Noise evaluation of MF285 tractor while pulling a trailer in an asphalt road

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Abstract: Tractors have been used for transportation on roads by many farmers in addition to use in the field operations. MF285 tractor is the popular kind of tractor in Iran (about 30% of all tractors) and almost this tractor has been used without cabin. Despite the problems caused by noise from the tractors and all its adverse effects on users and observers, no comprehensive research has been done on them. The result of this research indicate that the noise level of MF285 tractor, in 2,250 r/min engine speed, will be 90 dB(A) which in comparison with the standard value, 85 dB(A), is dangerous for operator's ears. The test site was prepared according to the international standards. The noise emitted by tractor in three gears (2, 3 and 4) and three speeds (1,500, 1,950 and 2,250 r/min) were measured and then analyzed statistically. Analysis of variance and Duncan's mean comparison test showed that the Sound Pressure Level (SPL) at the position of the driver in comparison to the observer position was statistically significant (P<0.01). Also, result showed the speed of engine has a pivotal role in the production of noise and should be investigated in different operations.

Keywords: noise, tractor, sound pressure level, ergonomics

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1 Introduction

Parallel to the development in technology, the use of machinery in mechanization processes of agricultural production has brought about the factors such as noise, vibration, gas, etc. which affect the working environment of users and inspectors of those machines. In order to increase the work success of the machines and to provide safety and comfort for users, these machines must be designed with respect to the human characteristics (Liljedahl et al., 1996). Otherwise, it causes an increase in occupational diseases and accident, and on the other hand, failure of expected work success. Noise is one of the most important environmental factors, which affects the workers' health and efficiency. Noise can increase the overall workload of operators during a specific task and can affect the performance. As a result, noise affects workers' health directly and indirectly (Parsons, 2000). Among these effects are weariness, backache, nervousness, nausea, careless, etc. (Lines et al., 1994; Ekerbicer and Saltik, 2008).

The topic of noise and its effects in agriculture has received much attention since 1960s (Matthews, 1968) and the research is ongoing in various dimensions today. Miyakita and Ueda (1997) said that a great amount of information was collected about the nature and source of noise, and its effects in connection with the exposure. Nowadays, widespread use of agricultural tractors and machines for field operations, in spite of their valuable advantages, have caused some occupational health and safety problems for operators of these machines, the

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excessive noise is an example (Sieswerda & Dekker, 1978; Maring, 1979; Talamo, 1987; Suggs, 1987; Brown, 1988; Crocker and Ivanov, 1993; Solecki, 1998, 2000; Aybek et al., 2010). However, research should continue to determine in which sound pressure levels hearing loss could be occurred. According to McBride et al. (2003), it is known that people working in agricultural facilities are exposed to some noise sources, but in recently years, the noise problem of agricultural machines in rural roads has been evaluated (Hassan-Beygi et al., 2007).

Due to the fact that the sensitivity of ear is different for each frequency, the distribution of frequency must be known to examine the effects of noise. By studying the obtained frequency distribution and the sensitivity levels of ear, the noise's effects on human body can be assessed. Duration of exposure is also a consideration as well as the frequency content and A-weighting curve is used in practical applications denoted by dB(A) and 85–90 dB(A) have been proposed to be the limiting values for 8 h exposure (Parsons, 2000). The effect is more profound to certain frequencies of noise (Parsons, 2000). The reduction in the hearing sensitivity usually begins in the region of 4 kHz and if the condition becomes severe, the ear becomes sensitive to a broader frequency band, including much lower and much higher frequencies as well (Parsons, 2000). The frequencies inducing hearing loss does not decrease below 1 kHz. It was shown that noise induced hearing loss increases up to 7 dB in the first 10 years at 1,000 Hz and 100 dB(A), and then gradually increases to 12 dB loss for exposure time of 40 years. The hearing loss is about 30 dB for the first ten years exposure at 4 kHz and 100 dB(A). It is clear that at 100 dB(A), the ear is much more sensitive to 4 kHz compared to 1 kHz. Maximum SPL for 8 h/day exposure is accepted to be 85 dB(A) at frequencies higher than 1,000 Hz. At levels lower than this value, the risk of noise becomes the least (Grandjean, 1988). Lonsbury-Martin and Martin (2004) stated that "the beginning region of impairment involves the sensitive mid-frequency range, primarily between 3 and 6 kHz, and the corresponding impairment is classically described as the 4 kHz notch. This particular pattern of maximal hearing loss, with little or no loss below 2 kHz, typically appears regardless of the noise exposure environment." Sanders and McCormick (1992) explained that the ear is more sensitive to noise at frequencies over 2 kHz and the sensitivity increases with age. Lonsbury-Martin and Martin (2004) gave audiogram results that showed audiometric patterns of hearing levels from patients in beginning stages of noise induced hearing loss and examples were given for males and females exposed to noise in different environments including industrial noise. Hearing loss was not observed at frequencies below 1 kHz and was sharpest above 2 kHz for a male industrial worker.

