NOISE REDUCTION AND COST SAVING ANALYSIS FOR PNEUMATIC AND ELECTRICAL SYSTEM OF MICROGRINDER AT CNC AREA

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NOISE REDUCTION AND COST SAVING ANALYSIS FOR PNEUMATIC AND ELECTRICAL SYSTEM OF MICROGRINDER AT CNC AREA

NUR ATIQAH BINTI ALIAS

This thesis is submitted as partial fulfillment of the requirements for the award of the Bachelor of Engineering (Hons.) in Mechatronics Engineering- (Dual Degree Programme with Karlsruhe University of Applied Sciences, HsKA, Germany)

Faculty of Manufacturing Engineering

UNIVERSITI MALAYSIA PAHANG (UMP)

MARCH 2018

Specially dedicated to

My father: Alias Bin Md Zain

My mother: Halimah Binti Pawan

My sisters and brothers:

Norhayati Binti Alias

Abdul Karim Bin Alias

Hafiza Binti Alias

Asmara Binti Alias

Abdul Rani Binti Alias

Aslina Binti Alias

My friends

And

My Lecturers

Thank You!

ACKNOWLEDGEMENTS

Alhamdulillah, all praises belongs to Allah, the Almighty and the most Merciful for his blessing and Peace and Prayer to the Prophet to complete this thesis and bachelor degree successfully. I would like to express my gratitude to En. Kamarulzaman Mahmad Khairai, Industry Supervisor at TT Electronic, Dr. Nafrizuan bin Mat Yahya, University Malaysia Pahang's supervisor and Prof. Dr.ing. Robert Weiss, Hochschule Karlsruhe's supervisor for the endless knowledge and also, I would like to thank technical support's staff and production's staff at TT Electronic, Kuantan for giving us thorough guidance and helping out with their technical expertise which are really useful in fulfilling my bachelor thesis.

I would also like thank my family who has been my biggest supporter throughout this journey. Classmates and others that may have been involved directly or indirectly during this project; I am forever thankful for their never-ending support and motivation and without them I will not be able to be at the position where I am today. There would be a full list of people without whom this final report might not have been written and to whom I am greatly indebted.

Last but not least, I would like to express my gratitude to TT Electronic, Kuantan, University Malaysia Pahang (UMP) and also Karlsruhe University of Applied Sciences (HsKA), Germany for all the support given by the university to help completed this bachelor thesis.

ABSTRACT

At TT Electronics, Kuantan, Malaysia the highest noise contribution is from pneumatic system during stripping process and also the main cause of reject during stripping process are over and insufficient stripping because of the air micro grinder that need frequently maintenance. Changes of system from pneumatic and electrical system is the main solution to this problem. After the changes, electrical system shows the lowest noise contribution to the surrounding and the changes help from 161% to 244% noise reduction. The permissible exposure limits (PELs) of noise based on Occupational Safety and Health (OSHA) criterion can also be meet when the changes of system occur. In addition, the benefits from the changes of the system is USD 273.26 with only 3 month of payback period and 97% return of investment (ROI). This high ROI means the investment's gain compare favorably to its cost. Based on total saving in term of labour cost, the total downtime of the machine is decreasing causing increasing of the effective hour and directly proportionally increase in total saving of labour cost. Indirectly when the system changes, the machine downtime is minimized that provide maximized efficiency, increases machine availability which in turn increase through output and minimized reject that also reduces order lead times and increase customer satisfaction. At the same time, ergonomic in occupational safety and health can be achieved when the noise exposure follows the OSHA criterion and it's also help increases the total saving in two main categories for the company itself which is in term of part and labour.

ABSTRAK

Di TT Elektronik, Kuantan, Malaysia penyumbang bunyi tertinggi adalah dari sistem pneumatik semasa proses pelarikan dan juga penyebab utama kerosakan semasa proses pelarikan adalah terlebih dan terkurang pelarikan kerana micro grinder angin yang memerlukan penyelenggaraan yang kerap. Perubahan sistem dari sistem pneumatik kepada elektrik adalah penyelesaian utama kepada masalah ini. Selepas perubahan, sistem elektrik menunjukkan penyumbang bunyi yang paling rendah kepada persekitaran dan perubahan sistem membantu pengurangan bunyi dari 161% hingga 244%. Had pendedahan bunyi yang dibenarkan berdasarkan kriteria Keselamatan dan Kesihatan Pekerjaan (OSHA) juga boleh dipenuhi apabila berlaku perubahan sistem. Di samping itu, faedah dari perubahan sistem adalah USD 273.26 dengan hanya 3 bulan tempoh bayaran balik dan pulangan pelaburan sebanyak 97%. Pulangan pelaburan yang tinggi bermakna keuntungan pelaburan lebih tinggi di bandingkan dengan kos pelaburan. Berdasarkan jumlah penjimatan dari segi kos buruh, jumlah downtime mesin berkurang menyebabkan peningkatan jam efektif dan secara tidak langsung berlaku peningkatan dalam jumlah penjimatan kos buruh. Apabila berlaku perubahan sistem, pembehentian mesin dapat diminimumkan dan kecekapan mesin dapat dimaksimumkan, ketersediaan mesin juga dapat dipertingkatkan yang seterusnya berlaku peningkatan keluaran dan mengurangkan kerosakan dan mengurangkan masa pesanan akhirnya meningkatkan kepuasan pelanggan. Pada masa yang sama, ergonomik dalam keselamatan dan kesihatan pekerjaan boleh dicapai apabila pendedahan bising mengikuti kriteria OSHA terlaksana dan ia juga membantu meningkatkan jumlah penjimatan dalam dua kategori utama untuk syarikat dari segi peralatan dan buruh.

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LIST OF SYMBOLS

c	*speed of sound in meter or feet per second*
f	*frequency in Hz*
λ	*wavelength in meters or feet.*

LIST OF ABBREVIATIONS

OSHA	*Occupational Safety and Health Administration*
NIOSH	*National Institute for Occupational Safety and Health*
PPE	*Personal Protective Equipment*
CNC	*Computerized Numerical Control*
PELs	*Permissible Exposure Limits*
ROI	*Return of Investment*
TWA	*Time Weighted Average*

CHAPTER 1

INTRODUCTION

1.1 Introduction

Sound is a sensation of acoustic waves in disturbance or pressure fluctuations setup in a medium whereas noise is generally unpleasant, unwanted and disturbing sound within a useful frequency band. Physically, there is no difference between sound and noise because sound is sensory perception and noise corresponds to undesired sound. Any discussion of noise, its effects and the Occupational Safety and Health Administration's (OSHA) attempts to limit noise-related injury presumes a grasp of the most basic physics of sound [1]. In manufacturing environment permanent hearing loss is the main health concern [2].

The most common noise source within manufacturing equipment is pneumatic [3]. When high velocity air mixes with the atmospheric air it creates excessive turbulence and particle separation therefore this is the main causes that make pneumatic system generate undesirable noise [4]. Thus, the air pressure setting for all pneumatic devices should be reduced or optimized to as low value as practical.

Basic definition of ergonomic is fitting the task and work environment to workers [5]. Ergonomics is also can be considered as user-centred approach to research and design. The design of the workplace and tasks and to work organisation is referred to ergonomics in occupational health and safety. Figure 2 shows elements in occupational ergonomics where it helps to improve from an ergonomics point of view. There are 10 main principles of ergonomics and the sixth principle of ergonomics is to minimize fatigue where this principle related to the element of work environment in occupational ergonomics. Fatigue could be avoided by prevent adverse outcome of noise exposure by reducing the noise level to acceptable levels. National Institute for Occupational Safety and Health (NIOSH) suggest that workers should not be exposed at a level that amounts to more than 85 decibels (dBA) for 8 hours [6]. Hierarchy of control as shown in figure 1 show that the best approach is to eliminate the source of hazardous noise. But when elimination is not possible, there is also substitution, engineering controls and administrative controls. The usage of personal protective equipment (PPE) should be considered as an interim measure.

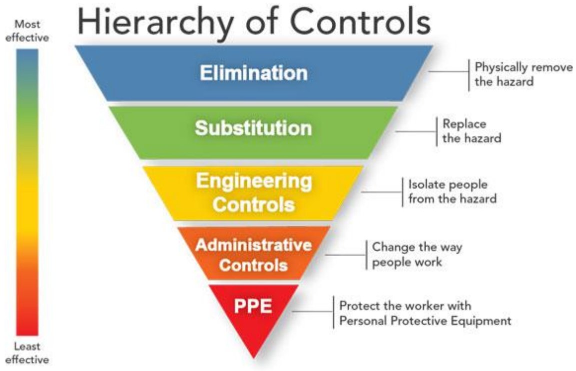


Figure 1: Hierarchy of Controls of Occupational safety and health professionals [7]

Figure 2 : The relationship between different elements [8]

BI Technologies Corporation Sdn. Bhd. is a division of TT Electronics an innovative global electronics company. It is established since 1976 and makes their operation at Jalan Tanjung Api, Kuantan, Pahang where it manufactures Magnetic components that supplies to the automotive, medical devices, industrial and defence component applications. UK, US, China and Malaysia are TT electronics global Electronics Manufacturing Services (EMS) operation based. The main product of BI Technologies are inductors, semiconductor products and connectors.

As EMS companies the crucial machine in TT Electronics is Computerized Numerical Control (CNC) machine where it makes winding air coil the first part that need to be produced before distributed to other production line to turn into the end-product. Thus, maintaining the performance of the machine is very essential so that the productivity of the line will not be disrupted.

In TT Electronic, the pneumatic system is widely used in its computer numerical control (CNC) Machine where it starts from the striping process until winding of the coil. This lead to high exposure of noise that require Personal Protective equipment such as ear muff to be wear in order to enter the CNC Area because of the noise exposure is higher than 85dB for 8 hours. By substitute the air micro grinder to electrical micro grinder could reduce the high noise exposure and also overcome the main problem occur during the winding of the coil especially on its stripping process. Most of the problem identify at TT is contribute by stripping process, whether insufficient or over stripping occur that causes from, if the micro grinder it's not oil daily or some part of the micro grinder is damaged. If the problem occurs because of damage at the any part of the micro grinder the micro grinder need to be replace as whole rather than only the small part that damage. Indirectly, the maintenance cost for the air micro grinder itself is high and the life span of it is short. Therefore, by using this substitution method, noise exposure at CNC Area could be reduced and proportionally improve ergonomic of occupational health and safety.

1.2 Problem Statement

The highest noise contribution is from pneumatic system during stripping process where the air micro grinder is easily damaged causing in high maintenance cost because once a problem occurs at any part of air micro grinder, whole of the micro grinder need to be changed. The air micro grinder also has short life span where it only has 3 months maximum. Air micro grinder need daily maintenance where between the adaptor and coupling need to be oil daily. The air micro grinder is the main cause occurs reject during stripping process that are over and insufficient stripping.

1.3 Objective

The main objective of this project is to:

1. To analyse and compare the noise produce between air and electrical die grinder at CNC Area.
2. To calculate saving in term of part and labour cost due to the changes of part from air die grinder to electrical die grinder.
3. To justify the need of changes from air die grinder to electrical die grinder at CNC Area in term of noise contribution and reduction and total cost saving in term of part and labour

1.4 Scope

1. The layout of the CNC Machine is only use at TT Electronic Kuantan Pahang Malaysia.
2. Only four CNC Machine that involved in this project that is CNC 1, 2, 3 that uses pneumatic system and CNC 4 that uses electrical system.
3. The noise of the system observed and measured are only during stripping process of the winding coil.
4. The CEN0053 Heavy Duty Data Logging Sound Level Meter is use as the instrument to measure the noise level at CNC Machine Area.

