COMPRESSOR VIBRATION ANALYSIS BASED ON MOUNTING TYPE CHANGES

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DEDICATION

This thesis is dedicated to my beloved family, whose unwavering support and encouragement have been my greatest source of strength throughout this journey. To my parents, for their endless love, sacrifices, and belief in my abilities; and to my siblings, for their constant support and understanding. I also dedicate this work to my supervisor, Dr. Muhammad Zulkairain, for his guidance and mentorship, which have been invaluable in my academic and personal growth. Finally, I dedicate this thesis to all my friends at Universiti Teknikal Malaysia Melaka (UTeM) who have shared this academic journey with me, providing companionship and support along the way.

ABSTRACT

This study investigates the impact of changing mounting types on the vibration characteristics of a 1 HP split-unit air conditioning compressor. Excessive vibration in compressors can lead to reduced efficiency, increased noise, and premature component failure, emphasizing the importance of effective vibration management. Experiments were conducted using three mounting types: the original rubber mount, a newly designed rubber mount, and a shock absorption spring head mount. Vibration levels were measured at two critical locations near the mounting base and the copper pipe connection using high-precision sensors. The results showed significant differences in vibration isolation capabilities among the mounts. The original rubber mount exhibited the highest vibration levels, while the new rubber mount reduced vibration by 40-45%. The shock absorption spring head mount demonstrated the best performance, achieving reductions of over 64%. Both the new rubber and spring head mounts complied with ISO 10816 standards for vibration severity, ensuring reliable and efficient operation. This research highlights the practical benefits of using improved mounting systems to enhance compressor performance and longevity. While the shock absorption spring head mount provided the most effective vibration isolation, the new rubber mount offered a cost effective alternative. The findings provide valuable insights for designing and maintaining air conditioning systems, contributing to advancements in vibration management technologies. Future work should explore broader applications, real world testing, and innovative materials for mounting systems to further improve performance.

ABSTRAK

Kajian ini menyiasat kesan perubahan jenis pelekap pada ciri getaran pemampat penyaman udara unit split 1 HP. Getaran yang berlebihan dalam pemampat boleh menyebabkan pengurangan kecekapan, peningkatan hingar, dan kegagalan komponen pramatang, menekankan kepentingan pengurusan getaran yang berkesan. Eksperimen telah dijalankan menggunakan tiga jenis pelekap: pelekap getah asli, pelekap getah yang direka bentuk baharu dan pelekap kepala spring penyerapan hentakan. Tahap getaran diukur di dua lokasi kritikal berhampiran pangkalan pelekap dan sambungan paip tembaga menggunakan penderia ketepatan tinggi. Keputusan menunjukkan perbezaan ketara dalam keupayaan pengasingan getaran di antara pelekap. Pelekap getah asal mempamerkan tahap getaran tertinggi, manakala pelekap getah baharu mengurangkan getaran sebanyak 40-45%. Pelekap kepala spring penyerapan kejutan menunjukkan prestasi terbaik, mencapai pengurangan lebih 64%. Kedua-dua pelekap kepala getah dan spring baharu mematuhi piawaian ISO 10816 untuk keterukan getaran, memastikan operasi yang boleh dipercayai dan cekap. Penyelidikan ini menyerlahkan faedah praktikal menggunakan sistem pelekap yang dipertingkatkan untuk meningkatkan prestasi pemampat dan jangka hayat. Walaupun pelekap kepala spring penyerapan kejutan memberikan pengasingan getaran yang paling berkesan, pelekap getah baharu menawarkan alternatif yang menjimatkan kos. Penemuan ini memberikan pandangan berharga untuk mereka bentuk dan menyelenggara sistem penyaman udara, menyumbang kepada kemajuan dalam teknologi pengurusan getaran. Kerja masa depan harus meneroka aplikasi yang lebih luas, ujian dunia sebenar dan bahan inovatif untuk sistem pelekap untuk meningkatkan lagi prestasi.

