Noise Attenuation Characteristics of Different Road Surfaces During Power Tiller Transport

S.R. Hassan-Beygi[1] and B. Ghobadian[2]

1. Assistant Professor, Department of Agricultural Technical Engineering, Abureihan Higher Education Complex, Tehran University, Tehran, Iran.
Tel: +98-0292-3021043; Fax: +98-0292-3031552; E-mail: rhbeigi@ut.ac.ir.

2. Assistant Professor, Department of Mechanics of Agricultural Machinery, School of Agriculture, Tarbiat Modarres University, Tehran, Iran.

ABSTRACT

Power tillers are the agricultural machines which are fitted with small diesel engines. Besides their on-farm application in Iran, they are also engaged in transportation of agricultural products and human beings on the grassland, asphalt, and dirt rural roads. In spite of their adverse effects due to noise on operators and bystanders, limited information is available concerning the noise investigation of these machines. So the objectives of this research were to study the noise propagation trends as well as noise attenuation characteristics of power tillers on different surfaces in transportation conditions. The power tiller used in this study was fitted with a 13-hp diesel engine. During measurement and recording the sound pressure signals of the power tiller, the variables of engine speeds and gear ratios were varied to cover the most normal range of the power tiller operation in transportation conditions for the asphalt, dirt rural roads, and grassland. The test sites were prepared according to SAE noise measurement test procedures. The results show that the maximum attenuation effect of grass cover for bystander position is in the range of 350-700 Hz. The overall noise in this case is about 2.5 dB(A) lower than the asphalt and dirt rural roads. The maximum overall noise measured at driver ear's position at different gear ratios in asphalt, dirt rural roads and grassland was about 92 dB(A) for 2200 rpm engine speed which is higher than allowable noise exposure prescribed by National Institute for Occupational Safety and Health (NIOSH).

Keywords: Power Tiller, Noise, Attenuation, Transportation, Noise Attenuation.

1. INTRODUCTION

Power tillers are agricultural machines which are fitted with small diesel engines. Besides their on-farm application in Iran, they are also engaged in transportation of agricultural products and human beings on the asphalt and dirt roads. Power tillers also pass through grasslands and plantations of ongoing farm activities. If they produce noise more than 85 dB(A) for 8 hours exposure (based on NIOSH noise exposure recommendations), it will be harmful to both drivers and bystanders (NIOSH, 1996).

Although the tractors and other agricultural equipments are beneficial in many ways, there are some occupational health and safety problems due to their farm operation. The excessive noise level is an example (Sieswerda and Dekker, 1978; Maring, 1979; Brown, 1988; Crocker and

Ivanov, 1993; Solecki, 1998, 2000). Previous investigations concluded that human beings are affected mentally, physically and socially by excessive noise levels (Irwin and Graf, 1979; Roth and Field, 1991; Crocker, 1998).

The tractors and other agricultural equipments and machineries have also been investigated regarding their emitted noise level and noise production sources (Crocker, 1972; Splinter *et al.*, 1972; Franzinelli *et al.*, 1987; Talamo, 1987; Liljedal *et al.*, 1989; Leviticus and Morgan, 1990; Meyer *et al.*, 1993; Gospodaric, 1995; Peng *et al.*, 1995, 1996; Kahil and Gamero, 1997; Schullkamp *et al.*, 2000).

Limited information is available concerning the noise investigation of power tillers. In an investigation regarding the ergonomic conditions of the power tillers, 200 farmers and 100 extension workers were studied. The study revealed that noise and vibration of power tillers played an important role in damages experienced by them (Kang *et al.*, 1988). On the other hand, the limited space of the small engines fitted on the power tillers and other limitations do not allow equipping them with sound absorbing materials or provide them with the driver's cab (Brown, 1988), though the noise received by bystanders is still another dilemma.

Some researchers believe that not only the noise and vibration of the power tillers, but also all machineries and equipments fitted with small engines suffer from the drawback of their higher noise production (Dubey *et al.*, 1991; Bhattacharya *et al.*, 1992; Ghobadian, 1994). This was the reason for the suggestion of replacing the diesel engines of the power tillers by electric power sources (Bodria and Fiala, 1995).

The present investigation was carried out for better understanding of the noise propagation trends as well as noise attenuation characteristics of power tillers on different surfaces in transportation conditions.

2. EXPERIMENTAL DETAILS AND MEASUREMENT PROCEDURE

The experimental details included the test site, instrumentation scheme, the variables range, the data measurement and data analysis. Experiments were conducted according to SAE noise measurement procedures (SAE J 1174, 1985; SAE J 1175, 1985). The test site specifications consisted of the noise measurement for operator's and bystander's position, explained briefly as follows:

2.1 Operator's Position

The test site was managed based on the SAE J1174. The test area was free from obstacles and consisted of a flat open space free from the effect of signboards, buildings and hillsides for at least 15 m from measurement zone. The suggested wind speed and other climate limitations were kept in mind during measurements. The microphone was mounted 1.7 m above the ground surface and 100 mm away from the driver's right ear in a horizontal position and pointed in the direction of travel. The background noise was at least 30 dB lower than that for the power tiller. Figure 1(a) shows the dimensions of the area in which the power tiller noise measurement was made. In this figure, R stands for the distance from the obstacles to the measurement zone, L and W are the length and width of measurement zone, respectively. The minimum values of R, L and

W were 15 m, 10 m and 2 m, respectively. Figure 1(b) shows the instrumentation set up for measurement of noise near the operator ear.

