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OCCUPATIONAL NOISE EXPOSURE AND CONTROL MEASURES OF GRASS CUTTING MACHINE

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Abstract

Over the last few years, interaction of humans with noisy power-driven agricultural tools and its possible adverse after effects has been realized. In the present study, investigation was carried out to determine the effect of noise from two types of grass-trimming machine on the operators in real working environment. It has found that both grass trimming machines produced high levels of noise, of the order of 85.5 and 93 dB (A) respectively, to which operators are exposed while working. It was also observed that situation aggravates when a number of operators simultaneously operate resulting in still higher levels of noise. Such a high level of noise exposure may cause physiological and psychological problems to the operators in long run. Fluctuation in blade lift and drag occurs due to housing and vortex shed from a preceding blade. In the 500 to 2000 Hz frequency range, edge noise due to turbulence shed from the trailing edge of the blade is found to be dominant.

In the present situation, it is, therefore, recommended that the grass trimmers should be provided with earplugs or earmuffs on one hand and redesigning the grass-cutting machine should be considered on the other. In case of grass trimmers, primary noise source is engine of the trimmer and it does not have any soundproof covering. Perhaps the situation can improve in terms of noise reduction by providing properly designed soundproof covering for the engines and using blade, which was 'swept forward' and had a sharpened trailing edge.

Index Terms: *Noise, Grass trimming machine, Primary noise source, Sound Proofing*

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1. INTRODUCTION

Grass trimming is one of the large-scale male-dominated operations carried out in almost all parts of India**.** Grass-trimming machine is an important machine used in maintenance of grass areas. The fast growth of grass in tropical areas makes the grass-trimming operation compulsory. The petrol-engine-driven grass trimmers are widely used in India for cutting long grass along the roadside and general agricultural land. The workers involved in these activities are generally contract workers with no or little awareness of the effect of noise on health. Highways authority maintains the sideways of the road by getting the grass cut by these contract workers. This is very large industry with a workforce of more than 20,000 workers. Safe and comfortable working environment is one of the factors required for the productivity of operators engaged in this work. Besides physical exertion, one of the major sources of discomfort to the workers operating a grass-trimming machine is the noise to which they are exposed. Recent studies show that noise is now recognized as a serious health problem in our modern societies. Both auditory and non-auditory effects are prevalent among the workers/operators working in a noisy environment. The non-auditory deleterious effects of noise include: annoyance, loss of memory, and sleep disturbances. Extensive research work has been carried out in agriculture field with special reference to noise exposure on operators.

Much research has been carried out to determine cut-off noise levels below which operators can be exposed to about eight hours a day without increased risk of hearing loss [1, 2]. Levels from 66-85 dB (A) can involve physical and neurological disorders and auditory damage. The metabolic activity taking place at the moment of the arrival of noise is important; heat, heavy work, infectious disease, and other causes of heightened metabolism increase the vulnerability of the sensory organs. Noise

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levels above 130 dB (A) induce turbulence in the ear and may also cause mechanical damage. In the United States, OSHA has specified 90 dB (A) as the maximum permissible exposure to continuous noise for 8-hour shift. The recommended exposure limit (REL) for workers engaged in the occupations such as engineering controls, administrative controls, and work practices is 85 dB(A) for 8-hour duration. NIOSH also recommended a ceiling limit of 115 dB (A). Exposure to noise levels greater than 115 dB (A) would not be permitted regardless of the duration of exposure. In India, the permissible limit for continuous noise exposure is 90 dB (A). Pace of research in the field of agriculture has been rather slow in developing countries, although extensive research in this field has been carried out in developed countries.

The lawn-maintenance industry grows in suburban areas; it has become a new and significant source of environmental noise and occupational noise exposure. Most lawn maintenance workers spend from 8–10 hr per day exposed to A-weighted sound levels greater than 85 dB, and it appears that few employees wear hearing protection. Going through the literature [3, 4], it is found that either no or very little work has been done in case of grass-trimming machine noise effects on operators. This area becomes all the more important to investigate as more and more workers are hired by Indian Government to beautify the tourist places by way of maintaining rapid grass-growing areas. Keeping this in view and based on the severity of the topic, the problem has been identified to control the noise emission from grass cutting machine. Two machines viz, walk behind Lawn Mower (146s) and grass trimmer machine (STIHL-FS130) have been selected for the study. These grass cutting machines are operated by same operator for cutting the grass in Institute campus, gardens, residential complex and industrial area. The machine is used daily for 8 hrs/day. During operation, the operator is not used any hearing protection during its operation.