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LIST OF SYSMBOLS AND ABBREVIATIONS

HP	-	Horse Power
SS	-	Stainless Steel
BSW	-	British Standard Withworth
HTS	-	High Tension
FFT	-	Fast Fourier Transform
ADC	-	Analogue-to-Digital Converter
mm/s	-	Millimeter per second
psi	-	Pounds per square inch

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CHAPTER 1

INTRODUCTION

1.1 Background

A split unit air conditioning system consists of two main components an indoor unit and an outdoor unit. The indoor unit, typically mounted on a wall, cools the air inside the room using a refrigerant. Meanwhile, the outdoor unit houses the compressor and condenser coil, which are responsible for releasing heat from the refrigerant. A fan in the outdoor unit helps dissipate the heat generated during the cooling process. Together, these units work in tandem to efficiently cool the indoor space, providing comfort and climate control. The air conditioning split unit compressor plays a pivotal role in ensuring efficient temperature regulation within indoor environments, and its performance is subjected to constant refinement through technological innovations (Philip, 2021).

Excessive compressor vibration may lead to misalignment, or damage to components, reducing the compressor's efficiency. Misalignment may happen at the brazing or flare nut sections of the copper pipe connection and can cause cracks. Additionally, vibrations can cause refrigerant leaks, compromising the system's ability to cool effectively. Regular maintenance and addressing vibration issues promptly are crucial to ensure optimal performance and longevity of the air conditioning system (Azizian, 2015).

Damage that occurs is when excessive vibration happens at a compressor while operating for a long period of time. If the excessive vibration that happens in a short period does not affect the compressor and system too much, excessive vibration can also lead to increased noise levels, which can be disruptive and unpleasant for the occupants of the space where the air conditioning unit is installed. Although a high-vibration shutdown can be costly, it is ultimately less expensive than completely replacing the compressor or any other parts, and the system can run efficiently.

This research focuses on a comprehensive analysis for the adverse effects of excessive compressor vibration in air conditioning split unit, specifically by investigating the effect of changing the size and shape of the absorption rubber on the mounting. Figure 1.1 show the location of mounting for split unit air coinditioning compressor. The motivation behind this study is grounded in the continuous pursuit of enhancing the operational efficiency and durability of air conditioning systems. With the advent of mounting absorption rubber modifications, understanding their influence on compressor vibration is essential for advancing industry practices, ensuring optimal system functionality, and contributing to the broader knowledge base within the field. This research holds significant implications for both practitioners and researchers, offering valuable insights that can inform the design, manufacturing, and maintenance strategies of air conditioning split units.

Figure 1.1 Location of rubber mounting in split unit air conditioning

1.2 Problem Statement

Excessive vibration on air conditioning split unit compressor will have an adverse effect on the compressor and the system. Damage can occur due to the high impact on the constituent parts of the compressor, which causes more significant potential and greater friction between components. These issues not only diminish the compressor's performance but also compromise the overall effectiveness of the cooling system. Recognizing the importance of timely intervention in addressing vibration-related concerns, this research seeks to delve into a comprehensive analysis of compressor vibrations. Specifically, the study aims to elucidate the influence of alterations in the size and shape of absorption rubber within mounting on compressor performance. The motivation behind this investigation lies in the continuous pursuit of refining operational aspects and durability in air conditioning systems. As modifications to mounting become more prevalent, understanding their specific impact on compressor vibrations becomes paramount for advancing industry practices (Suryadi et al., 2021).

1.3 Research Objective

This research aims to provide a comprehensive analysis of the impact of changing the size and shape of the absorption rubber mounting on the vibration patterns of air conditioning 1 Horse Power (HP) split unit compressors. By addressing this crucial aspect, we seek to enhance the industry's understanding of how technological modifications influence system performance, thereby contributing to improved design and maintenance practices.

1) To improve vibration absorption on compressor mounting.
2) To evaluate the effectiveness of changing the rubber mounting on compressor.

1.4 Scope of Research

This research project will specifically investigate the impact of altering the size and shape of absorption rubber on the mounting of 1 HP air conditioning split unit compressors. The scope includes a combination of theoretical analyses and practical experiments to elucidate the effects of these modifications on compressor performance, focusing on aspects such as vibration rate, energy efficiency, maintenance requirements, and overall system reliability. Additionally, the project extends to practical applications, evaluating the feasibility and efficiency of implementing insights gained from the analysis to enhance the short-term operational efficiency and reliability of 1 HP air conditioning split units in real-world scenarios. By adopting a holistic approach, this research aims to contribute valuable knowledge for advancing industry practices related to the design, manufacturing, and maintenance of air conditioning systems.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The impact of mounting type modifications on compressor vibration analysis in air conditioning systems is examined in this study of the literature. The proper interior climatic conditions are dependent on the effective functioning of compressors, which are essential parts of air conditioning systems. On the other hand, excessive vibration can cause misalignment, component damage, and decreased system efficiency, among other problems. By stabilising the compressor unit and reducing oscillations, mounting are essential in reducing these vibrations. Examining the literature and industry standards on the alteration of mounting types and their effects on compressor vibration analysis is the goal of this review.