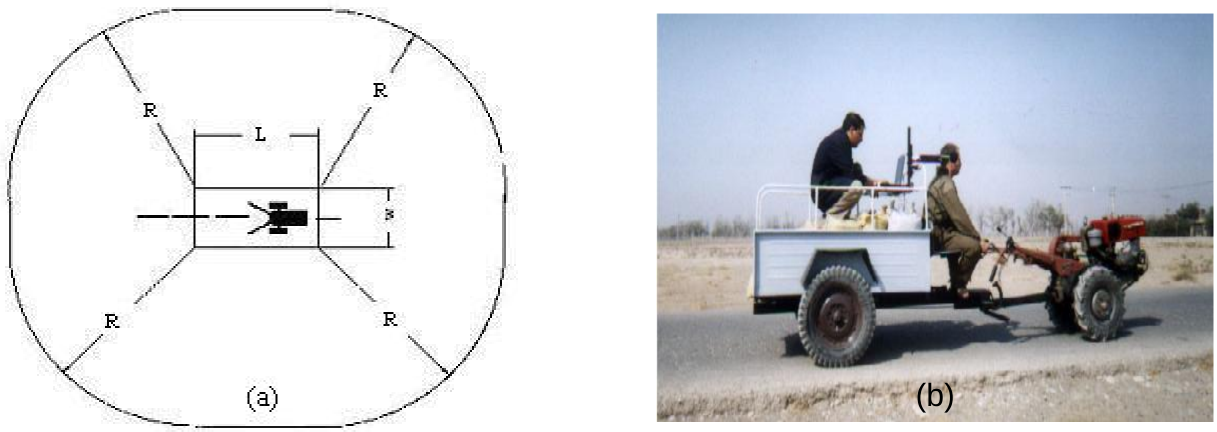


Figure 1. (a) Dimensions of the measurement area and (b) Test site for driver's position.

2.2 Bystander

The test site was managed based on the SAE J1175 recommended practice. The test area was consisted of flat open space free from the effect of signboards, buildings, or hillsides for at least 30 m from the measurement zone. Other test site specifications were chosen similar to the specifications mentioned earlier for the operator's position, with the exception that the microphone was mounted 7.5 m from the center line path of the power tiller and 1.2 m above the ground surface. The microphone was oriented perpendicular to the center line path of the power tiller. Figure 2(a) shows the dimensions of the test area. The minimum values of R and L were 30 m and 14.5 m, respectively. The distance between the center line path of the power tiller and microphone position (X) was 7.5 m. Figure 2(b) shows the instrumentation set up for measurement of noise exposed to the bystander.

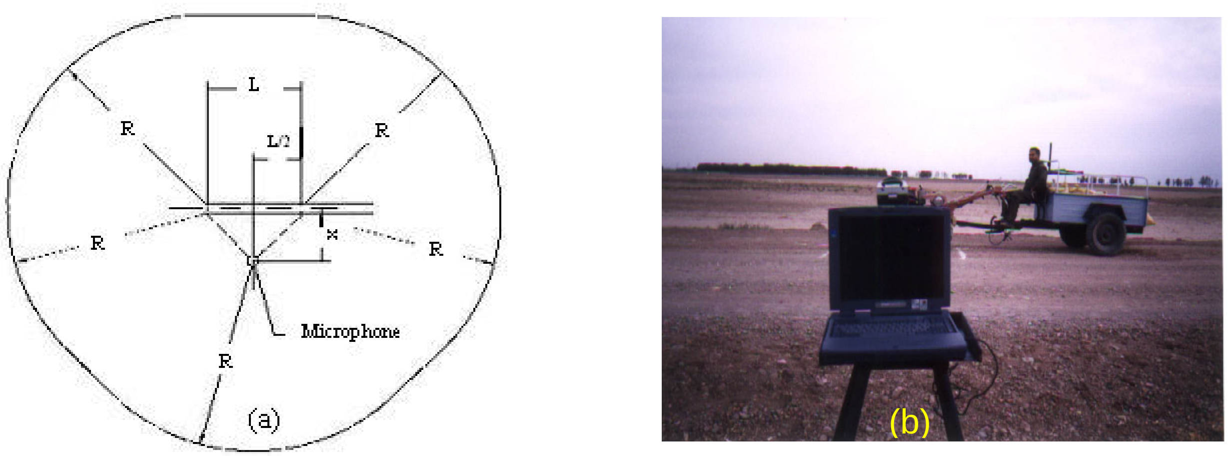


Figure2. (a) Dimensions of the measurement area and (b) Test site for bystander.

2.3 Instrumentation Scheme

The instruments used in this study, consisted of a sound level meter, a microphone, a tachometer, a lap-top computer and a few other devices. The detailed specifications of the instruments are shown in Table 1. The lap-top computer along with the software (Cool Edit 2000) and Yamaha OPL3-SAX, A/D sound card provided suitable means of sound recording instrumentation scheme instead of expensive and complex instrumentation (Hassan-Beygi, 2004).

