at selected speeds with six replications.

The results presented in Table 2, indicated that seat of mini tractor was significantly influenced by different speed treatments.

Table 2 Effect of mini tractor vibration on different speeds at tar macadam road on seat

Treatment	Mean acceleration of seat (m s^{-2}) with freq. (Hz)
Low speed (4.75 km h^{-1})	2.97(85-102.5)
Medium speed (10.46 km h^{-1})	3.62(77.5-122.5)
High speed (14.13 km h^{-1})	4.14(77.5-80.5)
S.E.M.	±0.21
C.D. at 5%	0.64
C.V. %	14.66

The results indicated that maximum vibration (4.14 m s^{-2}) with frequency (77.5-80.5 Hz) was obtained at high speed (i.e. 14.13 km h^{-1}). While minimum vibration (2.97 m s^{-2}) with frequency (85-102.5) was obtained at low speed (i.e. 4.75 km h^{-1}) on tar macadam road. The data and trend revealed that the vibration on seat of the mini tractor was found increased as forward speed of mini tractor increased.

3.2 Foot rest vibration of mini tractor on tar macadam road

The data on foot rest of mini tractor vibration on tar macadam road at selected speeds with six replications.

The foot rest vibration differed significantly due to different speed treatments (Table 3).

Table 3 Effect of mini tractor vibration on different speed at tar macadam road on foot rest

Treatment	Mean acceleration of foot rest (m s^{-2}) with freq. (Hz)
Low speed (4.75 km h^{-1})	6.98(47.5-755)
Medium speed (10.46 km h^{-1})	6.23(745-772.5)
High speed (14.13 km h^{-1})	4.19(77.5-935)
S.E.M.	±0.34
C.D. at 5%	1.03
C.V. %	14.37

The results showed that maximum vibration (6.98 m s^{-2}) with frequency (47.5-755 Hz) was obtained at low speed (i.e. 4.75 km h^{-1}), while the minimum vibration (4.19 m s^{-2}) with frequency (77.5-935 Hz) was obtained at high speed (i.e. 14.13 km h^{-1}) on tar macadam road. The data and trend revealed that the vibration on foot rest of the mini tractor was found decreased as forward speed of mini tractor increased

3.3 Brake vibration of mini tractor on tar macadam road

The data pertaining to brake vibration of mini tractor on tar macadam road at selected speeds with six replications.

The results (Table 4) showed that different speed treatments significantly affected on brake.

Table 4 Effect of mini tractor vibration on different speeds at tar macadam road on brake

Treatment	Mean acceleration of brake (m s^{-2}) with freq. (Hz)
Low speed (4.75 km h^{-1})	6.26 (95-820)
Medium speed (10.46 km h^{-1})	3.81(180-502.5)
High speed (14.13 km h^{-1})	3.15(110-497)
S.E.M.	±0.30
C.D. at 5%	0.91
C.V. %	16.84

The results indicated that maximum vibration (6.26 m s^{-2}) with frequency (95-820 Hz) was obtained at low speed (i.e. 4.75 km h^{-1}), while the minimum vibration (3.15 m s^{-2}) with frequency (110-497) was obtained at high speed (i.e. 14.13 km h^{-1}) on tar macadam road. The data and trend revealed that the vibration on brake of the mini tractor was found decreased as forward speed of mini tractor increased.

3.4 Clutch vibration of mini tractor on tar macadam road

The data concerned with clutch vibration of mini tractor on tar macadam road at selected speeds with six replications.

The data presented in Table 5 indicated that clutch of mini tractor was significantly influenced by different speed treatments.

Table 5 Effect of mini tractor vibration on different speeds at tar macadam road on clutch

Treatment	Mean acceleration of clutch (m s^{-2}) with freq. (Hz)
Low speed (4.75 km h^{-1})	2.69(374.5-985)
Medium speed (10.46 km h^{-1})	3.74(437-987)
High speed (14.13 km h^{-1})	4.07(467-982.5)
S.E.M.	±0.24
C.D. at 5%	0.74
C.V. %	17.14

The results indicated that maximum vibration (4.07 m s^{-2}) with frequency (467-982.5 Hz) was obtained at high speed (i.e. 14.13 km h^{-1}). While, minimum vibration (2.69 m s^{-2}) with frequency (374.5-985 Hz) was obtained at low speed (i.e. 4.75 km h^{-1}) on tar macadam road. The data and trend revealed that the vibration on clutch of the mini tractor was found increased as forward speed of mini tractor increased.

3.5 Steering vibration of mini tractor on tar macadam road

Effect of steering vibration on mini tractor on tar macadam road at selected speeds has six replications.

The result given in the Table 6 indicated that different speed treatments exerted their significant effect on steering.

The results indicated that maximum vibration (14.49 m s^{-2}) with frequency (77.5-80 Hz) was obtained at low speed (i.e. 4.75 km h^{-1}), while minimum vibration (10.34 m/s^2) with frequency (5-77.5 Hz) was obtained at high speed (i.e. 14.13 km h^{-1}) on tar macadam road. The data and trend revealed that the vibration on steering of the mini tractor was found decreased as forward speed of mini tractor increased.

Table 6 Effect of mini tractor vibration on different speeds at tar macadam road on steering

Treatment	Mean acceleration of steering (m/s^2) with freq. (Hz)
Low speed (4.75 km h^{-1})	14.49 (77.5-80)
Medium speed (10.46 km h^{-1})	13.86 (62.5-77.5)
High speed (14.13 km h^{-1})	10.34 (5-77.5)
S.E.M.	±0.44
C.D. at 5%	1.32
C.V. %	8.34

4 Conclusions

The major conclusions were drawn from this investigation. In mini tractor (8.7 kW), different speed levels on tar macadam test track were found as low speed (4.17 km h^{-1}), medium speed (10.46 km h^{-1}), high speed (14.13 km h^{-1}). The maximum vibration on seat was obtained as 4.14 m s^{-2} at high speed with frequency 77.5-80.5 Hz, 6.98 m s^{-2} at low speed with frequency 47.5-775 Hz was obtained for foot rest, 6.26 m s^{-2} at low speed with frequency of 95-820 Hz for brake pedal, 4.07 m s^{-2} at high speed with frequency of 82.5-467.9 Hz for clutch, and 14.49 m s^{-2} at low speed with frequency of 77.5-80 Hz for steering. The percentage increase in seat and clutch vibration was found from 21.88% to 39.39% and 39.03% to 51.30% with reference to low speed on tar macadam. The percentage decreases in foot rest, brake pedal, and steering vibration was found from 10.74% to 66.59%, 39.14% to 49.68% and 4.35% to 28.64%, respectively with reference to low speed on tar macadam.

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