

Study on Radial Drilling Machine Noise

A Dissertation submitted in partial fulfilment of the requirements for the degree of

Master of Engineering

in

Production Engineering

by

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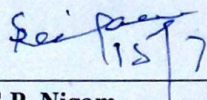
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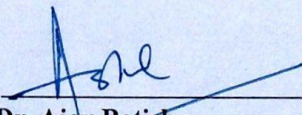
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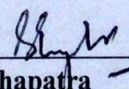


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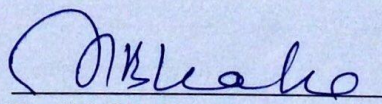


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Dedicated to my

FRIENDS

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Abstract

Noise is one of the physical environmental factors affecting our health in today's world. Noise is a physical form of pollution and is not directly harmful to the life supporting systems namely air, soil and water. Increased noise level with the technological advancement becomes a serious problem in the industries and it has become a crucial occupational hazard to its workers. Therefore it is necessary to study the noise generated by the machines at the work place.

The present work includes the study on a radial drilling machine noise. First the sound power of the machine is calculated by using an imaginary rectangular parallelepiped surface surrounded the source of noise. Equivalent continuous sound level (LA_{eq}) is calculated at the different reference points of the parallelepiped. Sound power is calculated at two different feeds by varying five spindle speeds. It is found that sound power increases with increase in spindle speed.

Sound pressure level measurement of a drilling operation at 1-1 octave band is carried out at different machining conditions to find out the parameters for optimum working conditions. Different parameters considered for the drilling operation are feed rate, spindle speed, diameter of drill bit and different workpiece materials. Sound level is recorded at each combination of the design parameters obtained by full factorial design. Frequency spectrum analysis has also been carried out to obtain the frequency range produces more sound level. It is found that the optimum parameters for less sound level are same for most of the cases and mid frequency sound waves are dominant for noise pollution at the work place. Environmental conditions and location of the machine also affects the sound pressure level generated by the machine.

Key words: Noise Pollution; Radial Drilling Machine; Sound Power; Sound Pressure Level; Frequency spectrum.

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Nomenclature

dB (A)	≡	A-weighted Decibel
dB	≡	Decibel
Hz	≡	Hertz
L_{eq}	≡	Equivalent Continuous Sound Level
L_p	≡	Average Sound Pressure Level
L_w	≡	Sound Power in dB (A)
NIHL	≡	Noise Induced Hearing Loss
RDM	≡	Radial Drilling Machine
SLM	≡	Sound Level Meter
SP	≡	Sound Power
SPL	≡	Sound Pressure Level

Chapter 1

Introduction

In this chapter, the basic details and concepts of related topics on noise associated with the thesis work are discussed.

1.1 Introduction to Noise

Noise is one of the physical environmental factors affecting our health in today's world. Noise is a physical form of pollution and is not directly harmful to the life supporting systems namely air, soil and water. Its effects are more directly on the receiver i.e. man. Noise pollution is the result of modern industrialized urban life and congestion due to over population.

In the industries increased noise level with the technological advancement becomes a severe problem and it has become a vital occupational hazard to its workers. The devices and machines used in industries are highly unlike in its nature and most of them emit high noise levels due to repeated operation of noise generating components such as electric, pneumatic elements and other fast moving mechanical components. The operational speed of machines is extremely increased and herald high productivity as well as effectiveness. However, parallel to technological and economical advancement, ever increasing industrial noise problem reached to a frightening level with the incident of undesirable consequences and poor health effects to its workers. The maximum noise level of some machines has reached 95 decibels. When a number of machines are placed in a room, collective noise level is reached to dangerous level where noise control becomes completely essential. Throughout the world, government has made many laws for securing the health status of employees by providing them healthy and satisfactory working conditions and expelling out unsafe practices [Jayawardana et al., 2014].

1.2 Sound and Noise

Sound, a normal feature of our life, is the way of communication and entertainment in most animals, including human beings. It is also a very effective alarm system. Basically, Sound is defined as a pressure disturbance that moves through a material at a speed which is dependent on

the material. That disturbance in the medium i.e. gas, liquid or solid can be detected by human ear. To be audible the disturbance must fall within the frequency range of 20 Hz to 20000 Hz. Sound propagates in the air with a speed of approximately 300m/sec, in liquids 1500m/sec (water), in solid 5000m/sec (steel). A low sound is pleasing whereas a loud sound is unpleasant. Nature of the sound for a person depends on its loudness, duration, rhythm and the mood of the person. But amongst all those parameters, loudness is certainly the most significant criterion. It converts sound into noise. Figure 1.1 shows the sound travel in air from a source to the receptor.

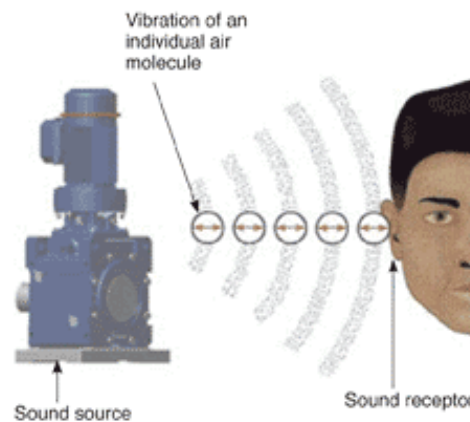


Figure 1.1: Mechanism of sound travel in air [Barron, 2001]

Noise is generally defined as the unpleasant sounds which bother the human being physiologically and physically and cause environmental pollution by destroying environmental properties. Sound becomes unwanted when it either interferes with normal activities such as sleeping, conversation, or disrupts or diminishes one's quality of life. Even though noise pollution is not serious to human life, yet its importance cannot be ignored because repeated exposure to noise reduces the sleeping hours and efficiency or productivity of a human being. It affects the peace of mind and invades the isolation of a human being. As the ill effects of noise on human health and environment are becoming obvious with each passing day, the importance of noise pollution as environmental problem is being recognized [W.3].

Exposure to continuous and general noise at a level higher than 85 dB (A) might leads to hearing loss. It differs from person to person with the level, frequency and duration of the noise exposed. Harmful effects of noise on human beings generally contain the effects of physiological

and psychological nature. The most common effect among the physiological ones is hearing loss. Sleeping disorders, blood pressure increases, appearance of muscle reflexes and heart beat accelerations may be considered among the other physiological effects. As compared to the physiological ones, psychological effects of noise are more common and they can be seen in the forms of concentration disorders, annoyance, anger, stress and as well as difficulties in resting and perception.

For carrying out a conversation, the level in a place can be at most 65 to 70 dB (A). Limit of work generally varies from 85 dB (A) to 90 dB (A) averaging in day for 8 hours. According to ISO time spent in a noise environment to be halved for each 3dB (A) rise in noise level above set limit. If the 8 hour is set at 90 dB (A) then, for example, 93 dB (A) is allowed for 4 hours. Table 1.1 contains the ambient noise standards adopted in India at day and night time.

Table 1.1: Ambient noise standards adopted in India [Singal, 1992]

Sr. No.	Area	Day Time* (L _{eq} dBA)	Night Time** (L _{eq} dBA)
1	Industrial Area	75	70
2	Commercial Area	65	55
3	Residential Area	55	45
4	Silence Zone	50	40
*Day time: 06 AM to 10 PM			
**Night time: 10 PM to 06 AM			

1.3 Sources of Noise

Noise pollution like other pollutants is also a by- product of industrialization, urbanizations and modern civilization. Broadly speaking, the noise pollution has two sources:

- Industrial sources
- Non- industrial sources

1.3.1 Industrial Sources

The industrial source includes the noise from various industries and big machines working at a very high speed and high noise intensity. Although industrial noise is one of the less prevalent community noise problems, neighbors of noisy manufacturing plants can be disturbed by sources such as fans, motors, and compressors mounted on the outside of buildings. Interior noise can also be transmitted to the community through open windows and doors, and even through building walls. These interior noise sources have significant impacts on industrial workers, among whom noise-induced hearing loss is unfortunately common.

1.3.2 Non-industrial Sources

Non- industrial source of noise includes the noise created by transport/vehicular traffic and the neighborhood noise generated by various causes. Automobile revolution in urban centers has proved to be a big source of noise pollution. Increasing traffic has given rise to traffic jams in congested areas where the repeated hooting of horns by impatient drivers pierces the ears of all road users. Noise from airplanes constitutes an increasing serious problem in big cities. The automobile repair shops, construction-works, blasting, bulldozing, stone crushing etc. are other sources of noise pollution [Singal, 1992].

On the other hand, the sources of sound can be categorized as:

- Point source
- Line source
- Plane wave source

1.3.3 Point Sources

When the dimensions of a sound source are small as compared to distance to the receiver and it radiates an equal amount of energy in all directions is known as Point source. A side and top view of a point source is shown in Fig. 1.2. Some industrial plants, aircraft and individual road vehicle are typical point sources. The sound pressure level decreases 6 dB (A) whenever the distance to a point source is doubled.

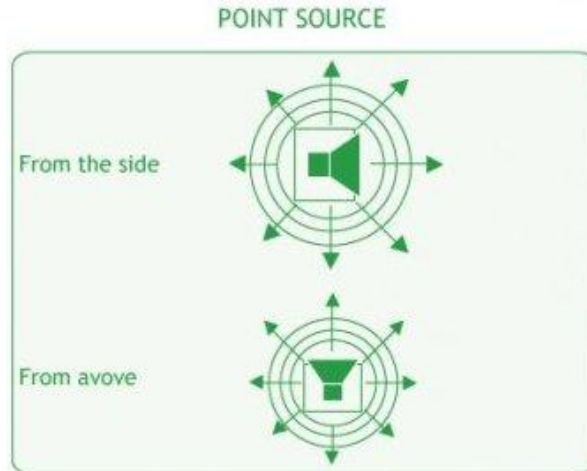


Figure 1.2: Point source of sound [W.4]

1.3.4 Line Source

When a large number of point sources are so closely spaced that their emission may be considered as line connecting them is known as line source of noise. A line source may be continuous radiation, such as pipe carrying fluid at high pressure. A side and top view of a line source is shown in Fig. 1.3. The sound pressure level decreases 3 dB (A), whenever the distance to a line source is doubled.

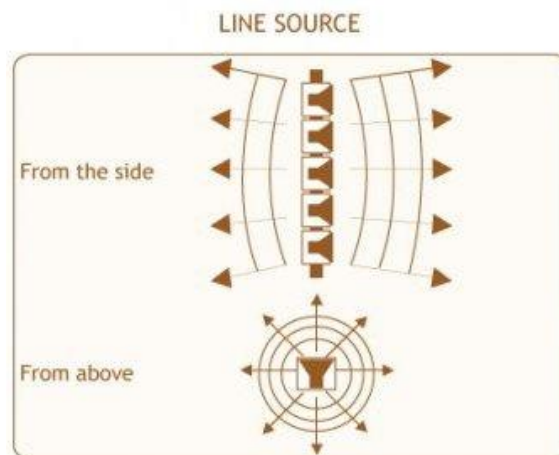


Figure 1.3: Line source of sound [W.4]

1.3.5 Plane Wave Source

An ideal plane wave source consists of a pulsating rigid surface that is infinitesimally thin and has infinite length and width. The surface radiates sound energy equally to its front and back directions. A plane wave source produces a plane wave, which (in the ideal case) does not exhibit geometric attenuation with increasing distance from the source. A side and top view of a plane wave source is shown in Fig. 1.4.

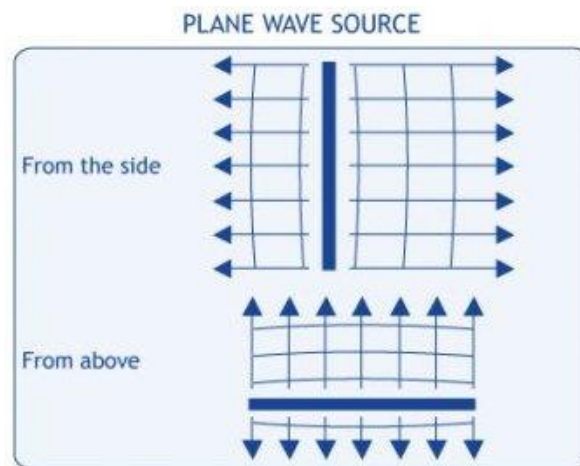


Figure 1.4: Plane wave source of sound [W.4]

1.4 Noise Measurement

For the planning of noise control measures or to judge the noise of a projected plant, starting point is the measurements of the noise. There are various reasons for carrying out noise measurements in industry. The most usual are:

1. Determination of noise levels to lead to permanent hearing damage. Further investigation should be done on equivalent sound pressure levels of over 85 dB (A) for an eight hour working day.
2. For obtaining the basis for noise control measures which can be applied to machines and equipment.
3. Determination of the sound radiation from single machines clearly e. g. to compare the measured values with values stated in a noise declaration.
4. To make sure that noise levels are not disturbing the residential areas.

A decibel is used as a standard for the measurement of noise which is measured on a logarithmic scale known as the decibel (dB) scale. The zero on a decibel scale is at the threshold of hearing, the lowest sound pressure that can be heard. A SPL change of 1 dB (A) can just be detected by the human ear. If a SPL is increased by 10 dB anywhere within the sort of hearing, the ear perceives it as a doubling its loudness. A drop of 10 dB is equally perceives as a halving in loudness. Generally, the noise of 20 dB (A) is whisper, 40 dB (A) the noise in a quiet office. 60 dB (A) is normal conversation, 80 dB (A) is the level at which sound becomes physically painful. A value of 140 dB is threshold of pain [Broach and Trampe, 1971]. Figure 1.5 is showing the noise level of various routine activities according to their loudness on a decibel scale.

The Noise quantum of some of the cities in our country indicate their pitch in decibel in the nosiest areas of corresponding cities, e.g. Delhi- 80 dB (A), Kolkata - 87, Bombay-85, Chennai-89 dB (A) etc.

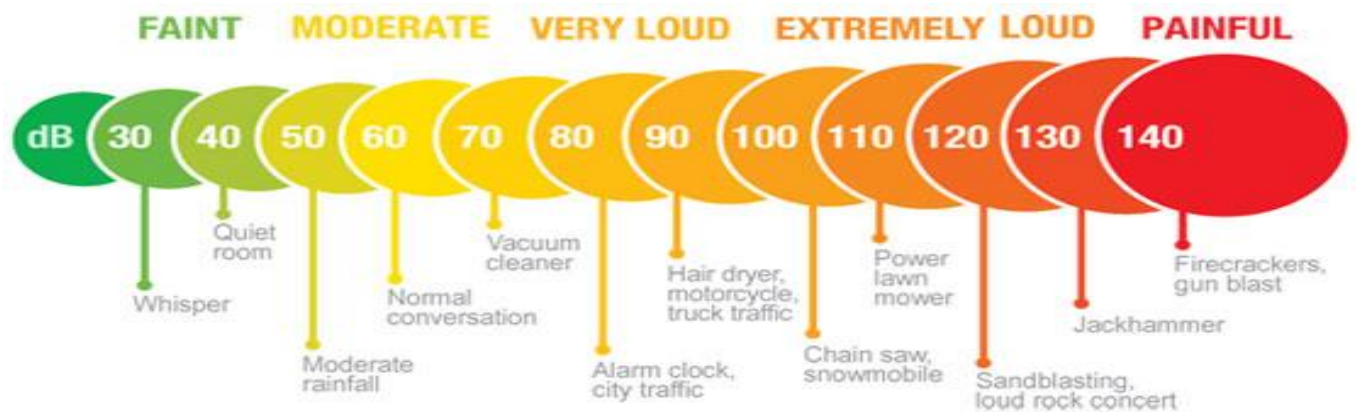


Figure 1.5 Decibel scale [W.5]

1.4.1 Measurement Techniques and Instrumentation

Sound pressure level (SPL) is the simplest physical measure of noise to be determined. It is measured on a logarithmic scale since the range of sound pressure that human listeners detect is very wide and logarithmic in character.

Sound pressure level L_p is defined as:

$$L_p = 20 \log_{10} P/P_o \quad (1.1)$$

P is the sound pressure measured and,

P_0 is the reference sound pressure i.e. 20 μPa (threshold of hearing).

There are several other criteria besides the sound pressure level to describe noise, which have to be taken into account. These are:

- i. Type of noise, i.e., whether it is variable, impulsive, continuous, repetitive or intermittent etc;
- ii. Spectral composition i.e. whether it is narrow band or complex mixture of many different frequencies;
- iii. Duration of sound; and
- iv. Time of the day.

Sound level meter (SLM) is the instrument that measures sound intensity or magnitude on a logarithmic scale in decibels. A SLM is designed to copy the human hearing as closely as is possible and practical, while giving an objective and repeatable value. A sound level meter during a measurement is shown in Fig. 1.6.



Figure 1.6: Sound level meter (with Wind screen) [W.3]

The basic parts of most SLM include a microphone, amplifiers, weighting networks, and a display indicating decibels. The microphone helps to convert the input acoustic signal into an electrical signal (usually voltage). This signal is exaggerated when it passes through an electronic pre amplifier. Modification of the amplified signal may then be done by the weighting network

to obtain the A-, Z-, or C-weighted signal. Digitization of this signal is takes place to drive the display meter, where the output is shown in decibels. The different type of display settings are “fast” response, “slow” response, “impact” response, or “peak” response. The “slow” response setting is usually used unless one is interested in measuring rapid noise fluctuations. To record or analyse the signal in an external instrument system an output jack may be provided.

Several items of auxiliary equipment are used with SLM includes a calibrator and a windscreen. For post-processing of data many SLM have output ports for making a connection with a PC. To calibrate the SLM, a calibrator is used which is portable, battery-operated instrument. For outdoor sound measurements, a windscreen should always be used. It is a spherical piece of open cell foam material that can be fitted over the microphone of the SLM. This is used to minimize the effect of wind turbulence over the microphone [Broach and Trampe, 1971].

(a) Frequency Weighting Networks

To different sound pressure level ranges a number of frequency weighting networks have been standardized, initially intended to be applied. These electronic filters are fitted within the instrument and used to adjust the method in which the instrument measures the noise. The most commonly used Frequency Weightings on a modern SLM are ‘A’, ‘C’ and ‘Z’. Figure 1.7 is showing the nature of frequency weighting curves on a frequency vs. attenuation graph.

- The shape of ‘A’ weighting filter approximates to the frequency sensitivity of the human ear and covers the full frequency range of 20 Hz to 20 kHz. A-weighted value of a noise source is an estimate to how the human ear perceives the noise. To show that the information is ‘A’ weighted decibels, measurements made using ‘A’ weighting are usually shown with dB (A).
- For the measurement of Peak SPL ‘C’ Weighting is a standard weighting audible frequencies which is commonly used. To show that the information is ‘C’ weighted decibels, measurements made using ‘C’ weighting are usually shown with dB (C).
- ‘Z’ weighting shows flat frequency response between 10Hz and 20 kHz ± 1.5 dB not including microphone response. To show that the information is ‘Z’ weighted decibels, measurements made using ‘Z’ weighting are usually shown with dB (Z).