Table 1. Specifications of the instruments used

Name of the Instrument	Sensitivity	Range/ Capacity	Accuracy/ Resolution	Make & Model
Prepolarized Condenser Microphone	50 mV/Pa	20-146 dB	-	B&K 4415 Denmark
Sound Level Meter	-	24-130 dB	0.1 dB	B&K 2230 Denmark
Digital Tachometer	-	0.5 –19999 rpm	1 rpm over 1000 rpm	LutronDT-2236 Taiwan
Digital Thermometer	-	-10 – 50 ^{o}C	0.1^{o}C	Testo Germany
Digital Anometer	-	0 - 15 m/s	0.01 m/s	Testo Germany
Lap-top	-	-	-	Toshiba Satellite 2335D, Malaise
Sound card	-	-	16 bits	Yamaha OPL3-SAX
RAM Memory	-	64 M bytes	-	NEC Japan
Hard Disk	-	8 G bytes	-	NEC Japan

2.4 Test Matrix and Variables Range

The selected variables were engine speeds, gear ratios and surface types. The range of variables considered to perform the test could cover the normal and safe operating range of the power tiller during operation. Table 2 shows the test matrix of the power tiller under test. Table 3 shows the specifications of the power tiller and its engine.

Table 2. Matrix of the experimentation (microphone in driver's ear and bystander positions)

Parameters	Levels of Parameters			
	1	2	3	4
Engine Speed (rpm)	1300	1650	2000	2200
Gear Ratio	2 high	2 low	3 high	3 low
Type of Test Courses	Asphalt Road	Dirt Road	Grassland	-

Table 3. Specifications of the test power tiller

Engine Specifications:	
Combustion system	Indirect injection
Number of cylinder	Single
Stroke cycle	4 Stroke
Air intake system	Naturally aspirated
Cooling system	Water cooled
Rated engine speed	2200 rpm
Power at rated speed	13 hp
Other Specifications:	
Type of clutch	Dry, multi-plates
Speed:	
Forward	6 stage
Reverse	2 stage
Steering	Side brake system
Wheel tread	Adjustable 49 cm to 61 cm

2.5 Data Measurement and Analysis

The analog sound pressure signals of the power tiller under test were transformed in discrete signal by sound card A/D converter with 48000 Hz sampling rate and recorded in time domain, $p_s(t)$, at operator's and bystander position (figure 3-a,c).The different combinations of the variables formed the main structure of the raw data recorded for processing and data analysis. Since the obtained signal in time domain could not reveal much information (figure 3-a,c), therefore, the recorded digital data in time domain were converted to frequency domain, $p_s(f)$, using a developed FFT computer program. Based on this analysis, the narrow band frequency sound pressure levels were obtained (figure 3-b,d).

To get more useful information, the octave, 1/3rd octave and finally A-weighted overall sound pressure levels were derived from the narrow band signal in frequency domain. Figure 4 shows the detail of data processing and analysis. The L_A, Lpi and Lpj represent the values of overall, octave and 1/3rd octave sound pressure levels, respectively.

3. RESULTS AND DISCUSSION

Figure 5 shows typical set of sound pressure signals in time domain and the respective narrow band frequency signals for the three surfaces. It is very obvious that the time domain signals (figure 5-a) does not show useful information about the noise pollution concept as required. The frequency domain signals depict the noise intensity and frequency (figure 5-b) and are therefore more attractive than time domain signals. Due to un-smoothed nature of narrow band frequency curves, comparing the data for different conditions is not so easy especially at higher frequencies. So, to explain the results, the smoother 1/3rd octave and octave noise frequency bands were selected.