Solecki (2000) showed that average noise dose of farmers in different months of the year was within 1.8 to 5.7 h. Therefore, it was recommended that noise level should not be more than 80 dB(A), though some countries are conducting noise reduction and control programs to bring noise level lower than 75 dB(A) (Crocker and Ivanov, 1993).

Behroozi Lar et al., (2012) investigated effect of cabin on SPL in driver ear in different gear with two types of tractors (Valtra T170 and MF399). They found that the SPL at the driver ear for the tractor without cab in all gears ranging from a low of 91 dB(A) to a high of 93 dB(A) were more than National Institute for Occupational Safety and Health (NIOSH) allowable 85 dB(A) criteria for 8 h of operation. Emam (2012) used an Artificial Neural Networks (ANNs) to predict the noise levels surrounding the tractor operator and in open and compared the results against noise levels from collected data.

International Labor Organization (ILO) accepts 85 dB(A) as warning limit and 90 dB(A) as danger limit for continuous work for 8 h. A-weighted equivalent SPL of 85 dB(A) results in temporary hearing losses and 90 dB(A) increases the blood pressure, accelerates the pulse and breathing, decreases brain liquid pressure, causes tension in muscles, and withdrawal of blood in the skin (Aybek et al., 2010).

However, there is not any extended study on sound pressure levels occurring in agricultural machine applications. The purposes of this study are:

- To determine the sound pressure levels at

A-weighted equivalent sound pressure levels for a MF285 tractor in pulling a trailer in asphalt road;

- To find out whether the determined sound pressure levels are within the limits required for healthy and efficient working.

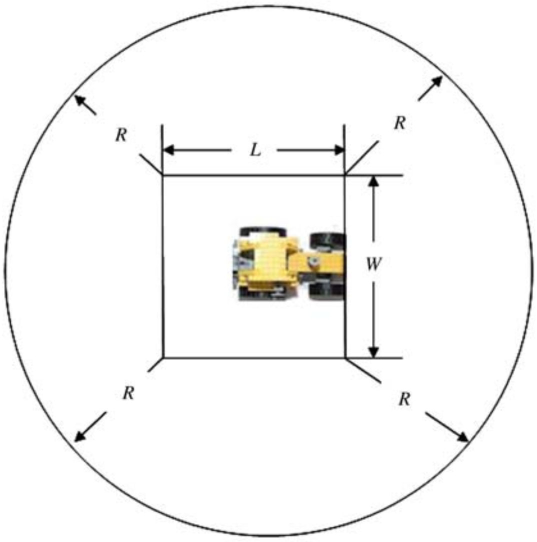
2 Materials and methods

In this study noise of a MF285 tractor has been investigated. This tractor is one of the most commonly used tractors in Iran (about 30% of all tractors (Tabatabaeefar and Omid, 2005)) and it was usually used without cabin. This is the reason of choosing this kind of tractors for this study. Before testing, all the necessary technical visits were carried out on the tractor.

A trailer (Figure 1) was attached to the tractor. The trailer was attached to the tractor to make closer the test condition to the real conditions of work.. It was connected to the drawbar system of the tractor. The loading capacity and weight of trailer were 5,000 kg and 1,400 kg, respectively.

Figure 1 Trailer which has been used in experiment

Test site was prepared and maintained according to ISO (ISO, 1992; ISO. 1996) sound measurement standard. The test area consisted of a flat open space free from obstacles and 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 background noise was at least 30 dB(A) lower than that for the tractor. Figure 2 shows the dimensions of the area in which the tractor noise measurement was carried out. Here, the minimum values of R, L and W were 40 m, 20 m and 15 m, respectively.



R- distance from the obstacles to the measurement zone;
L- length of measurement zone; *W*- width of measurement zone

Figure 2 Dimensions of the test site

It is important that the measuring equipment is properly selected to monitor and measure sound properties. When there is a basic situation in which it needs to assess the severity of environmental noise, it may need to measure only the overall SPL or the A-weighted level, using a simple sound level meter (Barron Randall, 2003).