This study aims to provide insights into how modifications to the mounting design affect the vibration characteristics of compressors by examining a wide range of experiments. It specifically investigates how vibration patterns and levels are affected by changes in mounting composition, size, shape, and mounting arrangements. Furthermore, the link between mounting adjustments and important performance indicators including longevity, energy efficiency, and system stability is examined in this research.

This study analyses trends, obstacles, and possibilities in improving mounting design for improved vibration analysis in air conditioning systems by a thorough synthesis of pertinent literature. It also looks at how these findings could affect field researchers, manufacturers, and practitioners. This paper is to aid in the creation of more efficient maintenance plans and system design techniques in the air conditioning sector by illuminating the intricate relationship between mounting types and compressor vibration analysis.

2.2 Anti Vibration Screw

An anti-loosening screw, also known as a self-locking or vibration-resistant screw function is quite similar to mounting in reducing vibration. Mounting designed to resist loosening under conditions of vibration or dynamic loads. These screws incorporate specific design features or use supplementary components to maintain their tightness even when subjected to constant vibrations, shocks, or other mechanical stresses. The tensile force produced by the bolt shaft's elongation (known as the bolt axis force) and the compression force produced by the items being tightened (known as the tightening force) hold materials secured with screws together. As long as there are no outside forces acting on the things that the screws are fastening, these two forces will stay balanced. Pretension force is the broad name for the forces that pull or bind the two materials together. The pretension force that was applied when the materials that make up the machinery were first attached may diminish in various circumstances, such as while the equipment is being used. There are several causes for this. In general, screw loosening refers to this spontaneous decrease in the pretension force (Bhattacharya et al., 2010).

2.2.1 Previous Research on Anti Vibration Mechanism

Contrary to popular belief, flat washers are not proven to significantly prevent loosening. Even with the application of an outside, inside, or spring washer, the antiloosening properties of the stainless steel (SS) British Standard Whitworth (BSW) bolts and the high tension (HTS) bolts examined are only marginally improved. In a vibrating environment, the nyloc nut has strong anti-loosening capabilities and a low probability of loosening for both HTS and SS BSW bolts. In order to prevent the bolt thread from loosening, the nyloc nut adds an additional friction grip. When compared to a single nyloc nut, a hybrid double nut that has one conventional nut inside and one nyloc nut outside efficiently prevents loosening. Adhesive-bonded nuts exhibit similar locking qualities to hybrid double nuts for both HTS and SS bolts, and as such, may be advised. They also offer sufficient resistance to loosening when compared to nyloc nuts (Panja and Das, 2013).

2.2.2 Advantages of Anti Vibration Screw Designs

Anti vibration screws and mountings are essential in many sectors where vibration control is vital because they provide a number of benefits. By absorbing and dampening vibrations, these mountings efficiently minimise vibration, improve operating efficiency, and lengthen the equipment's lifespan, reducing wear and tear and maintenance expenses. They ensure accuracy, which improves machinery performance and yields higher-quality and more productive production. They also lower noise levels, making workspaces more comfortable and quiet. They also improve workplace safety by reducing vibrations that can jeopardise equipment integrity and endanger employees. Anti vibration mountings sustain sensitive operations to assure consistent, high-quality goods in precision sectors like electronics production and labs. They also significantly reduce long-term costs by shielding nearby structures from vibration-induced damage (Philip, 2015).

2.3 Methods of Vibration Analysis

Accelerometers mounted on one or more orthogonal axes record vibration data. The accelerometer's sample rate must be quick enough to record the desired behaviour. To allow for digital reconstruction, the signal must then be digitalized at a suitable sampling rate. The oscillation amplitude as a function of time, or time waveform, represents the vibration along the axes of interest. The time waveform is then transformed into a vibration frequency spectrum using the FFT technique. The frequency spectrum's range is determined by the accelerometers and Analogue-to-Digital Converter (ADC) that are utilised. As was previously said, vibration analysis relies heavily on the correlation between frequency spikes and the physical properties of the system to provide information.