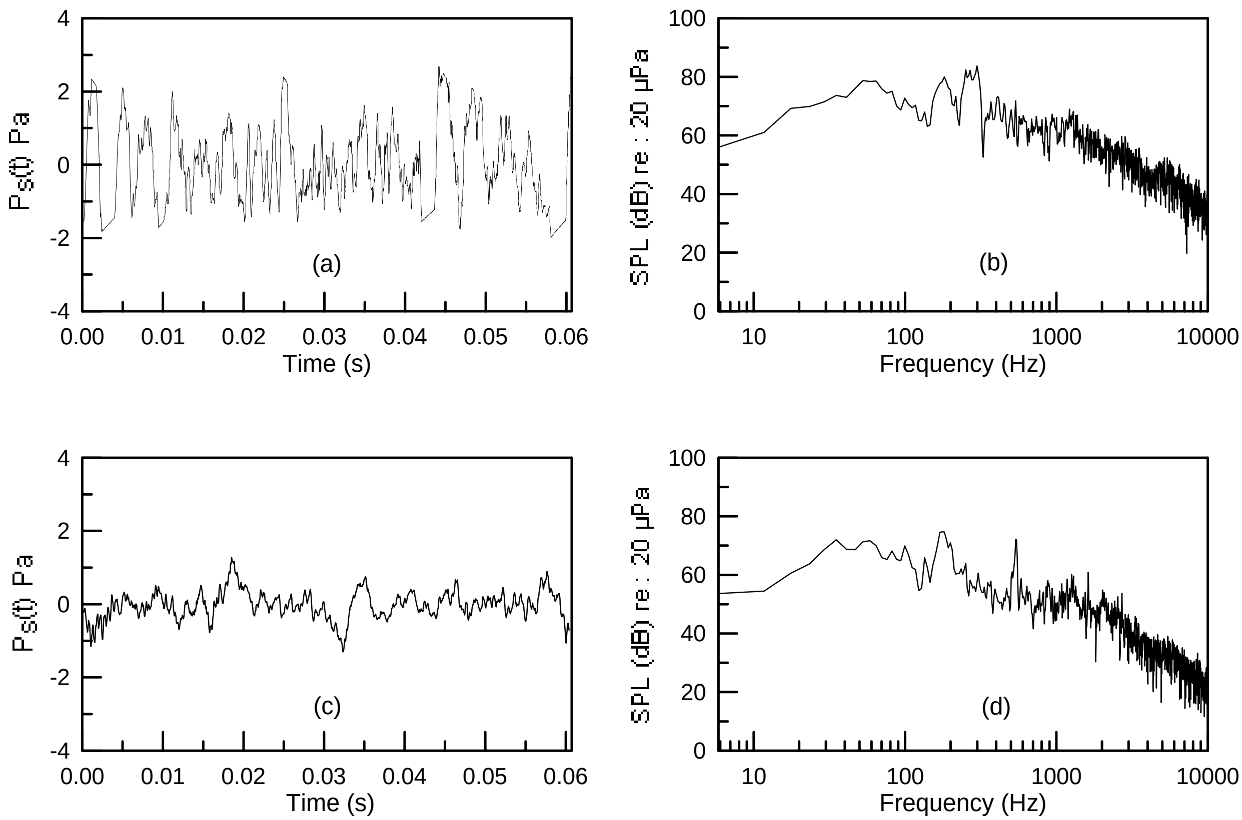


Figure 3. (a) The sound pressure signal time history and (b) Narrow band frequency domain signal for driver's position, (c) The sound pressure signal time history and (d) Narrow band frequency domain signal for bystander, at 2000 rpm engine speed and 2nd low gear ratio on rural asphalt surface.

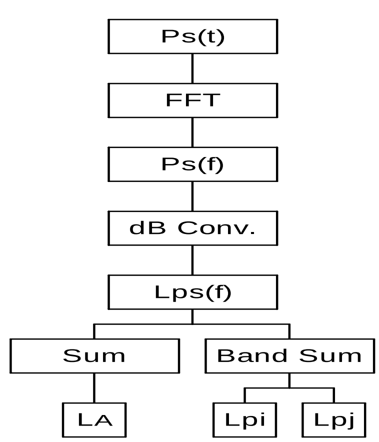
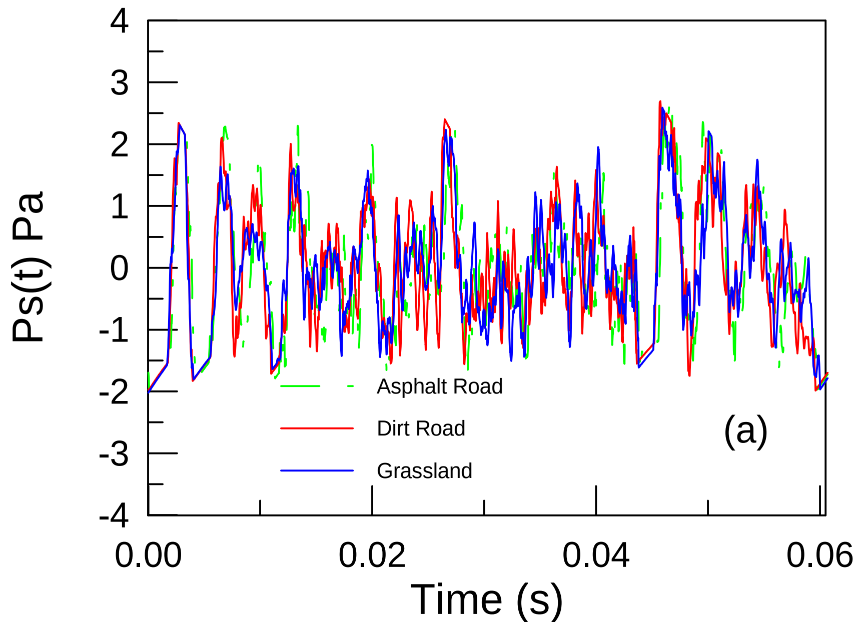


Figure 4. Data processing and analysis scheme (Hassan-Beygi, 2004).