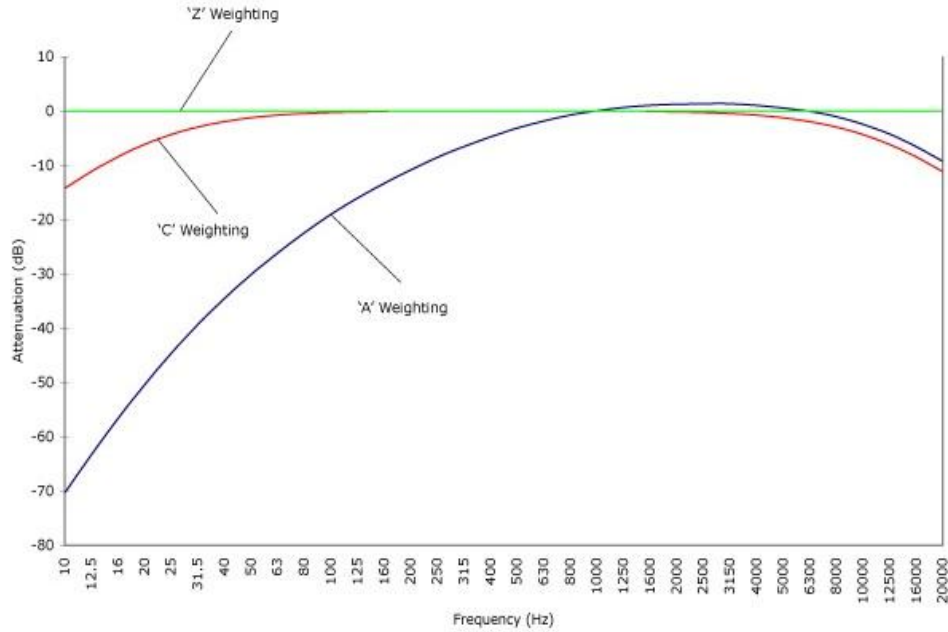


Figure 1.7: Frequency weighting curves [Barron, 2001]

(b) Time Weighting

The characteristics of the noise must be taken into account for choosing a suitable time weighting for the measurement. The level of a noise always varies to a greater or lesser extent. The display of the measuring instrument always has a certain time constant and cannot follow rapid sound level fluctuations, whether a traditional meter needle or digital display. In addition, the display of a SLM is consciously damped because the human eye cannot follow the rapid movement. There are generally three standardized time weightings or damping.

- For "S" time weighting, high damping giving a slow display movement; effective averaging time is approximately 1 s.
- For "F" time weighting, low damping giving a more rapid display movement; effective averaging time is approximately 0,125 s.
- For "I" time weighting, a very fast rising time constant and a very slow falling time constant is available. This time weighting intend to present a value that shows how loud the human ear courts a short duration sound, i.e. it is designed at annoyance rather than hearing damage risk.
- For "Peak" time weighting, in addition, there is a further possibility for measuring the actual peak SPL of a short duration sound. This is used to accurately record the peak

values of a sound whose duration may be as short as 50 micro-seconds. It is meant at hearing damage risk.

(c) Octave Band Filters

There is a different sound level at each frequency individually. Therefore to determine the composition of a sound it is necessary to determine the sound level at each frequency. These values are usually stated in octave bands. It is the frequency range in which the ratio of the upper to lower frequency limits for the range is equal to 2. These are generally added as a feature in SLM. Octave band (1/1) or (1/3) filters are generally used in fundamental acoustic engineering design and analysis work. The system characteristics that relate to the noise generation may be identified by observing the frequency band in which the maximum SPL occurs. [Naerum, 1986].

(d) Equivalent Sound Pressure Level (L_{eq})

The sound from noise sources regularly fluctuates widely during a given period of time. An average value can be measured as the equivalent SPL ($L_{Aeq,T}$). The $L_{Aeq,T}$ is the equivalent continuous sound level which would deliver the same sound energy as the actual A-weighted fluctuating sound measured in the same time period (T).

$$L_{eq} = 10 \log_{10} \left[\frac{1}{T} \int_0^T \left(\frac{P_{A(t)}}{P_o} \right)^2 dt \right] \quad (1.2)$$

where, $P_{A(t)}$ represents A-weighted sound pressure

T is the total time and

P_o is the reference pressure (20 μ Pa).

1.5 Noise Control

An excessive or disturbing noise may harm the activity or balance of human or animal life. There is a real danger of permanent hearing loss when a person is exposed to noise above a certain level. Therefore, the significance of noise control becomes ever more important for making the environment economically and operationally dependable. The acceptable noise environment may be essential for an individual, a group of people, an entire community or a piece of equipment that cannot work properly in extreme noise.

Basically a noise system has three components: source of noise, path of the noise, and the receiver. In many situations, of course, there are several sources of sound, various paths for the sound, and more than one receiver, but the basic principles of noise control would be the same as for the more simple case. Figure 1.8 is showing the transmission of noise and different components of noise system.

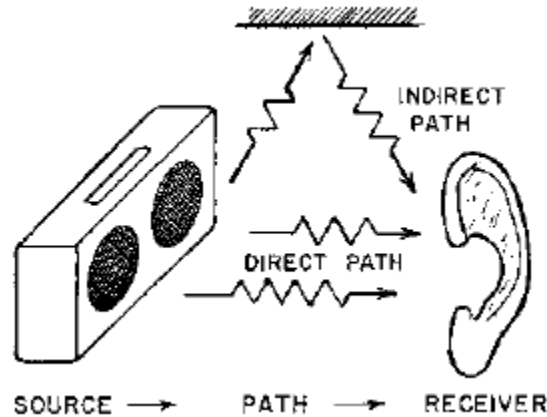


Figure 1.8: Transmission of noise [Barron, 2001]

The objective of most noise control programs is to reduce the noise at the receiver. This may be accomplished by making modifications to the source, the path, or the receiver, or to any combination of these elements. The path for the sound may be the air between the source and receiver, as is the case for machinery noise transmitted directly to the operator's ears. The path may also be indirect, such as sound being reflected by a wall to a person in the room.

Depending on the transmission medium, there are two types of sound, i.e. airborne and structure-borne. When the sound is transmitted through the air only, it is known as airborne sound. This can be easily detected by a human ear. Structure-borne sound is the one which spreads in solid bodies such as pipes, walls, heaters etc. It generates due to the vibration in the bodies. The structure-borne sound is transferred from the surface of the objects to airborne sound. For controlling such type of noise, it is very important to control the amplitude of vibration in a body.

1.5.1 Methods of Noise Control

Noise control is the strategy to reduce the impact of noise and make the environment reliable for work. There are three ways to control the noise:

- Noise reduction at source
- Noise control in the transmission path
- Noise control at the receiver end

(a) Noise Reduction at Source

The best place for noise control is at source i.e. stop the noise before it get started or generated. Noise at the source can be controlled by doing:

- some modification at the source of sound
- timely maintenance of the source
- damping of the vibrating surfaces
- the use of two units with the same combined capacity as one larger unit
- a change in the process of working

(b) Noise Control in Transmission Path

Modifying the path through which the noise is propagated is often used when modification of the noise source is not possible, not practical, or not economically feasible. Noise in the transmission path can be controlled by:

- moving the sound source farther away from the receiver, i.e. make the noise path longer
- installing the acoustic barriers
- using acoustic absorbing surfaces or applying acoustic absorbing material on the walls
- enclosing the sound source in an acoustic enclosure or enclose the receiver in a personnel booth
- using mufflers or silencers at the exhaust line of the device.

(c) Noise Control at the Receiver End

The human ear is the usual “receiver” for noise, and there is a limited amount of modification that can be done for the person’s ear. Some possible approaches to control the noise at receiver end are:

- to limit the time during which the person is exposed to high noise levels
- use of hearing protectors i.e. earplugs or acoustic muffs for preventing noise-induced hearing loss [Harris, 1991].

1.6 Basics of Acoustics

1.6.1 Frequency, Hertz:

The sound wave frequency expresses the number of vibrations per second in units of hertz, Hz. Sound exists over a wide frequency range. Audible sound for young people lies between 20 Hz to 20 kHz.

1.6.2 Amplitude:

The amplitude represents the strength of sound wave. Greater disturbance at the source leads to greater strength of wave and greater the amplitude.

1.6.3 Wavelength:

The wavelength of the sound wave is an important parameter in determining the behaviour of sound waves. The wavelength is the distance between successive peaks of the wave.

1.6.4 Infrasound and Ultrasound

Sound with frequencies under 20 Hz which is normally inaudible is called infrasound. Sound over 20000 Hz which is also normally inaudible is called ultrasound [Naerum, 1986].

1.6.5 Sound Power

When the sound is produced, transfer of energy takes place from the source to the surrounding air molecules. This rate of energy transfer is called Sound Power. The unit of sound power is Watt (W). The sound power level L_w of a source is given by:

$$L_w = 10 \log_{10} (W/W_0) \text{ dB} \quad (1.3)$$

where, W is the power of source in watts

and W_0 is the reference power in watts (10^{-12} W).

The range of audible sound power extends from 10^{-9} W to more than 1000 W. Sound power of 1000 W can create immediate hearing loss and 10^{-9} W is lowest level which can be heard.

1.6.6 Importance of Sound Power

Sound power is a basic measure of acoustic output for any source of noise. On the other hand, it is a fundamental physical property of the source alone, and is therefore an important absolute parameter which is widely used for rating and comparing sound sources. It does not depend on the environmental conditions and distance from the source at the same working conditions.

1.6.7 Frequency Analysis

Each sound wave contains different levels of frequency which varies with time. Various kinds of ear protectors and noise enclosures are efficient just at a range of frequencies. Therefore it is important to measure the frequency spectrum of the environmental noises. Graphic level recorders are used to plot frequency spectra on the charts. These graphs are useful in reducing the probability of errors. Frequency spectrum also helps in designing barriers or enclosures for a machine.

1.7 Background Noise

Background noise is the noise from unwanted sources. For measurements to be valid, it must be at least 10 dB below the level of the noise emitted by the source being considered. It is important to check the background noise before making measurements. However, if the difference between the source noises measured in the presence of background noise and the background noise alone lies between 3 and 10 dB (A), a correction may be made. Figure 1.9 shows the correction method for background noise. If this difference is less than 3 dB, the source noise level is less than the background noise level and a reliable value for the source noise alone cannot be obtained. If measurements are made in frequency bands, the background noise measured in each band should be at least 10 dB (A) lower than the source.

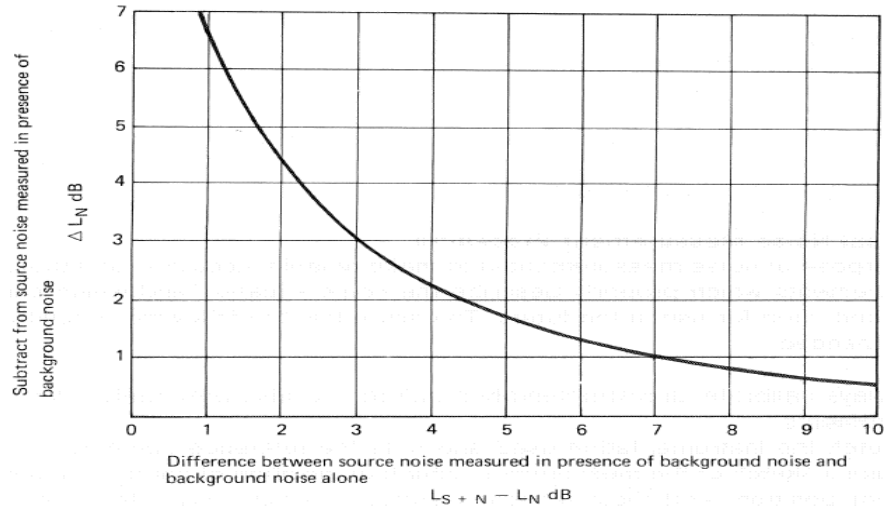


Figure 1.9: Correction of background noise [Broach and Trampe, 1971]

1.8 Addition of Noise from Several Source

A higher sound level is produced by the noise from different sound sources than from any individual source. The dB values are already algorithmic quantities so they cannot be directly added. Two equally strong sound sources together generate a sound level which is 3 dB (A) than one alone and ten sources produce a 10 dB (A) higher SPL. Figure 1.10 is showing the relation between difference of two sound levels and the value added to the higher level of noise.

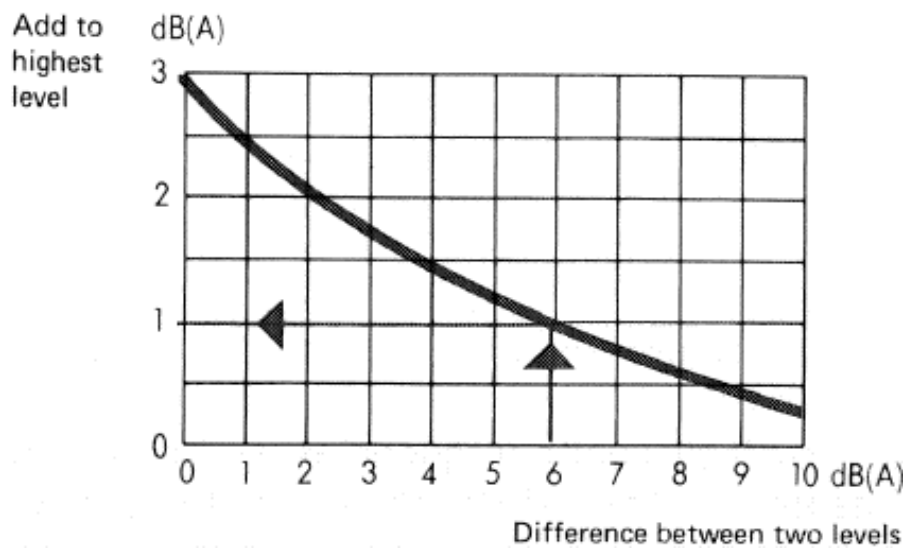


Figure 1.10: Addition of sound level [Naerum, 1971]

Chapter 2

Radial Drilling Machine Noise

2.1 Introduction to Radial Drilling Machine

Radial Drilling machine (RDM) is a machine fitted with a rotating cutting tool called drill bit. This radial drilling machine is used for drilling holes in various materials such as steel, cast iron and alloys. The use of machine is in the metal working industry. A RDM is a large gear headed drill press in which the head moves along the arm that radiates from the column of the machine. The arm of the machine can swing in relation to the base of the machine. This swing operation helps the drill head to move out of the way so a large crane can place the heavy work piece on the base of the radial drilling machine. Also this helps in drilling holes at different locations of the work piece without actually moving the work piece. Power feed of the spindle is a common feature. Also coolant system is a common feature of the radial drilling machine. When it comes to mechanical machining, radial drilling machine is used for all functions such as drilling, counter boring, spot facing, lapping, screwing reaming, tapping and boring. Radial drilling machines work well with a variety of materials such as cast iron, steel, plastic etc. Drilling machines hold a certain diameter of drill (called a chuck) rotates at a specified rpm (revolutions per minute) allowing the drill to start a hole.

A RDM or radial arm press is a geared drill head that is mounted on an arm assembly that can be moved around to the extent of its arm reach. The most important components are the arm, column, and the drill head. The drill head of the RDM can be moved, adjusted in height, and rotated. Aside from its compact design, the radial drill press is capable of positioning its drill head to the work piece through this radial arm mechanism. This is probably one of the reasons why more machinists prefer using this type of drilling machine. In fact, the RDM is considered the most versatile type of drill press. The tasks that a RDM can do include boring holes, counter sinking, and grinding of small particles in masonry works. Although some drill presses are floor mounted, the most common set-up of radial arm drill presses are those that are mounted on work benches or Tables. With this kind of set-up, it is easier to mount the drill and the work pieces. There is no need to reposition work pieces because the arm can extend as far as

its length could allow. Moreover, it is easier to maneuver large work pieces with the radial arm drilling machine. Large work pieces can be mounted on the Table by cranes as the arm can be swiveled out of the way [Jindal, 2011].

2.1.1 Components of Radial Drilling Machine

Some of the major parts of the radial drilling machine are shown in Fig. 2.1 and explained below.

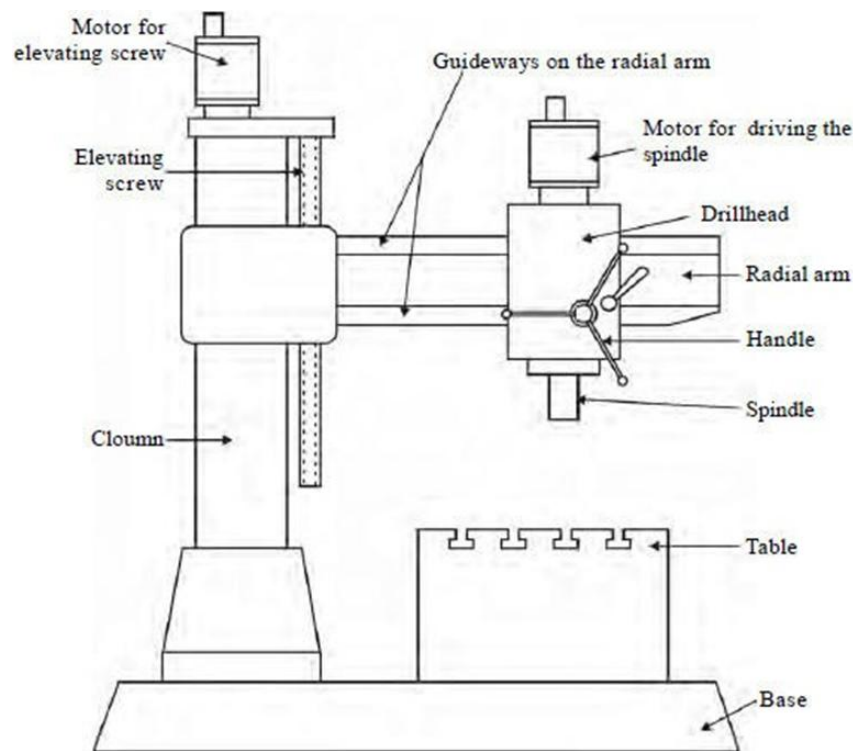


Figure 2.1: Schematic of Radial Drilling Machine [Rathi, 2014]

Base- The base of the drilling machine supports the entire machine and when bolted to the floor, provides for vibration-free operation and best machining accuracy. The top of the base is similar to the work table and may be equipped with t-slot for mounting work too large for the table.

Column- The column is cylindrical in shape and built rugged and solid. The column

supports the head and the sleeve or quill assembly.

Drill Head- The head of the drilling machine is composed of the sleeve, a spindle, an electric motor and feed mechanism.

Radial Arm- Holds and supports the drill head assembly and can be moved around on the extent of its length

Spindle- The spindle holds the drill or cutting tools and revolves in a fixed position in a sleeve.

Sleeve- The sleeve or quill assembly does not revolve but may slide in its bearing in a direction parallel to its axis. When the sleeve carrying the spindle with a cutting tool is lowered, the cutting tool is fed into the work: and when it's moved upward, the cutting tool is withdrawn from the work. Feed pressure applied to the sleeve by hand or power causes the revolving drill to cut its way into the work a fraction of an mm per revolution.

Worktable- The work table is supported on an arm mounted to the column. The work table can be adjusted vertically to accommodate different heights of work or it can be swung completely out of the way. It may be tilted up to 90 degree in either direction, to allow long pieces to be enduringly drilled.

2.1.2 Kinematic System of General Purpose Drilling Machine

Kinematic system in any machine tool is comprised of chain(s) of several mechanisms to enable transform and transmit motion(s) from the power source(s) to the cutting tool and the work piece for the desired machining action. The kinematic structure varies from machine tool to machine tool requiring different type and number of tool-work motions.

- **Cutting motion-** The cutting motion in drilling machines is attained by rotating the drill at different rotating speeds. Like centre lathes, milling machines etc, drilling machines also need to have a reasonably large number of spindle speeds to cover the useful ranges of work material, tool material, drill diameter, machining and machine tool conditions. It is shown that the drill gets its rotary motion from the motor through the speed gear box (SGB) and a pair of bevel gears. For the same motor speed, the drill speed can be changed by shifting the cluster gears in the SGB. The direction of rotation of the drill can be changed, if needed, by operating the clutch in the speed reversal mechanism.

- **Feed motion**-In drilling machines, generally both the cutting motion and feed motion are imparted to the drill. Like cutting velocity or speed, the feed (rate) also needs varying (with in a range) depending upon the tool-work materials and other conditions and requirements. The drill receives its feed motion from the output shaft of the SGB through the feed gear box (FGB), and the clutch. The feed rate can be changed by shifting the gears. And the automatic feed direction can be reversed, when required, by operating the speed reversal mechanism. The slow rotation of the pinion causes the axial motion of the drill by moving the rack provided on the quill. The upper position of the spindle is reduced in diameter and splined to allow its passing through the gear without hampering transmission of its rotation.

