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EXPERIMENTAL VIBRATION ANALYSIS OF PETROL ENGINE GRASS TRIMMER SYSTEM

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Abstract
The purpose of present research is to conduct experimental instigation on vibration analysis petrol engine grass trimmer during laboratory testing and Field testing. The frequency analysis of the grass trimmer was carried out to determine the dominant frequency components in accordance with ISO-5349-1(2001). The measurement of acceleration of handle vibration near hand grip position is carried out to determine the total value of vibration

Keywords: Grass Trimmer, Frequency Spectrum, Handle Vibration, Experimental Testing, Petrol Engine.

I. Introduction
All Grass trimmers are versatile tools are perfect for creating beautifully uniformed boarder edges, trimming around difficult terrain such as trees and garden ornaments, as well as clearing larger patches of unruly rough vegetation. The operator of trimmer may be subjected to large magnitude of hand arm vibration and may cause complex vascular and neurological and musculoskeletal disorder, collectively named as hand-arm vibration syndrome [1,2].Various techniques are used for controlling the vibration at the handle. These includes mounting of a dynamic vibration absorber on the grass trimmer, isolate the hand from the vibrating handle with the use of anti-vibration gloves [3,4,5] and isolate the tool handle form the vibrating source by using isolators [6,7]. However, to develop effective vibration reduction technique it is necessary to conduct vibration analysis of machine [8]. The purpose of present research is to carry detailed vibration analysis of grass trimmer to identify source of vibration and response of grass trimmer during grass cutting operation which is useful to develop vibration reduction technique.

II. Grass Trimmer System
A small petrol engine grass trimmer as shown in Figure 1 is considered in the present study. It is powered by an internal combustion engine mounted at one end of hallow circular pipe and rotating cutter head at other end. The nylon string attached to the cutter head cuts the grass. The rotating head is driven by engine through a long shaft supported inside hallow beam in the bearings. The speed of the cutter head is controlled by the throttle setting of the engine and accelerator on trimmer handle. The trimmer handle is mounted on hallow beam. The specifications of the grass trimmer used for numerical and experimental tests are listed in Table-.1

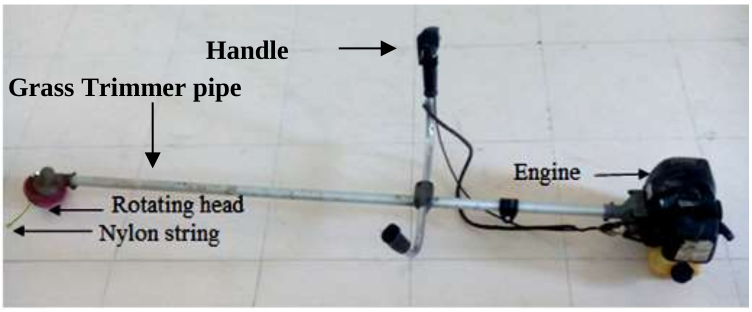

Figure 1: Grass trimmer system

Table-1: Specifications of grass trimmer.

Engine	TB 43 Mitsubishi Japan
Displacement	42.7 cm^3
Power output	1.3 H.P/ 6500 rpm
Fuel Tank Capacity	0.9 L
Handle	Double (W)
Pipe diameter	28mm
Gear ratio	14:19
Size (L x W x H)	1810 mm x 610 mm x 480 mm
Weight	8.3 Kg

III. Axis Systems for Vibration Measurements

The magnitude of hand-transmitted vibration is measured by means of the frequency-weighted root-mean-square (rms) acceleration a_{hw} as per ISO 5349-1(2001) [9] and expressed in m/s^2 is given as

$$a_{hw} = \sqrt{\sum_i (W_{hi} a_{hi})^2} \tag{1}$$

Where W_{hi} is the weighting factor for i-th one-third-octave band and a_{hi} is the rms acceleration measured in i-th one-third-octave band, in m/s^2. The vibration total value a_{hv} is calculated as [10]:

$$a_{hv} = \sqrt{a_{hwx}^2 + a_{hwy}^2 + a_{hwz}^2} \tag{2}$$

Where $a_{hwx,}$ $a_{hwy,}$ a_{hwz} are the value of $a_{hw,}$ for the axes denoted x, y and z respectively in m/s2. The vibration values $a_{hw,}$ are calculated from the frequency weighted rms. acceleration measured in three orthogonal axes of the handle as shown in Figure 2, according to the definition in ISO 5349-1, 2001. The z_h -axis is defined as the longitudinal axis from third metacarpal bone and is oriented positively towards the distal end of the finger. The x_h - axis is perpendicular with z_h -axis. The y_h - axis is perpendicular to other two axes and in the direction towards the thumb. As the single axis accelerometer is available, the sequential measurement (measure in one direction at a time) of vibration is carried using lightweight mounting block which is attached to vibrating surface as depicted in Figure 3. The accelerometer is attached to the block for the measurement of x, y and z direction and all the operating conditions remains same for three axis measurements [10].