1.5 Flow Chart

This flowchart is used during the execution of the project:

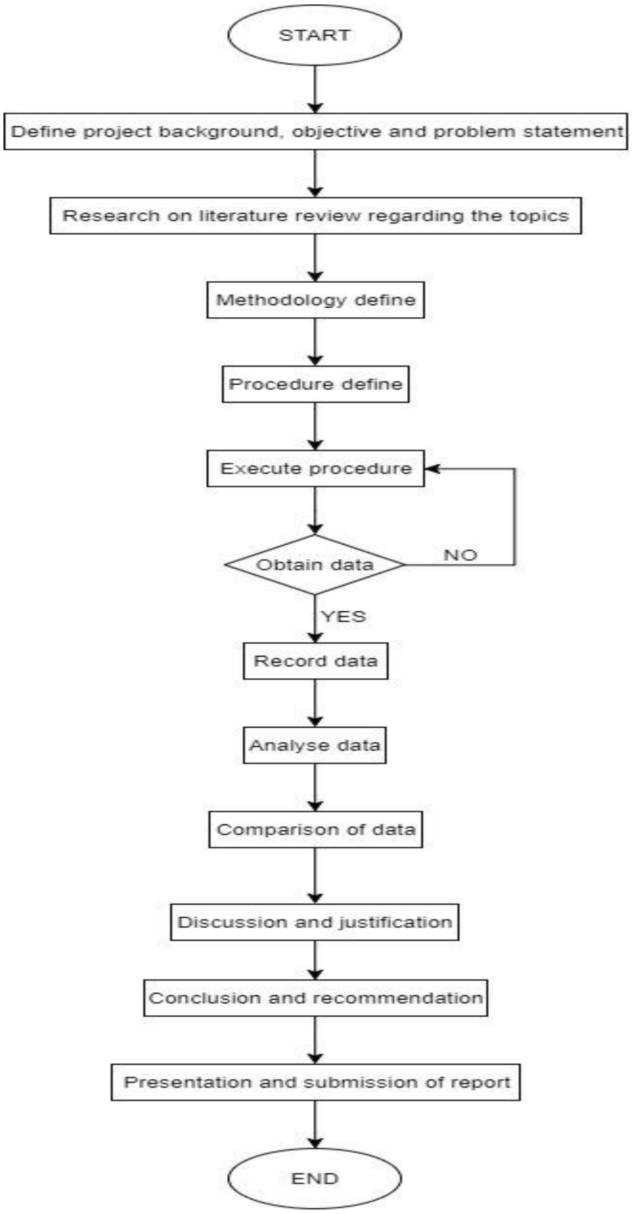


Figure 3: Flow chart of the project

CHAPTER 2

LITERATURE REVIEW

2.1 Basic Physic of Sound

2.1.1 Sound, noise and vibration

Sound can be defined as a rapid variation of atmospheric pressure caused by some disturbance of the air where the sound propagates as a wave through the medium of positive pressure disturbances and negative pressure disturbance [9]. Sound is produced by vibrating object. When the air molecules start to vibrate causes the ear to identify the variations in pressure as sound. Then the vibrations are converted into mechanical energy by the middle ear later the microscopic hairs start to move in the inner ear which in turn convert the sound waves into nerve impulses. Provided that the vibrations are too intense as the time goes by these microscopic hairs can be damaged, causing hearing loss. Whereas noise is unwanted sound [10]. Noise and vibration are both fluctuations in the pressure of air which affect the human body. Vibrations that are detected by the human ear are classified as sound. Noise and vibration work together can harm workers when they occur at high levels, or continue for a long time.

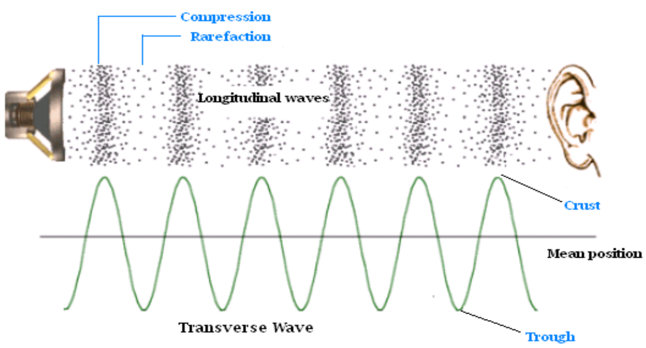


Figure 4: Sound Wave [11]

2.1.2 Type of noise

Most noise exposures, occupational and environmental, are not constant over time [12]. There are 3 types of noise:

1) Continuous noise

An interrupted sound level that varies less than 5 dB during the period of observation

2) Intermittent noise

A continuous noise that persists for more than 1 second that is interrupted for more than 1 second

3) Impulse Noise

A change of sound pressure of 40 dB or more within 0.5 second with a duration of less than 1 second.

2.1.3 Qualities of sound

2.1.3.1 Wavelength

Wavelength is the distance travelled by a sound wave during one sound pressure cycle where the distance between two high point or low points in a wave is measure. Frequency and wavelength is inversely related. The higher the frequency of a signal, the shorter the wavelength.

2.1.3.2 Amplitude and frequency

Amplitude is the size of the vibration and determine how loud the sound is.

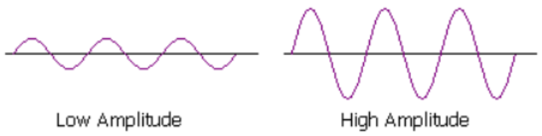


Figure 5: Amplitude [13]

Frequency is measured in hertz (Hz) where it measures the number of vibrations that occur per second and determine the pitch of the sound.

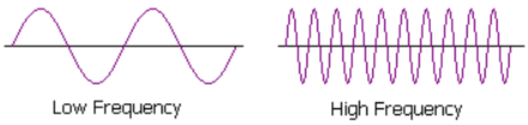


Figure 6: Frequency [14]

The higher the frequency, the more high-pitched a sound is detected. Whereas, the higher the frequency the more loudness is the sound. Each individual's ears sense varies frequency range. Normal hearing person can hear frequencies between approximately 20 Hz and 20000 Hz. The earliest to be affected by exposure to noise is when the portion of the ear that detect frequencies between 3000 Hz and 4000 Hz.

2.1.3.3 Speed

Density and compressibility of the medium through which the sound travelling determine the speed of the sound travels, c. The unit measurement speed of sound is meters per second or feet per second.

When elasticity of the medium decreases and the density of the medium increases then the speed increases. For example: In liquids and solid the speed of sound is much higher compared to the speed of sound in air at standard temperature and pressure. Frequency, wavelength and speed of sound are in correlation by the equation

$$c = f\lambda$$

where c = speed of sound in meter or feet per second, f = frequency in Hz and λ = wavelength in meters or feet.

2.1.3.4 Sound pressure

Force of sound on a surface area perpendicular to the direction of sound is called sound pressure [15]. The unit measurement for sound pressure are N/m^2 or *Pa*. A larger pressure variation produces a loud noise and vice versa.

Sound Pressure expressed in		
	Pa	µPa
Softest Noise just Heard by a Human Ear	20×10^{-6}	20
Launching of the Space Shuttle	2,000	2×10^{9}

Table 1: Sound pressure level expressed in Pa and µPa

A very wide range of sound pressure can be detected by the human ear. The threshold of hearing is the softest sound a normal human ear can detect that has a pressure variation of 20 µPa. a large pressure variation during very nosy events that can be produced at a short distance such as launching of the space shuttle with approximately 2000 Pa [16].

Source of Sound/Noise	Approximate Sound Pressure in µPa
Launching of the Space Shuttle	2,000,000,000
Full Symphony Orchestra	2,000,000
Diesel Freight Train at High Speed at 25 m	200,000
Normal Conversation	20,000
Soft Whispering at 2 m in Library	2,000
Unoccupied Broadcast Studio	200
Softest Sound Human can Hear	20

Table 2: Common sound or noise in terms of µPa

The level of sound pressure *P* is said to be Lp decibels greater than a reference sound pressure *Pref*.

Sound Pressure Level = $10 \log_{10}(P^2 / Pref^2)$ dB

$= 20 \log_{10}P - 20\log_{10}Pref$ dB

Where *P* is the sound pressure fluctuation and *Pref* is 20 µp which is approximately the threshold of hearing.

2.1.3.5 Decibels

A unit of measurement that indicates how loud a sound is called decibel [17]. dB is used for unweighted sound level using reference of 20 micro pascals whereas dB(A) is A-weighted scale of sound level using a reference level of 20 micro pascals. Small change in the number of decibels results in a huge change in the amount of noise and the potential damage to a person's hearing because the decibels are measured on a logarithmic scale.

2.1.3.6 Sound fields

Near field or far field is part of sound field category, a differentiation that is important to the reliability of measurements. The space immediately around the noise source is called near field that can be defined as within the wavelength of the lowest frequency component. The space outside the near field is called far field, meaning that the far field begins at least one wavelength distance from the noise source. Whereas, there are also free field which is a region that has no reflected sound wave. So, in this field sound radiates into space from a source uniformly in all directions.

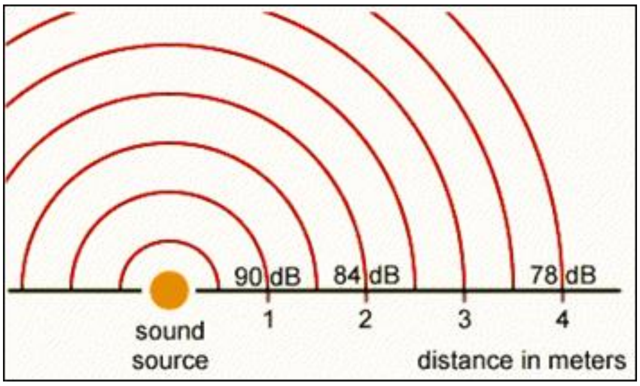


Figure 7: Sound pressure level in free field [18]

Figure 4 show that a sound pressure level of 90 dB is produce at a distance of 1 meter form a point source in a free field, at 2 meter the sound pressure level is 84 dB, at 4-meter 78 dB and so forth [19]. This principle holds true regardless of the units used to measure distance.

Sound fields are more complex in spaces defined by walls. The wave picture changes completely when sound objects such as walls or machinery are introduced into the sound field. The sound will be reflecting back when it reverberates rather than continuing to spread away from the source. These conditions mostly occur in industrial operation and many construction tasks.

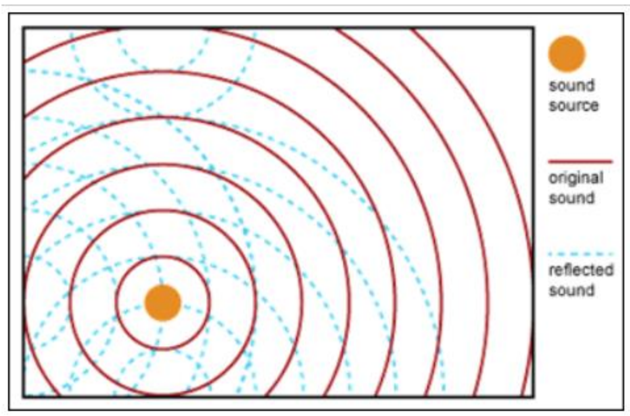


Figure 8: Sound radiating from sound source [20]

Figure 5 show that the net result is a change in the intensity of the sound [21]. The sound pressure decreases by less than 6 dB each time the distance from the sound source doubles. The reflected sound dominates when it's far from the noise source where this region is called the reverberant field. If the sound waves travel in all directions with equal probability and the sound pressure levels in reverberant field are uniform throughout the room the sound will be diffuse. However, ideal free fields and reverberant fields rarely exist because most sound fields are something in between.

2.1.3.7 Sound power

Sound power measurement unit is in watts which is the amount of energy per unit of time that radiates from a source in the form of acoustic wave. Relationship between sound pressure and sound power understanding is needed to predicting what noise problem will be created when particular sound sources are placed in working environment. How close workers will be working to the source of sound is an important consideration. Basic rule, doubling the sound power increases the noise level by 3 dB [22]. Sound power distributed over a spherical surface so that at any given point when it radiates from a point source in free space. It is expressed in units of watts per square meter and designated as intensity,

Sound intensity is heard as loudness, which can be detected differently depending on the individual distance from the source and the characteristic of the surrounding space. The sound intensity decreases if the distance from the sound source increases. The spherical surface over which the power is spread increases so the power is less intense but the sound power remains constant. The sound pressure level at some distance, r, from the source depends on that distance and the sound absorbing characteristic of the environment.

2.1.3.8 Filtering

Most noise consist of many frequencies simultaneously emitted from the source rather than a pure tone. In order to represent the total noise of a source, it is necessary to categorized in into its frequency components. This is due to people reaction towards low frequency and high frequency sounds differently. Certain sound level able to determine the frequency distribution of sound by passing it to several different electronics filters so that it can separate the sound into nine octaves on a frequency scale [23]. There are 2 common reasons for filtering sound:

1) Determine the most prevalent frequencies or octaves
2) Using several weighting methods to adjust the sound level reading

2.1.3.9 Octave bands

Octave band is one of the type of frequency band that are easy way to measure and describe the various frequencies that are part of a sound. When the upper band-edge frequency, f_2, is twice the lower band-edge frequency, f_1: $f_2 = 2 f_1$ [24].

$f_c = (f_1 f_2)^{1/2}$ is formula to calculate centre frequency where fc = centre frequency and f_1 and f_2 are the lower and upper frequency band limits, respectively.

Lower Band Limit (Hz)	Band Center Frequency (Geometric Mean in Hz)	Upper Band Limit (Hz)
22	31.5	44
44	63	88
88	125	177
177	250	354
354	500	707
707	1,000	1,414
1,414	2,000	2,828
2,828	4,000	5,656
5,656	8,000	11,312
11,312	16,000	22,624

Table 3: The centre, lower, and upper frequencies for the commonly used octave bands

Its bandwidth is equal to the upper band limit minus the lower band limit.

2.1.3.10 Loudness and weighting networks

Loudness depends primarily on sound pressure but is also influenced by frequency [25]. Sound measurement has three different internationally standardized characteristics: weighting networks A, C, and Z. Sound level meter's means of responding to some frequencies more than others used A and C weighting networks. The very low frequency hardly attenuated at all by the C-network, while A-network discriminated against attenuated quite severely. Measuring these weighting scales using this sound levels (dB) are designated by the appropriate letter such as dBA or dBC.