- **Tool-work mounting**-The taper shank drills are fitted in to the taper hole of the spindle either directly or through taper socket(s).Small straight shank drills are fitted through a drill chuck having taper shank. The workpiece is kept rigidly fixed on the bed (of the Table).Small jobs are generally held in vice and large or odd shaped jobs are directly mounted on the bed by clamping tools using the T-slots made in the top and side surfaces of the bed [Jindal, 2011].

2.1.3 General Purpose Drills

Drills can be categorized based on their different type of material, size, shape of shank, number of flutes and their specific applications.

According to Material of Drill

- High speed steel– most commonly used
- Cemented carbides
 - Without or with coating
 - In the form of brazed, clamped or solid

According to shank

- Straight shank– small size drill being held in drill chuck
- Taper shank- medium to large size drills being fitted into the spindle nose directly or through taper sockets.

According to number of flutes

- Two fluted – most commonly used

- Single flute – e.g., gun drill(robust)
- Three or four flutes–called slot drill

According to Size

- Micro drills of diameter 25 to 500 mm.
- Medium range (most widely used) diameter ranges between 3 mm to 25mm.
- Large twist drills of diameter around 40 mm.

According to specific applications

- Centre drills-for small axial hole with 60° taper end to accommodate lathe centre for support.

2.2 Source of Noise in Radial Drilling Machine

For the desired machining action, various kinematic systems work for transferring the motion and power from one part of machine to the other part. The completion of the effective work cycle depends on the different parts of machine i.e. electric motor, gear box, bearings etc. which produces sound during the operation. This is unwanted sound which has significant impact on industrial workers, among whom noise- induced hearing loss is unfortunately common. It decreases the efficiency of a worker.

2.2.1 Noise of Electric Motor

In the radial drilling machine, an electric motor mounted on the drill head used for driving the spindle is the major source of the noise. The electric motor noise may be generated by:

- 1) the periodic motion of its parts under the action of periodic forces,
- 2) the periodic interruption of the flow of cooling air, or
- 3) the excitation of the natural frequencies of components of the motor by magnetic forces.

Structureborne vibration may be transmitted through the motor mounting system directly to the substructure on which it rests. Airborne sound may be radiated directly to the surrounding air at the surfaces of the motor parts.

A considerable amount of noise is generated in an electric motor because of the following reasons:

- Dissymmetries, nonuniformities, eccentricities and nonlinearities in the manufacturing practice.

- Mechanical imbalance of the rotor.
- Improper lubrication and presence of irregularities, dirt and cracks on the surface of bearings.
- Rubbing and sliding between the carbon brushes and the metal surfaces.
- Flow of air through and out of an induction motor for ventilation.

2.2.2 Noise of Gear Box

There is a need of a large number of spindle speeds and different feeds to cover the useful ranges of work material, tool material, drill diameter, machining and machine tool conditions. For attaining the different spindle speeds and feeds, different type of gears are used in radial drilling machine. A speed gear box (SGB) is used to transfer motion to drill from the motor, which composed of a pair of bevel gears. The feed motion is provided to the drill from the output shaft of SGB through a feed gear box (FGB).

The noise generation process from a gearbox is consisting of three parts: excitation, transmission, and radiation. The origin of the noise is the gear mesh, in which vibrations are created (excitation), mainly due to transmission error. The vibrations are transmitted via the gears, shafts, and bearings to the housing (transmission). The housing vibrates, creating pressure variations in the surrounding air that are perceived as noise (radiation). Gear noise can be affected by changing any one of these three mechanisms.

Transmission error is caused by deflections, geometric errors, and geometric modifications. The other reasons are gear rattle from gears running against each other without load and noise generated by bearings. In the case of automatic gearboxes, noise can also be generated by internal oil pumps and by clutches [Harris, 1991].

2.2.3 Noise of Bearings

Bearings are used to allow linear and rotational movement between two machine members while transmitting load from one member to another. In a radial drilling machine, bearings are mainly used in gearbox, electric motor and in other rotational parts like sleeve and spindle head. Noise produced by bearings is usually caused by:

- Imperfect rolling surfaces

- Surface damage and distortion
- Unstable cage motion
- Improper lubrication
- Alignment and loading conditions
- Operational conditions

2.2.4 Noise of Drilling Operation

Drilling is a cutting process that uses a drill bit to cut or enlarge a hole in solid materials. When the drill bit comes in contact with the work piece during the drilling operation, it exerts some force to initiate the cut. Due to the friction between drill bit and the work piece, some noise and heat is produced. To prevent the heat, lubrication is used at the point of cutting but it is difficult to prevent the noise during the operation. One of the major sources of noise generation in drilling is the vibration of the drill bit. It also affects the surface finish and material removal rate of the work piece. Therefore, these factors of noise get added with the other factors and increase the sound level of the radial drilling machine.

Chapter 3

Literature Review

3.1 Introduction

Since last decades, a large work has been done in the area of noise measurement and reduction. But this topic is still the area of vast research which can be helpful to prevent the increasing noise pollution. The technological advancement of today's world is the major cause of noise pollution which become a hazard for the people. Therefore it is important to pay greater attention towards measuring noise pollution so that it can be controlled and eliminated. This chapter covers the extensive literature review of research work which has been done by different researchers on the different aspects of noise pollution in the past.

3.2 Literature Review

3.2.1 Noise Pollution: Sources and Effects

Berglund et al. (1996) studied the sources and effects of low frequency noise. In urban environment, low frequency noise is common as background noise. It is emitted from many artificial sources i.e. road vehicles, industrial machinery, aircrafts, mining explosion, compressors, turbines and other air conditioning units. Some natural origin low frequency noise sources are air turbulence, ocean waves, thunder, earthquakes and volcanic eruptions. Noise below 100 Hz is considered as low frequency noise. It is a factor of critical importance to the health. The attenuation of low frequency noise is difficult as compared to other noises. Respiratory impairment and aural pain can be produced by intense low frequency noise. Loudness judgment annoyance reactions are sometimes greater for low frequency noise. Low frequency noise can possibly provide some protection against the effects of simultaneous higher noise on hearing.

Levitt (2001) provided a brief overview of the issues involved and the various approaches for noise reduction in hearing aids. For the people with hearing loss, background noise is damaging to speech intelligibility. This is the problem of great difficulty and importance. Different techniques are ranges from relatively simpler forms of filtering to advanced signal processing methods. For the person with hearing loss, the redundancy is less in speech signal.

Hearing aids reduce the effects of noise and allow some degree of signal processing. Substantial room reverberation, a second interfering voice and a random noise, an similar intensity frequency spectra are the three types of noise that are damaging to speech intelligibility. Critical bands of hearing and low dynamic range of hearing are the main factors of noise reduction.

Xie et al. (2009) studied the impact of noise on sleep of patients and the effectiveness of noise reduction strategies in ICUs. The aim of this paper was to answer the following questions: is noise the most disruptive factor to sleep for patients or is noise only responsible for small percentage of the sleep disruption, what is the most disturbing noise source for sleep from patient's point of view, how effective are the noise reduction strategies to decrease the sleep disturbance in ICUs. After the study, it is concluded that the noise is only one of the factors that disturb the sleep of patients in ICUs. Generally, the most disturbing noises are staff conversation and alarms. Earplugs, behavioral modification, sound masking and acoustic absorption are the four interventions for sleep improvement.

3.2.2 Industrial and Vehicle Noise

Talukdar (2001) studied the sources, effects and controlling measures of the noise produced in textile industries. The high noise level produced in the industries cause psychological and physical damage including loss of concentration, irritability, increase in pulse rate and anxiety. A large number of workers of textile industries especially weavers suffer from occupational hearing loss. The noise above 80 dB (A) produces physiological effect. A permanent damage can occur by a long exposure at above 90-100 dB (A). An increase in the 10 dB (A) doubled the loudness with respect to human ear. In a textile industry, the noise level of spinning department was between 80 to 90 dB (A). An excessive noise of 94-99 dB (A) was generated in loom shed. The highest noise level was found in the front of machine. Different active and passive methods of noise and vibration control are used in textile industries. The active measures include the reduction in inertia forces of the machines and active noise control method. Passive measures include the blocking and absorption of airborne sound and damping techniques. Wide weaving machines also helped in reducing noise level.

Kanaksabai et al. (2005) conducted a study of noise level in Chennai central railway junction of southern railway. The observations of sound level were recorded at important platforms, near waiting rooms and driver's rest room. Equivalent continuous sound level was measured on different days. After the study it was concluded that during arrival and departure of trains at the platform, noise level increased by 27 dB (A) from normal level. The range of sound level was found to be 52 to 56 dB (A) near the waiting hall and 52 to 57 dB (A) in important platforms and driver's rest room. Therefore, to reduce the insidenoise level the rooms may have to be made sound proof or located at low noise levels.

Marathe (2012) conducted a road traffic noise survey on Gwalior city roads. The four areas selected for the study were commercial, industrial, completely residential and residential. Noise pollution level, equivalent sound level and traffic noise index were evaluated in the survey. Increasing traffic population increases the environmental problems. Noise pollution has detrimental effects on human beings. So it is important to pay great attention towards measuring noise pollution and eliminate and control it. The survey revealed that traffic flow speed, tire-road surface interaction, road surface condition and various parts of vehicles generating noise are the factors influence the traffic noise. It was concluded that the noise level exceeds the acceptable limits at all four sites. Traffic noise parameters increased with increase in traffic volume. Road dividers with shrubs and road side trees reduce the noise level considerably.

Jayawardana et al. (2014) conducted a study to analyze and control the noise in a textile factory. In some textile industries, the maximum noise level of the machines ia as high as 95 dB. An increase in cumulative noise level is caused by locating many machines in a single room. This research analyzed the distribution and quality of noise inside the industry. For predicting the noise distributing pattern, a mathematical model was developed and validated with the noise data gathered. For the noise control, a typical covering plant was selected and noise level of that plant was measured. A noise propagation pattern was developed. The noise level inside the plant was found well above the noise exposure action level. For noise control, an economically viable acoustic ceiling was designed.

3.2.3 Drilling and Machinery Noise in Mining

Visnapuu and Jensen (1975) experimentally modified a standard pneumatic rock drill to reduce the noise level. It was observed that the pneumatic rock drill emit the highest sound level, a range of 104 to 118 dB (A). The drilling noise is caused by three major noise sources: exhaust, drilling machinery noise and drill steel resonance. For preventing the exhaust noise, a close fitting case and muffler were fitted around the drill body which consists of viscoelastic absorber filled metallic honeycomb skeleton on the inside and a durable outer shell. A constrained layer treatment was done which consist of a tubular metal cover bonded to the outside of the rod by viscoelastic filler. These modifications reduce the drilling noise level from 115 dB (A) to 97 dB (A) in granite.

Burger et al. (2004) developed a low noise blast hole drilling system to limit the risk of NIHL in mining operations. In mining operations, NIHL has been identified as a major occupational health risk. The main required specification was noise level below 90 dB (A). Other design considerations were operation, setting up and ease of manual transport. A standard Seco S215 pneumatic drill was encapsulated in a composite material tube. With the help of a pneumatic cylinder, the tube was pushed onto the rock face and sealed there by elastic seal. A rope and pulley mechanism fitted inside tube pulled the drill towards the rock face. A second cylinder powered this mechanism. Two cam locks support the drill and the exhaust of drill was removed from encapsulated tubes via an exhaust tube at the end of stope so that air and noise pollution were disposed off away from personnel. This design offered enhanced robustness and reduction of cost of system. The operator could be relieved from supporting a vibrating machine due to its self thrusting features.

Vardhan et al. (2006) investigated the noise generation characteristics of heavy earth moving machinery as influenced by periodic maintenance. Heavy earth moving machinery has been identified as a major source of noise in mines. All the noise measurements were carried out in a large open pit coal mine. A-weighted one-third octave band SPL of ten dumpers and three dozers was measured and the effect of maintenance on noise production was analyzed. The measurements were carried out at the end of 300, 500, 700 and 1000 hours of use. The major noise generating systems were identified as exhaust, air system, fuel and cooling system. The study revealed that a large increase in sound level occurred between 750 and 1000 hours of use. After the 1000 hours maintenance schedule, the sound level reduced

about 6-7 dB for dampers and 4-5 dB for dozers. However, maintenance of the transmission, lubricant and hydraulic system bear no significant reduction in sound level.

Harper and O'Brien (2006) developed a methodology for noise elements provide a model for the prediction of composite SPL and equivalent noise exposure levels of groups of individuals from machines which were singly used. The SPL of underground environment was predicted based on the SPL of free field conditions. Considerations of the effect of hearing protection devices and use of multiple machines in combination were also included in methodology. It also indicated the potential cost of hearing compensation. Data was obtained for free field conditions and with the help of a spreadsheet based model, anticipated SPL for underground environment was analyzed. With the help of this distribution, probability and cost of NIHL compensations were predicted. It was found that simple muff type ear protection is sufficient for high drill rates.

Peterson et al. (2006) conducted a study of the SP of a roof bolter for reducing the noise exposure to roof bolter operators. The performance and SP emission of drilling the granite were determined under various drilling configurations. Various combinations of rotating speed and thrust, 25.4 mm. and 34.9 mm. diameter round and hexagonal drill steels, wet and vacuum conditions and drill media of different compressive strength were included in the test conditions. The experimental results revealed that the SP emission reduced in the case of drilling in water. For wet drilling conditions, hexagonal drill resulted lower SP emission than round drill steel and the reverse was true for vacuum drilling. Water also increased the performance of drilling. The drill bits of 25.4 mm. performed better than 34.9 mm. Drilling performance also increased by increase in thrust but higher rotation speeds gave reverse results.

Vardhan et al. (2009) experimentally investigated the estimation of rock properties like compressive strength and abrasivity during drilling using SPL. This study can help to select the suitable explosives and designing blast hole patterns for mining. A small portable pneumatic drill was used for the investigation on a laboratory scale. By varying the thrust and air pressure values, corresponding L_{eq} was measured. Five different rock samples i.e. gabbros, granite, limestone, hematite and shale were analyzed. After performing the experiment following were the conclusions:

- Sound level of 2.5 to 20 kHz was due to resonance of the steel parts of the drill steel.
- Increase in thrust increased the sound level at higher mid band frequencies in the noise spectrum.
- Sound level near the drill rod was higher than near the exhaust.
- Increase in sound level near drill rod was due to the vibrations produced while drilling the rocks of high compressive strength.
- Both the thrust and air pressure had a significant effect on the sound level.
- For an optimum penetration rate, higher air pressure and thrust to be applied.
- Increased compressive strength and lower abrasivity of rocks was resulted in higher sound level at operator's position.

Camargo et al. (2010) presented an acoustic assessment of pneumatic and electric jackleg drill used in a mining industry. This study involved noise source identification, operator's cumulative noise dose measurement, penetration rate measurements and the determination of SP levels. For the electric drill, one noise source was located at the drill and second source was located drill steel-rock interaction. For the pneumatic drill, one noise source was found, located at the drill. The SPL measurements found were 115.3 dB (A) for electric drill and 123.4 dB (A) for the pneumatic drill while drilling into granite. Electric drill had slower penetration rate than pneumatic drill. But the acoustic performance of electric drill overcame the benefits of traditional pneumatic drills.

Peterson et al. (2010) developed a damped drill steel to reduce roof bolting machine drilling noise. The research supported the objective of reducing NIHL. According to a field study, an average drilling noise is the loudest sound level to which a roof bolting machine operator would be exposed. Amongst the various noise generation factors, drill steel vibration proved to be the most severe. It was investigated that the vibration could be reduced by vibration damping material used with a constraining layer to encapsulate a drill steel and reduce noise vibrations. This damped drill steel reduced the overall SPL by 4.3 dB at the location of the operator.

Gupta et al. (2012) studied and monitored the environmental noise and operator noise dose generated by jack hammer drilling in the seven granite quarries. The ambient noise was monitored at the different distances and directions from the source. The safe zone limit for

each quarry was determined by the correlation study between distance and noise levels. For determining the combined influence of compressive strength, rock density and distance, a multiple analysis of data was conducted and a model for the prediction of noise levels was developed. The maximum noise level was found in the downwind direction. Noise level exceeded the prescribed limits at most of the locations in quarries and the safe zone limit was found 30 m. for each quarry. The higher noise dose was the consequence of rock properties, geology, hilly terrain adjacent to the drilling point. This can be minimized by the use of protective devices like ear plugs or ear muffs and by periodic maintenance of jack hammers.

3.2.4 Vibration Analysis of Radial Drilling Machine

Rao, G. et al. (2013) analyzed the passive damping technique using composite structures as a substitute for the base of the work piece on the radial drilling machine tool bed. Different number of layers of composite structure was used and signal and RMS amplitude, frequency and time period of vibrations were recorded. Experiments were also conducted without using any composite material below the work piece. It was observed that effective damping was obtained only by proper fixation of composites to the bed and work piece. Vibration amplitude increased abruptly with increase in number of layers of composites. The density of matrix phase also played an important role in damping the vibrations. Lower the matrix phase density more was the damping ability.

Shukla and Lodwal (2013) experimentally analyzed the vibration of a radial drilling machine with the help of piezoelectric sensors. For holding the sensor on the place either a permanent bolt, portable magnet or adhesives were used. Piezoelectric sensors used to measure the vibration of the radial drilling machine and give an output in the form of voltage or current proportional to vibration. Some vibrations are generated by the rotating parts of the machines at the specific frequencies. Vibration analysis is an important tool for identifying, predicting and preventing the failure in rotating machines. Experiment was conducted with feed rate of 0.045 mm/rev. and 10 mm. depth of cut. This study revealed that the intensity of vibration varies point to point. In this work, for speed of 660 rpm and drill of 12 mm. on mild steel work piece, vibrations was minimum at the base due to damping and decreased at spindle and job. The maximum vibration was at casing due to minimum deflection.

Ladha et al. (2013) measured the vibration on a radial drilling machine and compare the vibration signals between different materials. For the collection of data of vibration intensity, piezoelectric sensors were used and the visual basic based programme was used for developing the interface and data acquisition. The data was produced in time-amplitude domain while drilling operation. Three type of materials i.e. wood, aluminium and mild steel were used with two different diameter drills i.e. 5 mm. and 7.5 mm. Depth of cut (5mm.), speed(260rpm) and feed rate (0.0256mm/rev.) were remained constant throughout the experiment. The study revealed that vibration intensity varied from material to material. It was maximum for mild steel because it has more hardness, intermediate for aluminium and minimum for wood because it is very soft material.

Mohan, S. et al. (2014) analyzed and improved the surface finish during drilling operation on a radial drilling machine by controlling the unwanted vibrations in machine tool structure using composite materials. These unwanted vibrations results in unpleasant noise, shorter tool life and degraded quality on machined parts. Different thickness composite plates were used to arrest the unwanted vibrations as a base of work piece. Mild steel was used as a work piece and glass fibre epoxy and glass fibre polyester plates were used as composite material. A digital phosphor storage oscilloscope of Tektronix 1000 series was used to record the vibration amplitude. Surface roughness of machined mild steel work piece was measured by surface roughness tester machine. It was observed that with increase in number of composite layers, the vibrations were decreased considerably at an optimum level resulting in decrease in surface roughness. After comparison of two composites, it was found that glass fibre epoxy material can be used for better results. Use of composite layers reduced the surface value by 40%. Composite materials can be used as machine tool bed.

3.2.5 Gearbox Noise

Oswald et al. (1994) tested the spur and helical gears in NASA gear noise rig and compare the noise produced by different gear designs. SP measurements were taken just above the top surface of the gearbox under controlled conditions. Four spur and five helical gears were designed as nearly identical as possible. The deliberate difference was in the tooth geometry and contact ratio. During the test program a very large amount of data was collected and concluded that:

- Total control ratio is the most significant factor for the noise reduction. Increase in either the profile or face contact ratio reduce the gear noise.
- The non-involute tooth spur gears produced 3-4 dB much noise than conventional involute counterparts.
- An average noise reduction of 2 dB was obtained by high contact ratio spur gears.
- The double helical gears produced 4 dB higher noises than single helical gear.