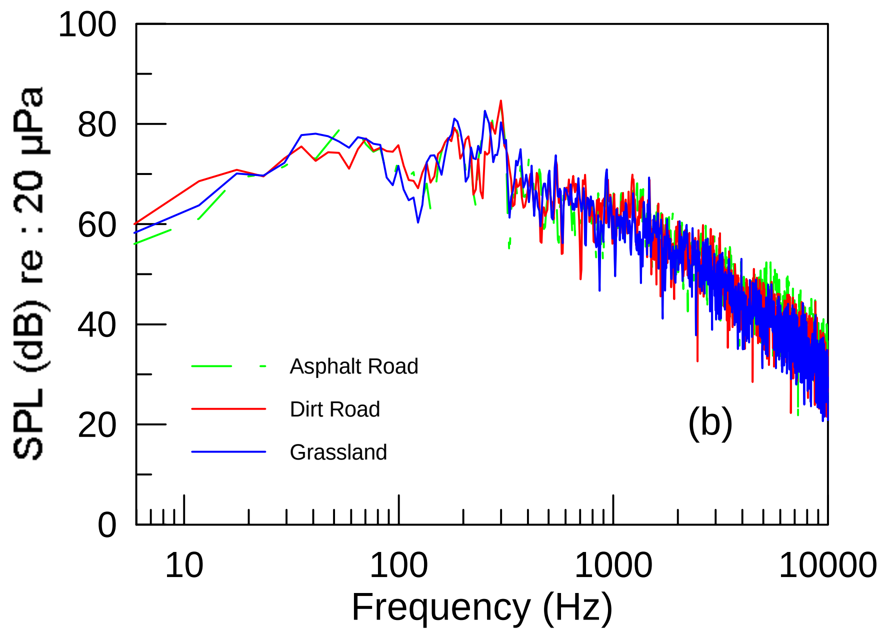


Figure 5. (a) The sound pressure signal time histories and (b) Narrow band frequency domain signals for driver's position, at 2000 rpm and 2nd low gear ratio on different surfaces.

Figure 6 shows the effect of surface types on 1/3rd octave band frequency noise of the power tiller at 2nd high gear ratio for driver ear's position. It can be seen from figure 6 that there are some peaks below 200 Hz which have been attributed to exhaust noise by the earlier investigators (Suggs, 1987; Sathyanarayana and Munjal, 2000). This means that exhaust is a main contributor to the power tiller noise which has to be investigated separately. From different parts of figure 6 in 200 Hz and higher frequencies, a diminishing trend can not be easily seen in

1/3rd octave band sound pressure signals when changing the surfaces from asphalt and dirt roads to grassland for the same power tiller conditions. This matter may be attributed to lack of distance between power tiller noise sources and microphone location.

Figure 7 shows the effect of surface types on 1/3rd octave band frequency noise of the power tiller at 2^{nd} high gear ratio for bystander position. The noise attenuation potential of the grassland is quite obvious and this is due to the damping effect of grass cover surface which is distinguished from the reflecting surface of asphalt and dirt roads. It can be easily seen from figure 7 that a diminishing trend in 1/3rd octave band sound pressure signals exist and is visible when changing the surfaces from asphalt and dirt roads to grassland for the same power tiller condition. This phenomenon could be related to the noise attenuation characteristics of different sound absorbing materials and surfaces known as “ground effect” (Attenborough *et al.*, 2000). It can be seen from figure 7 that there are some peaks below 200 Hz which may be attributed to exhaust noise (Suggs, 1987; Sathyanarayana and Munjal, 2000). The second most dominant peak occurs between 350–700 Hz frequencies. This peak is more obvious for 2000 and 2200 rpm engine speeds (figure 7-c,d). It is very interesting to see the attenuation imparted by grassland in this region of the frequency band (350-700 Hz). In the other words, the second most prevalent frequency range is between 350-700 Hz for asphalt and dirt surfaces which are attenuated by the surface covered with grass, damping the noise levels.

A comparison between the noise received by the operator (figure 6) and that of a bystander (figure 7) in corresponding conditions revealed that the noise level experienced by the power tiller operator is much higher than that received by a bystander, 7.5 m away from the power tiller center line path in whole range of frequency bands. The reduction in noise level is an average of about 10 dB when sound waves reach to the bystander. This is due to combined effect of the surface absorption and distance. Sound pressure level peaks in 200 Hz and higher frequencies for driver position are not attenuated by surface covered with grass. Due to lack of distance between power tiller noise sources and microphone position, grass can not play any role in the noise attenuation in this case.

Figure 8 shows the effect of engine speed on the A-weighted overall sound pressure level of the power tiller at driver ear’s position for different surface types and gear ratios. As shown in this figure with an increase in engine speed from 1300 rpm to 2200 rpm at different gear ratios and surface types, a maximum of 7 dB(A) increase in overall sound pressure level could be observed; but considerable ground effect for lawn covered road could not be seen.

The effect of engine speed on the A-weighted overall sound pressure level at bystander is shown in figure 9 for different surface types and gear ratios. It is clear that, at different gear ratios with increasing engine speed from 1300 to 2200 rpm, the maximum increase of the overall sound pressure level was 11 dB(A) as well as the attenuation of grassland increased from about 1.4 to 2.5 dB(A), respectively. Meyer *et al.* (1993) have also reported that in soybean farm, A-weighted sound pressure level measured in bystander position was about 2 dB(A) lower than those measured out of farm. Meanwhile it can be seen that the maximum noise produced by the power tiller in bystander position for asphalt, dirt road and grassland was 84, 83.5 and 81.5 dB(A), respectively.