The A-weighted sound level measurement is adopted by OSHA in its noise standards because its provide a rating of industrial noise that indicates the injurious effects such as noise has on human hearing. On the other hand, unweighted scale is using Z-weighted measurement which provides a flat response across the entire frequency spectrum from 10 Hz to 20000 Hz. The C-weighted scale able to characterize low frequency sound that capable of inducing vibrations in building or other structures and used as an alternative to the Z-weighted measurement.

In 1993, reported by a pair of investigators named Fletcher and Munson the networks evolved from experiments designed to determine the respond of the human ear to sound. As a result, Fletcher-Munson or equal-loudness contours are born.

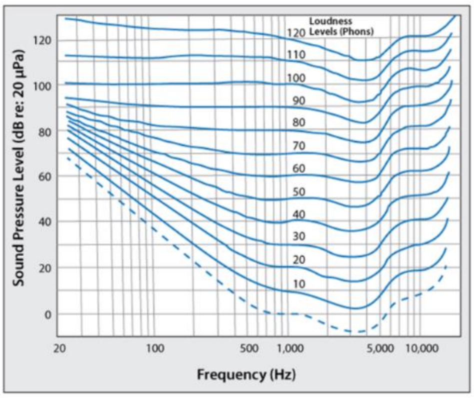


Figure 9: The Fletcher-Munson contours [26]

Figure 6 represent the sound pressure level necessary at each frequency to produce the same loudness response in the average listener. As the sound pressure level is increase, the non-linearity of the ear’s response is shown by the changing contour shapes. The dashed curve at lower part indicates the threshold may vary by as much as 10 decibels in either direction.

2.2 Instrument for Noise Measurement

2.2.1 Sound level meters

The pre-amplifier and a weighted filter over a specified range of frequencies of the sound level meter is fed with the electrical signal from the transducer. Further amplification prepares the signal for output direct reading on the meter. RMS value of the signal given by the rectifier then it is exponentially averaged using a time constant of 0.1 s (“FAST”) or 1s (“SLOW”) and the result is displayed digitally.

If the display scale is linear in dB and its dynamic range is usually much greater using log converter. The advantage of this display is by providing the same precision at any level and allowed a better appreciation in the range of fluctuations of the noise to be measured. [27]

IEC 60651 are the given specifications of sound level meter for four types 0,1,2,3 that differ in measurement precision. The type increase causes the measurement precision decreases affecting manufacturing costs significantly. There are 4 characteristics of IEC 60651: Directional characteristics, frequency weighting characteristics, time weighting, detector and indicator characteristics and last but not least sensitivity to various environment.

TYPE	INTENDED USES
0	Laboratory reference standard
1	For laboratory use and for field use where the acoustical environment has to be close specified and controlled
2	For general field application
3	Primarily for field noise survey applications

Table 4: Type of sound level meter

2.2.2 Time weightings

Once, there is no digital technology readily available and readings were presented to the user via analogue displays. Which, causes the needle of the sound meters moved back and forth across a scale to give reading. Problem occurs due to different manufactures producing these needles to different specification. The needles will always be in a constant motion because noise rarely stays at a constant level. Different length of needles response at different speeds even though it is the same amount of sound produce proportionally produce different result. Due to that problem, time weightings are created as a set of standards that specified the speed at which the needle had to move. Comparable to now, analogue needles are no longer in use but time weightings remain a measurable variable in sound. Hence, this show that the result can always be replicate with a different meter.

Fast time weighting is 8 times quicker the slow weighting at corresponds to 125 milliseconds whereas slow time weighting records sound at 1 second interval.

2.2.3 Frequency weightings

This refer to different sensitivity scales for noise measurement.

A-Weighting

The A-weighted sound levels almost match the perception of loudness by the human ear or could be define as it follows the frequency sensitivity of the human ear at low level and it predicts the damage risk of the ear. A-weighting scale filter out much of the low frequency noise they measure similar to the response of the human ear. Noise measurement made with the A-weighting scale are designated dBA.

C-Weighting

Its follow the frequency sensitivity of the human ear at very high noise levels and includes much more of the low frequency range of sounds than the A because the scale is quite flat.

C-Weighting scale initially designed as predictor of the ear's sensitivity to tones at high noise levels. However nowadays most of noise measurements for hearing conservation measured in dBA because the ears' damage risk for noise is not the same as the ear's loudness sensitivity for tones. Even though the low frequencies and high frequencies are recognized as being equally loud at high sound level, but much of the low frequency noise are being filtered out by ear to make it less likely to cause damage. Thus, A-Weighting scale replicates this filtering process of the human ear.

Previously, hearing conservation's key documents rely on dBC in determining noise exposures. However today all noise measurement for hearing conservation are measured in dBA, producing error when figuring attenuation from hearing protectors. Hence, OSHA set a guideline to differentiate between C and A-Weighting.

If your industrial noise measurements are in dBC, subtract the NRR of the hearing protector from the dBC noise measure to determine the protected noise level for the worker.

EXAMPLE	Noise Level	105 dBC
	Hearing Protector	25 NRR
	Protected Noise Level	80 dB

If your industrial noise measurements are in dBA, subtract 7 from the NRR of the hearing protector as an error cushion for C-A differences, then subtract the resulting lower NRR from the dBA noise measure to determine the protected noise level for the worker.

EXAMPLE	Noise Level	105 dBA
	Hearing Protector	25 NRR – 7 dB = 18 NRR
	Protected Noise Level	87 dB

Figure 10: Difference between A and C-Weightings as advice by OSHA [28]

2.3 Ergonomic in Occupational Health and Safety

2.3.1 Noise control – concept and basic principle

Hierarchy of control strategies should be used in noise control attempt using the paradigm:

Noise from machinery is basically waste energy. Thus, the best way to minimize noise is to take measure the problem at the source. But, if tackle the problem at the source is difficult task or added more cost for the companies then next option is reduction at path where it added barrier or enclosing the equipment or adding sound absorbent materials. Then the last possible way of noise reduction is reduction at receiver or in other word those employees who engaged with the machineries. The approach of this way is either removing the employee from the sound field, limiting the working time in the area or the use of hearing protective equipment (HPE). However, the usage of HPE is fully dependant on consistent adequate human behaviour to work appropriately, the need of robust management commitment and enforcement that can be considered less effective. Therefore, HPE ranks lowest in the hierarchy of noise control strategies and should not be regard as primary means of noise control but as a means of last resort for controlling noise exposure.

2.3.2 Hierarchy of controls of occupational safety and health

This is methods determining how to implement feasible and effective controls solutions.

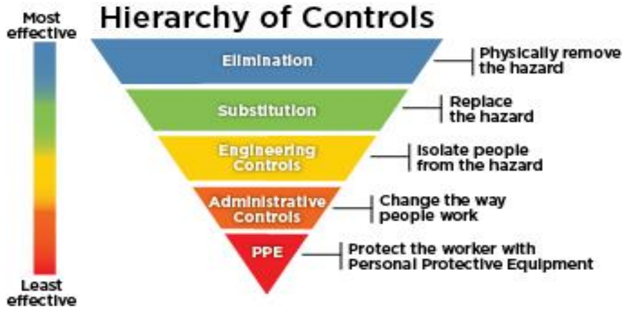


Figure 11: Hierarchy of Control by NIOSH [29]

2.3.2.1 Elimination and substitution

This method tends to be most difficult to implement in an existing process but the most effective at reducing hazard. If this elimination and substitution of hazards is introduced when the process is still at the design or development stage it may be inexpensive and simple to implement.

2.3.2.2 Engineering controls

This is the most favourable method for controlling existing worker exposures in the workplace because they are designed to remove the hazard at the source before it comes in contact with the worker. A well-designed engineering controls is highly effective in protecting workers and usually be independent of worker interactions to provide this high level of protection. The initial cost of engineering controls can be higher compared to the cost of administrative controls or PPE however over the longer term, operating costs are usually lover and can provide a cost savings in other areas of the process.

2.3.2.3 Administrative controls and personal protective equipment (PPE)

Existing process where hazards are not particularly well controlled is where frequently administrative controls and PPE are used. This program can be relatively inexpensive to establish but over the long term may be very costly to sustain. A significant effort require by the affected workers is the reason these methods for protecting workers to be less effective than other measures.

2.3.2.4 Noise reduction measure

Department of Safety and Health (DOSH) requires the risks arising from exposure to noise to be eliminated or reduced to a minimum at the same time take into account of technical progress and the availability of measures to control the risk at the source. There are a few different noise reduction measures in the directive, such as: noise reduction by technical means, choose of other working methods, appropriate maintenance programmes for work equipment and organisational measures of noise control.

2.4 Noise Regulation and Standard

2.4.1 NIOSH recommendation

In order to minimize occupational noise induced hearing loss, recommendation from The National Institute for Occupational Safety and Health (NIOSH) that all worker exposures to noise should be below or equivalent to 85 dBA for eight hours Others recommendation by NIOSH is 3 dBA exchange rate thus, every increase 3 dBA doubles the amount of the noise and halves the recommend of exposure time. NIOSH Noise Meter as shown in figure 5 show examples of some common source and their expected noise levels.

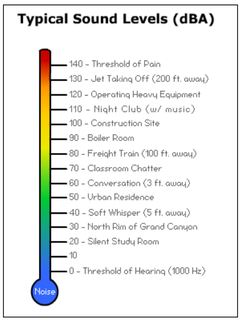


Figure 12: NIOSH Dose Meter [30]

2.4.2 OSHA permissible exposure limit

Limit on noise exposure in the workplace is set based on worker's time weighted average over an 8-hour day. 90 dBA is set as Occupational Safety and Health's (OSHA's) permissible exposure limits (PELs) for all workers for an 8-hour day. Exchange rate of 5 dBA is used by OSHA. Significantly when noise level is increased by 5 dBA, the amount of time a person can be exposed to a certain noise level to receive the same dose is cut in half [31].

In 1981, new requirements had been implemented by OSHA to protect all workers in general industry for employers to implement a Hearing Conservation Program where workers are exposed to a time weighted average noise level of 85 dBA or higher over and 8-hour work shift. This program requires employers to measure noise levels, arrange free annual hearing exams and free hearing protection, provide training and administer evaluation of the adequacy of the hearing protectors in use except that changes to tools, equipment and schedules are made so that they are less noisy and worker exposure to noise is less than 85 dBA.

2.4.3 OSHA vs NIOSH

NIOSH suggested limiting the 8-hour exposure to less than 85 dBA whereas at 10 dBA NIOSH recommends less than 15 minutes of exposure per day. In contrast, OSHA allows 8 hours of exposure to 90 dBA however only 2 hours of exposure to 100 dBA sound levels [32].

2.5 Return of Investment (ROI)

The main reason of calculate ROI is to validate a proposal's potential cost savings. [33]

2.5.1 ROI formula

$$ROI = \frac{(Benefits - Costs)}{Costs} \; x \; 100\%$$

2.5.2 Payback period

$$Payback\ period = \frac{Costs}{Benefits}$$

2.5.3 Calculating benefits

Common project benefits: cost reduction, productivity increases, process improvements and waste reduction.

$$Benefits = Current\ Cost - Cost\ after\ Change$$

CHAPTER 3

METHODOLOGY

3.1 Observation Point

This project takes place at CNC Machine Area at TT Electronics, Kuantan, Malaysia. It has 15 CNC Machine that makes air coil winding for round and flat wire with bending of either 180° or 90°. However, this project only focuses on CNC Machine 1, 2, 3 and 4 and only when the machine running model that needed stripping process. This is because the point of observation is only to justified the need of changes from pneumatic system to electric system at stripping process. Stripping is a physical separation process of some part of the wire depends on the customer requirement in order to ease it dipping into the flux then continue other process to become end product.