The petrol engine grass trimmer is operated at the speed which depends on the type of grass and operator's judgment. The grass used for study is well-developed and dense for which the speed of grass trimmer was around 7000 to 7500 rpm. For laboratory testing and field test the speed of grass trimmer is selected as 7250 rpm.

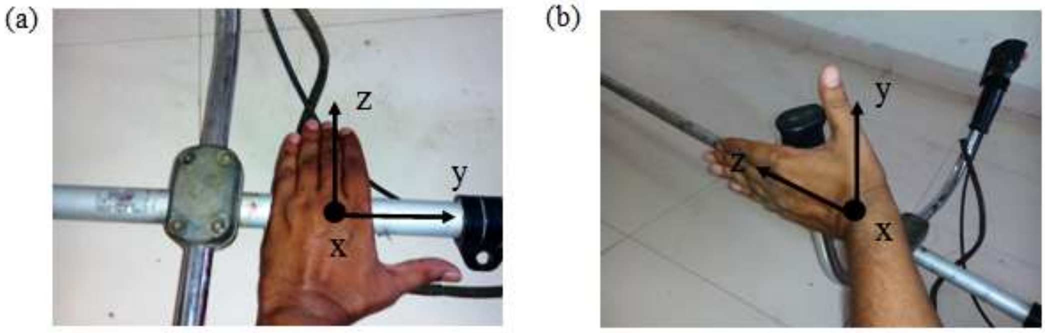

Figure 2 Axis systems for vibration measurement on (a) trimmer pipe,(b) trimmer handle.

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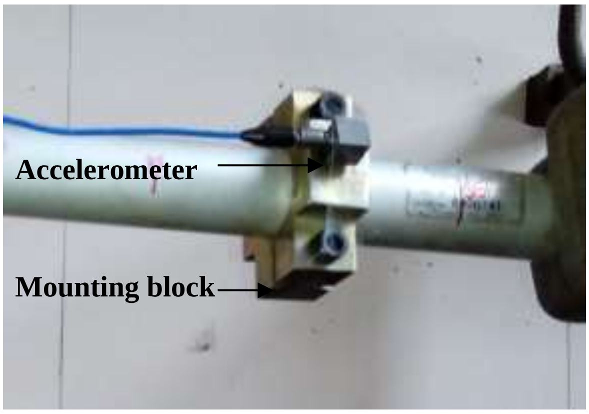

Figure 3: Mounting block for vibration measurement.

IV. Frequency Analysis of Grass Trimmer

The frequency analysis of the grass trimmer was carried out to determine the dominant frequency components in accordance with ISO-5349-1(2001) and Figure 2(a) shows the axis system for the trimmer pipe. To find the primary source of vibration, the frequency spectrums of grass trimmer near engine support location and handle location for cutting condition are studied as shown in Figure 4. The acceleration spectrum of grass trimmer measured in x y and z axes are illustrated in Figure 5 for engine location. Frequencies only in the operating speed range 0-200 Hz are shown. Table 2 list the magnitudes of the acceleration in x y and z axes at engine and handle location of the grass trimmer

Figure 4: Frequency spectrum measurement of trimmer during cutting operation.

Table-2 Magnitude of acceleration in ‘g’ at engine and handle location of grass trimmer.

