MATHEMATICAL MODELLING OF EFFECTS OF NOISE ON MACHINE OPERATORS

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ABSTRACT
In this study, the effects of noise on machine operators were investigated and modeled. Major hearing losses have been traced to noise generated by machinery. The results show that hearing loss increases with increase in frequency and age; and is influenced by the loudness level and sound intensity. At age 25 and 40 years, the hearing losses are 3dB and 8dB respectively. Age causes the intensity to rise exponentially. This confirms that hearing impairment worsens with age. This brings about temporary or permanent deafness in the operators. This in turn, results in poor performance, illness and low productivity. The sound intensity considered ranges from 0-1.0dB and the maximum intensity occur at 275dB which is largely due to the nearness (distance) of operator to the machinery. The simulation of the model shows that sound intensity and age were independent predictors. The loudness level was found to be 230-280dB. In conclusion, chronic exposure to noise at intensity of 0.9-1.0dB from machinery can impair hearing acuity; increases the incidences of headache, deafness and psychiatric disorders. Duration of exposure and age are associated risk factors.

Keywords: Noise, Machine Operators, Sound Intensity, Machinery, Hearing.

1.0 INTRODUCTION
Due to the ever increasing level of individualization, industrial noise is an ever growing problem. It is very important to be able to quantify and control this noise and thus its effect on man and its environment. This can be better achieved if planning ahead of an envisaged potential danger which may be caused eventually if not controlled. Even though standards are set for some of the most major noise source, monitoring them has ever been a bone of contention (Nunez, 1998). Although normally, individual noise is one of the less prevalent community noise problems, neighbours of noisy manufacturing plants can be disturbed by sources such as fans, motors, compressors etc. mounted on the outside building. Interior noise can also be transmitted to the community through windows or through porous walls. This interior noise sources have their most significant impact on the individual workers who bear the brunt of the noise (Suter, 1991).

Results from field studies indicate that men incur more hearing loss than women from comparable noise exposures; and that Caucasians appear to be more susceptible than Blacks to noise-induced hearing loss (Royster et al., 1980). Other factors, such as age, pre-exposure hearing threshold level, general health, and use of alcohol, have not yet proved to be reliable predictors of susceptibility (Ward, 1986). Evidence suggests that noise is the most widespread stressor in the physical work environment (Kjelberg, 1990).

Theoretically, noise may affect workers physical well being and the resultant sickness absence because of its contribution to information overload at work. A noisy environment can be expected to contribute to higher cognitive load because it distracts employees from their task focus; this increase in cognitive load often produces adverse stress-related physiological reactions (Fournier et al, 1999).

An attempt has been made to develop a fuzzy model for determining the work efficiency of humans as a function of noise level, exposure time, and the type of task. The modeling technique was based on the concept of fuzzy logic. It was established on the basis of surveys that the impact of noise on work efficiency depends to a large extent on the type of tasks. Also, the duration of noise exposure is an important factor in...
determining the work efficiency. The model results were compared with the deduction based on the criterion of Safe Exposure Limit recommended for industrial workers (Zaheeruddin et al., 2004). In another study, structural equation models of memory performance across noise conditions and age groups were developed. Memory tests were carried out and memory was found to be invariant across age groups and across noise exposure conditions. Although latent variable structures were invariant across age groups, the youngest group recorded a bit of variability (Enmarker et al., 2006).

In an environment where noise poses a great threat to the general well being of the people, safety precautions in order to reduce the effect are necessary to be put in place. Safety devices such earmuffs and earplugs can also be used properly even though these do not actually reduce the effect of noise on the operator (Lebovics, 2000) since the effect of noise on the operators are not immediately obvious, taking years in some cases to manifest. In most cases, the operators themselves are ignorant of the effect of noise on their well being and insensibly accept it and the physiological and psychological deterioration that accompanies it as an inevitable part of their lives (Nunez, 1998).

An understanding of people’s subjective response to noise allows environmentalists and engineers to reduce noise in more effective ways. For example, noise should be reduced in the frequency range in which the ear is most sensitive. Noise reduction should be by a magnitude which is subjectively significant. There are several other subjective parameters which are important in hearing (Kewal, 2004).

For occupational noise, the most important effect is the possibility of permanent loss of hearing caused by habitual exposure to excessive noise, as can occur on a daily basis over many months or years in the workplace. The scientific evidence is in controvertible that excessive noise may cause physiological damage to the human hearing mechanism. Such hearing impairment, known as noise-induced hearing loss (NIHL), often progresses slowly over many years and may go unnoticed until permanent damage occurs. The objectives of this study is to develop a mathematical model that can predict the effects of noise on machinery operator under any given environment and hence the solution to them.

2.0 MATERIALS AND METHODS

2.1 The Models

Hearing Loss Caused by Intense Noise

The hearing loss was modeled using 4th order Newton difference scheme, the major factor in modeling the loss was operator’s age. The result was simulated using MATLAB program and the result below was generated.