3.2 CNC Layout

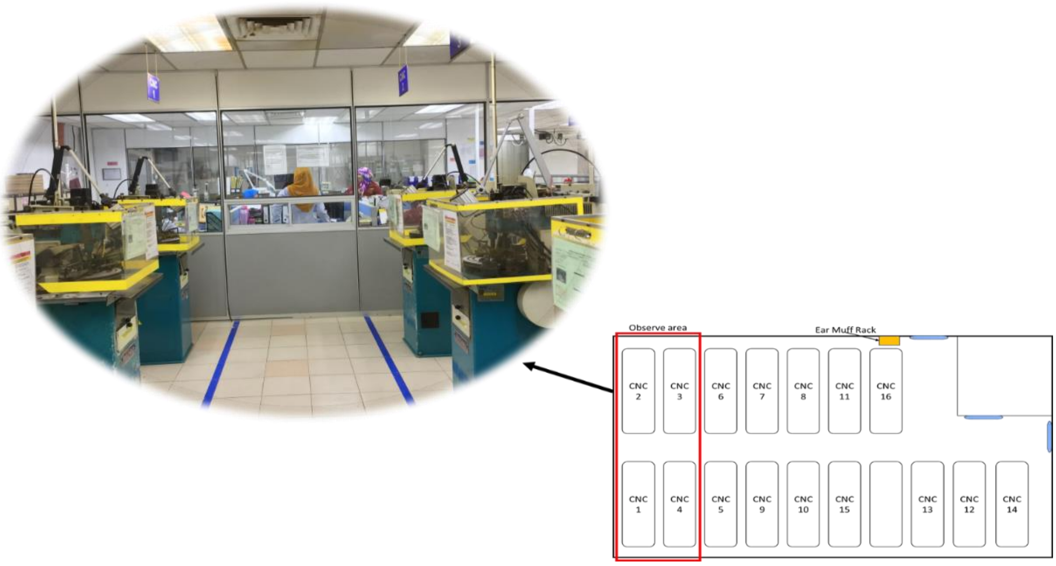


Figure 13: CNC 1, 2, 3 and 4 arrangements in CNC Area

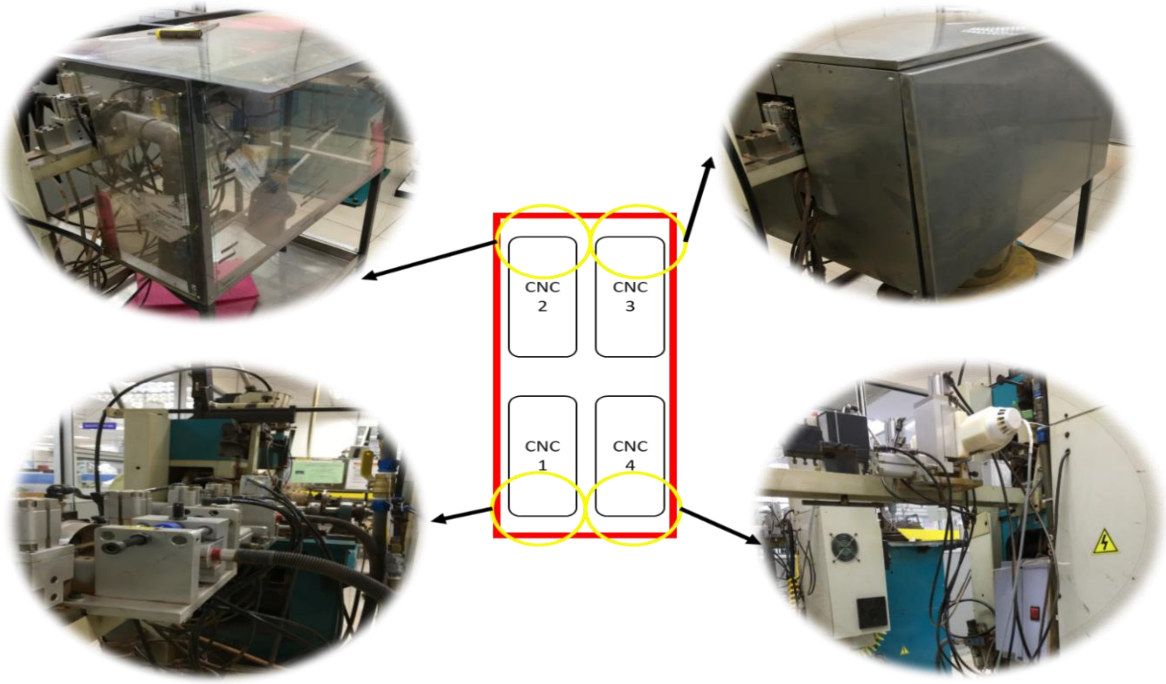


Figure 14: CNC 1, 2, 3 and 4 Stripping Area

3.3 Instrument Used

Instrument used in this project is CEN0053 Heavy Duty Data Logging Sound Level Meter to measure the noise produce from pneumatic system and electrical system during stripping process. This Sound Level Meter will record the noise data over specified time then this recorded data can be view from its software SE323.

Figure 15: CEN0053 Heavy Duty Data Logging Sound Level Meter

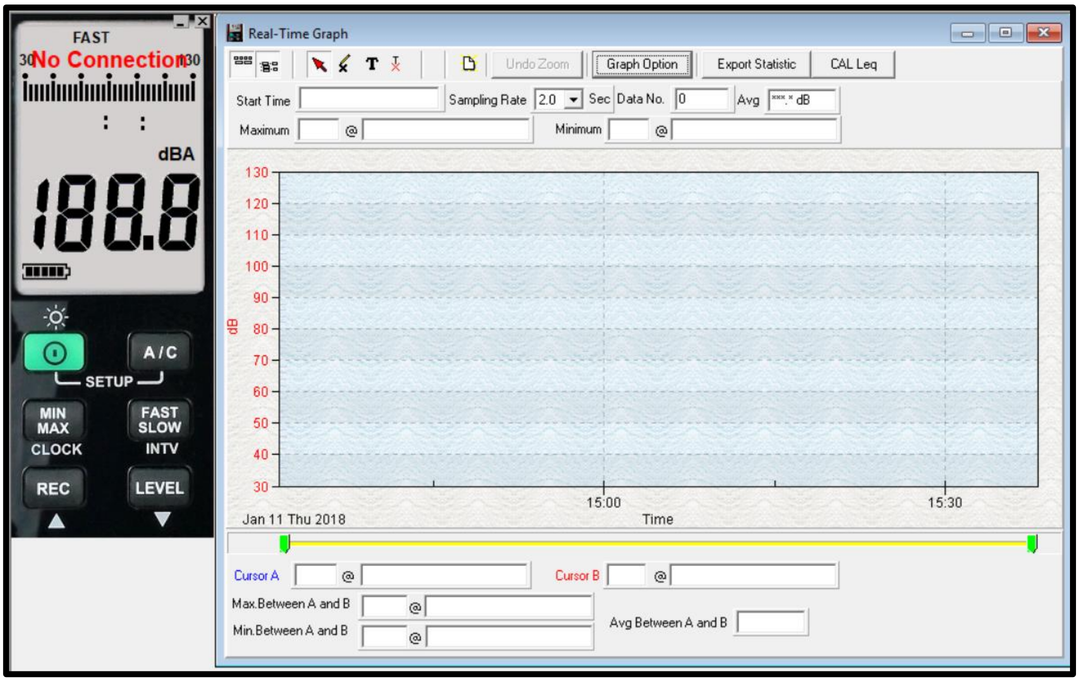


Figure 16: SE323 Sound Level Meter Software

3.3.1 Features and specification of instrument

Specification of measuring instrument used as follows:

- PC interface via Micro USB cable
- 64000 records datalogger
- Bar graph indication
- Auto power off
- MAX/MIN function
- Clock display
- AC/DC signal output
- IEC 61672-1 class 2
- Level Range: 30~130dB
- Accuracy: ±1.4dB (ref 94dB@1KHz)
- Frequency Weighting: A / C
- Time Weighting: Fast, Slow
- Frequency Range: 20Hz to 8KHz
- Microphone: Electret condenser microphone
- Auxiliary Outputs: AC/DC Output

- Battery: 1.5V AAA x 4
- Dimensions: 264 x 63 x 29mm
- Weight: 245g

3.4 Mode of Data Collection

There are three mode of data collection used in this project with 3 condition CNC machines need to satisfies in order to take data for these three modes:

1) In operation machine is where the machine is fully switch on and the all the process are running.
2) Not in operation is where the machine is fully switch off and the process is not running.
3) Pause mode is where the process is not running but the compressor is not switch off.

3.4.1 Desired CNC in operation with condition

This is real life situation where this is actual situation that happen inside the CNC machine area.

CONDITION WHEN TAKING READING DURING MACHINE IN OPERATION																	
READING TAKEN AT	WHILE																
	ON									OFF					MAINTENANCE		
CNC 1	CNC 2	CNC 3	CNC 4	CNC 5	CNC 9	CNC 10	CNC 11	CNC 14	CNC 15	CNC 6	CNC 12	CNC 13			CNC 7	CNC 8	
CNC 2	CNC 1	CNC 3	CNC 5	CNC 7	CNC 9	CNC 10	CNC 11	CNC 14	CNC 15	CNC 4	CNC 6	CNC 12	CNC 13		CNC 8		
CNC 3	CNC 1	CNC 2	CNC 4	CNC 5	CNC 6	CNC 8	CNC 9	CNC 10	CNC 15	CNC 11	CNC 12	CNC 13			CNC 7	CNC 14	
CNC 4	CNC 3	CNC 5	CNC 6	CNC 9	CNC 7	CNC 11				CNC 1	CNC 2	CNC 12	CNC 13	CNC 14	CNC 8	CNC 10	CNC 15

Table 5 : Desired CNC in operation with condition

For example, when reading is taken at CNC 1 during stripping process while at the same time CNC 2,3,4,5,9,10,11,14,15 is also in operation whereas CNC 6,12 and 13 is not in operation and CNC 7 and 8 under maintenance.

3.4.2 Only desired CNC in operation while other CNC not in operation

This is experimental mode that had been created for this project.

TAKING READING DURING MACHINE IN OPERATION														
READING TAKEN AT	WHILE													
	OFF													
CNC 1	CNC 2	CNC 3	CNC 4	CNC 5	CNC 6	CNC 7	CNC 8	CNC 9	CNC 10	CNC 11	CNC 12	CNC 13	CNC 14	CNC 15
CNC 2	CNC 1	CNC 3	CNC 4	CNC 5	CNC 6	CNC 7	CNC 8	CNC 9	CNC 10	CNC 11	CNC 12	CNC 13	CNC 14	CNC 15
CNC 3	CNC 1	CNC 2	CNC 4	CNC 5	CNC 6	CNC 7	CNC 8	CNC 9	CNC 10	CNC 11	CNC 12	CNC 13	CNC 14	CNC 15
CNC 4	CNC 1	CNC 2	CNC 3	CNC 5	CNC 6	CNC 7	CNC 8	CNC 9	CNC 10	CNC 11	CNC 12	CNC 13	CNC 14	CNC 15

Table 6: Only Desired CNC in Operation while other CNC not in Operation

For example, when reading is taken at CNC 1 during stripping process, only CNC 1 is in operation whereas all other CNC is fully turn off and all maintenance work are stop for a while during this mode.

3.4.3 Desired CNC during machine in pause mode

This mode act as a constant in order to calculate roughly the contribution of noise for pneumatic and electric system.

TAKING READING DURING MACHINE IN PAUSE MODE														
READING TAKEN AT	WHILE													
	PAUSE													
CNC 1	CNC 2	CNC 3	CNC 4	CNC 5	CNC 6	CNC 7	CNC 8	CNC 9	CNC 10	CNC 11	CNC 12	CNC 13	CNC 14	CNC 15
CNC 2	CNC 1	CNC 3	CNC 4	CNC 5	CNC 6	CNC 7	CNC 8	CNC 9	CNC 10	CNC 11	CNC 12	CNC 13	CNC 14	CNC 15
CNC 3	CNC 1	CNC 2	CNC 4	CNC 5	CNC 6	CNC 7	CNC 8	CNC 9	CNC 10	CNC 11	CNC 12	CNC 13	CNC 14	CNC 15
CNC 4	CNC 1	CNC 2	CNC 3	CNC 5	CNC 6	CNC 7	CNC 8	CNC 9	CNC 10	CNC 11	CNC 12	CNC 13	CNC 14	CNC 15

Table 7: Desired CNC during Machine in Pause Mode

For example, when reading is taken at CNC 1 during stripping process whereas others CNC are put in pause mode and all maintenance are stop for a while.

3.5 Data Collection

3.5.1 Instrument setup

Both time weighting of ‘FAST’ and ‘SLOW’ is used where fast time weighting is 8 times quicker the slow weighting corresponds to 125 milliseconds whereas slow time weighting records sound at 1 second interval. The result obtains using both of time weighting is not much differ and give much more accuracy in taking noise measurement.

For frequency weighting, A-Weighting option is chosen because it acts much more like human ear where this effectively cuts off the lower and higher frequencies that the average person cannot hear. The unit represent this weighting is denoted as dBA.

Figure 17: Instrument setup

3.5.2 Positioning of instrument

The instrument is positioning at 100 cm height and 25 cm width. As shown in the figure 18, this is the best position to take the reading as it is the height of the and also the width is where the operator and technician distance from the system when operating or repairing.