Tuma (2009) reviewed the procedures and practical techniques employed to quieter gear boxes and transmission units. It was proved that the gear box noise problem should be solved at the very source by introducing an enclosure as a means to reduce the radiated noise. This article also reviewed the progress in the technique of gear angular vibration analysis and their effect on gear noise due to self excited vibrations. The experiment was performed on a truck gear box. The results show that a gear box enclosure is the best protection against noise. A gear box requires a sufficiently rigid housing, gear, shaft and tooth surface modification for design load. Gears finished by grinding are needed.

Ognjanovic and Kostic (2012) studied the effect of gear unit housing on the noise generation caused by gear teeth impacts. The gear unit housing has an important role in the transformation of disturbance power and modulation of sound emitted to surroundings. In this article, the process of spreading disturbance power through elastic structure and especially the role of gear unit housing was explained. The gear noise consist of three sub processes i.e. disturbance power generation by the components of gear unit, disturbance spreading through the structure and emission of disturbance power through vibrations and noise of gear unit. After performing an experiment on gear unit, it was found that gear unit housing has a dominant effect on level and frequency content of the emitted noise of gear unit. The noise emitted by gear unit was because of the disturbing energy absorbed during the operation of the machine parts.

3.2.6 Bearing Noise

Nagamatsu and Fakuda (1978) measured the noise generated from ball bearings rotating vertically at the high speeds and analyzed the nature of sound under many kinds of supports of the outer races of bearing. The ball bearings are used in various types of machines because of their capability to support heavy load. In this research two types of bearings with different

diameter were adopted. These bearing were rotated high speeds till 900 rpm. Five types of support material used were steel, silicon rubber, epoxy plastic, vibration proof metal and shrunk ring. Experimental study revealed that the SPL was higher in soft support than in hard support with high rotating speed and it became reverse at low speed. Vibration proof metal also reduced the sound level.

Tendon and Chaudhury (1999) presented a review of vibration and acoustic measurement methods which helps in detection of defects in rolling element bearings. Both noise and vibration of the bearings were studied with respect to different working conditions. Vibration response due to localized defects and distributed defects was studied with the help of time and frequency domain along with signal processing technique. Sound pressure, intensity and emission have also been studied. From a review of studies, it was found that vibration measurement methods are emphasized. More work has been done on the localized defects study. For the detection of defect location, frequency domain vibration measurement has been used mostly. High frequency resonance technique is the most popular, but the advanced damage is difficult to determine by this method.

Rho et al. (2004) investigated the effects of the design parameters on the noise of rotor bearing system. Journal bearings were used with oil lubrication. The different factors taken for the study were effect of radial clearance, lubricant viscosity, width of bearing and mass eccentricity of the rotor. A-weighted sound level of bearings was measured for different speeds of the rotor. The results revealed that high viscosity of lubricant slightly decreased the noise of the bearing but at high speed its effect was relatively low. It was found that noise decreases lubricant viscosity increased, mass eccentricity of rotor decreased, width of bearing increased and radial clearance decreased. These results could aid to design an oil lubricated journal bearing with low noise rotor bearing system.

Ban et al. (2007) numerically investigated the nature of sound in roller bearings which were operated under radial load. It was assumed that roller bearings were infinitely long, acoustic energy losses were neglected and noise produced by pressure fluctuations of oil film was taken as line source. Improper installation, manufacturing inaccuracy, supported load and operating speeds were some factors which influence the noise generated by rolling element bearings. Radial clearance of bearing, number of rollers and viscosity of lubricant were taken as study factors. The study revealed that with the increase in inner race speed and rotational

speed the sound level increased. But sound level decreased as the rotational speed increased for a high load. With increase in number of rollers sound level decreased at low rpm. However, sound level increased with number of rollers and increase in radial clearance but decrease with decrease in lubricant viscosity.

3.2.7 Electric Motor Noise

Iorgulescu (2010) analyzed the electric motor noise for obtaining the fault detection information. Noise spectra of a healthy motor and a faulty motor were observed. The high frequency spectral analysis was used to detect faults. Different noise sources and quality of noise were analyzed for noise diagnostic. A single phase and a three phase induction motors were used for experiment. Fast Fourier transformation technique was used to evaluate the motor conditions and verified by the experimental results. The experimental results showed that broken bars in the single phase motor and bad bearings in the three phase motor were the faults analyzed.

Hillhouse (2010) discussed the basic knowledge of sound level for an electric motor application. Nature, interpretation and measurement of the sound data were explored in this research. Reliable acquisition of sound data with proper equipment and procedure were also reviewed. Various causes and method of mitigation of electric motor sound were discussed simultaneously. In the present arrangement, the motor was placed on a reflective plane such as concrete floor and walls and ceiling were covered with sound absorbing material. Three types of microphones were used i.e. free field, random incidence and pressure. Free field microphones interpret the sound in field measurements whereas random incidence pressure microphones were used in highly reverberant and semi-anechoic measurements respectively. Every microphone must be calibrated before use. Different type of data acquisition systems with an analysis software are available. The main sources for industrial motors noise are magnetic forces, mechanical contact and windage. Proper electric design and venting and replacing and replacing or repairing of damaged components reduced the effect of these sources.

3.2.8 Taguchi Design

Tyagi et al. (2012) reported a study of drilling machining of mild steel on a CNC drill machine with the help of a high speed steel tool. The taguchi method was applied to

formulate the experiment layout. This study focused on a good surface finish and high material removal rate by selecting the optimal machining parameters i.e. depth of cut, spindle speed and feed rate. A L9 orthogonal array was generated and experiment was conducted using machining centre. It was found that surface finish mainly affected by spindle speed and material removal rate largely affected by the feed rate of drilling machine.

Chapter 4

Problem Formulation

This chapter includes the gaps found in the literature survey and formulation of the problem objective for the present thesis work.

4.1 Gaps in Literature

From the literature review presented in the previous chapter, it is seen that a lot of work has been done by researchers in the area of noise measurement and control. Noise measurement has been done in different fields like industries, road traffic, automobiles, hospitals, and in mining operations. The sources, causes and the effect of noise on the human beings have also been studied at large scale. In the mining industries, a lot of work has been done on the noise of drilling and heavy earth moving machinery. But the noise induced hearing loss is a very serious problem in the mining work which can be studied further to prevent the hearing loss of workers. The rock mass properties can also be investigated with the help of drilling noise. In the industrial machinery, noise of gearboxes, bearings and electric motors is the major source of noise pollution. A considerable work has been carried out in the area of vibration analysis of a RDM. But very limited literature for noise analysis of the RDM has been recorded.

4.2 Objective of the Study

Based on the literature gaps mentioned above and problem of increasing noise pollution, an objective is drawn for the present thesis work. The aim of the study is to analyze the Sound pressure level of a radial drilling machine placed in the workshop. This noise causes problem for the people working around. Noise produced during drilling operation for different materials need to be studied.

Chapter 5

Experimental Methodology

Noise measurement and reduction has become the need of the today's world. Noise pollution of the machines in the work places is a serious problem for the surrounding. Therefore it has to be measured and controlled for making the working conditions safe. This can be done by using appropriate materials and methods. This chapter includes the experimental set-up, different materials and methods used for the completion of current work.

5.1 Experimental Set-Up

To study the noise generated by a RDM, the sound power and pressure level of a machine needs to analyze. Sound power of the machine is measured without conducting a drilling operation and for the measurement of pressure level; drilling operation is carried out at different machining parameters. Three different size drill bits of HSS material and three different workpiece materials are used in the experiment. Two type of feeds and three different rotational speeds of spindle on RDM are taken as working parameters for analyzing SPL of the machine. For measuring SP of the machine, equivalent SPL is measured at five different spindle speeds and two different feed rates. Lubrication is done manually using water as coolant.

Equipments used in the experiment are:

- Radial Drilling Machine
- Sound level meter

Various input parameters are:

- Spindle Speed
- Feed Rate
- Drill bit diameter
- Work piece material

Output parameters are:

- Sound pressure level
- Sound power
- Frequency spectrum

5.1.1 Radial Drilling Machine

A RDM manufactured by New Bharat Engg. Works pvt. Ltd. is used in the experiment shown in Fig. 5.1.



Figure 5.1: Radial drilling machine

To analyze the acoustic level of the machine, different parameters like rotational speed, feed rate, diameter of drill bit and work piece material are varied and their sound level is recorded. These parameters can be varied according to the specifications of machine and requirement of the work. Table 5.1 contains the general specifications of this RDM. Dimensions of the machine are 134x71x211 mm.

Table 5.1: General specifications of RDM

Drilling Capacity	ϕ 12 mm. max.
Number of spindle speeds	8
Spindle speed range	80-890 rpm
Number of feed rates	2
Feed rate range	10-325 mm/min.
Power of spindle motor	0.97/1.4 kW
Rotation speed of spindle motor	1400/2800 rpm
Power of column traverse motor	0.37 kW
Rotation speed of column traverse motor	1400 rpm
Angle of drill head rotation	360°
Rotation of radial arm around column	360°
Horizontal traverse of radial arm	Hand feed type
Vertical traverse of radial arm along column	Motorized

Depending on the power and rotational speed of the spindle motor, the spindle speeds are categorized in two ranges i.e. low and high. Different speeds can be obtained by the adjustment of two levers located at the control panel of the machine shown in Fig. 5.2. and Table 5.2 contains the values of rotational speeds at the two ranges.

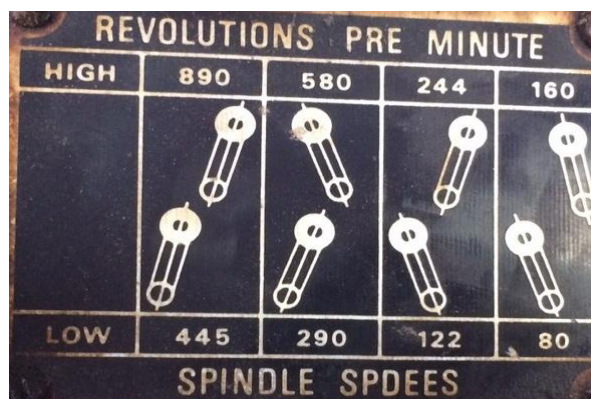


Figure 5.2 Adjustment of the gear levers for obtaining different speeds

Table 5.2 Values of rotational speeds of RDM

Low (rpm)	80	122	290	445
High (rpm)	160	244	580	890

There are two types of feed settings i.e. Fine and Coarse, given on the control panel of the machine. Fine feed can be used for low feed rate and coarse feed can be used for high feed rate. A lever is used to set a required feed rate. Feed rate of the machine also changes with the change in rotational speed of the spindle. Table 5.3 and 5.4 contains the approximate values of feed rates at low speed range and high speed range respectively.

Table 5.3: Values of feed rate at low speed range

LOW (rpm)	80	122	290	445
Fine (mm/min)	10	15	35	115
Coarse (mm/min)	15	24	54	182

Table 5.4: Values of Feed rate at High Speed range

HIGH (rpm)	160	244	580	890
Fine (mm/min)	21	31	71	151
Coarse (mm/min)	30	44	100	324

5.1.2 Drill Bit

In the experiment, three different diameter twist drill bits are used. The material of all drill bits is high speed steel (HSS). These drill bits are designed to allow easier starting with little bit drift and chatter and provide more accuracy. The HSS drill bits have high cutting speed. Figure 5.3 is showing the nomenclature of the twist drill bit and the three drill bits used in the experiment are shown in Fig. 5.4.

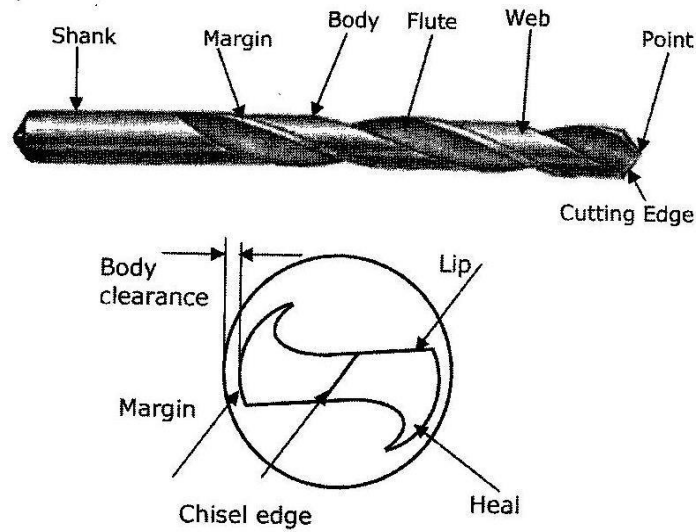


Figure 5.3: Nomenclature of tool [Rathi, 2014]

. The three drill bit diameters used are:

- 8mm
- 10mm
- 12mm.



Figure 5.4: Drill bits

5.1.3 Material of Workpiece

Depending on the hardness of materials, three different types of materials are selected.

These materials are:

- Aluminium
- Cast Iron
- Mild Steel

Rectangular bars of size 230x38x10 mm are used in the experiment and drilling operation is carried out on these bars. Water is used as a coolant in the process for removing the heat generated during the operation. Figure 5.5 is showing the three rectangular bars after drilling operation.



Figure 5.5: Workpiece materials

5.2 Design of Experiment

For obtaining the objective of the study, effect of different design variables on the noise level is analyzed. For conducting the experimental study of SPL, various considered factors and their levels are shown in Table 5.5.

The spindle speeds in the design are selected according to the cutting speed of the HSS tool which is 13-15 m/min. The cutting speed is considered to prevent the breakage of the tool during operation. For safe working, the maximum spindle speed obtained after the calculations is 398 rpm. Therefore these three spindle speeds are selected.

Table 5.5: Factors and Levels for DOE

Factors	Levels
Feed rate	i. Fine ii. Coarse
Spindle speed (rpm)	i. 80 ii. 122 iii. 290
Drill bit diameter (mm)	i. 8 ii. 10 iii. 12
Workpiece material	i. Aluminium ii. Mild steel iii. Cast iron

Sound power of the machine is measured at both feeds and following five spindle speeds (rpm):

- 80
- 122
- 160
- 244
- 290

For SPL measurements, a full factorial design of experiment is followed after taking in consideration the above mentioned design variables. According to the selected design variables, a factorial design with 54 maximum possible machining combinations is generated. The effect of variation in input process parameters will be studied on these response parameters and as per the full factorial design the experimental data will be analyzed to find out the optimum machining conditions and percentage contribution of each factor. The factorial design with optimum machining parameters is presented in Table 5.6.

Table 5.6: Full factorial design

Sr. No.	Feed rate	Workpiece material	Drill bit diameter	Spindle speed
1	Fine	Mild Steel	10	290
2	Fine	Mild Steel	10	80
3	Fine	Cast Iron	12	290
4	Fine	Cast Iron	12	80
5	Fine	Cast Iron	10	80
6	Fine	Mild Steel	12	80
7	Fine	Aluminium	10	122
8	Fine	Cast Iron	8	80
9	Fine	Aluminium	8	122
10	Fine	Cast Iron	8	290
11	Fine	Mild Steel	12	290
12	Fine	Mild Steel	10	122
13	Fine	Aluminium	10	80
14	Fine	Aluminium	8	290
15	Fine	Aluminium	10	290
16	Fine	Aluminium	12	80
17	Fine	Cast Iron	10	122
18	Fine	Aluminium	8	80
19	Fine	Aluminium	12	290
20	Fine	Cast Iron	8	122
21	Fine	Mild Steel	8	122
22	Fine	Aluminium	12	122
23	Fine	Mild Steel	8	80
24	Fine	Mild Steel	12	122
25	Fine	Mild Steel	8	290
26	Fine	Cast Iron	12	122
27	Fine	Cast Iron	10	290
28	Coarse	Aluminium	10	80
29	Coarse	Cast Iron	8	290

30	Coarse	Mild Steel	8	290
31	Coarse	Aluminium	8	290
32	Coarse	Aluminium	12	80
33	Coarse	Aluminium	12	122
34	Coarse	Cast Iron	10	80
35	Coarse	Mild Steel	12	290
36	Coarse	Cast Iron	10	290
37	Coarse	Mild Steel	10	80
38	Coarse	Cast Iron	8	122
39	Coarse	Mild Steel	10	290
40	Coarse	Cast Iron	10	122
41	Coarse	Cast Iron	12	80
42	Coarse	Aluminium	8	122
43	Coarse	Cast Iron	12	122
44	Coarse	Aluminium	12	290
45	Coarse	Mild Steel	12	80
46	Coarse	Aluminium	10	290
47	Coarse	Aluminium	10	290
48	Coarse	Aluminium	8	80
49	Coarse	Cast Iron	8	80
50	Coarse	Mild Steel	8	122
51	Coarse	Aluminium	8	80
52	Coarse	Aluminium	10	122
53	Coarse	Mild Steel	10	122
54	Coarse	Cast Iron	12	290

Additionally, the frequency spectrum of the noise signals generated during the experiment will be analyzed and the contribution of the different frequencies during the operation of drilling will be studied. SPL on different frequencies will be compared with different machining conditions. This will help in selecting an appropriate method for reducing the noise of the machine.

5.3 Measurement of Noise

Measurement procedure of different noise parameters contains SP measurement of the machine at different rotational speeds and feeds on the reference points shown in the grid in Fig 5.8. A-weighted equivalent SPL measurements are recorded on 1/1 octave band on slow time weighting. SPL measurement of the machine is recorded from a distance of 1 meter at an angle of 45° as shown in Fig. 5.6 according to the machining conditions provided by the full factorial design mentioned above.



Figure 5.6: Sound pressure level measurement

A Sound level meter (CESVA SC310) is used in the experiment shown in Fig. 5.7 for recording the noise measurements at different points. Frequency spectra of the noise signals are analyzed and compared at different machining conditions.



Figure 5.7: Sound level meter (CESVA SC310)

5.3.1 Measurement of Sound Power

The sound power of the noise source is measured with the help of sound pressure level with following steps:

1. The sound source is surrounded by a hypothetical surface of area S (rectangular parallelepiped shown in Fig. 5.8).
2. The area of this hypothetical surface,

$$S = ab + 2(ac + bc) \quad (5.1)$$

where, a , b , c are the length, width and height of the rectangular parallelepiped.

3. The sound pressure is measured at designated points on the hypothetical surface and average pressure level (L_p) is obtained with the help of equation 1.2.
4. The final sound power is calculated by

$$L_w = L_p + 10 \log_{10}(S/S_0) \quad (5.2)$$

where, S_0 is the reference area, (1m^2) and S is the hypothetical area.

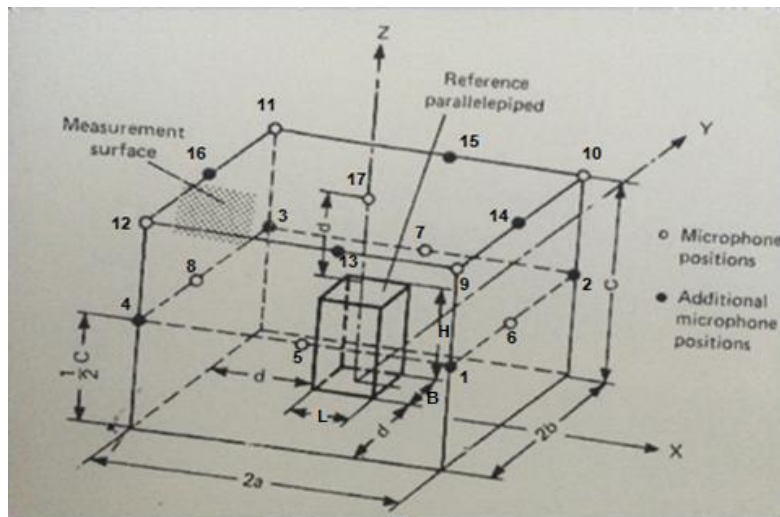


Figure 5.8: Array of microphone positions on an imaginary parallelepiped surface around the machine [Harris, 1991]

Chapter 6

Results and Discussion

This chapter includes the results of the experiments conducted to measure the sound power and pressure level and frequency spectra of the noise signals as discussed in the previous chapter. The results obtained are also discussed and verified as per the observations recorded.