On using the Newton’s difference scheme we have:

\[
H = H_0 + \frac{(A - A_0)\Delta H}{h} + \frac{(A - A_0)(A - A_1)\Delta^2 H}{2!h^2} + \frac{(A - A_0)(A - A_1)(A - A_2)\Delta^3 H}{3!h^3} + \frac{(A - A_0)(A - A_1)(A - A_2)(A - A_3)\Delta^4 H}{4!h^4}
\]
\[ H(A) = \frac{4(A - 20)}{10} + \frac{5}{6 \times 10^5} (A - 30)(A - 40) - \frac{14}{24 \times 10^4} (A - 20)(A - 30)(A - 40)(A - 50) \]

\[ H(A) = 0.4A^4 - 8 + 0.00833A^2 - 0.0749A^2 + 2.1658A^2 - 19.992 - 0.00005834A^4 - 0.008162A^3 \]

\[ - 0.41393A^2 + 8.9782A - 69.96 \]

\[ A(A) = - 97.952 + 0.008995A^3 - 0.4889A^2 + 11.544A - 0.0000583A^4 \]

i.e.

\[ H = \alpha A^4 + \beta A^3 + \delta A^2 + \gamma A + \theta \] ................................. (1)

Where

\[ \alpha = -5.83 \times 10^{-5} \]

\[ \beta = 8.995 \times 10^{-3} \]

\[ \delta = -4.889 \times 10^{-1} \]

\[ \gamma = 11.544 \]

\[ \theta = -97.952 \]

The human hearing mechanism is essentially a very sensitive electro-acoustic transducer responding to sound waves of a wide range of frequencies, intensities and wave forms. It translates acoustic pressure fluctuation into pulses in the auditory nerve. The human hearing loss is related with patient’s threshold of authority \( I \) and threshold of the person having normal hearing with \( I_o \) and threshold of normal ear.

\[ H = 10 \log \frac{I}{I_o} \text{ (db) (William, 1971)} \] ................................. (2)

\[ I_o = \text{Threshold of sound intensity for normal ear.} \]

\[ I = \text{Threshold of sound intensity of patient’s ear.} \]

\[ H = 10 \log \frac{I}{I_o} = \alpha A^4 + \beta A^3 + \delta A^2 + \gamma A + \theta \]

\[ I = I_o \left( \frac{\alpha A^4 + \beta A^3 + \delta A^2 + \gamma A + \theta}{I_o} \right) \] ................................. \( \quad \) (3)

Loudness Level = \[ 10 \log \frac{I}{10^{-12}} \] phones

\[ = 10 \log \left[ I_o \frac{10^\frac{1}{10} (\alpha A^4 + \beta A^3 + \delta A^2 + \gamma A + \theta)}{10^{-12}} \right] \]

Intensity Spectrum Level (ISL),

\[ \text{Where, ISL} = 10 \log \frac{I}{I_o} \Delta f = 10 \log \left[ 10^{\frac{1}{10} (\alpha A^4 + \beta A^3 + \delta A^2 + \gamma A + \theta)} \right] + 10 \log \Delta f \]

And, IL is the Intensity Level.

**Model Assumptions:**

(a) 20-year group used as reference.

(b) Maximum age of machine operator is 60 years.
3.0 RESULTS AND DISCUSSION

The results of simulation of machinery operators’ noise effects model are presented in Fig. 1.

Figure 1: Hearing Losses of Machine Operators

Figure 1 shows hearing loss of machine operators with respect to their ages. The hearing loss at various ages shows a significant positive correlation. This implies that the age of operator is important in the modeling of hearing loss found among machinery operators. The figure shows operators age range from 20-60 years. At age 25 years, the hearing loss is 3dB and at 40 years, the hearing loss is 8dB. This confirms that hearing impairment worsens with age. The sharp increase in hearing loss between the ages of 20-30 years is due to the early frequent exposure to such a high level of sound. However, it is not certain whether the positive relationship with the duration of exposure is linked with age. As there was significant elevation of hearing loss at all ages.
Figure 2: Effect of Loudness Level on Machine Operators

Figure 2 shows Loudness level with respect to sound intensity. The graph shows a steady increase of loudness level over sound, this confirm that sound intensity correlate significantly with frequencies (Bisong, 2004). The sound intensity causes ranges from 0-1.0dB and the maximum intensity occur at 275dB which is largely due to the nearness (distance) of operator to the machinery. The modeled showed that sound intensity and age were independent predictors. The loudness level was found to be 230-280dB.

![Graph showing sound intensity against operators' age.]

Figure 3: Effect of Sound Intensity on Machine Operators

Figure 3 shows sound intensity in relation with operators’ age. From the graph, age causes the intensity to rise exponentially. The result is significantly higher than that of Malcom (1975). It is therefore likely that the hearing impairment observed may have been due to the exposure of noise generated by the machines in the factory. This was shown by the elevation of sound intensity at all ages and most markedly between age 55-60years.

4.0 CONCLUSION

The effect of noise on machine operator has been investigated and modeled. Results of this study indicate the need for implementation of appropriate hearing conservation programme to minimize the long-term exposure to noise. It can be concluded that hearing loss increases with increase in frequency and age and is influenced by the loudness level and sound intensity which brings about temporary or permanent deafness in operators. This in turn, results in poor performance, illness and low productivity. This causes operators to develop habit of shouting, which can lead to psychiatric disorders.

In conclusion, chronic exposure to noise at intensity of 0.9-1dB from machinery can impair hearing acuity increase the incidence headache and deafness. Duration of exposure and age are associated risk factors.

REFERENCES