Examining "synchronous peaks," or peaks that are harmonics of the shaft's basic rotational frequency, is the first step in the correlation process. Machine vibration analysis can be improved by using time-waveform analysis. It should be used as a tool to offer supplementary insights rather than as the main one. Since it shows the machine's motion, it can be helpful in low-speed applications. For example, gear analysis is a common application of time-waveform analysis. There is a crossover point at around 100 RPM; below that speed, frequency analysis is ineffective, and time-waveform analysis yields superior findings. Phase analysis is an additional technique that supports frequency and time waveform analysis (Lammel, 2019).

2.3.1 Application of Vibration Analysis in Compressor Systems

Vibration analysis is an organised approach to quantifying and analysing vibrations in industrial air compressors. It offers information on the amplitude, frequency, and intensity of vibrations, enabling a thorough understanding of the equipment's state. Early problem identification, less downtime, longer lifespans, more safety, better maintenance, financial savings, and increased energy efficiency are some advantages. Compressor-specific frequency analysis and severity evaluations are part of it. Data interpretation, accurate sensor installation, upfront expenses, and the requirement for specialised training are some of the challenges (Brown, 2023).

2.3.2 Importance of Accurate Vibration Measurement

Accurate vibration measurement is crucial for diagnosing issues in compressors, as it allows for early detection of problems that could lead to significant operational disruptions and costly repairs. By capturing detailed vibration data, maintenance teams can identify specific faults such as bearing failures, misalignment, unbalance, and mechanical looseness before they escalate. This predictive maintenance approach helps in scheduling repairs during planned downtimes, thereby minimising unplanned outages and extending the equipment's lifespan (King, 2023).

For instance, vibration analysis can pinpoint the exact component within a compressor that is failing, such as distinguishing between issues in the rolling element, inner or outer race, or the cage of a bearing. This detailed insight allows for precise maintenance actions, improving the overall reliability and efficiency of the machinery. Additionally, accurate vibration measurement contributes to safety by preventing catastrophic failures that could pose risks to personnel and equipment (King, 2023).

The implementation of vibration monitoring involves using sophisticated sensors like accelerometers, velocity sensors, and displacement sensors, which measure various aspects of vibration such as amplitude, frequency, and phase. These measurements are then analysed to understand the health of the machinery, facilitating timely interventions (Peter Brown, 2021). This not only optimises maintenance scheduling but also helps reduce energy consumption and operational costs, ultimately enhancing the performance and longevity of compressors (King, 2023).

2.4 Effects of Anti Vibration Screw Type Changes on Compressor Performance

The effects of changing anti vibration screws in compressors are significant and multifaceted. Anti vibration screws are essential in mitigating vibrations, which can impact compressor performance, reliability, and longevity. One primary benefit of using anti vibration screws is the reduction in mechanical stress on the compressor components. Vibration can lead to fatigue and failure of parts such as bearings, seals, and rotors. By minimising vibrations, anti vibration screws help extend the operational lifespan of the compressor, reducing the frequency and cost of maintenance (Bratek et al., 2019).

Furthermore, the use of anti vibration screws can enhance energy efficiency. Vibrations often lead to energy losses in the form of heat and noise. By stabilising the compressor, these screws ensure that more of the energy is used for compression rather than being dissipated as waste, thereby improving overall energy efficiency (Byeon et al., 2017).

Anti vibration screws also contribute to a quieter and safer working environment. High vibrations can cause significant noise, which can be detrimental to both operators and nearby equipment. Reducing these vibrations helps in maintaining a quieter operation, which is critical in maintaining workplace safety and comfort (Byeon et al., 2017).

2.4.1 Relationship Between Vibration Reduction and Compressor Efficiency

Numerous research investigations and real-world applications have demonstrated the importance of the relationship between compressor efficiency and vibration reduction. Compressor vibration reduction methods, such as sophisticated vibration control algorithms, have demonstrated significant advantages in terms of improving overall performance and energy efficiency. For example, structural vibrations may be greatly decreased by the enhanced Filtered-U Least Mean Square method, which is used to decrease compressor vibration and noise. This results in less mechanical wear and tear and increased operational stability (Wu et al., 2022).

Additionally, a thorough investigation into the impacts of on-synchronous vibration in axial compressors revealed how reducing these vibrations might improve compressor stability and energy efficiency. Compressors can function more effectively and with a lower risk of mechanical failure by addressing aerodynamic forcing and making sure that casing pressure and blade vibration are properly synchronised (Wu et al., 2022).