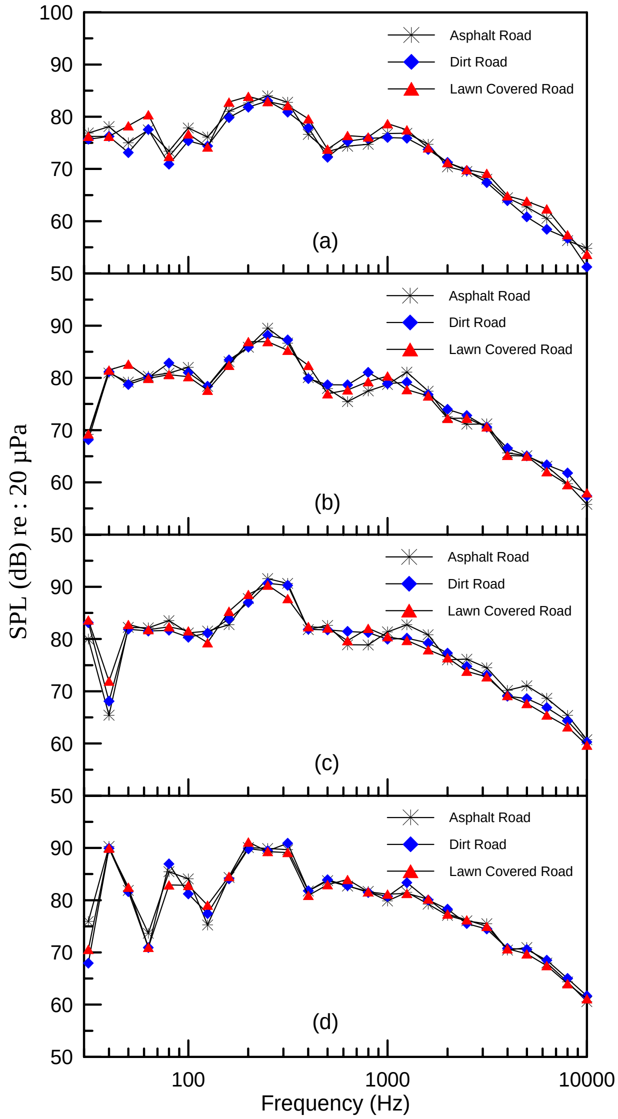


Figure 6. The effect of surface types at 2nd high gear ratio on 1/3rd octave sound pressure level of test power tiller for driver's position at (a) 1300, (b) 1650, (c) 2000 and (d) 2200 rpm.

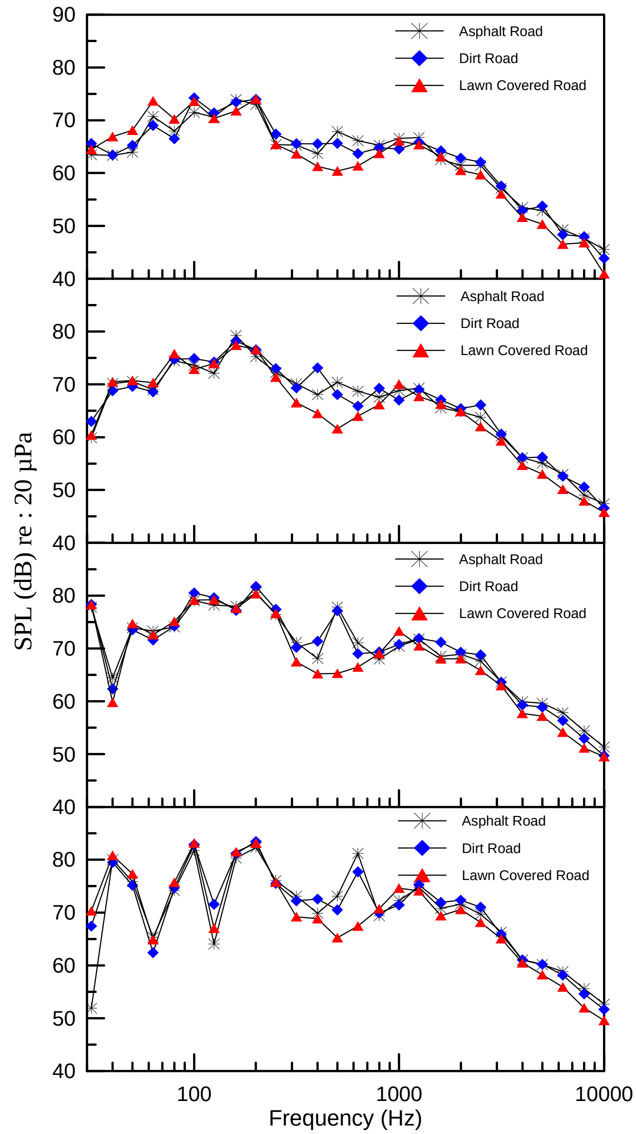


Figure 7. The effect of surface types at 2nd high gear ratio on 1/3rd octave sound pressure level of test power tiller for bystander position at (a) 1300, (b) 1650, (c) 2000 and (d) 2200 rpm.

4. CONCLUSION

It can be concluded that the noise attenuation of grassland, at driver ear's position was not considerable, but at bystander position was maximum 2.5 dB(A). The frequency range in which the noise attenuated by grassland was from 350 to 700 Hz. The maximum overall noise produced by the power tiller, in operator's position at different gear ratios in asphalt and dirt rural roads and grassland reaches up to 92 dB(A) which is higher than the allowable noise exposure prescribed by NIOSH. It can be said that a noise conservation and management program is needed to be applied to the power tiller operators.