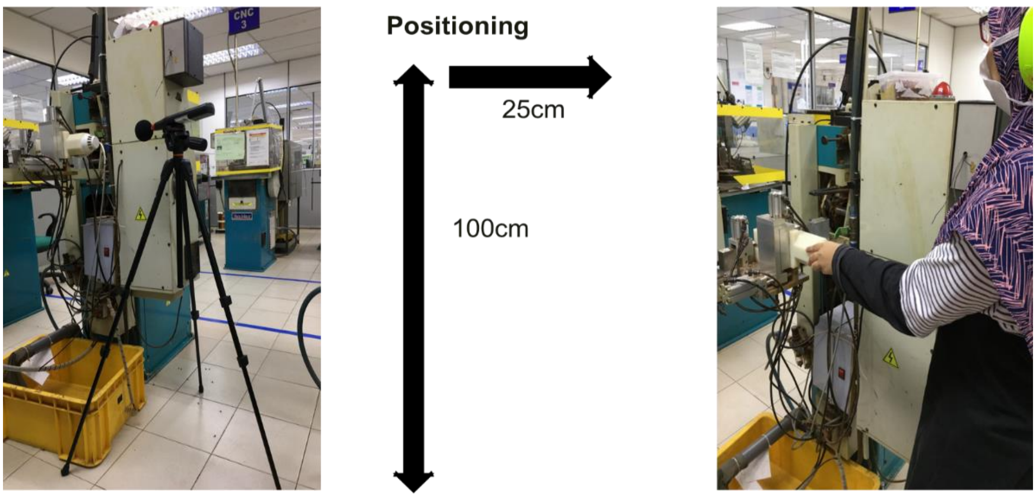


Figure 18: Positioning of Instrument

3.5.3 Data taken for noise measurement

The noise is measure within a period of time. The data is recorded in the sound level meter itself. Then, the data is imported to its software and the data collected is plotted as graph shown in figure 19 where it shows the maximum, minimum and also average of data taken.

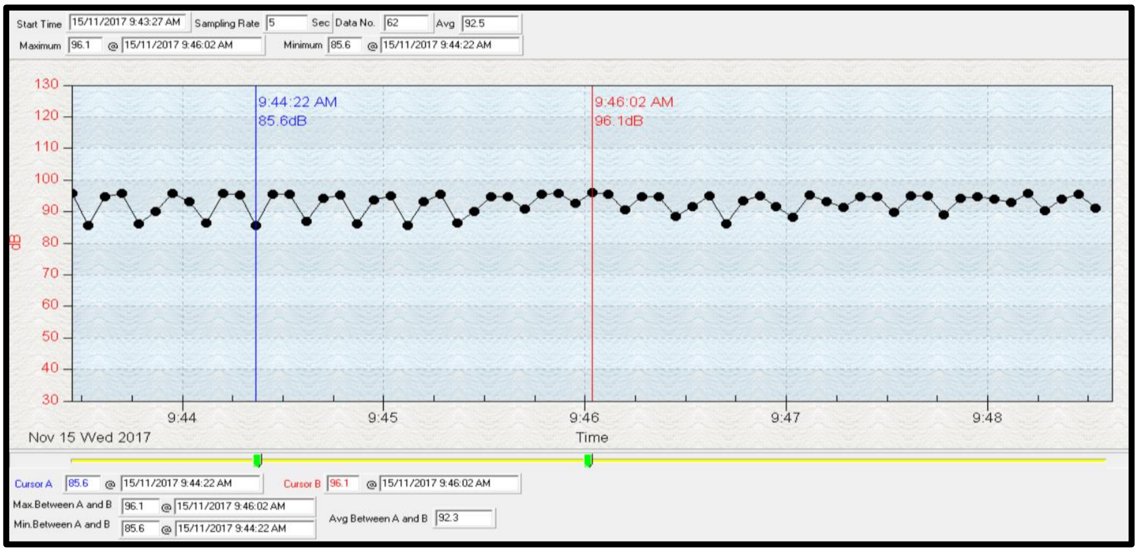


Figure 19: Reading from the sound level meter transfer into SE323 and plotted as graph

Next, the data will be tabulate. The data for mode desired CNC in operation with condition and desired CNC during machine in pause mode is taken twice with different time weighting each to get an accurate data. However, for mode only desired CNC in operation while other CNC not in operation the data is taken twice with only one time weighting due to a few limitations that will be stated in the chapter 5. Then the average of all the data will be calculated using calculation in 3.6.1 average noise.

Then, from the data noise reduction and contribution can be obtained and tabulate for on with condition and on without condition.

Noise contribution is obtained by subtraction value from mode desired CNC in operation with condition or only desired CNC in operation while other CNC not in operation and desired CNC during machine in pause mode for each CNC average value. Then the ratio of noise contribution is calculated. Next, the percentage of noise contribution is calculated by using the value of ratio of noise contribution time 100% as shown in figure 20.

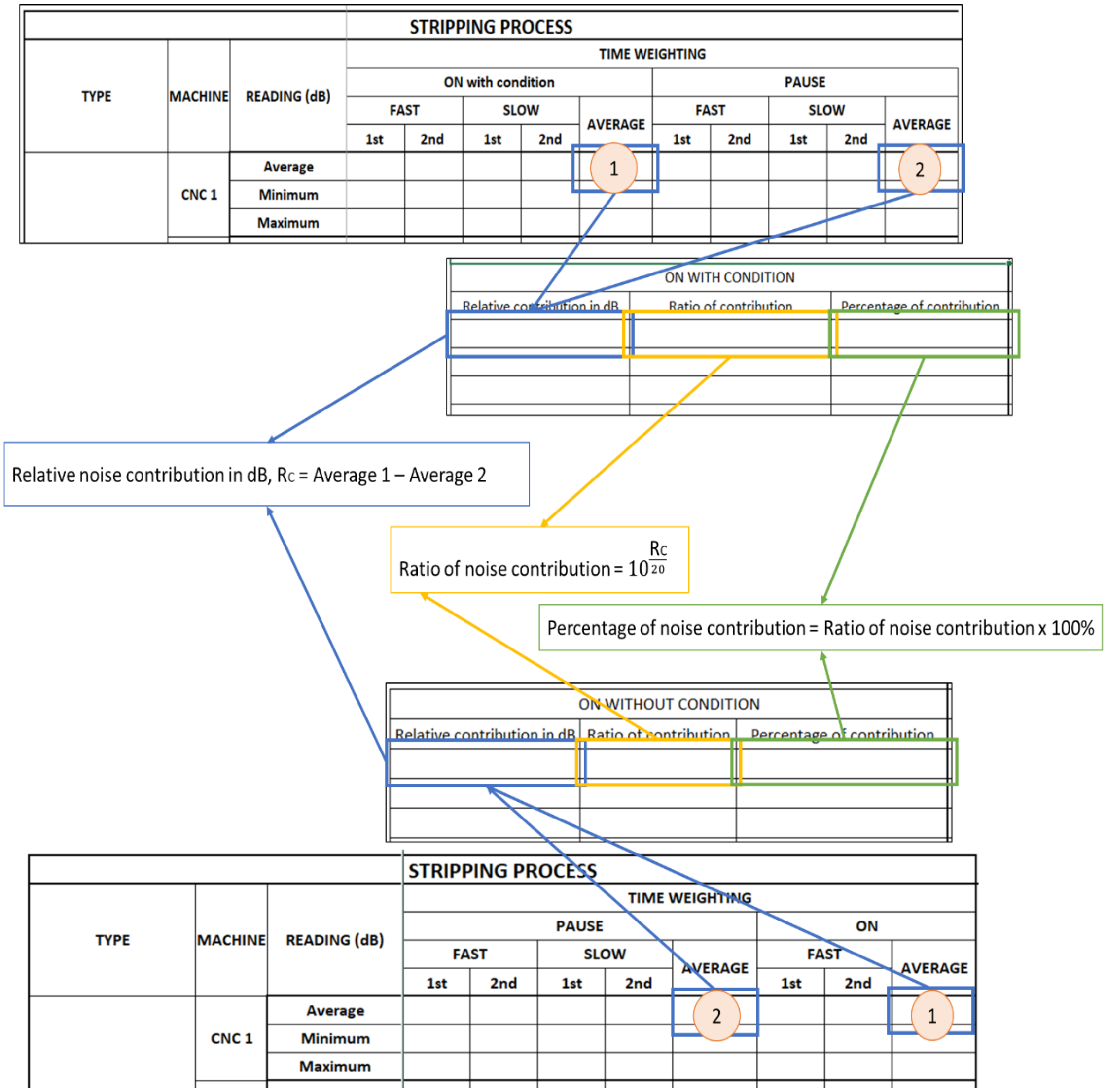


Figure 20: Noise contribution calculation

Likewise, noise reduction is obtained by subtraction of initial value and final value. Then the ratio of noise reduction is calculated. Next the percentage of noise reduction is calculated by using the value of ratio of noise reduction time 100% as shown in figure 21.

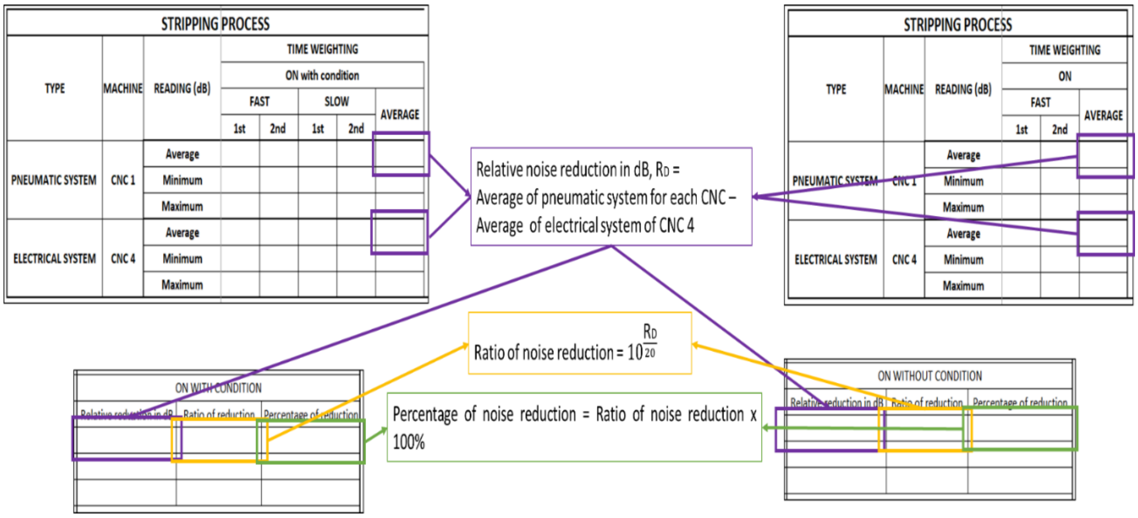


Figure 21: Noise reduction calculation

After all data already obtained and tabulate. The data will be plotted into graph to show the trendline of the noise measurement and to make comparison between electrical and pneumatic system during stripping process at CNC 1,2,3 and 4 and plotted data for noise contribution and noise reduction with its percentage.

3.5.4 Data taken for part in term of cost

This part of data is collected through interview method with the responsible technician and engineer. The purchasing price and life span of part for both system is needed in order to calculate the cost saving in term of part. The collected data will then tabulate.

3.6 Calculation

3.6.1 Noise data averaging

To give average noise energy over the entire 24-hour period.

$$a = 10^{\frac{L}{10}}; a_1 = 10^{\frac{L_1}{10}} \ldots; a_n = 10^{\frac{L_n}{10}} \text{ where L} = \text{A} - \text{weighted sound level}$$ --- Eq 3.1

$$sum\ of\ antilog = \sum a + a_1 + \cdots + a_n$$ --- Eq 3.3

$$b = \frac{sum\ of\ antilog}{number\ of\ sample}$$ --- Eq 3.2

$$average\ of\ noise = 10\ x\ \log b$$ --- Eq 3.4

3.6.2 Time weighted average level

A time weighted average is used to calculate a worker's daily exposure to a hazardous agent averaged to an 8-hour workday, taking into account the average levels of the agent and the time spent in the area.

$$Total\ noise\ dose, D = 100\left(\frac{C_1}{T_1} + \frac{C_2}{T_2} + \cdots + \frac{C_n}{T_n}\right) \qquad \text{--- Eq 3.5}$$

$$where\ C_n = the\ total\ time\ exposure\ at\ a\ specific\ noise\ level$$

$$T_n = using\ equation\ of\ refence\ duration, T$$

$$Reference\ duration, T = \frac{8}{2^{\frac{L-90}{5}}} \qquad \text{--- Eq 3.6}$$

$$where\ L = is\ the\ measured\ A - weighted\ sound\ level$$

TWA based on OSHA regulation

$$TWA = 16.61\ \log\frac{D}{100} + 90 \qquad \text{--- Eq 3.7}$$

3.7 Cost Saving

3.7.1 Return of investment in term of cost

$$ROI = \frac{(Benefits - Costs)}{Costs}\ x\ 100\% \qquad \text{--- Eq 3.8}$$

3.7.1.1 Benefits

$$Benefits = Current\ Cost - Cost\ after\ Change \qquad \text{--- Eq 3.9}$$

3.7.1.2 Payback period

$$Payback\ period = \frac{Costs}{Benefits} \qquad \text{--- Eq 3.10}$$

3.7.2 Cost saving in term of labour cost

The total cost saving in term of labour cost is calculated based on down time of machine. When down time of machine is reduced, the total effective working hours is increased. Thus, total saving in term of labour cost will be increased.

$$Total\ effective\ working\ hours$$
$$= total\ working\ hour\ per\ month - total\ downtime\ of\ machine \quad \text{--- Eq 3.11}$$

$$Total\ effective\ working\ hours\ per\ shift = \frac{total\ effective\ working\ hours}{2} \quad \text{--- Eq 3.12}$$

$$Technician\ rate\ per\ hours = \$1.79$$

$$Total\ saving\ in\ term\ of\ labour\ cost$$
$$= technician\ rate\ per\ hours\ x\ total\ effective\ working\ hours\ per\ shift \quad \text{--- Eq 3.13}$$

The total saving is calculated for 6-month time and plotted into graph to observe the trendline of total saving in term of labour cost.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Noise Measurement Deduction

The whole tabulation of data for CNC 1,2,3 and 4 for noise measurement can be refer to Appendix B. Frequency A-weighting is used throughout the noise measuring for CNC 1,2,3 and 4 because it follows the frequency sensitivity of the human ear at low levels and it also predicts quite well the damage risk of the ear. The readings are taken two times each for both time weighting of 'FAST' and 'SLOW' in order to get an accurate and consistent data for each mode except for the only desired CNC in operation while other CNC not in operation mode.