In this study, an SLM (TES-52 SOUND LEVEL METER) was mounted 1.2 m above the ground surface and 7.5 m away from the center of the tractor path way in a horizontal position and pointed in the direction of travel. To measure the noise near the operator's ears, the microphone of dosimeter (Model TES-1354/1355) was attached to the operator's clothes. The SLM and dosimeter calibration was performed by using TES-1356 sound level calibrator before data gathering.

Most sound level meters have three "weighting" networks, called the A-, B-, and C-scales. Originally, the A-scale was designed to correspond to the response of the human ear for a SPL of 40 dB at all frequencies. The B-scale was designed to correspond to the response of the human ear for a SPL of 70 dB at all frequencies. The C-scale was approximately flat (constant) for frequencies between 63 and 4,000 Hz. The A-scale is widely used as a single measure of possible hearing damage, annoyance caused by noise, and compliance with various noise regulations. The sound levels indicated by the A-scale network are denoted by LA, and the units are designated dB(A) (Barron Randall, 2003).

It was needed to choose the range of variables before trying to perform the tests, i.e., engine speed, gear ratio and the microphone position. The ranges of variables were selected to sustain most of operational condition of MF285 tractor on asphalt road. After determining the range of variables, table test was developed based on completely randomized split plot factorial test (Table 1). All tests were done with three replications.

Table 1 Matrix of the experimentation

Parameters	Levels of parameters		
	1	2	3
Engine speed/r·min^{-1}	1500	1950	2250
Gear ratio	2	3	4
Position of microphone	dosimeter	SLM	-

The data obtained in this study were analyzed using SPSS 19.0 software. Variance analyses for SPL (dB) at A-weighted equivalent SPL (dB(A)) were done for each working condition. Duncan test was used for multiple comparisons of mean values of sound pressure level.

3 Results and discussion

ANOVA analysis of overall noise of MF285 tractor has been shown in Table 2 and Table 3. As it can be seen Variance analyses showed that the engine speed and gear ratio on the overall sound level values for tractor were statistically significant ($P < 0.01$) , but engine speed × gear ratio interactions for sound pressure levels was not statistically significant ($P < 0.01$).

In the following interaction effects of variables on the overall sound level values will be discussed separately.

Table 2 Analysis of variance (ANOVA) of dosimeter sound level

Source	Mean square	df	Sum of squares	F
Gear	47.787	2	23.893	47.751**
Engine speed	117.420	2	58.710	117.333**
Engine speed* gear	0.893	4	0.223	0.446^{ns}
Error	9.007	18	0.500	-
Total	207945.190	27	-	-

Note: **=statistically significant ($P < 0.01$);
ns = statistically not significant.

Table 3 Analysis of variance (ANOVA) of SLM sound level

Source	Mean square	df	Sum of squares	F
Gear	36.921	2	18.460	13.689**
Engine speed	94.687	2	47.344	35.108**
Engine speed* gear	2.733	4	0.683	0.507^{ns}
Error	24.273	18	1.349	-
Total	187442.010	27	-	-

Note: **=statistically significant ($P < 0.01$);
ns = statistically not significant.

Interaction effect of engine speed and position of the microphone on sound level values are presented in Table 4. By increasing the average of engine speed, average value of sound level in dosimeter and SLM positions have been increased. Also, differences between the three levels of engine speed had been statistically significant ($P < 0.01$), except to average related to the 1,500 and 1,900 r/min of engine speed at the SLM position. In addition, the maximum significant increasing value in overall SPL due to increase of engine speed (from 1,500 to 2,250 r/min) for dosimeter and SLM position have been 5.10 dB(A) and 4.42 dB(A), respectively.

Table 4 Duncan's test results of effect of microphone position and engine speed on overall sound level in dB(A)

Parameters	Engine speed/r·min^{-1}		
	1500	1900	2250
Dosimeter	85.26 ^{c}	87.56 ^{b}	90.36 ^{a}
SLM	80.72 ^{b}	83.99 ^{a}	85.14 ^{a}

Note: The values with same letter don't have a statistically significant difference ($P < 0.01$).

Gear ratio × microphone position interaction effect has been reported in Table 5. This table implies that the difference between the average SPL of the MF285 tractor for 2 and 3 gear ratios and also 3 and 4 is not statistically significant ($P < 0.01$), whereas the difference related to the gears 2 and 4 is statistically significant ($P < 0.01$).

Table 5 Duncan's test results of effect of microphone position and gear ratio on overall sound level in dB(A)

Parameters	Gear		
	2	3	4
Dosimeter	85.94 ^{b}	88.08 ^{ab}	89.14 ^{a}
SLM	81.92 ^{b}	83.16 ^{a}	84.78 ^{a}

Note: The values with same letter don't have a statistically significant difference (P < 0.01).