6.1 Results of Sound Power measurement

Sound power is measured when the machine is in working condition but no drilling is carried out. It is the power of sound emitted only by source i.e. RDM. After measuring the SPL at each point of the imaginary rectangular parallelepiped surfaces shown in Fig. 5.8, their average SPL is calculated by using equation 1.2 and some corrections are made in the results with the help of data shown in Fig. 1.9 to compensate the background noise. Then, SP of the machine is calculated at different speeds and feeds by using equation 5.2. The area of the hypothetical surface is calculated as 13.78 m^2 by using equation 5.1.

Measurements recorded at different points of the imaginary rectangular parallelepiped shows that SPL is maximum at point 17, because of the noise generated by the electric motor mounted on the top of the machine (See Appendix A). SPL is recorded higher at the points in front of the machine than the points in the back (See Appendix A). SPL is more near the drill head because of the rotational noise of drill spindle.

From the Fig. 6.1, it can be seen that the SP is more at coarse feed than fine feed. SP increases gradually with increase in spindle speed. With an instant increase in speed, SP also increases rapidly (See Appendix B). From the speed 80 to 122 rpm, SP remains almost constant at fine feed. But it increase gradually at coarse feed from 80 to 160 rpm. From speed 122 rpm, there is a gradual increase in SP up to 160 rpm at fine feed. After that with instant increase in speed, SP suddenly increases. Further with increase in speed, there is a gradual increase in SP.

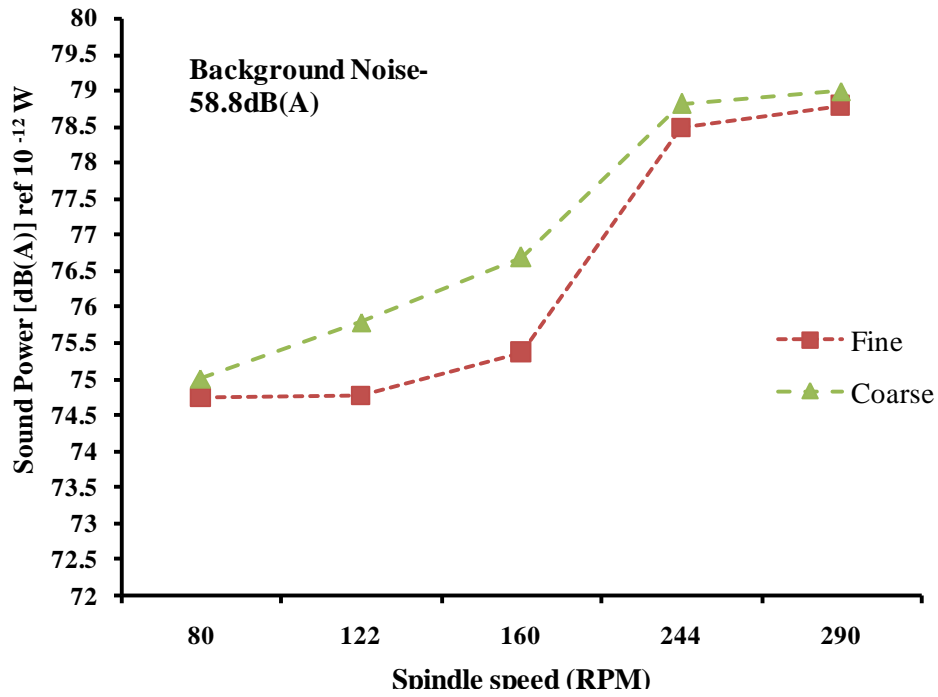


Figure 6.1: Sound power vs. spindle speed at different feed rates

6.2 Results of Sound Pressure Level measurement

6.2.1 Sound Pressure Level for Aluminium workpiece

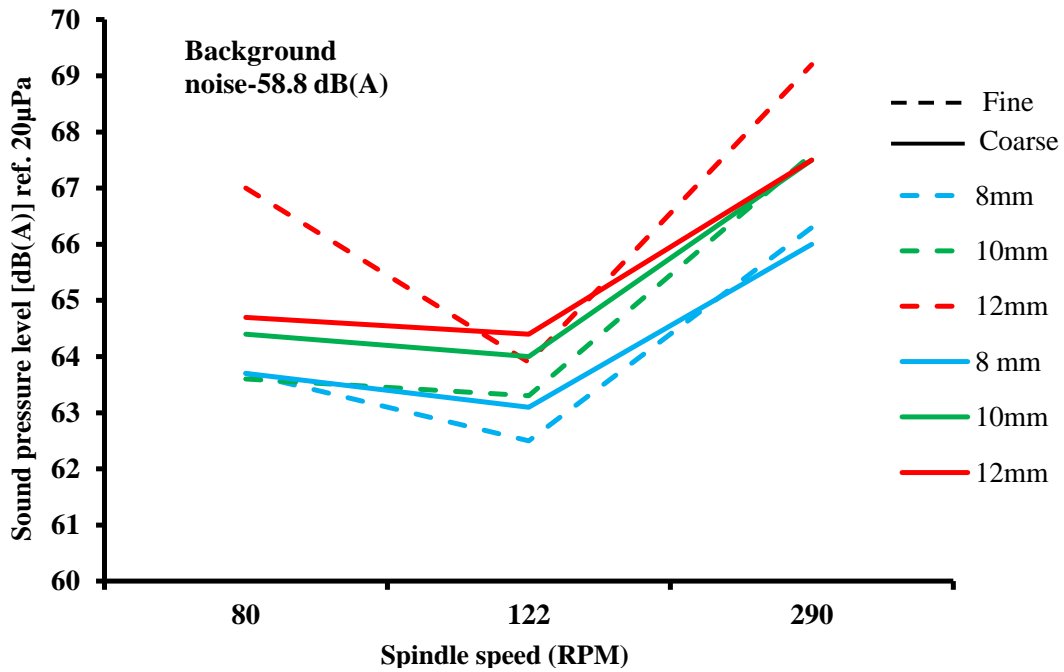


Figure 6.2: Sound pressure level vs. Spindle speed at different feeds for aluminium workpiece

As shown in Fig. 6.2, SPL is maximum at 290 rpm and minimum at 122 rpm for most of the cases. Percentage increase or decrease in sound level at different spindle speeds and feeds is calculated by taking SPL at 80 rpm as reference value. Table 6.1 and 6.2 shows percentage increase or decrease in SPL for aluminium at fine and coarse feed respectively. It can be seen that percentage increase in SPL at 290 rpm is higher in case of fine feed than coarse feed. When speed increases from 80 rpm to 122 rpm there is a percentage decrease in SPL. Maximum variation can be seen in the case of 12 mm drill bit.

Table 6.1: Percentage increase/decrease in SPL at different spindle speeds and fine feed for aluminium workpiece

Spindle speed (rpm)	80	122		290	
Drill Diameter (mm)	Noise level, dB(A) (Reference value)	Noise level, dB(A)	%age increase/ decrease(-)	Noise level, dB(A)	%age increase/ decrease (-)
8	63.7	62.5	-1.92	66.3	4.08
10	63.6	63.3	-0.47	67.6	6.28
12	67	63.9	-4.85	69.2	3.28

Table 6.2: Percentage increase/decrease in SPL at different spindle speeds and coarse feed for aluminium workpiece

Spindle speed (rpm)	80	122		290	
Drill Diameter (mm)	Noise level, dB(A) (Reference value)	Noise level, dB(A)	%age increase/ decrease(-)	Noise level, dB(A)	%age increase/ decrease (-)
8	63.7	63.1	-0.95	66.0	3.61
10	64.4	64.0	-0.62	68.5	6.36
12	64.7	64.4	-0.46	67.5	4.32

For aluminium workpiece, percentage increase or decrease in SPL with respect to drill bits at fine and coarse feed is shown in Table 6.3 and 6.4 respectively. Percentage increase or decrease in sound level at different drill bits and feeds is calculated by taking SPL at 8 mm drill bit as reference value. SPL is increasing with increase in drill bit diameter except in the case of 80 rpm, SPL decreases when drill diameter increases from 8 mm to 10 mm at fine feed.

Table 6.3: Percentage increase/decrease in SPL at different drill bits and fine feed for aluminium workpiece

Spindle speed (rpm)	80	122	290
Drill Diameter (mm)	Noise level, dB(A)	Noise level, dB(A)	Noise level, dB(A)
8 (Reference value)	63.7	62.5	66.3
10	63.6	63.3	67.6
%age increase/decrease(-)	-0.15	1.28	1.96
12	67	63.9	69.2
%age increase/decrease(-)	5.34	2.24	4.37

Table 6.4: Percentage increase/decrease in SPL at different drill bits and coarse feed for aluminium workpiece

Spindle speed (rpm)	80	122	290
Drill Diameter (mm)	Noise level, dB(A)	Noise level, dB(A)	Noise level, dB(A)
8 (Reference value)	63.7	63.1	66.0
10	64.4	64.0	68.5
%age increase/decrease(-)	1.09	1.42	3.78
12	64.7	64.4	67.5
%age increase/decrease(-)	1.56	2.06	2.27

At the same machining conditions with change in feed, SPL also changes. Percentage increase or decrease in SPL at different feed is shown in Table 6.5. SPL at fine feed is taking as reference value. With 10 mm drill bit, SPL is more at coarse feed than fine feed. There is a mixed reaction of SPL at 8 mm and 12 mm drill diameters.

Table 6.5: Percentage increase/decrease in SPL at different feeds for aluminium workpiece

Spindle speed (rpm)		80	122	290
Drill Diameter (mm)	Feed	Noise level, dB(A)	Noise level, dB(A)	Noise level, dB(A)
8	Fine (Reference value)	63.7	62.5	66.3
	Coarse	63.7	63.1	66.0
	%age increase/decrease(-)	0	0.96	-0.45
10	Fine (Reference value)	63.6	63.3	67.6
	Coarse	64.4	64.0	68.5
	%age increase/decrease(-)	1.25	1.10	1.33
12	Fine (Reference value)	67	63.9	69.2
	Coarse	64.7	64.4	67.5
	%age increase/decrease(-)	-3.55	0.78	-2.51

6.2.2 Sound Pressure Level for Cast Iron workpiece

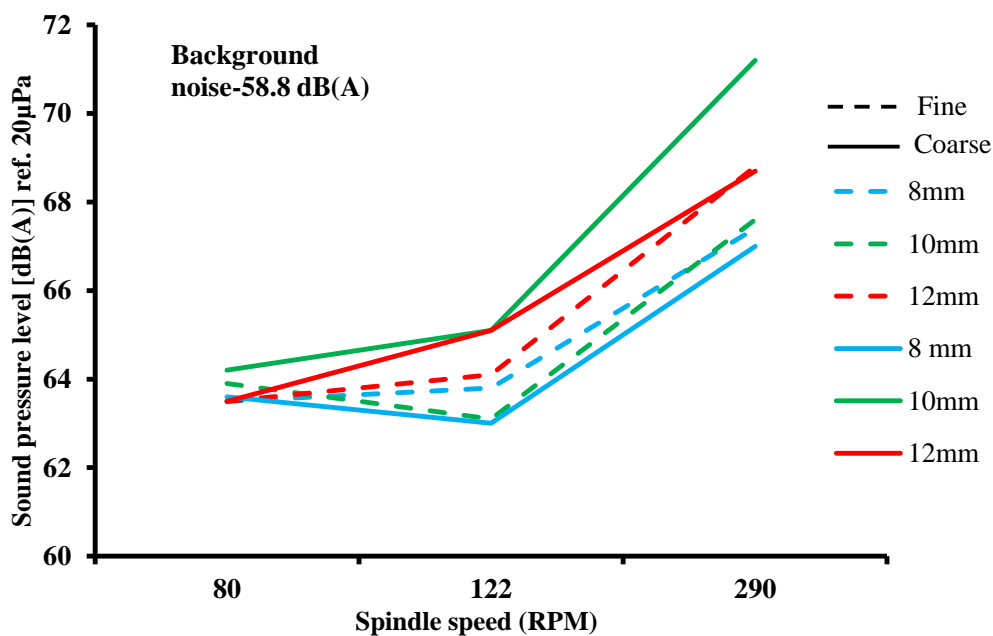


Figure 6.3: Sound pressure level vs. Spindle speed at different feeds for cast iron workpiece

For the cast iron workpiece, SPL at different machining conditions is shown in Fig. 6.3. It can be seen that with 10 mm and 12 mm drill bit, SPL generating at the coarse feed is more than fine feed. But with 8 mm drill bit, SPL at fine feed is more than coarse feed.

Table 6.6: Percentage increase/decrease in SPL at different spindle speeds and fine feed for cast iron workpiece

Spindle speed (rpm)	80	122		290	
Drill Diameter (mm)	Noise level, dB(A) (Reference value)	Noise level, dB(A)	%age increase/ decrease(-)	Noise level, dB(A)	%age increase/ decrease (-)
8	64.4	64.1	-0.46	69.4	7.76
10	63.1	62.1	-1.61	72.5	14.89
12	64.1	65.9	2.80	69.4	8.26

Table 6.7: Percentage increase/decrease in SPL at different spindle speeds and coarse feed for cast iron workpiece

Spindle speed (rpm)	80	122		290	
Drill Diameter (mm)	Noise level, dB(A) (Reference value)	Noise level, dB(A)	%age increase/ decrease(-)	Noise level, dB(A)	%age increase/ decrease (-)
8	63.7	63.1	-0.15	66.0	4.15
10	64.4	64.0	-5.33	68.5	13.59
12	64.7	64.4	2.85	67.5	13.15

At different spindle speeds and feeds, SPL of the cast iron workpiece is shown in Table 6.6 and 6.7. From Table 6.6 and 6.7, it can be seen that SPL is decreasing when spindle speed increases from 80 rpm to 122 rpm but with 12 mm drill bit it get reverse. There is high percentage increase in SPL when speed becomes 290 rpm.

Percentage increase and decrease in SPL at different drill bits and feeds for cast iron workpiece is shown in Table 6.8 and 6.9. At fine feed on 80 and 122 rpm, SPL is decreasing with drill bit diameter increases from 8 mm to 10 mm but it increases in the case of 290 rpm. SPL is equal at 290 rpm for 8 mm and 12 mm drill bit. At coarse feed, SPL generated by 8 mm drill bit is maximum at 80 rpm.

Table 6.8: Percentage increase/decrease in SPL at different drill bits and fine feed for cast iron workpiece

Spindle speed (rpm)	80	122	290
Drill Diameter (mm)	Noise level, dB(A)	Noise level, dB(A)	Noise level, dB(A)
8 (Reference value)	64.4	64.1	69.4
10	63.1	62.1	72.5
%age increase/ decrease(-)	-2.06	-3.22	4.46
12	64.1	65.9	69.4
%age increase/ decrease(-)	0.46	2.80	0

Table 6.9: Percentage increase/decrease in SPL at different drill bits and coarse feed for cast iron workpiece

Spindle speed (rpm)	80	122	290
Drill Diameter (mm)	Noise level, dB(A)	Noise level, dB(A)	Noise level, dB(A)
8 (Reference value)	65	64.9	67.7
10	61.8	65.1	70.2
%age increase/ decrease(-)	-5.17	0.308	3.69
12	63.1	64.9	71.4
%age increase/ decrease(-)	-3.01	0	5.46

Table 6.10 shows the change in SPL at different feeds for cast iron workpiece. At 290 rpm, drill bits of 8 mm and 10 mm diameter are generating high SPL at fine feed but drill bit of 12 mm diameter generating high SPL at 290 rpm. At 80 and 122 rpm, drill bit of 12 mm is generating high SPL at fine feed.

Table 6.10: Percentage increase/decrease in SPL at different feeds for cast iron workpiece

Spindle speed (rpm)		80	122	290
Drill Diameter (mm)	Feed	Noise level, dB(A)	Noise level, dB(A)	Noise level, dB(A)
8	Fine (Reference value)	64.4	64.1	69.4
	Coarse	65	64.9	67.7
	%age increase/decrease(-)	0.93	1.24	-2.51
10	Fine (Reference value)	63.1	62.1	72.5
	Coarse	61.8	65.1	70.2
	%age increase/decrease(-)	-2.10	4.83	-3.27
12	Fine (Reference value)	64.1	65.9	69.4
	Coarse	63.1	64.9	71.4
	%age increase/decrease(-)	-1.58	-1.54	2.88

6.2.3 Sound Pressure Level for Mild Steel workpiece

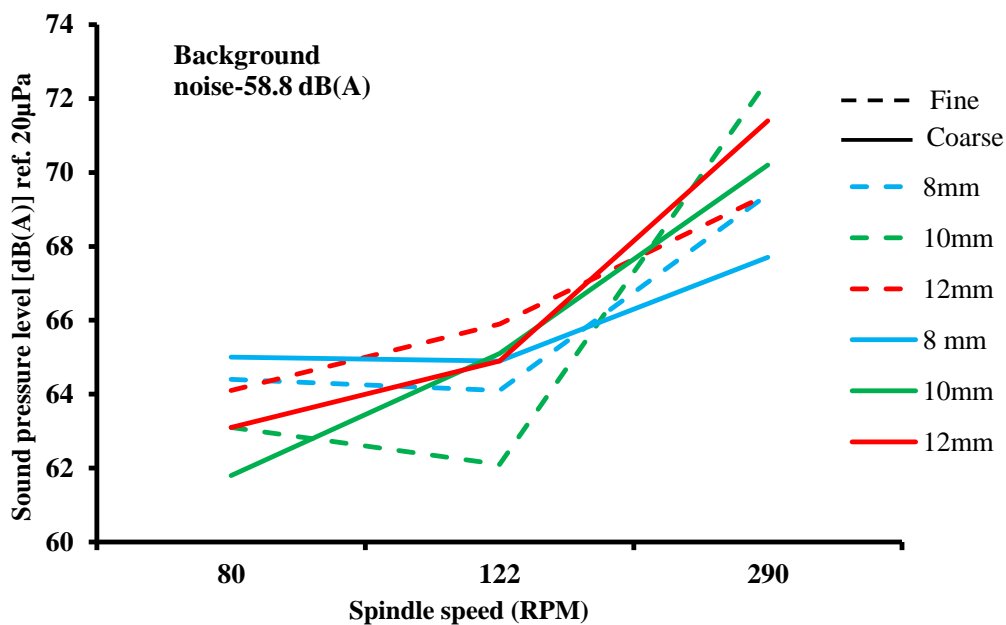


Figure 6.4: Sound pressure level vs. Spindle speed at different feeds for mild steel workpiece

Table 6.11: Percentage increase/decrease in SPL at different spindle speeds and fine feed for mild steel workpiece

Spindle speed (rpm)	80	122		290	
Drill Diameter (mm)	Noise level, dB(A) (Reference value)	Noise level, dB(A)	%age increase/ decrease(-)	Noise level, dB(A)	%age increase/ decrease (-)
8	63.5	63.8	0.47	67.4	6.14
10	63.9	63.1	-1.26	67.6	5.79
12	63.5	64.1	0.94	68.8	8.34

Table 6.12: Percentage increase/decrease in SPL at different spindle speeds and coarse feed for mild steel workpiece

Spindle speed (rpm)	80	122		290	
Drill Diameter (mm)	Noise level, dB(A) (Reference value)	Noise level, dB(A)	%age increase/ decrease(-)	Noise level, dB(A)	%age increase/ decrease (-)
8	63.6	63.0	-0.95	67.0	5.34
10	64.2	65.1	1.40	71.2	10.90
12	63.5	65.1	2.51	68.7	8.18

Table 6.13: Percentage increase/decrease in SPL at different drill bits and fine feed for mild steel workpiece

Spindle speed (rpm)	80	122	290
Drill Diameter (mm)	Noise level, dB(A)	Noise level, dB(A)	Noise level, dB(A)
8 (Reference value)	63.5	63.8	67.4
10	63.9	63.1	67.6
%age increase/ decrease(-)	0.62	-1.10	0.29
12	63.5	64.1	68.8
%age increase/ decrease(-)	0	0.47	2.07

Table 6.14: Percentage increase/decrease in SPL at different drill bits and coarse feed for mild steel workpiece