2. METHODOLOGY

2.1 Machine description

The string trimmer is a small machine that uses a rapidly spinning plastic line to impact and break off plants rather than cutting them. Trimmers are used for landscaping tasks such as trimming, edging, and scalping. These machines can typically cut within a radius of 15-30 cm. There are several variations found in these types of machines depending upon engine size, location, type of shaft, and handle shape. In these machines, through a long flexible driving shaft, the engine drives the cutting head containing the plastic cutting line. These engines operate the cutting head in the range of 1000-6000 rpm but full speed is typically 8000-10000 rpm, depending on engine power, number of cutting lines, and type and depth of grass. Noise-producing machines have primary as well as secondary sources of noise. In most cases, the primary source of noise is of interest for the analyst whereas contribution of secondary source is negligible. In the present case, grass-trimming machine engine is primary source of noise whereas motorized cutter with plastic lines is secondary source of noise. When machine is operated the operators are subjected to high level of noise, the greater the speed of the cutter (in rpm) more will be the noise, causing more inconvenience to the operator. In these studies two machines STIHL-FS130 and 146s were chosen because of their widespread use in India. The grass trimmer machine is placed at the back of operators while trimming the grass as shown in [Fig-1].

Fig-1: Experimentation on Lawn Mower and Grass Trimmer on Institute ground

2.2 Experimental Procedure

The experiment was conducted in real working environment. It was assured that no obstruction in any form (building, active road, trees, and fences) should be there in a radius of 500 meters. Therefore Institute play ground has been selected for conduction of the study. An outdoor site at NPL was assessed for suitability in accordance with the requirements given in ISO 3744. The site, as shown in Figure 2 was found to be acceptable for test requirements. The experiments were carried out in the month of October, although it is a routine operation throughout the year. Due to moderate and heavy rain throughout the year, growth of grass is uniform and requires maintenance.

Recognizing that environmental conditions, such as wind and temperature, can have an adverse effect on acoustic propagation, meteorological conditions were checked prior to carrying out noise measurements, at a specially set up monitoring station adjacent to the test site. In all cases the wind strength was negligible and temperature and pressure conditions were suitable for noise measurements. The walk behind lawn mower (146s) and backpack type grass-trimming machines STIHL-FS130 were used for the purpose of grass-trimming operation. Widespread use of these trimmers made it compulsory choice for present study.

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The noise level was measured with the help of sound level meter which is also a data storage and display device (Larson and Davis LxT). The sound level meter was calibrated before the actual measurements. The grass trimmer was kept at the center of the grid lines with engine operating to rotate cutting head at 5000 ± 200 rpm. This particular value of cutting head speed was chosen because it was observed during grass-trimming operation that the speed of cutting head varies depending upon the number of cutting lines, type, and depth of grass. But the average cutting head speed seldom goes below or above the value considered. The noise was measured in accordance with the guidelines furnished in ISO-1999 standards. As recommended by the ISO, microphone was placed 100 mm away from the ear of the operators so as not to disturb the sound field under investigation. Larson and Davis Type (LxT) was used to record the equivalent sound pressure level (L_{eq}). The results have been analyzed, particularly to examine typical A-weighted repeatability uncertainties for two machines, and presented and discussed in next section.

Both the machine was operated for a period of approximately 10 minutes for stabilizing. Measurements should be started immediately following this period. Requirements for both stationary and travelling conditions are given. For measurements with the machinery stationary it is required that no operator should be present, the ground drive be disengaged, and the maximum operating engine/motor speed be used.

2.3 Limitations and Scope

The project had practical and economic constraints, such that the range of machines tested had to be limited. In selecting the machines, the approach was to consider, as best as possible, different types of machinery with a range of operational characteristics, from machines which are generally operated in a relatively continuous mode to actively operated machines. All machines examined were designed for use outdoors and considered to be small noise sources. Different types of machinery to those examined, especially large assemblies may exhibit different levels of repeatability uncertainty due to operating conditions. The values determined from the measurements conducted under this project will not necessarily be appropriate to describe the repeatability uncertainty for all machines. It is also noted that the machines employed for the investigation were not new and had been in service for varying degrees of time. It is acknowledged that the degree of repeatability determined for the selected machines may differ from machines tested straight off the production line. However, the machines used were determined to be in good working order and where appropriate had received regular servicing. It could be considered that the outcome of the investigation is representative of the worst-case repeatability. Finally, it is noted that the scope of the investigation has been to consider only A-weighted values. This reflects the common requirements in practice, where for example, it is the single A-weighted value that is used for declaration purposes in accordance with Directive 2000/14/EC. Frequency data was however acquired and could if required by analyzed as part of a further investigation.