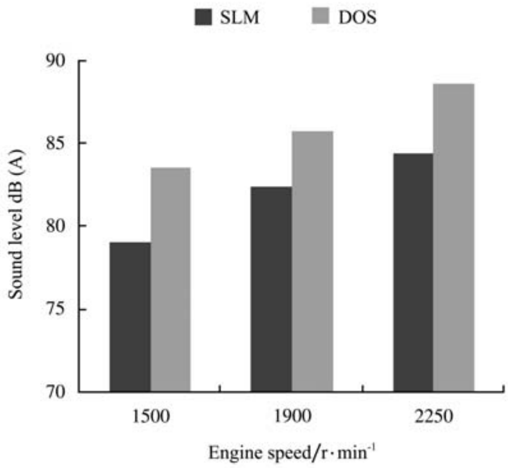
The difference between the average of sound level of SLM position related to 3 and 4 gear ratios is not statistically significant ($P < 0.01$). While, there is statistically significant ($P < 0.01$) difference between the averages values of sound level of gear number 2 with other gears. The data in Table 5 shows that the maximum differences of average value of SPL for dosimeter and SLM positions for different gear ratios have been 3.2 dB(A) and 2.86 dB(A), respectively.

Generally, it can be stated that changing of position of the microphone placement from dosimeters to SLM has been reduced the level of sound at all levels of engine speed and gear ratio. This might be due to increasing in distance of noise source to microphone and damping effect of environment and road (Crocker, 1998; Crocker and Ivanov, 1993). Researches conducted by Crocker (1998), Crocker and Ivanov (1993) Meyer et al. (1993) have represented reducing of sound level of tractors and agricultural machinery in observer position compared to the driver's ear position.

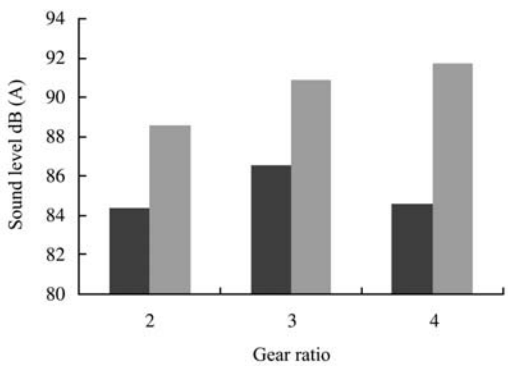
Increasing in engine speed (all three levels of engine speed) has been gotten a statistically significant ($P < 0.01$) effect on sound level of MF285 tractor in dosimeter position (Figure 3a). The same results have been reported by Crocker (1998) and Meyer et al. (1993).

Although, overall sound level increases with gear ratio (Figure 3b), the effect of gear ratio on sound level was not statistically significant ($P < 0.01$). The results of Meyer et al. (1993) experiment showed the same effect. They stated that the gear ratio in agricultural machinery has not a significant effect on their sound level.

The overall sound level values were measured in this study showed that sound level in the driver's ear position in all levels of gear ratio and engine speed is higher than standard sound level (85 dB(A)). Therefore, the use of ear protection device is recommended for driver. Also, the measurements in this study showed that sound level at the observer position in all levels of engine speed and gear ratio often is lower than 85 dB(A). Therefore, it is recommended that workers on farms adjacent to rural roads who do not use ear protection and for those who have to pass through the way of MF285 tractors, at least be away 5 m from the path of MF285 tractor. For those who are less than 7.5 m away from the tractor MF285 using ear protection device is recommended. Also, Aybek et al., (2010) reported similar result as discussed in this section. They stated that the SPL of three types of tractor in the driver's ear position is more than the permissible value.



a. Sound level in different engine speed (gear artio = 2)



b. Sound level in different gear ratio (rpm = 2250)

Figure3 Effect of: a. engine speed b. gear ratio, on overall sound level

4 Conclusion

This study consists of measurements and analyses of noise of MF285 tractor while pulling a trailer in an asphalt road. SPL were determined at center frequencies. Variance analyses were conducted to determine whether the engine speed and the gear ratio had an effect on the sound pressure levels and A-weighted equivalent sound pressure levels. The findings of this study could be summarized as follows:

1) SPL increased with increasing of engine speed;

2) According to variance analyses, engine speed, engine speed ×microphone interactions were found to be

significant (P <0.01).

Based on the results and discussion in this study, the following recommendations could be made:

- Low engine speed should be taken as often as possible to avoid higher level of sound level and noise, especially during working on tractors without using ear protection device;
- Personal protection such as earplugs should be used to insulate noise on MF285 tractors without cabins.

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