Spindle speed (rpm)	80	122	290
Drill Diameter (mm)	Noise level, dB(A)	Noise level, dB(A)	Noise level, dB(A)
8 (Reference value)	63.6	63.0	67.0
10	64.2	65.1	71.2
%age increase/decrease(-)	0.94	3.33	6.26
12	63.5	65.1	68.7
%age increase/decrease(-)	-0.15	3.33	2.53

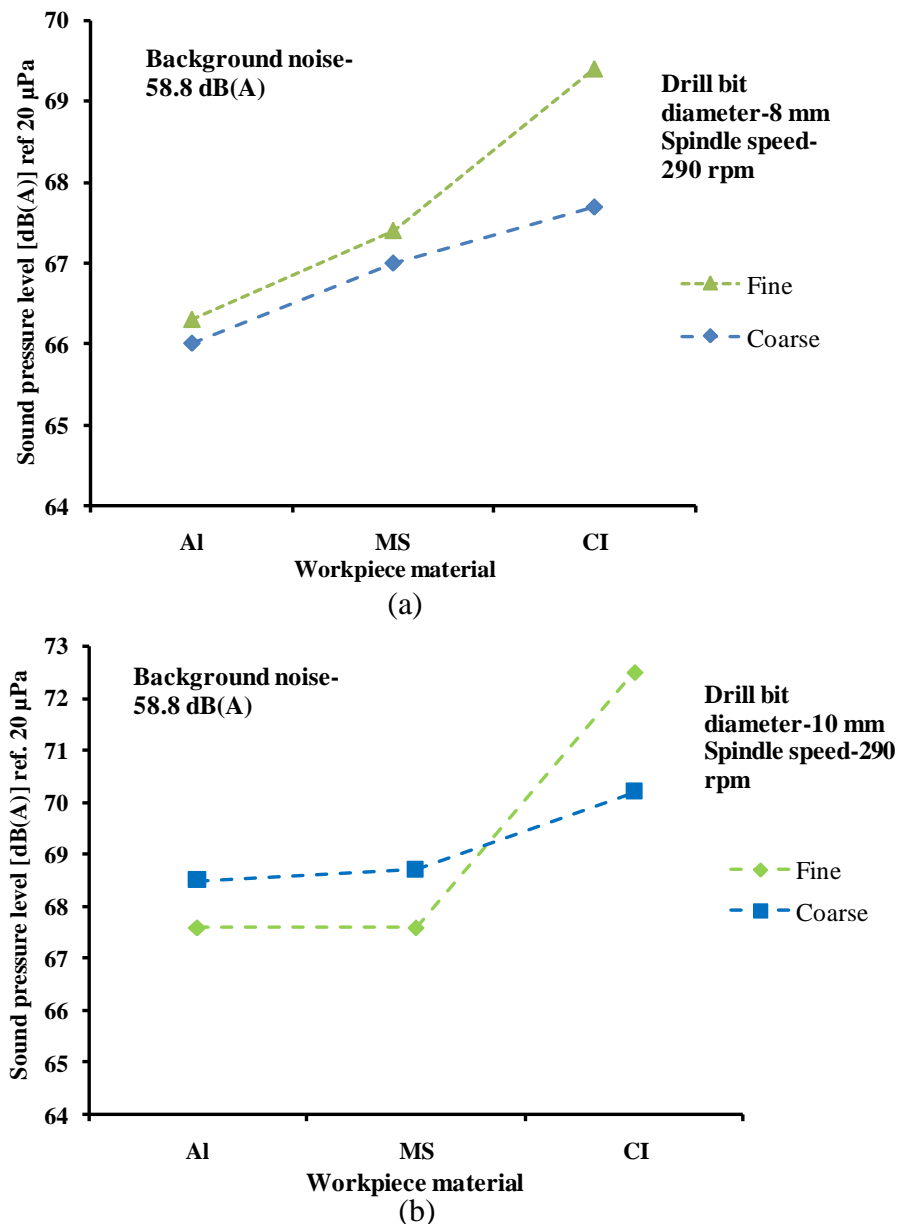
Table 6.15: Percentage increase/decrease in SPL at different feeds for mild steel workpiece

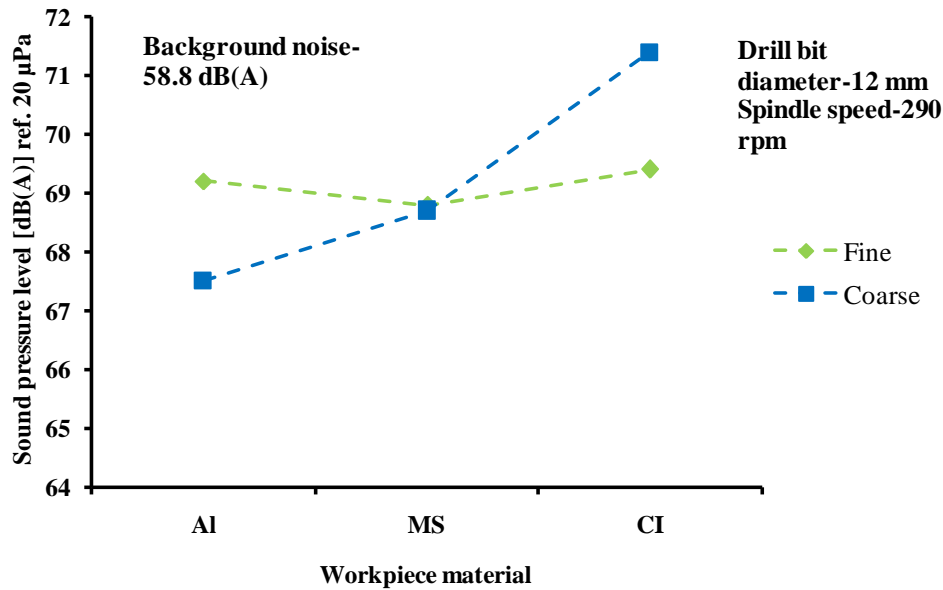
Spindle speed (rpm)		80	122	290
Drill Diameter (mm)	Feed	Noise level, dB(A)	Noise level, dB(A)	Noise level, dB(A)
8	Fine (Reference value)	63.5	63.8	67.4
	Coarse	63.6	63.0	67.0
	%age increase/decrease(-)	0.15	-1.26	-0.59
10	Fine (Reference value)	63.9	63.1	67.6
	Coarse	64.2	65.1	71.2
	%age increase/decrease(-)	0.46	3.16	5.32
12	Fine (Reference value)	63.5	64.1	68.8
	Coarse	63.5	65.1	68.7
	%age increase/decrease(-)	0	1.56	-1.47

From Table 6.11 and 6.12, it can be seen that SPL increases with increase in spindle speed with all drill bits except for 10 mm drill SPL decreases when speed increases from 80 to 122 rpm at fine feed. At coarse feed, SPL decreases when speed increases from 80 to 122 rpm for 8 mm drill bit.

As shown in Table 6.13 and 6.14, SPL decreases at 122 rpm when drill bit diameter increases from 8 mm to 10 mm at fine feed. SPL decreases at 80 rpm when drill bit diameter changes from 8 mm to 12 mm. At 290 rpm, drill bits of 8mm and 10 mm generates high SPL at fine feed as shown in Table 6.15. Drill bit of 8 mm generates high SPL at fine feed on 122 rpm.

6.2.4 Comparison of Sound Pressure Level of different materials





(c)

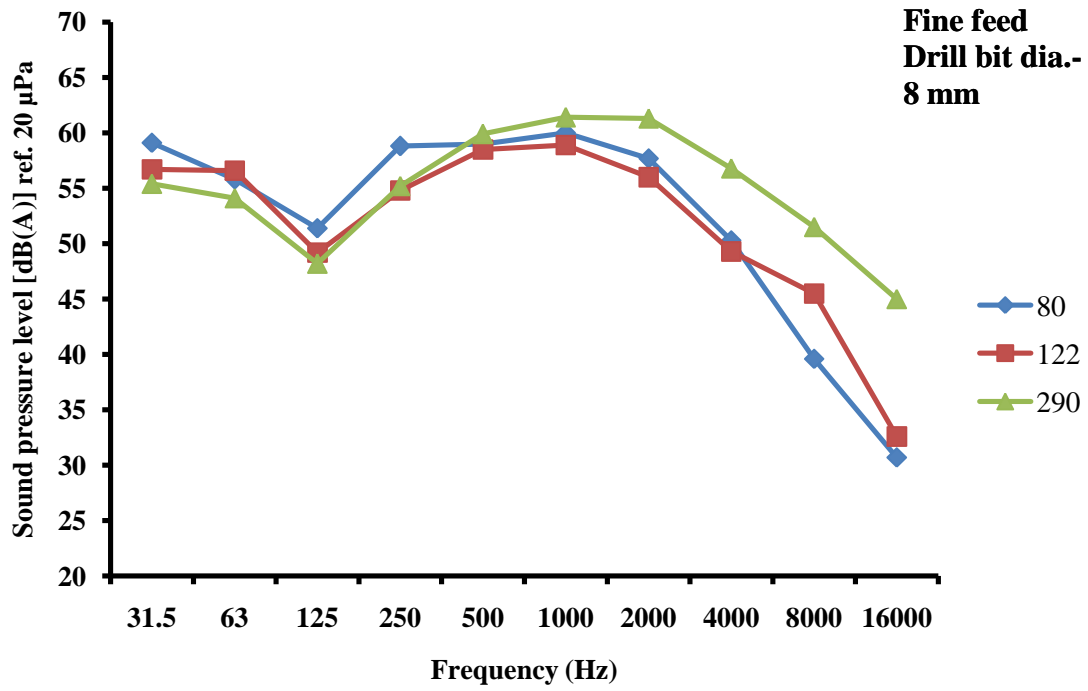
Figure 6.5: Sound pressure level vs. Workpiece material at different feeds and drill bit diameters

Amongst all the three spindle speeds, 290 rpm generates highest SPL in all the machining operations. Therefore this speed is assumed for comparing the different materials at different drill bits and feeds. As shown in Fig. 6.5(a), with drill bit of 8 mm and at 290 rpm speed, fine feed is purely generating more SPL than coarse feed. With 10 mm drill bit, there is a large difference between the SPL of mild steel at fine and coarse feed. For aluminium and mild steel, the difference in SPL at different feeds is not much whereas in the case of cast iron, it is considerable. Cast iron is generating maximum SPL in most of the cases.

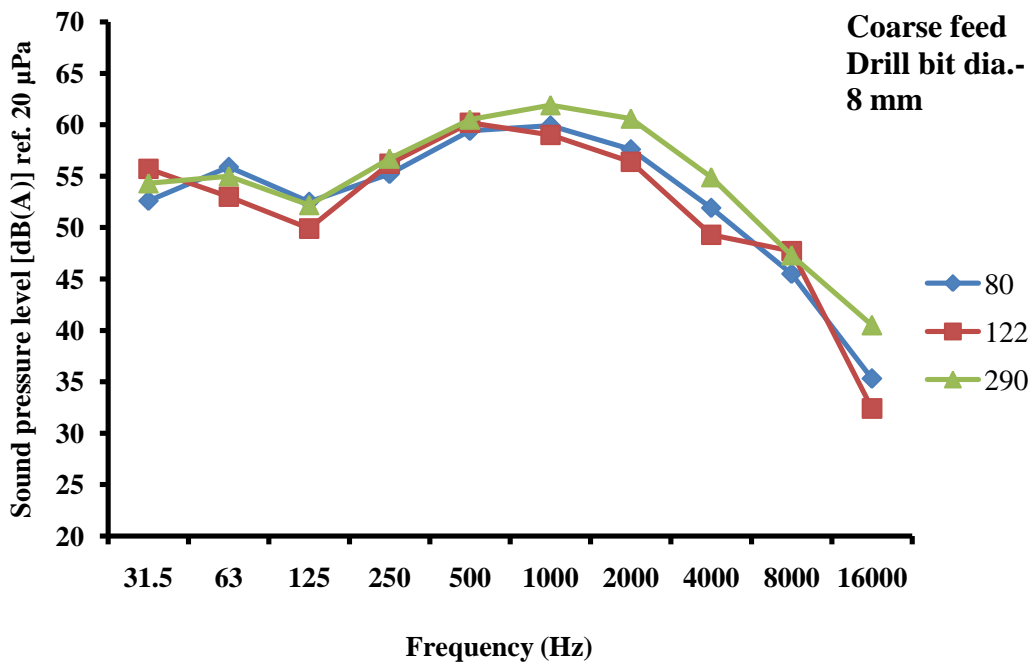
6.3 Frequency Spectrum of Sound Pressure Level

6.3.1 Frequency spectrum of Aluminium workpiece

Figure 6.6(a) and 6.6(b) shows the frequency spectrum of aluminium workpiece at fine feed and coarse feed respectively with 8 mm drill bit. In both of the above figures, a similar trend of frequency spectra can be seen. Mid frequencies along with some low noise frequencies are generating a peak SPL and very high noise frequencies contribute lesser in noise level.

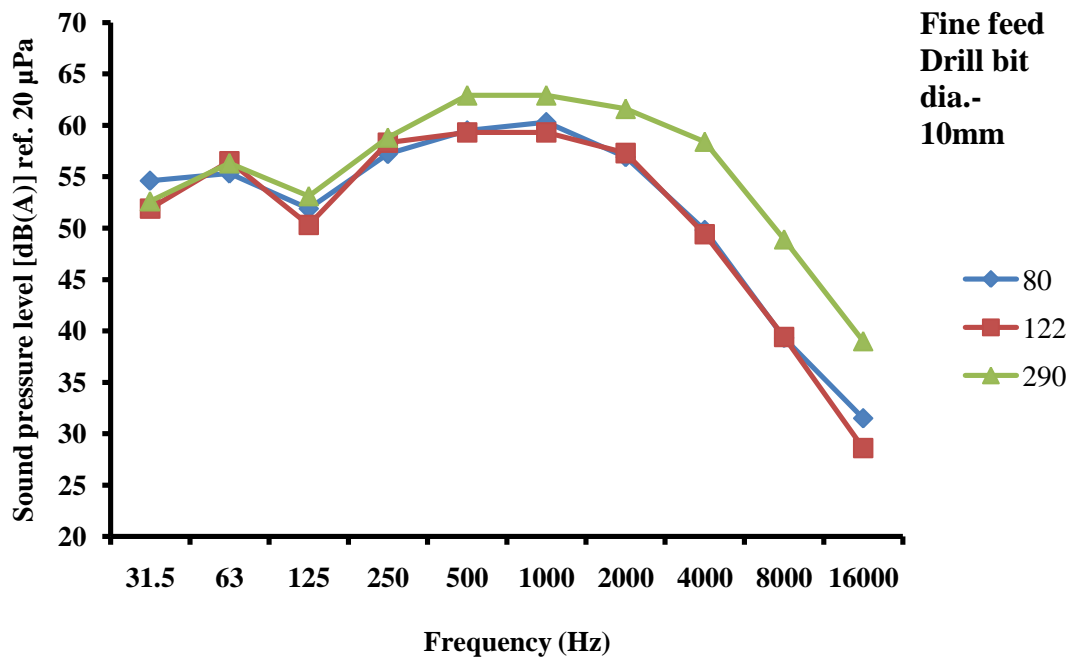


(a)

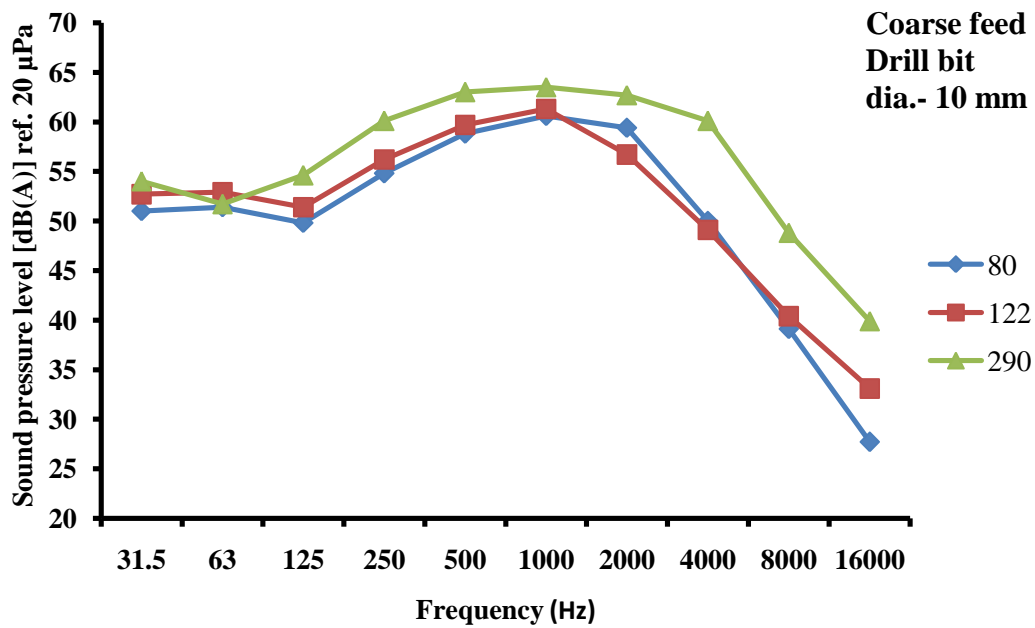


(b)

Figure 6.6: Sound pressure level vs. Frequency for aluminium workpiece at 8 mm drill bit



(a)

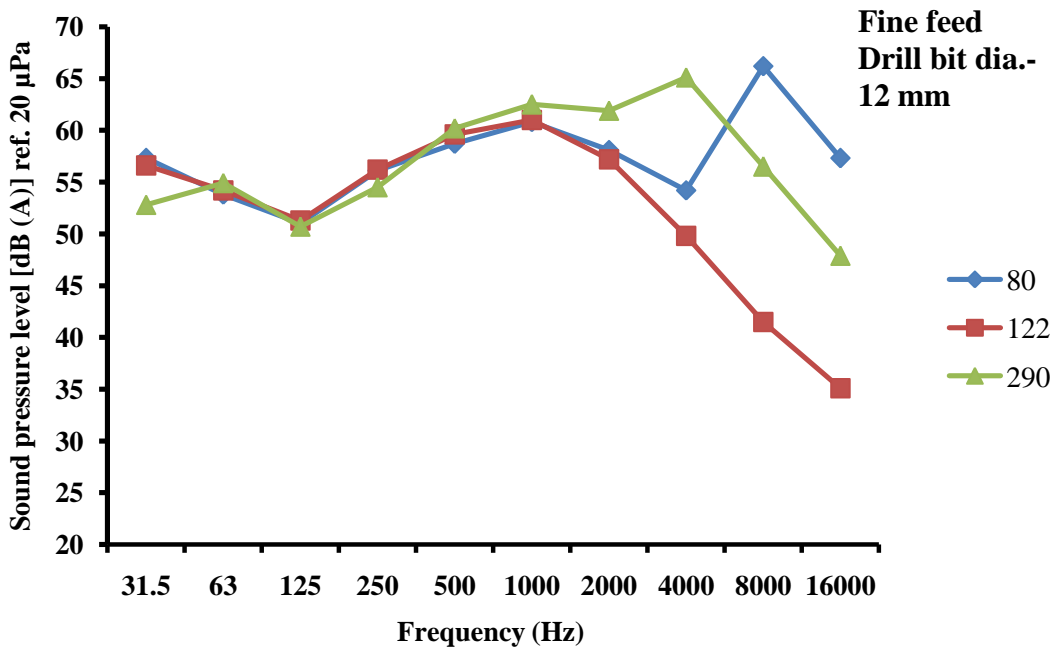


(b)

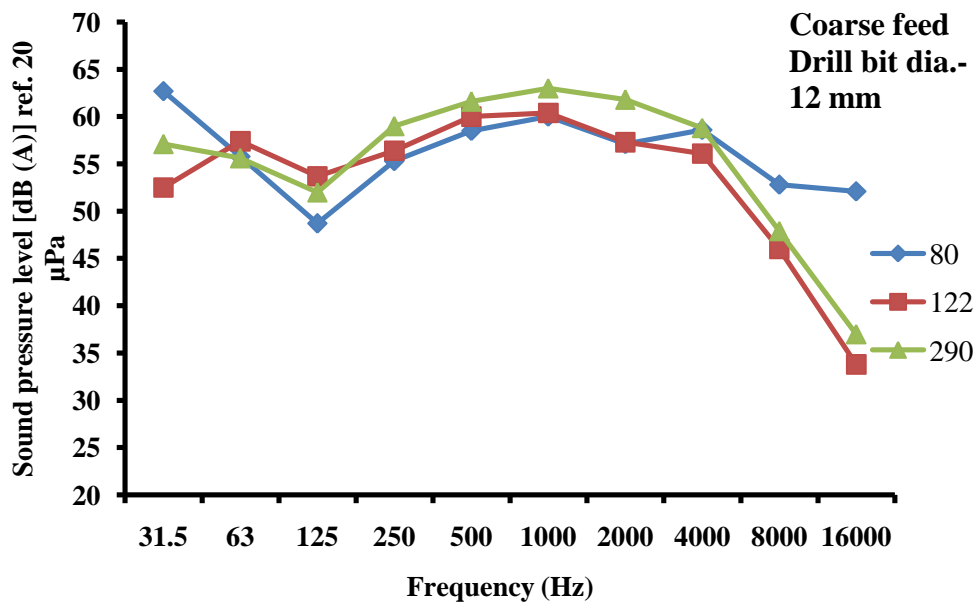
Figure 6.7: Sound pressure level vs. Frequency for aluminium workpiece at 10 mm drill bit

Figure 6.7(a) and 6.7(b) shows the frequency spectrum of aluminium workpiece at fine feed and coarse feed respectively with 10 mm drill bit. At coarse feed, amplitude of SPL

for mid frequencies is higher than the fine feed. Low frequencies are also dominant at coarse feed.