Vibration reduction has a direct impact on compressor energy efficiency. Compressors with low-speed airends and direct-drive motor integration are efficient since they use less energy and produce more. This correlation emphasises how crucial it is to reduce vibrations in order to preserve mechanical integrity and achieve maximum energy efficiency, which may save a substantial amount of money over the course of the compressor's lifespan (Kaeser, 2017).

2.5 Case Studies: Anti Vibration Screw Changes in Compressor Systems

The benefit of replacing anti vibration screws in enhancing compressor performance is demonstrated by a number of practical cases. A boiler feed pump that has a history of high vibration levels because of imbalance and misalignment was the subject of one case study. Anti-vibration screws were used to stabilise the pump, which greatly decreased vibration and increased bearing longevity. Additionally, by reducing maintenance expenses, this intervention increased overall operational reliability (Graney, 2011).

Additionally, a tutorial on air compressor vibration troubleshooting described how to successfully use anti-vibration screws to resolve mounting concerns. Excessive vibrations were reduced by properly fastening mounting bolts and brackets with anti-vibration screws, guaranteeing steady and effective compressor performance. This strategy avoided potential compressor damage in addition to enhancing performance (Oberkirch, 2020). These case studies show that anti-vibration screws are an effective way to improve compressor system stability and performance, which may save money, cut down on downtime, and lengthen equipment life.

2.5.1 Performance Improvements Observed in Industrial Settings

First, these screws help reduce the mechanical stress on compressor components, leading to an extended operational lifespan. By minimizing vibrations, the wear and tear on internal parts such as bearings, seals, and rotors are significantly decreased, resulting in fewer maintenance requirements and lower operational costs (Greenfield and Roche, n.d.)(Qureshi, 2022).

Energy efficiency is another notable improvement. Vibrations in compressors often result in energy losses through heat and noise. Anti-vibration screws help maintain better alignment and operational precision, which translates into more efficient energy use and reduced operational costs (Greenfield and Roche, n.d.).

Noise reduction is also a critical benefit. High vibration levels can lead to excessive noise, which is detrimental to both the work environment and the health of workers. Anti-vibration screws help create a quieter and safer working environment, which is essential for compliance with occupational health and safety regulations (Greenfield and Roche, n.d.)(Qureshi, 2022).

Additionally, the precision in the installation and calibration of these screws is crucial. Properly installed anti vibration screws ensure that the vibrations are effectively dampened, leading to optimal compressor performance. Incorrect installation, on the other hand, can lead to inadequate performance and potential exacerbation of vibration issues (Greenfield and Roche, n.d.)(Qureshi, 2022)

Overall, the use of anti-vibration screws in industrial compressors results in enhanced performance, greater energy efficiency, extended equipment life, and a safer, quieter working environment. These improvements underscore the importance of integrating advanced vibration damping solutions in industrial settings to optimize compressor operations and maintenance practices (Greenfield and Roche, n.d.)(Qureshi, 2022)

2.6 Summary

This literature review examines the impact of anti-vibration screw type changes on compressor vibration in air conditioning systems. Compressors are essential for maintaining indoor climate conditions, and their efficiency can be significantly affected by excessive vibration, leading to issues such as misalignment, component wear, and reduced system performance. Anti-vibration screws help mitigate these vibrations, enhancing compressor stability. The review analyses various studies to understand how modifications in screw material, shape, size, and mounting configurations influence vibration levels and patterns, and how these changes affect system stability, energy efficiency, and longevity.

Anti vibration screws are designed to resist loosening under dynamic loads, maintaining their tightness despite vibrations. These screws balance tensile and compressive forces to secure components and prevent spontaneous reduction in pretension force, known as screw loosening (Bhattacharya et al., 2010). Different designs, such as nyloc nuts, hybrid double nuts, and adhesive-bonded nuts, offer varying degrees of resistance to loosening (Panja and Das, 2013). The review highlights the benefits of these screws in reducing vibrations, minimising wear and maintenance costs, lowering noise levels, and improving safety in industrial settings (Philip, 2015).

Vibration analysis is crucial for understanding and managing compressor performance. Data collected using accelerometers is analysed through time waveform and frequency spectrum analysis using the FFT (Lammel, 2019). This helps identify machine issues by correlating frequency spikes with system properties. Techniques like time-waveform and phase analysis supplement the understanding of vibration characteristics, enabling early problem detection and predictive maintenance (Brown, 2023). Accurate vibration measurement allows for identifying specific faults, improving maintenance efficiency, and preventing costly failures (King, 2023).