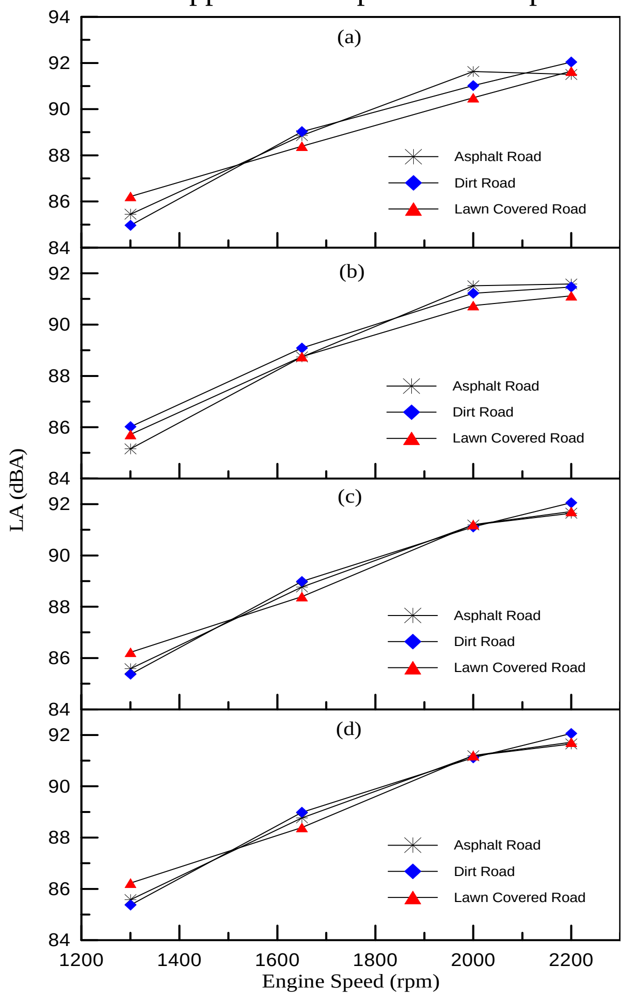


Figure 8. The effect of engine speed on A-weighted overall sound pressure level of test power tiller at different surface types for driver's position at (a) g2h, (b) g2l, (c) g3h, and (d) g3l. The legends g2h, g2l, g3h and g3l means the 2nd high, 2nd low, 3rd high and 3rd low gear ratios, respectively.

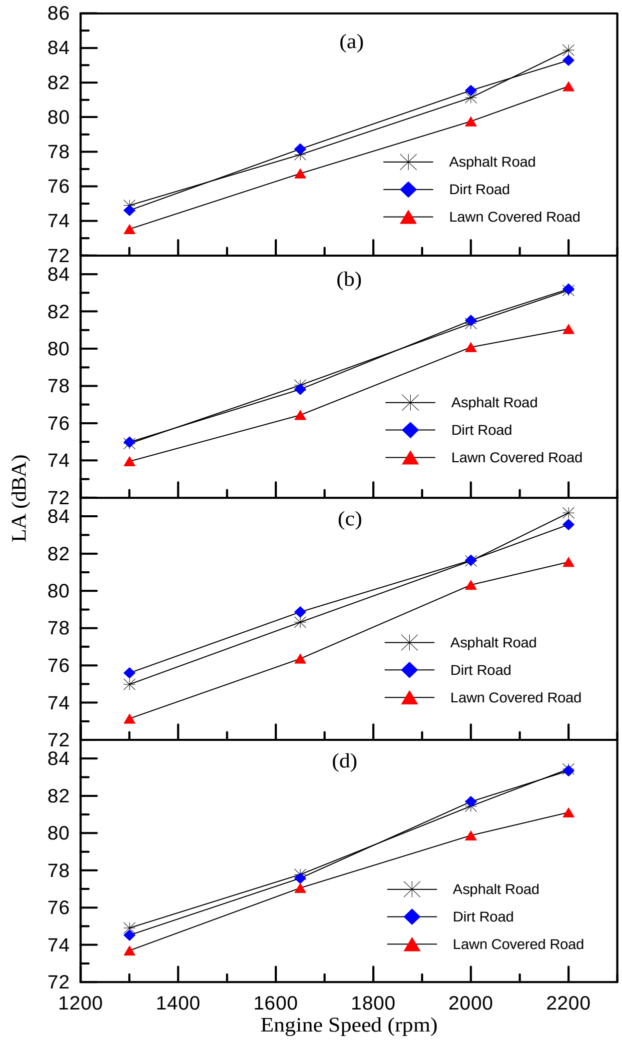


Figure 9. The effect of engine speed on A-weighted overall sound pressure level of test power tiller at different surface types for bystander position at (a) g2h, (b) g2l, (c) g3h, and (d) g3l. The legends g2h, g2l, g3h and g3l means the 2nd high, 2nd low, 3rd high and 3rd low gear ratios, respectively.

5. REFERENCES

Attenborough, K., T. Waters-Fuller, K.M. Li, and J.A. lines. 2000. Acoustical properties of farmland. *Journal of Agricultural Engineering Research*, 76: 183- 195.

Bhattacharya, M., B. Ghobadian, S.C. Jain, N. Singh, and P.S. Mehta. 1992. An estimation of combustion and mechanical noise components of a small DI diesel. Proceeding of the National Symposium on Acoustics, Madras, India.