4.1.1 Desired CNC in operation with condition

This mode is real life situation where this is actual situation that happen inside the CNC machine area. The noise measure in this mode is much realistic as this is what actually the operators and technician experience on daily basis. When noise reading is taken on desired CNC there always at the same time, others CNC machine either in operation, maintenance or not be used.

STRIPPING PROCESS							
TYPE	MACHINE	READING (dB)	TIME WEIGHTING ON with condition				
			FAST		SLOW		AVERAGE
			1st	2nd	1st	2nd	
PNEUMATIC SYSTEM	CNC 1	Average	92.5	92.4	93.3	93.2	92.9
		Minimum	86.4	86.1	87.7	87.3	86.9
		Maximum	98.4	98.2	98.2	98.4	98.3
	CNC 2	Average	94.4	93.2	94.7	94.5	94.2
		Minimum	88.0	87.0	89.5	89.7	88.6
		Maximum	100.1	98.2	98.0	98.2	98.6
	CNC 3	Average	95.7	95.3	95.6	95.4	95.5
		Minimum	92.9	92.6	93.3	93.1	93.0
		Maximum	100.1	100.6	98.7	98.6	99.5
ELECTRICAL SYSTEM	CNC 4	Average	88.5	88.2	89.2	89.0	88.7
		Minimum	86.8	86.8	87.1	87.2	87.0
		Maximum	93.3	96.2	93.7	92.2	93.9

Table 8: Data tabulation for desired CNC in operation with condition mode

Table 8 show all the collected data value in dBA for desired CNC in operation with condition mode that had already been transferred into the table with value of its average, minimum and maximum. After that the average value of its attribute is calculated. Then the value is plotted into the graph.

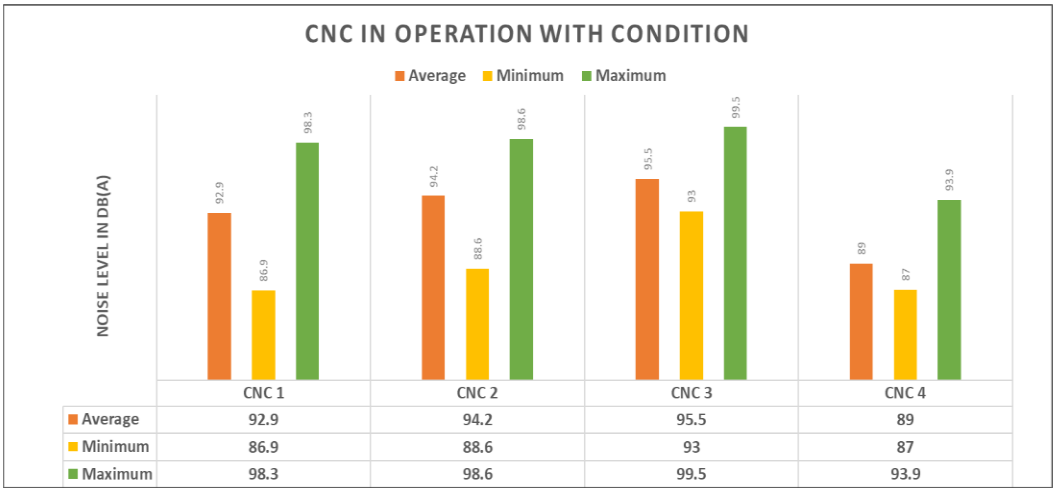


Figure 22: Plotted graph for desired CNC in operation with condition

Figure 22 show the data from the table 8 plotted into graph. From the graph based on it average value, it can be seen that the highest noise measurement is from CNC 3 that used pneumatic system with reading of 95.5 dBA whereas the lowest noise measurement is from CNC 4 with reading of 89 dBA that used electrical system.

4.1.2 Only desired CNC in operation while other CNC not in operation

This mode is regard as experimental mode as it is not possible to apply this situation in daily basis inside the CNC machine area. Limitation on conducting this mode is that the noise reading couldn't take multiply time with two different mode of time weighting. The reason behind this are the limitation of time to conduct this mode where it could only be done during production break that was less than 30 minutes. The 30 minutes production break cannot fully utilize because once the machine stops, it need to wait for a while to make sure the machine does not produce any more noise and at the idle state before turning on the desired CNC. This process of waiting almost take 15 minutes of the production time. This part is considered crucial so that the result produce is accurate and to make sure only the noise from the desired CNC machine is measures with no disturbance of external noise at all. Then, it also depends on the availability of technician to assist in this mode as the switch off and on of the CNC machine can be done by expertise and depend on the model running on that CNC machine need stripping process or not.

STRIPPING PROCESS					
TYPE	MACHINE	READING (dB)	ON		
			FAST		AVERAGE
			1st	2nd	
PNEUMATIC SYSTEM	CNC 1	Average	92.4	91.9	92.2
		Minimum	86.2	86.1	86.2
		Maximum	106.9	98.4	102.7
	CNC 2	Average	90.8	90.8	90.8
		Minimum	86.3	87.8	87.1
		Maximum	97.5	94.7	96.1
	CNC 3	Average	93.5	93.2	93.4
		Minimum	93.1	87.3	90.2
		Maximum	95.0	98.4	96.7
ELECTRICAL SYSTEM	CNC 4	Average	85.5	85.7	85.6
		Minimum	84.3	84.6	84.5
		Maximum	88.9	87.3	88.1

Table 9 : Data tabulation for only desired CNC in operation while other CNC not in operation

Table 9 show all the collected data value in dBA for only desired CNC in operation while other CNC not in operation mode that had already been transferred into the table with value of its average, minimum and maximum. After that the average value of its attribute is calculated. Then the value is plotted into the graph.

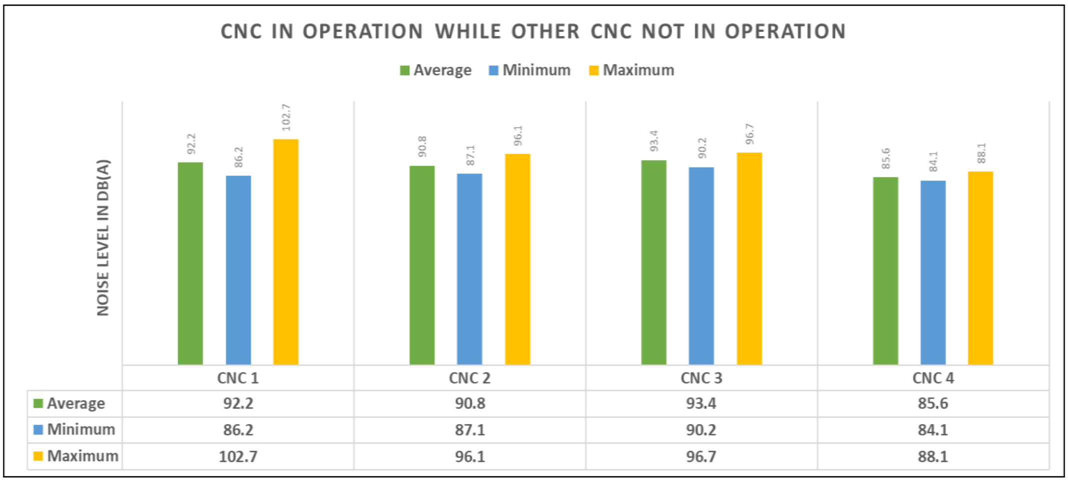


Figure 23 : Plotted graph for only desired CNC in operation while other CNC not in operation

Figure 23 show the data from the table 9 plotted into graph. From the graph based on it average value, it can be seen that the highest noise measurement is from CNC 3 that used pneumatic system with reading of 93.8 dBA whereas the lowest noise measurement is from CNC 4 with reading of 85.6 dBA that used electrical system.

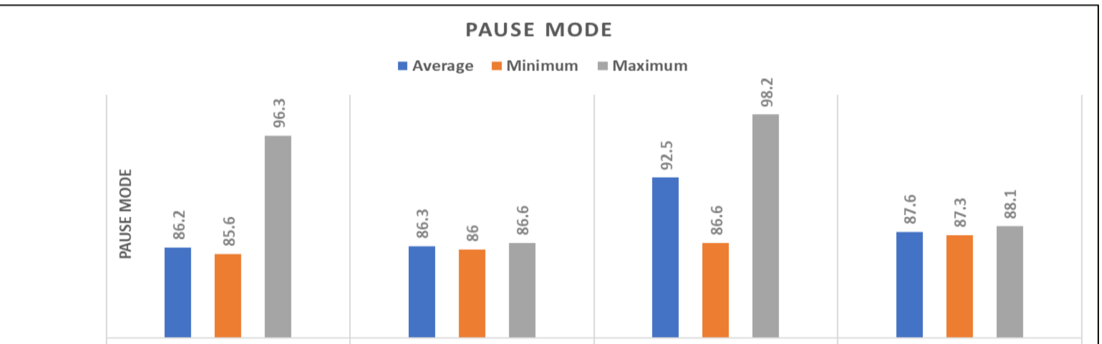
4.1.3 Desired CNC during machine in pause mode

This mode is needed to calculate roughly the contribution of noise for pneumatic and electric system during stripping process.

STRIPPING PROCESS							
TYPE	MACHINE	READING (dB)	PAUSE				
			FAST		SLOW		AVERAGE
			1st	2nd	1st	2nd	
PNEUMATIC SYSTEM	CNC 1	Average	86.0	85.9	86.2	86.2	86.1
		Minimum	85.6	85.6	85.5	85.6	85.6
		Maximum	86.7	86.1	95.0	96.3	91.0
	CNC 2	Average	86.6	86.5	87.1	86.3	86.6
		Minimum	85.8	85.9	86.3	86.0	86.0
		Maximum	88.8	89.6	88.5	86.6	88.4
	CNC 3	Average	93.5	93.3	91.2	92.5	92.6
		Minimum	93.3	92.8	86.5	86.6	89.8
		Maximum	94.1	94.6	97.8	98.2	96.2
ELECTRICAL SYSTEM	CNC 4	Average	87.4	87.3	88.9	87.6	87.8
		Minimum	86.4	86.3	86.7	87.3	86.7
		Maximum	87.9	88.0	92.6	88.1	89.2

Table 10 : Data tabulation for desired CNC during machine in pause mode

Table 10 show all the collected data value in dBA for desired CNC during machine in pause mode that had already been transferred into the table with value of its average, minimum and maximum. After that the average value of its attribute is calculated. Then the value is plotted into the graph.



	CNC 1	CNC 2	CNC 3	CNC 4
Average	86.2	86.3	92.5	87.6
Minimum	85.6	86	86.6	87.3
Maximum	96.3	86.6	98.2	88.1

Figure 24 : Plotted graph for desired CNC during machine in pause mode

Figure 24 show the data from the table 10 plotted into graph. From the graph based on it average value, it can be seen that the highest noise measurement during pause mode is from CNC 3 that used pneumatic system with reading of 92.5 dBA whereas the lowest noise measurement during pause mode is from CNC 4 with reading of 87.6 dBA that used electrical system.

4.2 Relative Noise Contribution

Relative noise contribution is calculated in order to observe how much noise is contribute for that particular CNC during stripping process to surrounding. The level changes of noise contribute to double of factor where the double of loudness occur every time increasing in dB.