Practical case studies demonstrate the effectiveness of anti-vibration screws in improving compressor performance. Stabilising high-vibration pumps with anti-vibration screws has increased bearing longevity and operational reliability (Graney, 2011). Properly installed screws reduce mounting issues, enhance performance, and prevent potential compressor damage (Oberkirch, 2020). However, according to the literature, there are lack of studies on compressor vibration analysis based on anti vibration screw and mounting type changes specifically for split unit air conditioning 1 HP.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describes the thorough technique used to investigate the effects of altering the mounting rubber's types in a compressor for a 1 HP split unit air conditioner. The primary objective of this research is to improve vibration absorption on compressor mounting. A complete summary of the research design, proposed methodology, experimental setup, parameters, and equipment utilised, as well as the approach's limitations, will be presented in this part. The objective of this study is to evaluate the effectiveness of changing the rubber mounting on compressor.

The methodology is designed to integrate both qualitative and quantitative analyses to achieve the research objectives. The qualitative component involves a thorough review of existing literature to establish the theoretical underpinnings and current state of knowledge regarding anti-vibration technologies and their applications in compressor systems. The quantitative component consists of a series of controlled experiments aimed at measuring and analysing the vibration levels of a 1 HP split unit compressor with various configurations of rubber mounts. By systematically change the type of mounting, this study seeks to determine the most effective configurations for reducing vibration and improving compressor performance.

3.2 Research Design

This study's research design combines qualitative and quantitative analysis, which aim to reduce vibration. In order to comprehend the theoretical underpinnings and present level of knowledge about anti vibration technologies and their applications in compressor systems, the qualitative aspect includes a thorough analysis of the body of available literature. In order to quantify and assess the vibration levels of a 1 HP split unit compressor under various rubber mounting configurations, a series of controlled trials is used in the quantitative aspect. Through systematic modifications of the absorption rubber's sizes, the research attempts to identify the ideal arrangements that reduce vibration and enhance compressor efficacy. As shown in Figure 3.1 below, this is the flow chart for this experimental process.