	x-axis	y-axis	z-axis
Engine location	7.8	0.72	0.18
Handle location	4.7	0.77	0.52

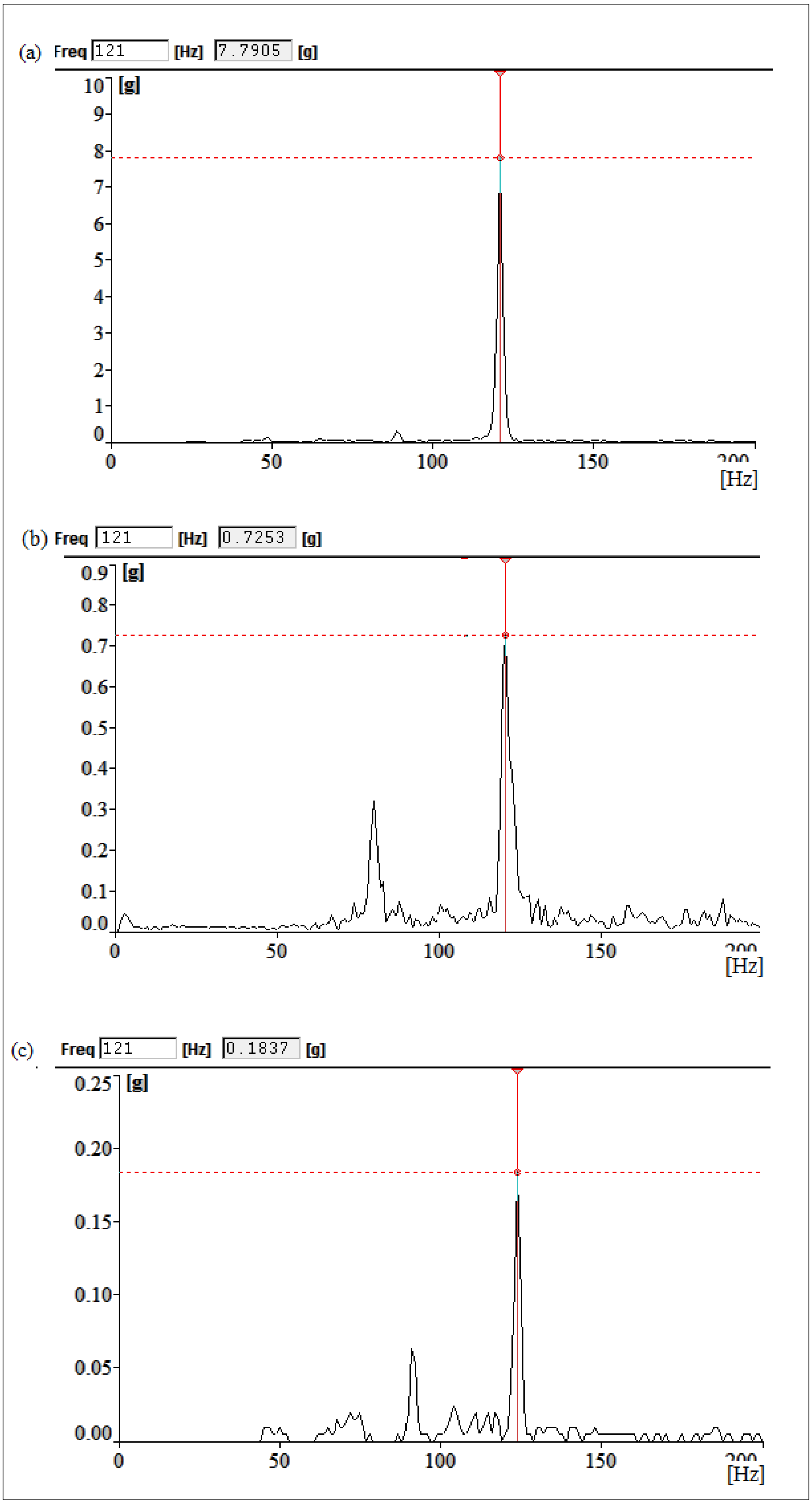

Figure 5: Input spectrum of trimmer in x-direction (Figure–a), y-direction (Figure-b) and z-direction (Figure–c)near engine.

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V. Experimental Testing of Trimmer

Figure 6 shows the experimental setup for vibration measurement along grass trimmer pipe with in laboratory. The grass trimmer suspended horizontally in a "free-free" orientation approximated by two bungee cords as shown in Figure 6. The vibration amplitudes are measured at thirty points on the trimmer surface by the accelerometer and recorded by vibration analyzer to plot experimental steady state response of trimmer pipe rotating at 7250 rpm (i.e.121Hz). Figure 7 depicts seedy state deformed shape of trimmer pipe in x, y and z direction.

Figure 6: Grass trimmer setup for vibration measurements along pipe.