4.2.1 Noise contribution by subtracting desired CNC in operation with condition mode value and pause mode value

TYPE	MACHINE	READING (dB)	STRIPPING PROCESS		
			ON WITH CONDITION		
			Relative contribution in dB	Ratio of contribution	Percentage of contribution
PNEUMATIC SYSTEM	CNC 1	Average	6.8	2.18	218%
		Minimum	1.3	1.16	116%
		Maximum	7.3	2.31	231%
	CNC 2	Average	7.6	2.39	239%
		Minimum	2.6	1.34	134%
		Maximum	10.3	3.25	325%
	CNC 3	Average	2.9	1.39	139%
		Minimum	3.2	1.44	144%
		Maximum	3.3	1.47	147%
ELECTRICAL SYSTEM	CNC 4	Average	0.9	1.11	111%
		Minimum	0.3	1.04	104%
		Maximum	4.7	1.72	172%

Table 11: Data tabulation for noise contribution by subtracting desired CNC in operation with condition mode value and pause mode value

Table 11 show all the calculated data in dB for noise contribution by subtracting desired CNC in operation with condition mode value and pause mode value that had already been transferred into the table for each value of its average, minimum and maximum. Then the ratio of contribution or loudness factor is calculated. In addition, the percentage of calculation also are shown in table 11. Then the noise contribution in dB and percentage of contribution are plotted into graph.

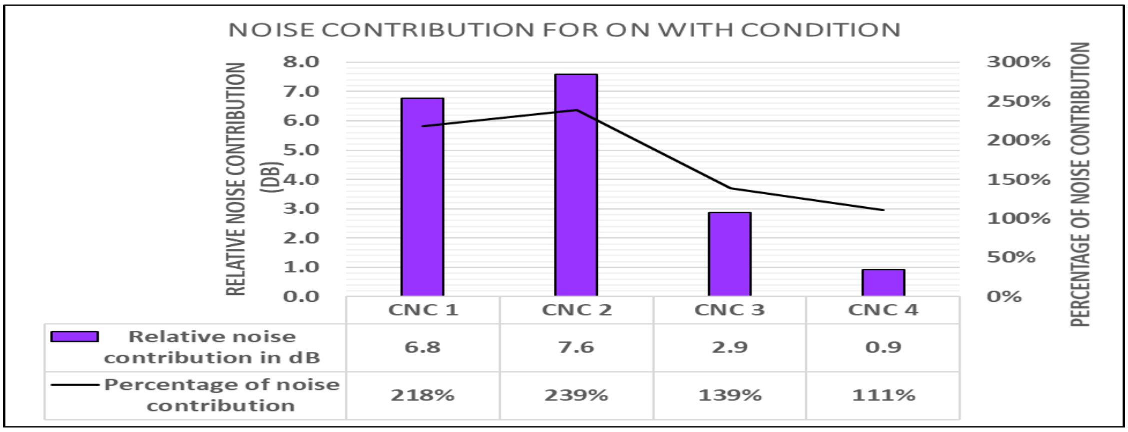


Figure 25 : Plotted graph for noise contribution by subtracting desired CNC in operation with condition mode value and pause mode value

Figure 25 show the data from the table 11 plotted into graph. From the graph based on it average value, it can be seen that the highest relative noise contribution is from CNC 2 that used pneumatic system with 7.6 dB that equals to loudness factor of 2.39 with 239% contribution of noise to the surrounding, whereas the lowest relative noise contribution is from CNC 4 with 0.9 dB that equals to loudness factor of 1.11 with 111% contribution of noise to the surrounding that used electrical system.

4.2.2 Noise contribution by subtracting only desired CNC in operation while other CNC not in operation mode value and pause mode value

TYPE	MACHINE	READING (dB)	STRIPPING PROCESS		
			ON WITHOUT CONDITION		
			Relative contribution in dB	Ratio of contribution	Percentage of contribution
PNEUMATIC SYSTEM	CNC 1	Average	6.1	2.01	201%
		Minimum	0.6	1.07	107%
		Maximum	11.6	3.81	381%
	CNC 2	Average	4.2	1.62	162%
		Minimum	1.1	1.13	113%
		Maximum	7.7	2.43	243%
	CNC 3	Average	0.7	1.09	109%
		Minimum	0.4	1.05	105%
		Maximum	0.5	1.06	106%
ELECTRICAL SYSTEM	CNC 4	Average	-2.2	0.78	78%
		Minimum	-2.2	0.77	77%
		Maximum	-1.1	0.89	89%

Table 12: Data tabulation for noise contribution by subtracting only desired CNC in operation while other CNC not in operation mode value and pause mode value

Table 12 show all the calculated data in dB for noise contribution by subtracting only desired CNC in operation while other CNC not in operation mode value and pause mode value that had already been transferred into the table for each value of its average, minimum and maximum. In addition, the percentage of calculation also are shown in table 12. Then the noise contribution in dB and percentage of contribution are plotted into graph.

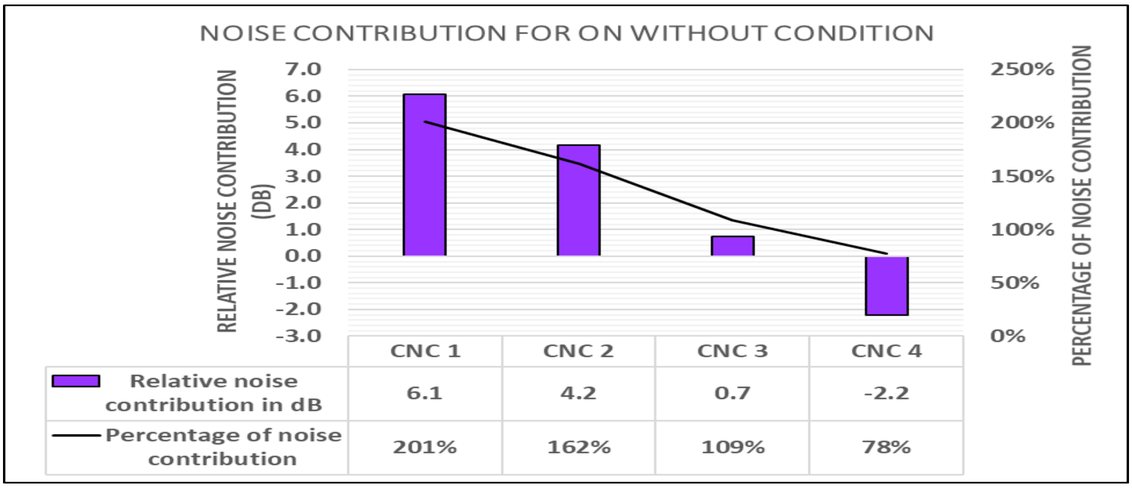


Figure 26 : Plotted graph for noise contribution by subtracting only desired CNC in operation while other CNC not in operation mode value and pause mode value

Figure 26 show the data from the table 12 plotted into graph. From the graph based on it average value, it can be seen that the highest relative noise contribution is from CNC 1 that used pneumatic system with 6.1 dBA that equals to loudness factor of 2.01 with 201% contribution of noise to surrounding, whereas the lowest noise contribution is from CNC 4 with -2.2 dBA that equals to loudness factor of 0.78 that only contribute 78% of noise to surrounding that used electrical system. The negative reading is due to the pause data is much higher because the data taken at the machine during pause mode is where the machine is not running but the compressor is not switch off thus there is still external noise contribute during data collection this contribute to higher noise reading compared to experimental mode where all machine are fully switch off and make sure no external noise is leaking during data collection.

4.3 Relative Noise Reduction

Relative noise reduction is calculated in order to observe how much noise can be reduced after undergo changes of the system.

4.3.1 Noise reduction by subtracting desired CNC in operation with condition mode value for CNC 1,2,3 with CNC 4

TYPE	MACHINE	READING (dB)	STRIPPING PROCESS		
			ON WITH CONDITION		
			Relative reduction in dB	Ratio of reduction	Percentage of reduction
PNEUMATIC SYSTEM	CNC 1	Average	4.1	1.61	161%
		Minimum	-0.1	0.99	99%
		Maximum	4.5	1.67	167%
	CNC 2	Average	5.5	1.88	188%
		Minimum	1.6	1.20	120%
		Maximum	4.8	1.73	173%
	CNC 3	Average	6.8	2.18	218%
		Minimum	6.0	2.00	200%
		Maximum	5.7	1.92	192%
ELECTRICAL SYSTEM	CNC 4	Average			
		Minimum			
		Maximum			

Table 13 : Data tabulation for noise reduction by subtracting desired CNC in operation with condition mode value for CNC 1,2,3 with CNC 4

Table 13 show all the calculated data in dB for noise reduction by subtracting desired CNC in operation with condition mode value for CNC 1,2,3 with CNC 4 that had already been transferred into the table for each value of its average, minimum and maximum. Then the ratio of contribution or loudness factor is calculated. In addition, the percentage of calculation also are shown in table 13. Then the noise reduction in dB and percentage of reduction are plotted into graph.

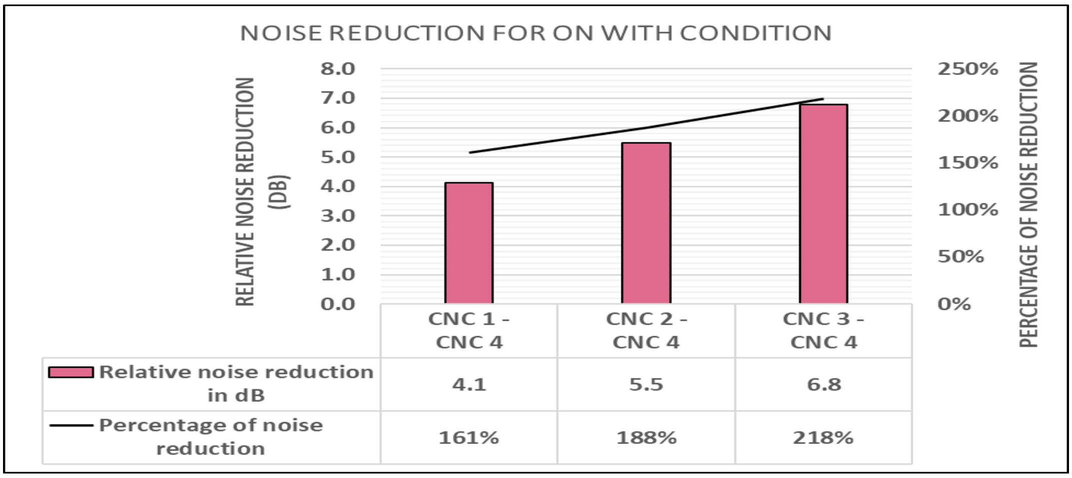


Figure 27 : Plotted graph for noise reduction by subtracting desired CNC in operation with condition mode value for CNC 1,2,3 with CNC 4

Figure 27 show the data from the table 13 plotted into graph. From the graph based on it average value, it can be seen that the highest noise reduction is from CNC 3 – CNC 4 with 6.8 dBA that has loudness factor of 2.18 to be reduced up to 218% of noise, whereas the lowest noise reduction is from CNC 1 – CNC 4 with 4.1 dBA with loudness factor of 1.61 can be reduced only 161% of noise.

4.3.2 Noise reduction by subtracting only desired CNC in operation while other CNC not in operation mode value for CNC 1,2,3 with CNC 4

TYPE	MACHINE	READING (dB)	STRIPPING PROCESS		
			ON WITHOUT CONDITION		
			Relative reduction in dB	Ratio of reduction	Percentage of reduction
PNEUMATIC SYSTEM	CNC 1	Average	6.6	2.13	213%
		Minimum	1.7	1.22	122%
		Maximum	14.6	5.34	534%
	CNC 2	Average	5.2	1.82	182%
		Minimum	2.6	1.35	135%
		Maximum	8.0	2.51	251%
	CNC 3	Average	7.8	2.44	244%
		Minimum	5.8	1.94	194%
		Maximum	8.6	2.69	269%
ELECTRICAL SYSTEM	CNC 4	Average			
		Minimum			
		Maximum			

Table 14 : Data tabulation for noise reduction by subtracting only desired CNC in operation while other CNC not in operation mode value for CNC 1,2,3 with CNC 4

Table 14 show all the calculated data in dB for noise reduction by subtracting only desired CNC in operation while other CNC not in operation mode value for CNC 1,2,3 with CNC 4 that had already been transferred into the table for each value of its average, minimum and maximum. Then the ratio of contribution or loudness factor is calculated. In addition, the percentage of calculation also are shown in table 14. Then the noise reduction in dB and percentage of reduction are plotted into graph.