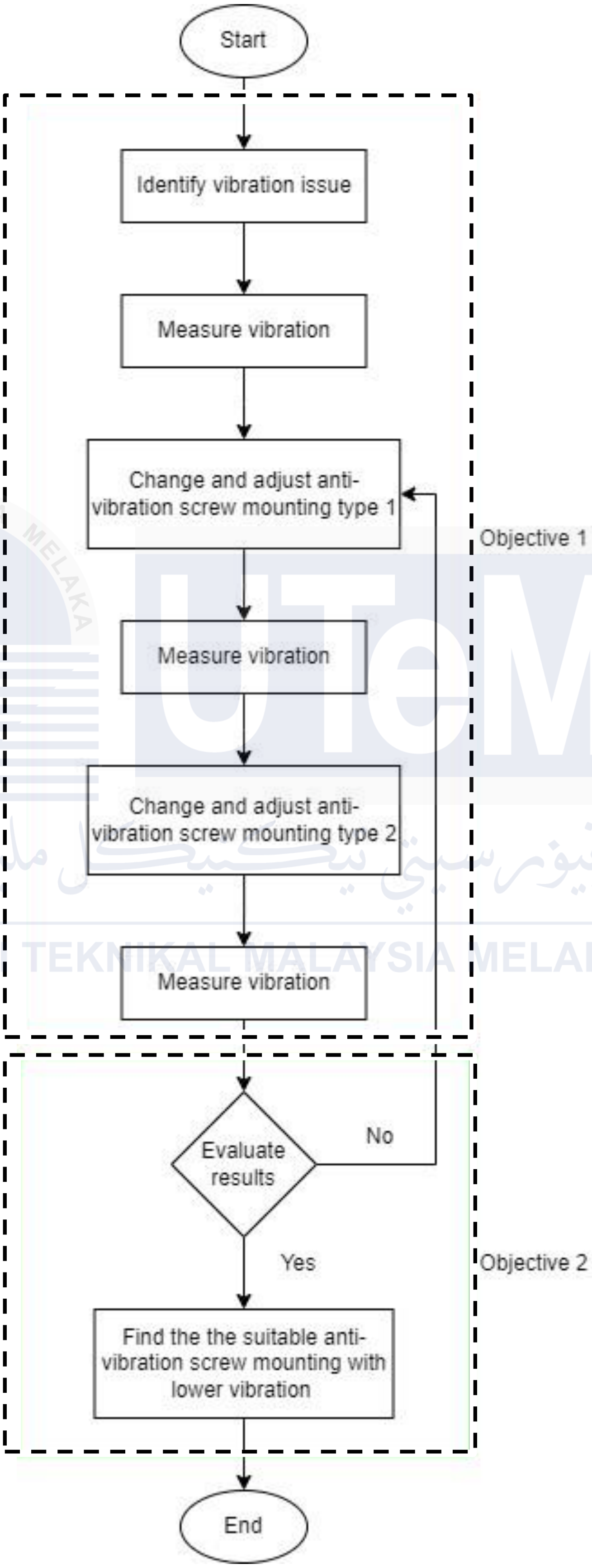

Figure 3.1 Flow chart

3.3 Proposed Methodology

The proposed methodology is structured to achieve the research objectives through a series of methodical steps. Initially, a baseline vibration profile of the compressor will be established using standard rubber mounting. Subsequent experiments will involve changing the size and shape of the absorption rubber on the mounting and measuring the resultant vibration levels. These experiments will be conducted under controlled conditions to ensure the reliability and validity of the results. Data will be collected using high-precision accelerometers and analyzed using advanced vibration analysis software. The methodology also includes a comparative analysis of the performance of different configurations to determine the most effective anti vibration solutions.

3.3.1 Experimental Setup

The experimental setup is designed to simulate real-world operating conditions of a 1 HP split unit air conditioning compressor. The setup includes a test rig where the compressor is mounted and equipped with sensors to monitor vibration. The key components of the experimental setup are detailed below.

3.3.1.1 Parameters

The primary parameters to be measured in this study include vibration velocity RMS. These parameters will be recorded across different configurations type of mounting. The specific configurations tested will include variations in the size and type of mounting.

3.3.1.2 Equipment

The equipment used in the experimental setup includes a high precision vibration analyzer measuring vibration levels and a software package for analyzing the vibration spectra. Manifold gauge is used to monitor the refrigerant pressure in the system. The compressor test rig is designed to securely hold the compressor and allow easy modification of the compressor mounting. The setup also includes a control unit to simulate different operating conditions and load scenarios. Table 3.1 below shows some of the equipment that will be used to record data.

Table 3.1 List of equipment and description

Equipment	Description
m+p VibPilot measurement	The m+p VibPilot is a compact hardware platform designed for vibration control and dynamic signal analysis, using specialized software to meet high-performance requirements.
Manifold gauge	A manifold gauge is a tool used to measure the pressure of refrigerants in HVAC systems.

3.3.1.3 Testing

To run the test as outlined in the methodology, a detailed procedure begins with establishing a baseline vibration profile. Use the 1 HP split unit air conditioning compressor and equip it with standard rubber mounts. Using high-precision accelerometers, record the baseline vibration profile in a controlled environment to avoid external influences. To accurately measure vibrations on the compressor, place accelerometers on the compressor body, preferably near the mounting points and at the brazing or flare nut sections of the copper pipe connections. These locations are critical for detecting vibrations transferred from the compressor to the mount and for identifying potential issues such as refrigerant leaks or misalignment over time. Ensure the vibration sensor are securely attached to the compressor and connected to a data acquisition system to record the vibration.

Next, modify the anti vibration configurations by changing the size and shape of the mounting. Consider variations in thickness, diameter, and shape. For each configuration, measure the resultant vibration levels using vibration sensor. Analyze the data using vibration analysis software, comparing the performance of different configurations to determine the most effective anti vibration solutions.

Conduct a comparative analysis to evaluate performance, focusing on configurations that reduce vibrations most effectively while considering the overall impact on compressor performance, including noise reduction and energy efficiency. Document all experimental setups, measurements, and observations systematically, maintaining a detailed log of each configuration tested. Prepare a comprehensive report summarizing the findings, including tables and graphs to illustrate the effects of different configurations on vibration levels.