3. RESULTS & DISCUSSION

Table-1: Noise Readings

Noise Parameters	Walk Behind Lawn mower	Grass Trimmer
L(eq)	81.3 dB(A)	91.4 dB(A)
L(max)	85.8dB(A)	93 dB(A)
L(min)	78dB(A)	87.4 dB(A)
L(peak)	98.4dB(Z)	107.8 dB(Z)
L(90)	78.8dB(A)	88 dB(A)

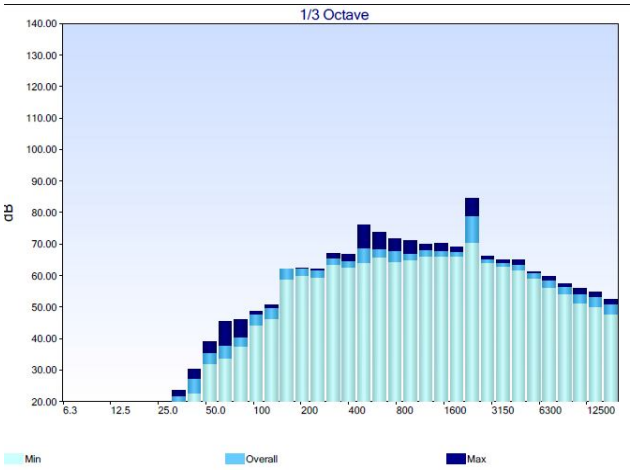

Fig-2: 1/3 octave Frequency curve for walk behind Lawn Mower

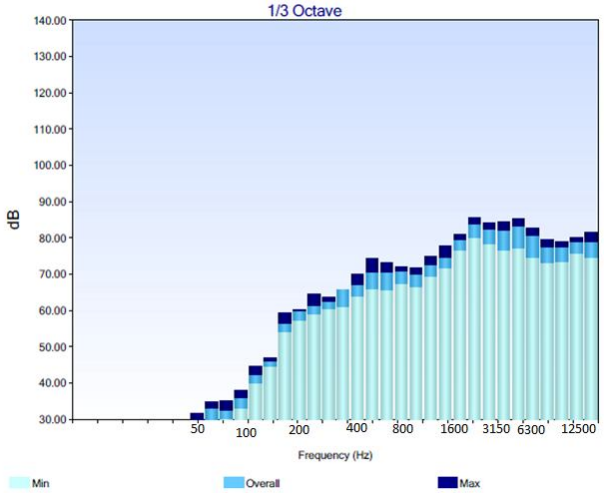

Fig-3: 1/3 octave Frequency curve for Grass Trimmer

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The grass trimmers under investigation typically cut grass at approximately 5000 ± 200 rpm. During the cutting operation, the speed changes due to various reasons, such as, ground condition, length and type of the grass, grass surface levels, etc. Table 1 shows the sound pressure levels that were recorded. It can be seen that SPL values maintained approximately constant decreasing trend by 2 dB (A) as measured at a distance of 2, 4, 6, 8, 10, and 12 meters, respectively, from the center (0,0) coordinate. The frequency analysis of SPL (L_{eq}) of one-third octave band observed at grid point of highest noise for each trimmer (BG-328 and SUM- 328 SE) is presented in [Figure 1]. It was observed that the main peaks of noise were at 500 Hz and 630 Hz for both Lawn Mower and grass trimmers, respectively. It can also be concluded from the frequency curve that variation in noise level beyond 1000 Hz is rather more as compared to variation up to 1000 Hz.

The SPL contours of the two grass cutting machines are presented in [Figure 2] and [Figure 3]. The SPL was maximum at the (0,0) coordinate, that is, at the place where the operator operates the machine (90.5 dB(A) for lawn mower and 93 dB(A) for trimmer). The difference in values of SPL produced by two trimmers at source by 2.5 dB (A) may be due to constructional feature of the engines. It is to be noted that in other noise-producing machines/equipments, operators are not so close to the point of noise-producing source. But in the present study, operators perform grass-trimming operations while machine engine is located at their back [Figure 1]. This close location of noise source and receiver makes the situation more alarming.

3.1 Combined sound level during operation

Trimming operation is carried out throughout India irrespective of the season. It is also a common practice that several operators come together while performing the grass-trimming operation. Generally the operators work in a group. This leads to high level of noise and thus the ill effects. If two sounds (of frequencies and temporal characteristics that are both random) occur at the same time, their combined SPL can be calculated from the following formula.

$$SPL = 10 \log\{\sum_{i=1}^{n} 10^{L_{pi}/10}\} \quad (1)$$

Where SPL is sound pressure level expressed in dB.