(a)



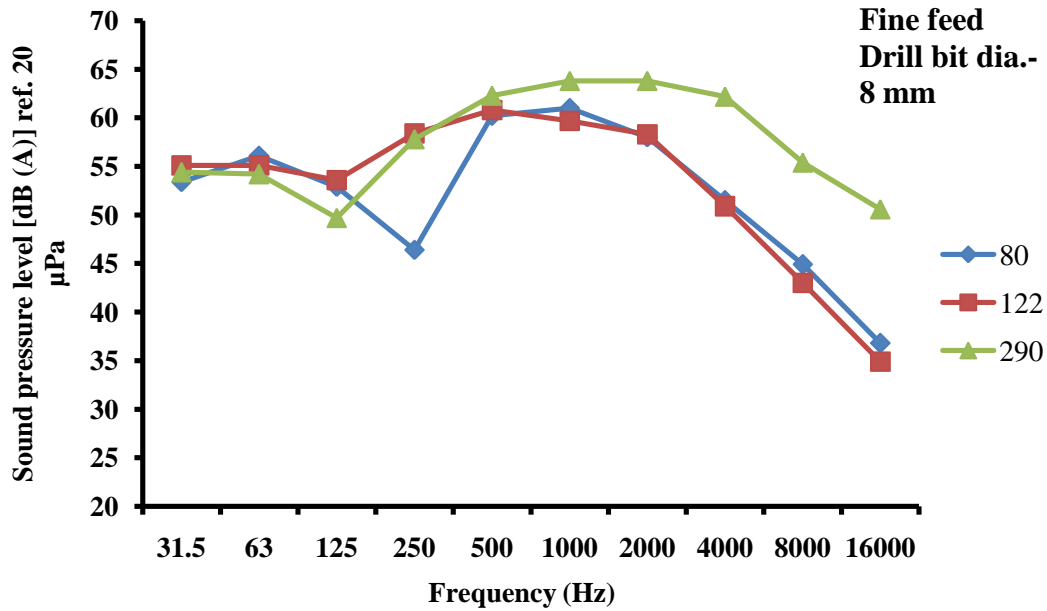
(b)

Figure 6.8: Sound pressure level vs. Frequency for aluminium workpiece at 12 mm drill bit

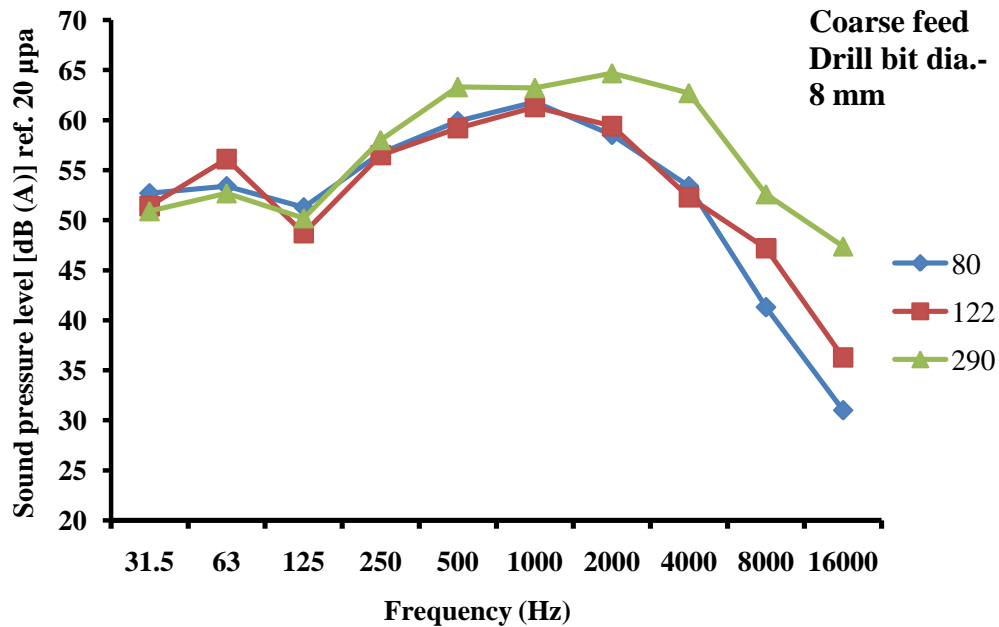
Figure 6.8(a) and 6.8(b) shows the frequency spectrum of aluminium workpiece at fine feed and coarse feed respectively with 12 mm drill bit. In this case, there is a high

disturbance in low and high frequencies of noise at 80 and 290 rpm. At 80 rpm, the value of low and high frequencies rise above the mid frequencies.

6.3.2 Frequency spectrum of Cast Iron workpiece



(a)



(b)

Figure 6.9: Sound pressure level vs. Frequency for cast iron workpiece at 8 mm drill bit

Figure 6.9(a) and 6.9(b) shows the frequency spectrum of cast iron workpiece at fine feed and coarse feed respectively with 8 mm drill bit. The trend of frequency spectrum is similar for both the feeds except a trough is shown at 250 Hz at fine feed. Mid frequencies are dominant otherwise.

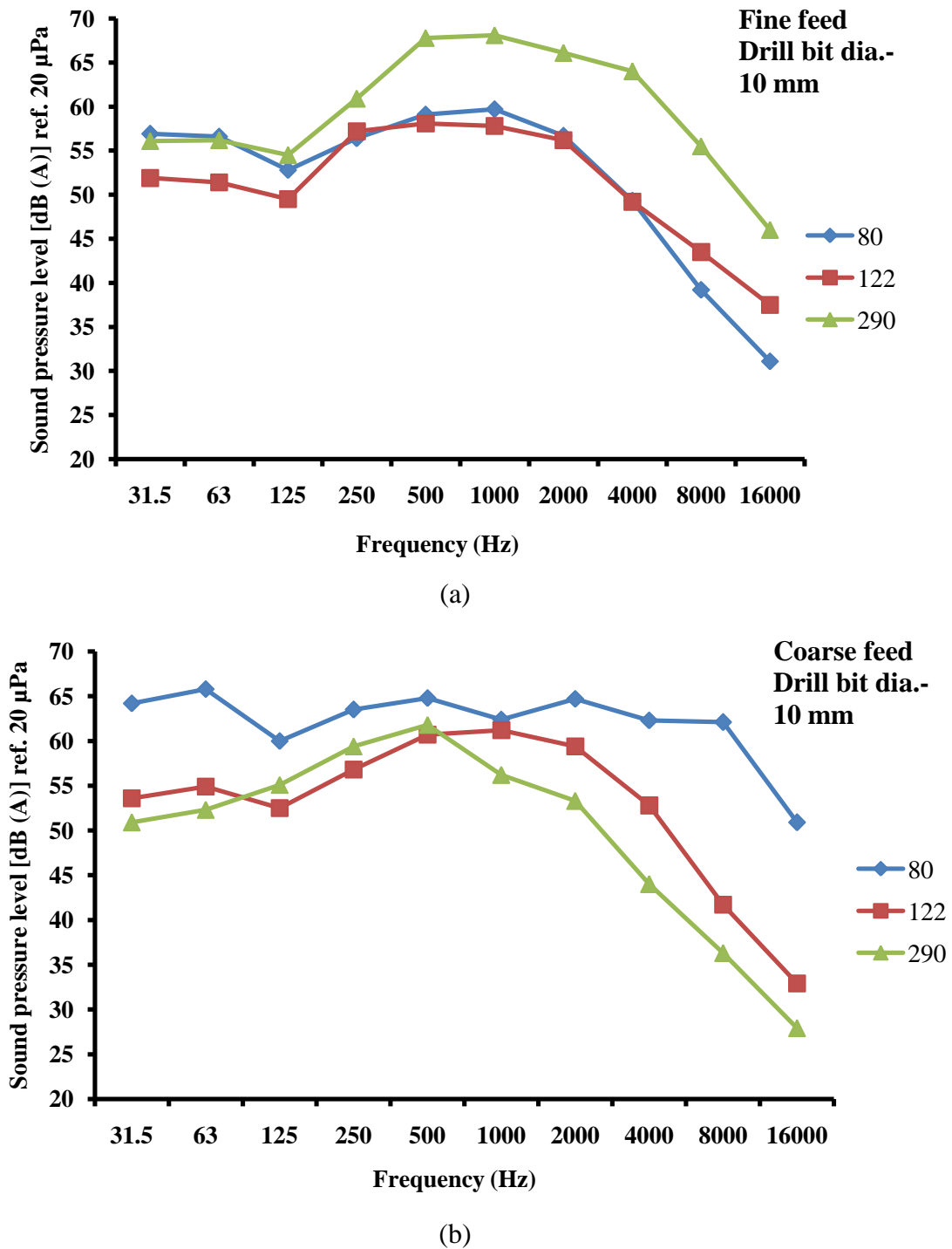
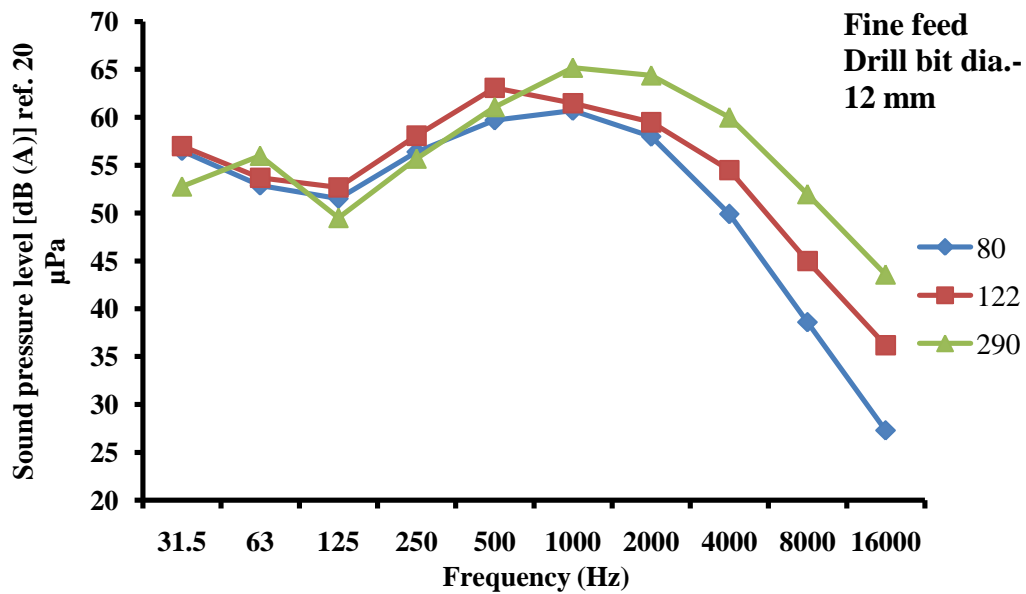
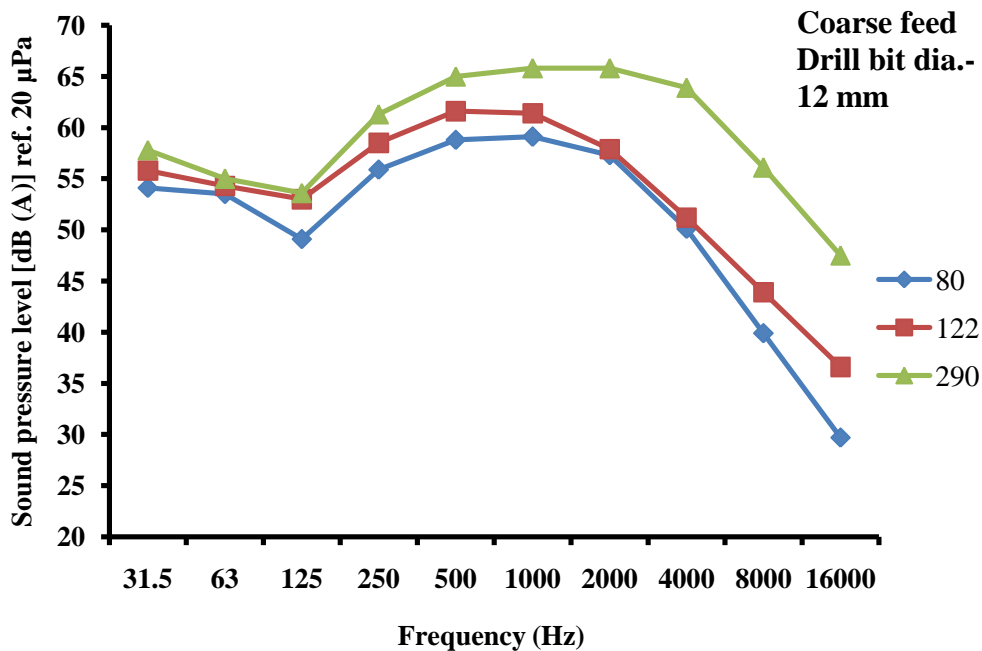


Figure 6.10: Sound pressure level vs. Frequency for cast iron workpiece at 10 mm drill bit

Figure 6.10(a) and 6.10(b) shows the frequency spectrum of cast iron workpiece at fine feed and coarse feed respectively with 10 mm drill bit. A non linear behaviour of frequency spectrum is shown at 80 rpm at coarse feed. SPL at whole range of frequencies is almost equal in this case. At fine feed, amplitude of SPL at 290 rpm is very high at mid frequencies.



(a)

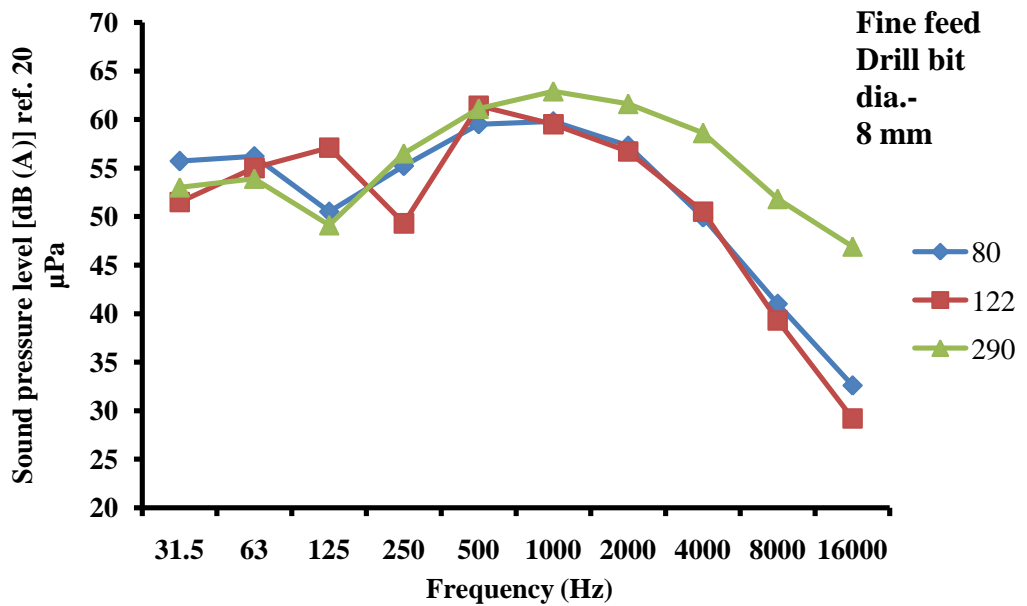


(b)

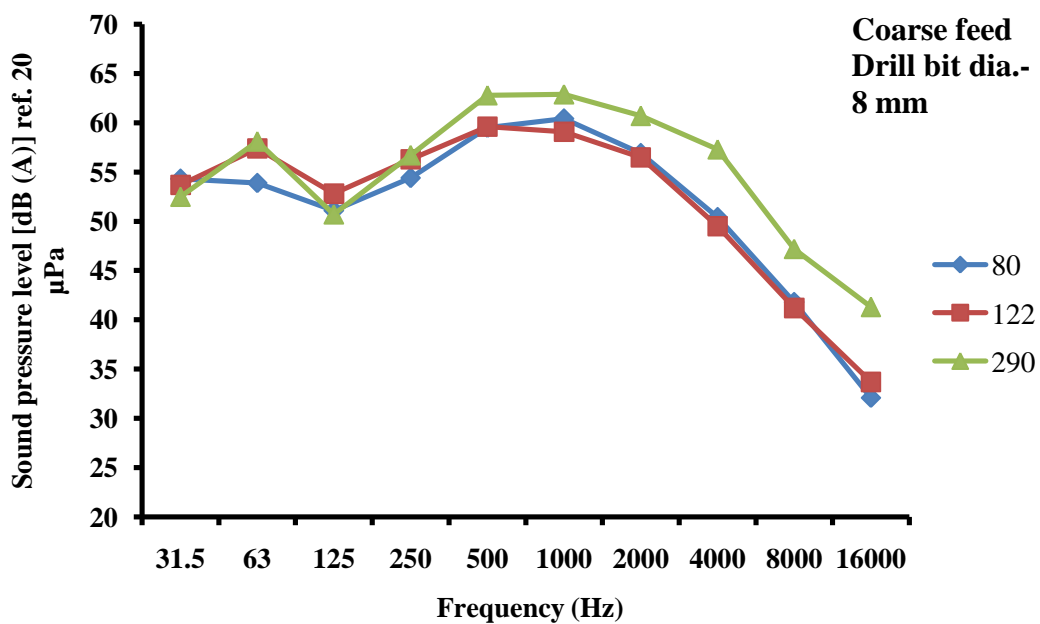
Figure 6.11: Sound pressure level vs. Frequency for cast iron workpiece at 12 mm drill bit

Figure 6.11(a) and 6.11(b) shows the frequency spectrum of cast iron workpiece at fine feed and coarse feed respectively with 12 mm drill bit. A very linear trend of frequency spectrum can be seen in this case. Mid frequencies contributes the most in noise level. Sound pressure at 31.5 Hz at 290 rpm is an exception.