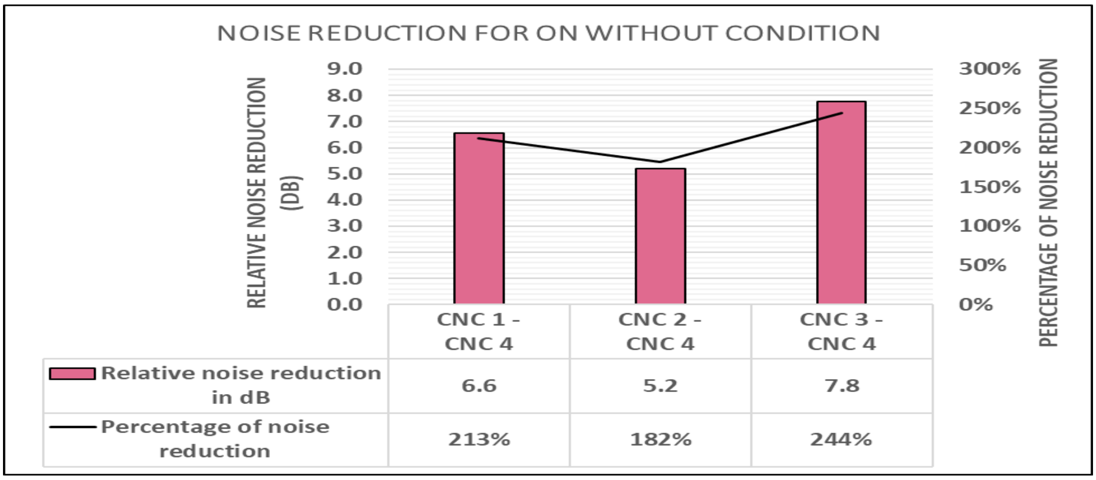


Figure 28 : Plotted graph for noise reduction by subtracting only desired CNC in operation while other CNC not in operation mode value for CNC 1,2,3 with CNC 4

Figure 28 show the data from the table 14 plotted into graph. From the graph based on it average value, it can be seen that the highest noise reduction is from CNC 3 – CNC 4 that with 7.8 dBA with loudness factor of 2.44 that can be reduced up to 244% of noise, whereas the lowest noise reduction is from CNC 2 – CNC 4 with 5.2 dBA with 1.82 loudness factor that only reduced 182% of noise.

4.4 Time Weighted Average

TWA is a concentration expressed over time that is used by OSHA to determine whether the measured concentration exceeded the permissible exposure limits (PELs) of noise. Table 15 show the calculated TWA of each CNC for OSHA criterion.

		DOSE	TWA
OSHA Criterion level: 90 dB Action level: 85 dB Exchange rate: 5dB	CNC 1	176.90%	94.1dB
	CNC 2	196.90%	94.9dB
	CNC 3	264.40%	96.5dB
	CNC 4	87.10%	89dB

Table 15 : TWA calculation for OSHA criterion

From table 15 using OSHA criterion it can be seen that CNC 4 is following the OSHA criterion.

4.5 Total Saving

Cost savings is calculated to convince management to support the changes of the system and implementation of the new system and nature the confidence in understanding what real effective and measurable this new system is.

4.5.1 Total saving in term of part

This quantifies project value and show its ability to the management in dollar figure the project's worth.

COMPARISON		
FACTOR	**AIR MICROGRINDER**	**ELECTRIC MOTOR**
Purchasing price (USD)	$ 68.60	$ 138.37
Life span (MONTH)	1	6
Ratio	6	1

Table 16 : Tabulation of data for air micro grinder and electric motor purchasing price and its life span

From table 16, the purchasing price of electric motor is $138.37 which is 101% higher compared to the purchasing price of air micro grinder. However, the life span of air micro grinder is much shorter than electric more with ratio of 6:1. In 6-month duration, only once the electric motor need to changes or under goes maintenance. On the other hand, air micro grinder need to change for 6 times in 6-month duration.

TOTAL SAVING IN TERM OF PARTS		
Current Cost	Cost after Change	Benefits
$ 411.63	$ 138.37	$ 273.26

Table 17 : Total saving in term of parts

From table 17 show that the benefits from the changes of the system is $273.26. From this, the payback period and return of investment of the part changes are calculated.

PAYBACK PERIOD (Month)	0.5	3.0
ROI	97%	

Table 18 : Payback period and return of investment of part changes

From table 18 show that the payback period of the part changes takes only 3 months in 6-month duration to recover the initial outlays in term of profits and saving with 97% return of investment and this high ROI means the investment's gain compare favourably to its cost.

4.5.2 Total saving in term of labour cost

This help to see raising in labour productivity. Decreasing in machine downtime cause decreasing of non-productive labour while increasing machine production hours.

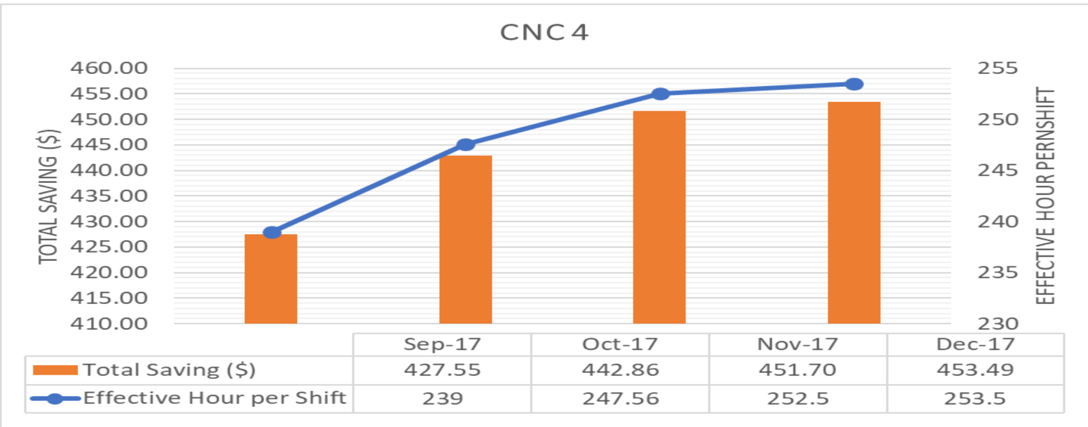


Figure 29 : Plotted graph for total saving in term of labour cost

From figure 29, show increasing trendline in total saving in term of labour as well as the effective hour per shift.

4.6 Justification of changes

Based on all collected data and analysis of data throughout this project timeline of three month. The changes from air die grinder to electrical die grinder at CNC Area during stripping process of flat wire is strongly recommended. Pneumatic system or air micro grinder that currently been used in the company has clearly show that it contributes the highest noise to the surrounding with the factor of loudness 2.39 and 2.01 for each real-life mode and experimental mode compared to 1.11 and 0.78 factor of loudness of electrical system for each mode of real life and experimental mode. By applying the substitution method by changing the system, the factor of loudness can be reduced up until 2.18 and 2.44 for each of the mode. The calculation of TWA also shown that changes from pneumatic system to electrical system make it possible to achieved the OSHA criterion level of 90 dB with the calculated TWA of 89 dB. The changes also bring benefit to the company in term of cost saving of part with 273.26 USD with payback period of 3 month and a very high ROI of 97%. In conjunction to that, the total labour saving also show increasing of trendline by increasing the labour productivity.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From the result can be seen that from the two modes that the lowest noise contribution is from CNC 4 that uses electrical system and its possible to reduce from 161% up to 244% of noise when changing from pneumatic system to electrical system.

Based on TWA calculation it is also possible that when changing from pneumatic to electrical system the PEL (permissible exposure limit) of noise for electric system could follow the OSHA criterion.

Based on the total saving in term of part, the purchasing price of the electric motor is much higher in compared to air micro grinder. However, the life span of electric motor is much higher than air micro grinder with ratio 1:6. The benefits from the changes of the system is USD 273.26 with only 3 month of payback period and 97% ROI. This high ROI means the investment's gain compare favourably to its cost.

Based on total saving in term of labour cost, it can be seen that when the total downtime of the machine is decreasing, the effective hour is increasing that causing the increasing trendline of total saving. The total downtime is decreasing for CNC 4 because the changes of the system helping to overcome the highest problem of over and insufficient stripping during stripping process and reduce non-productive labour or un-planned maintenance.

In conclusion, all the result and analysis are favourably show the need of changes from pneumatic to electrical system. In term of noise, the electrical system contributes the lowest noise to the surrounding and help reducing noise when the system changes. The changes of the system also make it possible to follow the OSHA criterion. In addition, a clarification for the support of management, the high ROI does bring a benefit to the company and also help in labour productivity when the problem during stripping process that causing machine downtime is reduced.

In relation to each other, when the system changes, the machine downtime is minimized that provide maximized efficiency, increases machine availability which in turn increase through output and minimized reject that also reduces order lead times and increase customer satisfaction. At the same time, ergonomic in occupational safety and health can be achieved when the noise follows the OSHA criterion and it's also help increases the total saving in two main categories for the company itself which is in term of part and labour.

5.2 Recommendation

Room for improvement is always open in every project. Currently, the substitution method was used by replacing the hazard in this case from pneumatic system to electrical system. From the result and analysis can be seen how this method given an impact to the company itself. However, this only focussed on stripping part of the machine.

For further work, other part of the machine should be observed and studied in order to see the possibilities of applying substitution method. Applying substitution method for stripping part only at one CNC machine already give a huge impact in term of ergonomic occupational safety and health and at the same time given a high saving for the company.

It should be in the future the impact much higher when all hazard at the CNC area are substitute where not only at stripping part and for only one CNC but applied it for every part of the machine and for each machine.

There always some cons in everything, the possibilities of changing each part and for every machine at once may be expensive. As a suggestion, the room of improvement and applying of the substitution method should be done part by part and machine by machine.

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APPENDIX A

STUDY OF NOISE REDUCTION AT CNC AREA

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TT SUPERVISOR : EN. KAMARULZAMAN MAHMAD KHAIRAI
UMP SUPERVISOR NAME : ASSOC. PROF. DR. NAFRIZUAN BIN MAT YAHYA

No.	Task Description	P- Plan A- Actual	November					December				January					February			
			W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18
			(1-3)	(6-10)	(13-17)	(20-24)	(27-1)	(4-8)	(11-15)	(18-22)	(25-29)	(1-5)	(8-12)	(15-19)	(22-26)	(29-2)	(5-9)	(12-16)	(19-23)	(26-2)
1	Define problem statement	P																		
		A																		
2	Define objective and scope of study	P																		
		A																		
3	Research on literature review regarding the topics	P																		
		A																		
4	Define methodology	P																		
		A																		
5	Define procedure	P																		
		A																		
6	Collecting data for cost, life span and maintenance from technical support	P																		
		A																		
7	Measuring noise level at the height of 100 cm with distance of 25 cm for CNC 1,2,3,4 in operation with condition	P																		
		A																		
8	Measuring noise level at the height of 100 cm with distance of 25 cm for CNC 1,2,3,4 in pause mode	P																		
		A																		
9	Measuring noise level at the height of 100 cm with distance of 25 cm for CNC 1,2,3,4 in operation only	P																		
		A																		
10	Record data	P																		
		A																		
11	Analyse data	P																		
		A																		
12	Comparison for all collected data	P																		
		A																		
13	Discussion and justification	P																		
		A																		
14	Conclusion and recommendation	P																		
		A																		

APPENDIX B

STRIPPING PROCESS															
TYPE	MACHINE	READING (dB)	TIME WEIGHTING												
			ON with condition					PAUSE					ON		
			FAST		SLOW		AVERAGE	FAST		SLOW		AVERAGE	FAST		AVERAGE
			1st	2nd	1st	2nd		1st	2nd	1st	2nd		1st	2nd	
PNEUMATIC SYSTEM	CNC 1	Average	92.5	92.4	93.3	93.2	92.9	86.0	85.9	86.2	86.2	86.1	92.4	91.9	92.2
		Minimum	86.4	86.1	87.7	87.3	86.9	85.6	85.6	85.5	85.6	85.6	86.2	86.1	86.2
		Maximum	98.4	98.2	98.2	98.4	98.3	86.7	86.1	95.0	96.3	91.0	106.9	98.4	102.7
	CNC 2	Average	94.4	93.2	94.7	94.5	94.2	86.6	86.5	87.1	86.3	86.6	90.8	90.8	90.8
		Minimum	88.0	87.0	89.5	89.7	88.6	85.8	85.9	86.3	86.0	86.0	86.3	87.8	87.1
		Maximum	100.1	98.2	98.0	98.2	98.6	88.8	89.6	88.5	86.6	88.4	97.5	94.7	96.1
	CNC 3	Average	95.7	95.3	95.6	95.4	95.5	93.5	93.3	91.2	92.5	92.6	93.5	93.2	93.4
		Minimum	92.9	92.6	93.3	93.1	93.0	93.3	92.8	86.5	86.6	89.8	93.1	87.3	90.2
		Maximum	100.1	100.6	98.7	98.6	99.5	94.1	94.6	97.8	98.2	96.2	95.0	98.4	96.7
ELECTRICAL SYSTEM	CNC 4	Average	88.5	88.2	89.2	89.0	88.7	87.4	87.3	88.9	87.6	87.8	85.5	85.7	85.6
		Minimum	86.8	86.8	87.1	87.2	87.0	86.4	86.3	86.7	87.3	86.7	84.3	84.6	84.5
		Maximum	93.3	96.2	93.7	92.2	93.9	87.9	88.0	92.6	88.1	89.2	88.9	87.3	88.1