Bodria, L. and M. Fiala. 1995. Design and testing of an electric-powered walking tractor. *Journal of Agricultural Engineering Research*, 60: 57-62.

Brown, R.H. 1988. Handbook of Engineering in Agriculture, Volume (2).1st edn.London: Prentice – Hall, Inc,U.K.

Crocker, M.J. 1972. Noise sources, noise measurements and noise reduction. ASAE Paper No.72-812.

Crocker, M.J.1998. Handbook of Acoustics. 1st edn. New York: John Wiley & Sons.

Crocker, M.J. and I.N. Ivanov. 1993. Noise and Vibration Control in Vehicles.1st ed. St.Petersburg, Russia: Interpublish Ltd.

Dubey, O.P., B. Ghobadian, M. Bhattacharya, and P.S. Mehta. 1991. An experimental investigation of engine noise and exhaust smoke on a small DI diesel. SAE Paper No. 911255.

Franzinelli. A., A. Fattorini, M. Maiorano, and D. Cardelli. 1987. A critical study of the assessment of noise levels produced by agricultural machinery and on the measurement of noise levels for workers. *Rivista di Ingegneria Agraria*, 7: 217-220.

Ghobadian, B. 1994. A parametric study on diesel engine noise. Unpublished PhD diss. Roorkee, India: Roorkee University, Department of Mechanical and Industrial Engineering.

Gospodaric, Z., S. Ivancan, and E. Stefanek. 1995. Noise at the operator's ear of combine harvesters. Current problems in agricultural engineering, 85-93.

Hassan Beygi, S.R. 2004. Investigating and analyzing of power tiller noise. Unpublished PhD diss. Tehran, Iran: Tarbiat Modarres University, Department of Mechanics of Agricultural Machinery.

Irwin, J.D. and E.R. Graf. 1979. Industrial Noise and Vibration Control.1st ed. London: U.K.: Prentice-Hall, Inc.

Kahil, MA. and CA. Gamero. 1997. Noise levels: Ergonomics evaluation of some tractors and farm eqiupment. Energia na Agricultura, 12: 46-53.

Kang, C.II. N.J. Park, I.S. Oh, and Y.B. Lee. 1988. Study on the handling of power tiller in view of ergonomics. Research Reports of the Rural Development Administration Agricultural Engineering and Farm Management, 30: 67-71

Leviticus, L.I. and L. Morgan. 1990. Nebraska and OECD tractor test data. University of Nebraska, Lincoln,NE.

Liljedal, J.B., P.K. Turnquist, D.W. Smith, and M. Hoki. 1989. Tractors and Their Power Units. 4th edn. New York: Van Nostrand Reinhold.

Maring, J. 1979. Tractor noise. Field measurements of noise at ear level. Wageningen, 15pp.

Meyer, R.E., C.V. Schwab, and C.J. Bern. 1993. Tractor noise exposure levels for bean-bar riders. *Trans. ASAE*, 36: 1049-1056.

NIOSH. 1996. Criteria for a recommended standard occupational noise exposure revised criteria.

Peng, Y., A. Sasao, S. Shibusawa, and T. Yoshida. 1995. Active noise control around operator riding on agricultural machinery (Part1): Study on adaptive filter. *Journal of the Japanese Society of Agricultural Machinery*, 57: 21-28.

Peng, Y., A Sasao, S. Shibusawa, A. Sawamura, and T. Yoshida. 1996. Active noise control around operator riding on agricultural machinery (Part2): Noise reduction experiment on a tractor. *Journal of the Japanese Society of Agricultural Machinery*, 58: 57-63.

Roth, O.L. and L.H. Field. 1991. Introduction to Agricultural Engineering. 2nd edn. New York: Van Nostrand Reinhold.

SAE J1174. 1985. Operator ear sound level measurement procedure for small engine powered equipment.

SAE J1175. 1985. Bystander sound level measurement procedure for small engine powered equipment.

Sathyanarayana, Y. and M.L Munjal. 2000. A hybrid approach for aeroacoustic analysis of the engine exhaust system. *Applied Acoustics*, 60 : 425-450.

Schullkamp, T., J.W. Biermann. and K.H. Kromer. 2000. Sound emissions from farm machines-Using the amazone airplanter ED451 K as an example. Landtechnik, 55: 9. 348-349.

Sieswerda, V. and J.C. Dekker. 1978. Deafness caused by tractor noise. Landbouwmechanisatia , 29: 1001-1003.

Solecki, L.1998. Occupational hearing loss among selected farm tractor operators employed on large multi-production farm in Poland. *International Journal of Occupational Medicine and Environmental Health*, 11(1): 69-80.

Solecki, L. 2000. Duration of exposure to noise among farmers as an important factor of occupational risk. *Ann Agric Environ Med*, 7: 89-93.

Splinter, W.E., M.L. Mumgaard, G.W. Steinbruegge, and L.F. Larsen. 1972. Sound level test of agricultural tractors. *Trans. SAE*, 2147-2152.

Suggs, C.W. 1987. Noise characteristics of field equipment. ASAE Paper No.87-1598.

Talamo, J.D.C. 1987. Noise problems in the agricultural industry. Proceedings of the Institute of acoustics, 9: 399-402.