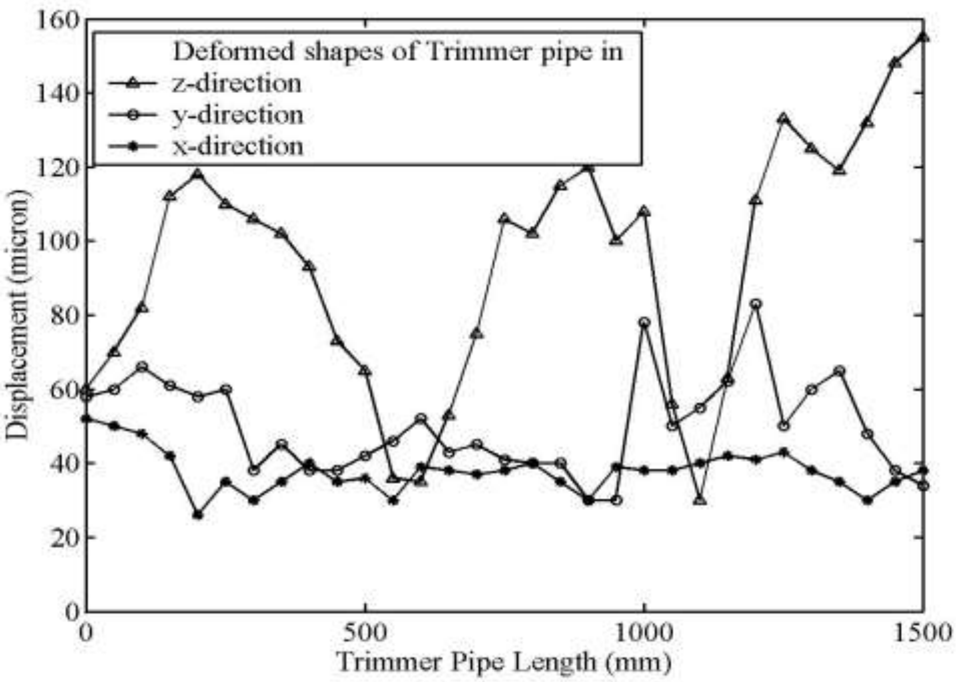

Figure 7: Steady state deformed shape of trimmer pipe.

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5.1 Frequency-weighted rms Acceleration of Handle Vibration

Figure 8. Shows the measurement of acceleration of handle vibration near hand grip position is carried out to determine the total value of vibration. The measured values of acceleration are listed in Table 6. The handle vibrations are measured by means of the frequency-weighted root-mean-square (rms) acceleration, expressed in m/s^2 as per ISO 5349-1(2001). Table 7 illustrates the frequency weighting rms acceleration (x_h, y_h and z_h axes) and vibration total value measured at handle of grass trimmer during no cutting (Laboratory testing) and cutting conditions (Field testing).

Figure 8: Handle vibration measurement during cutting operation.

Table 6: Acceleration (rms) of grass trimmer handle.

Condition	x-dir m/s^2	y-dir m/s^2	z-dir m/s^2	Total Vibration m/s^2
No Cutting	25.4	35.1	46	63.20
Cutting	39.2	33.4	48.2	70.54

Table 7: Frequency weighted rms acceleration of grass trimmer handle.

Condition	x-dir m/s^2	y-dir m/s^2	z-dir m/s^2	Total Vibration m/s^2
No Cutting	3.30	4.56	5.98	8.21
Cutting	5.096	4.34	6.26	9.16

VI. Result and Discussions

It is observed form Figure 5 that grass trimmer employed in this study had highest peak in the x-axes of magnitude 7.8 g at 121 Hz. This frequency is correlated with the speed of the engine 7250 rpm which is the primary source of vibration excitation. The vibration magnitude at 121 Hz in the y axis was 0.72 g. and peak in z- axis of magnitude 0.18g. There is a second peak in x y and z axis with 90 Hz which is due to rotating cutter head speed 5400 rpm (gear ratio 14:19). The magnitude of this source of excitation is small compared to engine excitation, hence neglected. Meanwhile near handle location the magnitude of vibration at 121 Hz in the x- axis was 4.7g, y axis was 0.77 g, and in z-axis was 0.52g.

It is pragmatic form Table 6 that the acceleration of handle vibration near hand grip position during no cutting (Laboratory testing) and cutting conditions (Field testing) is need to reduce y and z-direction for vibration suppression at handle location on grass trimmer

VII. Conclusion

Frequency spectrum measurement of trimmer during field cutting operation shows engine is the primary source of vibration. There is a second source due to rotating cutter head and magnitude of this source of excitation is small compared to engine excitation, therefore required to be neglected The rms acceleration of handle vibration reveals that vibration suppression is necessary in y and z direction. These results are useful for the vibration suppression approach of grass trimmer.

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