In the present study it was found that, when two or more operators perform grass-trimming operation simultaneously using different grass trimmers then combined SPL to which workers are exposed are rather high. The value was observed in real working environment when operators were working within a radius of five meters. However, the effect was negligible when operators performed trimming operation at a radius of 15 meters from each other. It can also be seen that the SPL for different combinations of trimming machines reach a value that is much higher than exposure limit of noise for 8-hour workday recommended by ISO.

3.2 Related health effects on operators

The high noise levels, to which operators of grass trimmers are often exposed for long period of time, may lead to substantial hearing impairment and health problems. The Recommended Exposure Limit (REL) for workers engaged in occupations such as engineering controls, administrative controls, and/or work practices is 85 dB(A) for 8-hour duration according to NIOSH. The SPL in present study at the operators' ear is definitely higher than recommended. Situation further worsens when several operators work close to each other. The noise levels may also reach up to 100 dB(A) when two grass machines are operated together. Therefore, performing grass-trimming operation in a group can cause both temporary and permanent noise-induced hearing loss. In case of farm machinery, operators work for small intervals specifically during nonpeak season, whereas, the operators of grass trimmers work for long hours irrespective of the season. Therefore, considerable attention must be paid to reduce the noise level of machines.

The level of noise to which these operators are exposed may have immediate as well as long-term effects. High level of noise can cause both psychological and physiological problems. Often physiological problems are associated with headaches, dizziness, nervousness, stress, annoyance, sleep disturbance, and loss of concentration. The mental arithmetic processing ability of people weakens under the impact of noise. The most common effects of noise exposure appear in tasks such as proofreading and solving of challenging puzzles. Direct and indirect noise impacts cause cardiovascular effects. Noise studies have turned up alarming connections between blood pressure and noisy environments. Research studies observed that sounds in the range of 75-90 dB (A) cause tiny blood vessels in the toes, fingers, skin, and abdominal organs to contract. Studies have indicated the adverse effects of industrial noise. These studies conclude that industrial noise exposure for 5-30 years can cause increase in blood pressure and significant increase in the risk of hypertension, compared to workers in control areas.

4. NOISE CONTROL

According to the National Institute for Occupational Safety and Health (1998), the maximum exposure time at 85 dB (A) is 8 hours. To control the noise level and bring

them below standard, it equally important to identify the noise source from the machine.

4.1 Noise Sources

4.1.1 Mechanical Vibration

The engine causes the structure of the mower to vibrate and vibrating structure in turn radiates sound. In case of walk behind mower, the deck is relatively stiff to reduce the noise substantially.

4.1.2 Blade

The blade on a rotary mower serves these functions:
a) To lift the grass in preparation for cutting.
b) To cut it.
c) To lift the cuttings into a bag or distribute them.

The blade moves air, thereby generating noise. On a walk behind mower, the blade is one of the most important noise sources. There are five main mechanisms whereby the blade produces its noise. In the 100 to 500 Hz frequency range, these mechanisms are steady blade lift and drag, blade thickness, fluctuating blade lift and drag due to housing and fluctuating blade lift and drag due to vortex shed from a preceding blade. In the 500 to 2000 Hz frequency range edge noise due to turbulence shed from the trailing edge of the blade is dominant.

4.1.3 Exhaust

Exhaust noise arises from the pulse of the exhaust gas emitted each time the engine fires. This source is important because at the present time small engine are not very well muffled.

4.1.4 Engine

Engine noise, in addition to Exhaust noise, includes - Intake noise, casing noise, cooling fan noise, valve noise, piston slap and noise from play in the big end of the connecting rod.
The following noise sources have observed during operation of both the grass cutting machine;

- The noise from the rotating blade is the dominant source.
- High speed engine is also extremely noisy.
- The mower with the grass catcher is noisier because more of the undressed of the deck is exposed.
- More lift often means more noise but better bagging.
- Less blade clearance means more noise.
- Use of different muffler can reduce the noise to much lower level.
- It is also found that a walk-behind mower makes the greatest noise when It is not cutting, because the blade, which are the main source of noise, move faster than the unloaded.
- A high blade tip speed is required for good cut. If the blade is slowed, one way of reducing its noise, than its performance in thick grass and weeds will degrade.
- The bagging ability of a mower is primarily determined by the lift on the blade.
- If the blade is slowed, then its lift will be reduced and will adversely affect the performance.