6.3.3 Frequency spectrum of Mild Steel workpiece



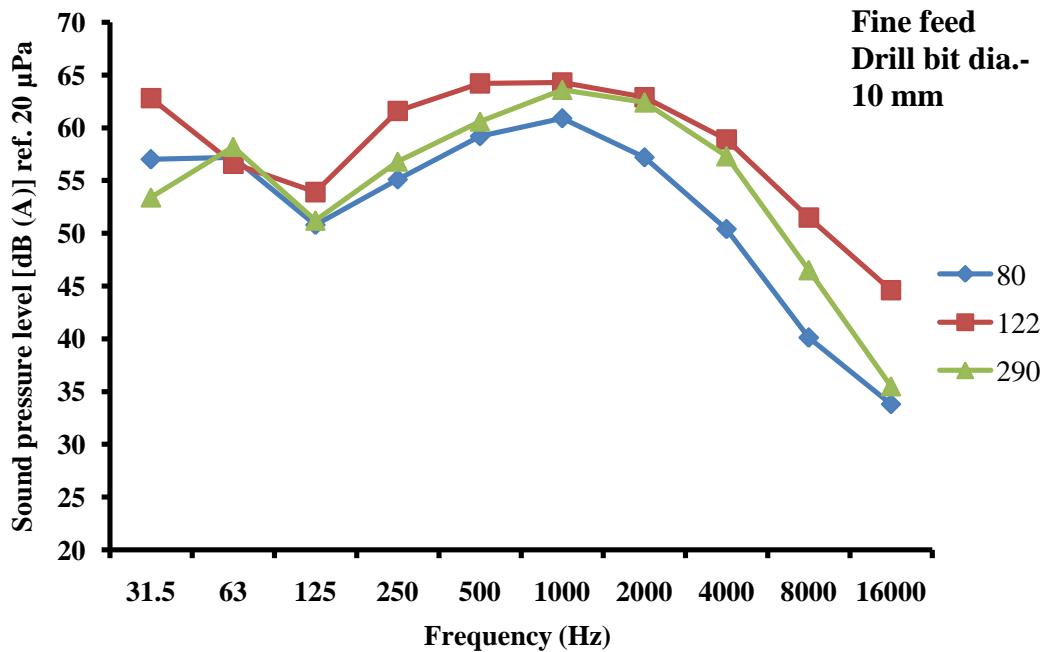
(a)



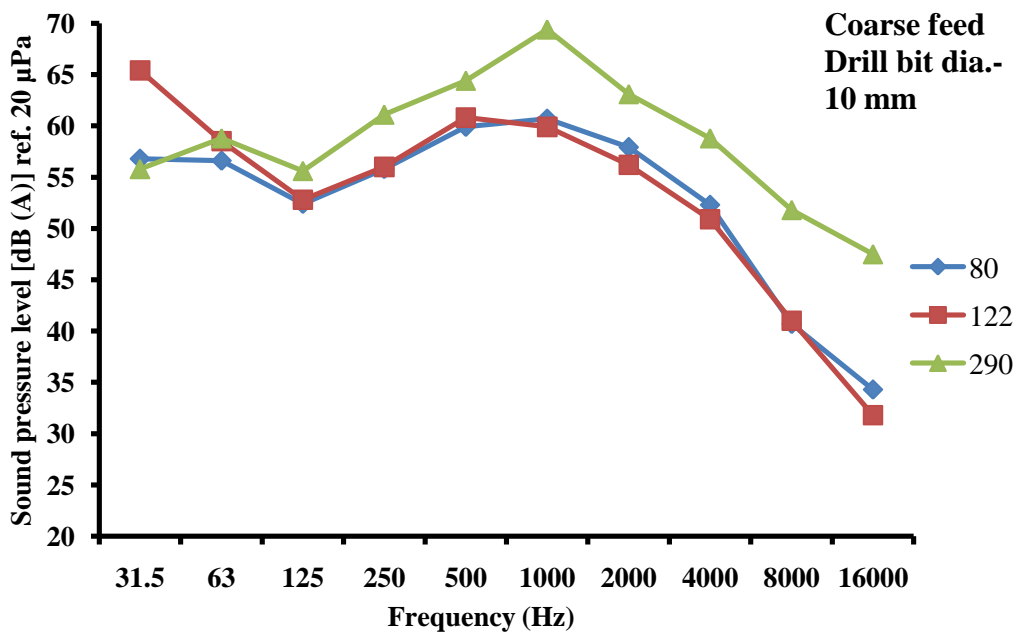
(b)

Figure 6.12: Sound pressure level vs. Frequency for mild steel workpiece at 8 mm drill bit

Figure 6.12(a) and 6.12(b) shows the frequency spectrum of mild steel workpiece at fine feed and coarse feed respectively with 8 mm drill bit. A trough can be seen at 250 Hz with 290 rpm which is not common in other cases. Mid frequencies are producing highest amplitude of SPL.



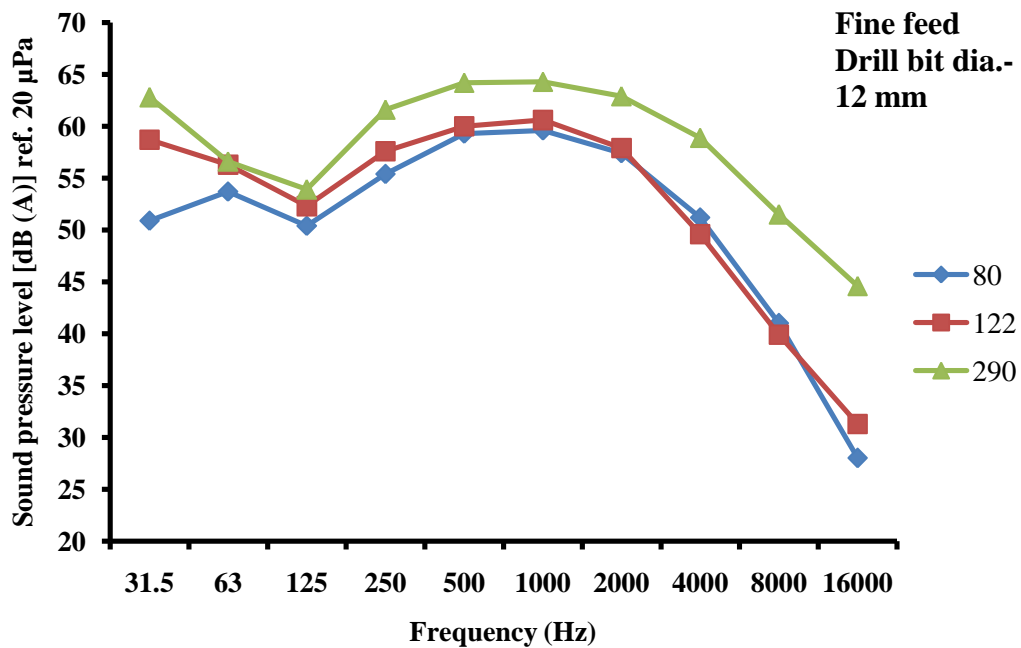
(a)



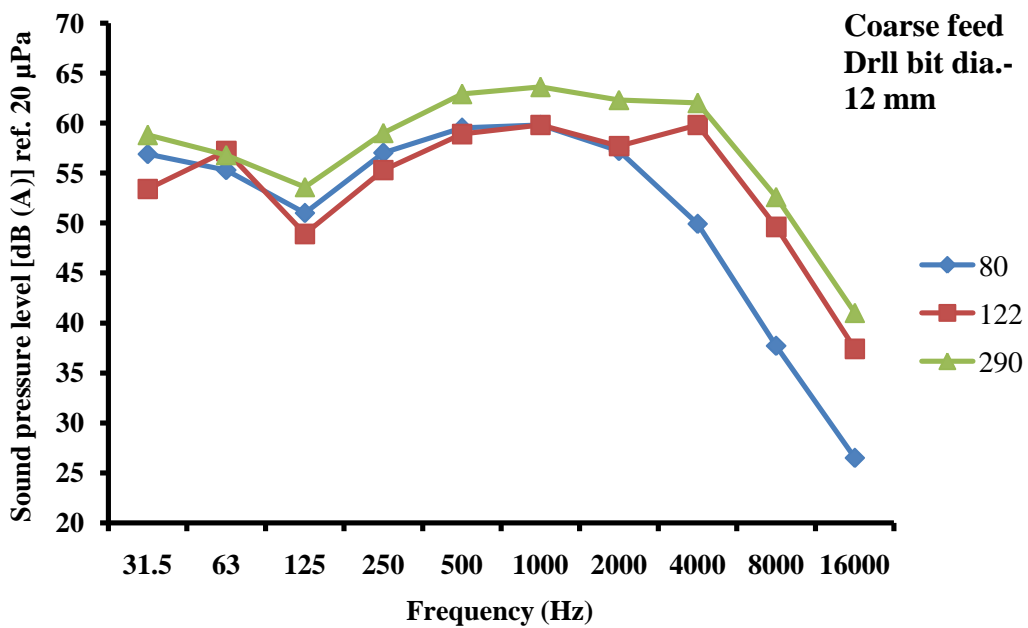
(b)

Figure 6.13: Sound pressure level vs. Frequency for mild steel workpiece at 10 mm drill bit

Figure 6.13(a) and 6.13(b) shows the frequency spectrum of mild steel workpiece at fine feed and coarse feed respectively with 10 mm drill bit. At 122 rpm, frequency of 31.5 Hz is significantly contributing in the noise level of the operation. At fine feed, speed of 122 rpm contributes significantly whereas at coarse feed, 290 rpm is generating highest noise level at mid frequencies.



(a)



(b)

Figure 6.14: Sound pressure level vs. Frequency for mild steel workpiece at 12 mm drill bit

Figure 6.14(a) and 6.14(b) shows the frequency spectrum of mild steel workpiece at fine feed and coarse feed respectively with 12 mm drill bit. At 122 rpm, during working on coarse feed, a noise frequency of 4000 Hz added to the noise level of the operation and increases the sound pressure level.

Chapter 7

Conclusions and Future Scope

7.1 Conclusions

Data was collected on noise generating parameters of a RDM and applied to calculate the SP, SPL and frequency spectrum of the noise signals. From the present study following conclusions are drawn:

- SP of the machine increases with increase in spindle speed of the RDM.
- SP of the machine at the coarse feed is more than the SP at fine feed.
- A-weighted equivalent continuous sound level (LA_{eq}) is recorded maximum at the top of the RDM because of the noise generated by the electric motor mounted on the drill head of the machine. (see Appendix A)
- Electric motor of drill head annoys more than the other sources of noise generation in RDM.
- A-weighted equivalent continuous sound level (LA_{eq}) is recorded more in the front of the RDM than the other positions. (see Appendix A)
- SPL generated at spindle speed of 290 rpm is maximum and minimum at 122 rpm.
- SPL is recorded minimum with drill bit of 12 mm in most of the cases.
- When SPL of drilling is compared at 290 rpm by varying the other factors, it is found that cast iron produces highest noise level than mild steel and aluminium.
- SPL generated at mid frequencies (250 Hz to 2000 Hz) is more than the sound level of low frequency (31.5 Hz to 125 Hz) and high frequency (4000 Hz to 16000 Hz) sound waves.

A human ear is most sensitive at mid frequency sound waves which create annoyance and a factor of critical importance to human health. Therefore it needs to be control.

7.2 Future scope of work

Noise measurement and reduction has become the need of the today's world. Noise pollution of the machines in the work places is a serious problem for the surrounding.

Therefore it has to be measured and controlled for making the working conditions safe.

This present work has following future scopes:

- This work does not contain the control measures of the noise generated by RDM. A study on noise control can be done to reduce and control the noise level.
- A noise study can be done on different sources of noise generation in RDM i.e. bearings, electric motor and gears.

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Appendix

A: Average noise pressure level in dB (A) for different speeds and feeds at different
microphone positions

Spindle speed	80 rpm		122 rpm		160 rpm		244 rpm		290 rpm	
Microphone position	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse
1	62.6	62.4	62.1	62.4	62.6	62.8	63.7	64.1	64.8	64.7
2	62.3	62.8	62.3	63.2	62.4	62.1	64.6	65.3	65.1	66.1
3	62.3	62.7	62.0	62.7	62.3	62.9	64.9	65.1	65.7	65.0
4	62.2	62.1	62.5	63.0	62.6	63.2	64.9	65.4	65.8	65.7
5	63.3	63.3	62.3	62.7	62.2	62.6	65.7	65.7	66.0	66.3
6	62.1	62.0	62.3	62.6	62.5	62.6	65.8	65.4	66.0	66.1
7	63.3	63.6	63.4	64.3	63.5	64.4	66.1	66.4	66.9	67.0
8	61.8	61.8	62.1	62.5	62.2	62.7	65.1	66.8	65.5	66.7
9	61.9	62.3	62.7	62.3	62.6	62.5	64.5	65.0	65.2	65.2
10	61.8	62.1	62.1	62.4	62.2	62.3	64.7	65.5	65.2	65.8
11	61.9	62.1	62.0	62.4	62.1	62.2	64.1	64.2	64.9	64.8
12	61.4	61.5	61.5	62.3	61.4	62.5	64.4	64.1	64.6	64.7
13	62.6	63.6	62.7	63.6	62.4	63.7	65.4	65.3	66.5	65.9
14	62.8	63.7	63.7	63.9	63.9	63.8	66.2	66.5	66.5	66.9
15	62.5	62.7	62.6	63.4	62.9	63.5	65.6	65.9	65.7	66.2
16	62.8	63.0	62.7	63.1	62.8	63.3	64.8	65.2	64.9	65.3
17	67.7	67.9	67.4	68.7	67.9	68.6	69.2	69.5	70.1	70.1

B: Sound power at different speeds

Spindle speed (RPM)	Feed rate	Sound Power, L_w dB(A)
80	Fine	74.73
	Coarse	75
122	Fine	74.76
	Coarse	75.78
160	Fine	75.36
	Coarse	76.68
244	Fine	78.47
	Coarse	78.81
290	Fine	78.78
	Coarse	78.98

C: Sound pressure level at different frequencies for full factorial design of machining operations

Sr. No.	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz	16000 Hz	LA dB(A)	LA _{peak} dB(A)
1	53.4	58.2	51.2	56.8	60.6	63.6	62.4	57.3	46.5	35.5	67.6	78.8
2	57	57.2	50.8	55.1	59.2	60.9	57.2	50.4	40.1	33.8	63.9	75.7
3	52.8	56	49.5	55.7	61.1	65.2	64.4	60	52	43.6	69.4	82.4
4	56.5	52.9	51.5	56.4	59.7	60.7	58	49.9	38.6	27.3	64.1	76.3
5	56.9	56.6	52.8	56.4	59.1	59.7	56.7	49.3	39.2	31.1	63.1	75.2
6	50.9	53.7	50.4	55.4	59.3	59.6	57.4	51.2	41	28	63.5	75.8
7	51.9	56.5	50.3	58.3	59.3	59.3	57.3	49.4	39.4	28.6	63.3	75.3
8	53.4	56.1	52.9	46.4	60.2	61	58	51.5	44.9	36.8	64.4	76.2
9	56.7	56.6	49.2	54.8	58.5	58.9	56	49.3	45.5	32.6	62.5	75.2
10	54.4	54.2	49.7	57.8	62.3	63.8	63.8	62.2	55.4	50.6	69.4	82.4
11	62.8	56.6	53.9	61.6	64.2	64.3	62.9	58.9	51.5	44.6	68.8	82.1
12	64.2	57.5	51.5	56.1	59.2	59.7	56.6	50.2	40.1	31.1	63.1	75.3
13	54.6	55.3	51.9	57.2	59.5	60.3	56.9	49.8	39.3	31.5	63.6	75.1
14	55.4	54.1	48.2	55.2	59.9	61.4	61.3	56.8	51.5	45	66.3	79.6
15	52.6	56.3	53.1	58.8	62.9	62.9	61.6	58.4	48.9	39	67.6	79.5
16	57.3	53.8	51	56.1	58.7	60.8	58.1	54.2	66.2	57.3	67	81.5
17	51.9	51.4	49.5	57.2	58.1	57.8	56.2	49.2	43.5	37.5	62.1	74.9
18	59.1	55.8	51.4	58.8	59	60	57.7	50.3	39.6	30.7	63.7	75.7
19	52.8	54.9	50.7	54.5	60.2	62.5	61.9	65.1	56.5	47.9	69.2	84.2
20	55.1	55.1	53.6	58.4	60.8	59.7	58.3	50.9	43	34.9	64.1	84.3
21	51.5	55	57.1	49.3	61.4	59.5	56.7	50.5	39.3	29.2	63.8	77.1
22	56.6	54.2	51.3	56.2	59.6	61	57.2	49.8	41.5	35.1	63.9	77.2
23	55.7	56.2	50.5	55.2	59.5	59.8	57.3	49.9	41	32.6	63.5	75.5
24	58.7	56.3	52.3	57.6	60	60.6	57.9	49.6	39.9	31.3	64.1	77.4
25	53	53.9	49.1	56.5	61.1	62.9	61.6	58.6	51.8	46.9	67.4	79.9
26	57	53.7	52.7	58.1	63.1	61.5	59.5	54.5	45	36.2	65.9	79.5
27	56.1	56.2	54.5	60.9	67.8	68.1	66.1	64	55.5	46	72.5	85.9
28	51	51.4	49.8	54.8	58.8	60.6	59.4	50	39.1	27.7	64.4	77.6
29	50.9	52.7	50.2	58	63.3	63.2	64.7	62.7	52.6	47.4	67.7	83.1
30	52.5	58.1	50.7	56.7	62.8	62.9	60.7	57.3	47.2	41.3	67	77.9
31	54.3	55	52.2	56.7	60.5	61.9	60.6	54.9	47.3	40.5	66	78.8

32	62.7	55.8	48.7	55.3	58.5	60	57.1	58.6	52.8	52.1	64.7	79.5
33	52.5	57.4	53.7	56.4	60	60.4	57.3	56.1	46	33.8	64.4	77.8
34	64.2	65.8	60	63.5	64.8	62.4	64.7	62.3	62.1	50.9	70.2	98
35	58.8	56.8	53.6	59	62.9	63.6	62.3	62	52.6	41	68.7	84
36	50.9	52.3	55.1	59.4	61.8	56.2	53.3	44	36.3	27.9	61.8	77
37	56.8	56.6	52.4	55.8	59.9	60.7	57.9	52.3	40.7	34.3	64.2	76.1
38	51.4	56.1	48.7	56.5	59.2	61.3	59.4	52.3	47.2	36.3	64.9	78.6
39	55.8	58.8	55.6	61.1	64.4	69.4	63.1	58.8	51.8	47.5	71.2	83.4
40	53.6	54.9	52.5	56.8	60.7	61.2	59.4	52.8	41.7	32.9	65.1	77.3
41	54.1	53.5	49.1	55.9	58.8	59.1	57.3	50.1	39.9	29.7	63.1	75.9
42	55.7	53	49.9	56.2	60.2	59	56.4	49.3	47.7	32.4	63.1	75.5
43	55.8	54.3	53	58.5	61.6	61.4	57.9	51.2	43.9	36.6	64.9	77.9
44	57.1	55.6	52	59	61.6	63	61.8	58.8	47.9	37	67.5	81.4
45	56.9	55.3	51	57	59.5	59.8	57.2	49.9	37.7	26.5	63.5	76.2
46	54	51.7	54.6	60.1	63	63.5	62.7	60.1	48.8	39.9	68.5	80.4
47	53.4	57.2	48.9	55.3	58.9	59.8	57.7	59.8	49.6	37.4	65.1	79.1
48	54.3	53.9	51.1	54.4	59.5	60.4	56.9	50.4	41.8	32.1	63.6	75.3
49	52.7	53.4	51.3	56.7	59.9	61.8	58.5	53.4	41.3	31	65	79.1
50	53.7	57.4	52.8	56.3	59.6	59.1	56.5	49.5	41.2	33.7	63	75.5
51	52.6	55.9	52.5	55.2	59.4	59.9	57.6	51.9	45.5	35.3	63.7	79.1
52	52.7	52.9	51.4	56.2	59.7	61.3	56.7	49.1	40.4	33.1	64	75.9
53	65.4	58.5	52.8	56	60.8	59.9	56.2	50.9	41	31.8	65.1	76.5
54	57.8	55	53.6	61.3	65	65.8	65.8	63.9	56.1	47.5	71.4	84.6