4.2 Suggested Control Measures to reduce noise from grass cutting machine

It is possible to reduce typical noise levels of mower by fitting currently available items to the machines. Two levels of effort are possible with this approach. The sound levels quoted here are the median levels for the machine.

4.2.1 Level 1- Muffler

Use best muffler available. Current engine exhaust muffler can reduce exhaust noise to a point where it is no longer a major noise source. Fully enclosing the engine prevents the noise from escaping, but at the same time blocks cooling air from entering & leaving the enclosure. A partial enclosure surrounding the cylinder head on a walk-behind mower solves the air problem but does not provide as much air quieting.

4.2.2 Level 2- Muffler and slow engine

Use best muffler and reduce engine speed. The walk-behind mower engine runs at 3200rpm. A significant noise reduction can be obtained by slowing the engine to 2800rpm or so. Doing so reduces the frequency of the engine noise and slows the blade so that it, too, is quieter. However, at the same time, grass cutting performance is degraded by reduction in speed. This can be improved by increasing the speed by gear mechanism.

4.2.3 Level 3- Redesign of the blade

By the use of quiet blade, which was 'swept forward' and had a sharpened trailing edge, the blade noise reduction of about 7 dB (A) was produced. Other noise control approaches include reducing the tolerances on manufacturing the engine so that there is less valve noise piston slap and connecting rod noise as well as soft mounting the engine to reduce the vibration transmitted to the mower.

4.2.4 Level 4-Muffler and Quiet Blade

We retain the muffler used to achieve Level 1 and add a quiet blade. We can achieve a reduction of 5.5 dB (A).

4.2.5 Level 5-Muffler, Slow engine & Quiet Blade

We do not fit a quiet blade to a machine which already has a good muffler & slow engine. The improvement is not very great, since blade noise is already low because of slow engine.

4.2.6 Level 6-Muffler, Slow engine & Partial enclosure

At this level engine noise is reduced by a partial enclosure & the engine tolerance in walk behind mowers are lowered Blade noise now dominates on the walk behind mower which means that we get only a 5.5 dB (A) reduction.

4.2.7 Level 7-Muffler, Slow engine, Partial enclosure and quite blade

The treatment is the same as level 5 with the addition of a Quiet blade. We now have an 8.5dB (A) reduction on walk behind mower.

4.2.8 Level 8-Muffler, Slow engine, Full enclosure & Soft mounting

The treatment is the same as level 5 with the addition of a soft mounting. We now have a 6 dB (A) reduction on walk behind mower.

4.2.9 Level 9 - Muffler, Slow engine, Full enclosure, Soft mounting & Quiet Blade

The treatment is the same as level 7 with the addition of a Quiet blade. We can have a total 10 dB (A) reduction be achieved. In the present situation, it is recommended that the grass trimmers should be provided with earplugs or earmuffs on one hand and redesigning the grass-cutting machine should be considered on the other. In case of grass trimmers, primary noise source is engine of the trimmer and it does not have any soundproof covering. Perhaps the situation can improve in terms of noise reduction by providing properly designed soundproof covering for the engines under reference.

5. CONCLUSION

- The maximum SPL produced by both grass cutting machines was found to be above 85 dB (A), i.e. more than recommended standard. The difference in produced SPL may be attributed to constructional features of two trimming engines under investigation.
- Operators are exposed to high levels of SPL (100 dB (A)) if machine is operated in group, indicating the necessity of control measures to reduce noise.
- Operators should be instructed to operate not in group but individually keeping a safe radius of 15 meters or more. Thus, by placing operators at least 15 meters apart could reduce the noise level to certain extent. However, it should be noted here that the word 'safe' does not actually mean safe for the hearing because one machine alone can be so noisy that it is harmful to hearing.
- From the obtained results, it is proved that the exposure to loud sound can cause first temporary, then permanent hearing loss. This hearing damage is usually expressed as an increase in the subject's Threshold of hearing. The magnitude of a threshold shift varies according to the intensity of the sound, its duration and its spectral distribution, as well as the duration of periods of rest between exposures. Individual seem to vary in susceptibility to a given noise.
- A lawn mower produces the noise is above 85 dB, the level at which Occupational Safety and Health Administration recommends hearing protection. Therefore it is recommended that the operator must use either earplugs or earmuffs. However, operator must wear both properly for them to be effective, putting earplugs all the way in and wearing earmuffs flush against the head. Contrary to popular belief, wearing ear protection against loud background noise, such as that produced by mowers, makes it easier to hear.

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