Acknowledge the limitations and considerations of the experiments, noting that they are conducted in controlled laboratory conditions that may not precisely replicate real-world variations and that the results are specific to the 1 HP air conditioning split unit compressor. Ensure that all sensors and equipment are properly calibrated for accurate measurements. This structured approach ensures a comprehensive evaluation of how different anti-vibration configurations affect the performance and longevity of a 1 HP split-unit air conditioning compressor.

As shown if Figure 3.2 below, vibration sensor will place at the critical point like point 1 and point 2. For the first point, it is near to the rubber mounting and nut at the bottom of the compressor. For the 2nd point, it is located at the inlet and outlet of the coper piping. This critical point is the point where the vibration is propagated through.

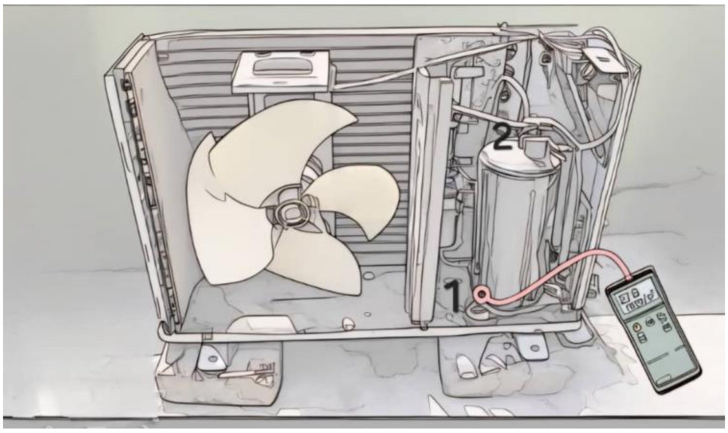

Figure 3.2 Location for vibration reading on compressor

3.4 Limitations of Proposed Methodology

There are a few limitations to the proposed methodology, even with the strict approach taken in this study. At first, experiments are carried out in carefully regulated laboratory conditions, which could not precisely replicate the variations experienced in actual installations. Second, since the study only looks at a specific type of compressor, a split unit air conditioning 1 HP compressor, the results may not apply to other types or sizes of compressors. Furthermore, the study's focus is limited to the effects of rubber mounts, ignoring other variables such as system load variations and the type of refrigerant that may affect compressor vibration. Lastly, the condition and calibration of the sensors and other equipment used influence how precise the measurements are.

3.5 Summary

In summary, this chapter has outlined the comprehensive methodology employed in this study to analyze the impact of changing the size and shape of mounting rubber in a 1 HP split unit air conditioning compressor. The research design integrates both qualitative and quantitative approaches, with a strong emphasis on controlled experimental analysis. The detailed experimental setup, including the parameters measured and equipment used, ensures a thorough investigation into the effects of the proposed modifications. While acknowledging the limitations, this methodology aims to provide valuable insights into enhancing compressor performance and longevity through optimized anti-vibration solutions. The findings from this study are expected to contribute significantly to the design, maintenance, and operational strategies in the air conditioning industry.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, we will delve into the results and provide a comprehensive discussion of the findings from the experiments conducted. The analysis presented will address two main objectives: improving vibration absorption in compressor mounting and evaluating the effectiveness of replacing existing rubber mounting on compressors. The results presented in this chapter are derived from experiments conducted on a split-unit air conditioning system, which was subjected to rigorous testing to assess how changes in the compressor mounting affect its overall vibration.

Furthermore, this chapter provides an in-depth discussion of the data obtained from the tests, interprets the results, compares them with initial expectations, and analyses how the modifications align with the stated objectives. The findings and their implications are critically evaluated to offer insights into the practical benefits and limitations of the proposed changes to the compressor mounting system. By the end of this chapter, the reader will have a clear understanding of the experimental results and their significance in achieving the objectives. This discussion bridges the gap between theoretical expectations and practical results, offering valuable conclusions for further research or application in similar systems.

4.2 Results

The experiments involved testing the split unit air conditioning compressor with various mounting types, including the original rubber mounting, new rubber mounting, and shock absorption spring head mounting. The vibration levels were measured using a vibration analyzer, Figure 4.1 shown the experimental setup for conduct an experiment in laboratory. The reading for each type of mounting and location were taking 3 times. The refrigerant R22 for the split unit system maintain at working pressure around 65 psi monitored using a manifold gauge. Figure 4.2 and Figure 4.3 shown the vibration sensors at the compressor are placed in 2 locations on the compressor which is bottom (near to mounting) and top (near to copper pipe).

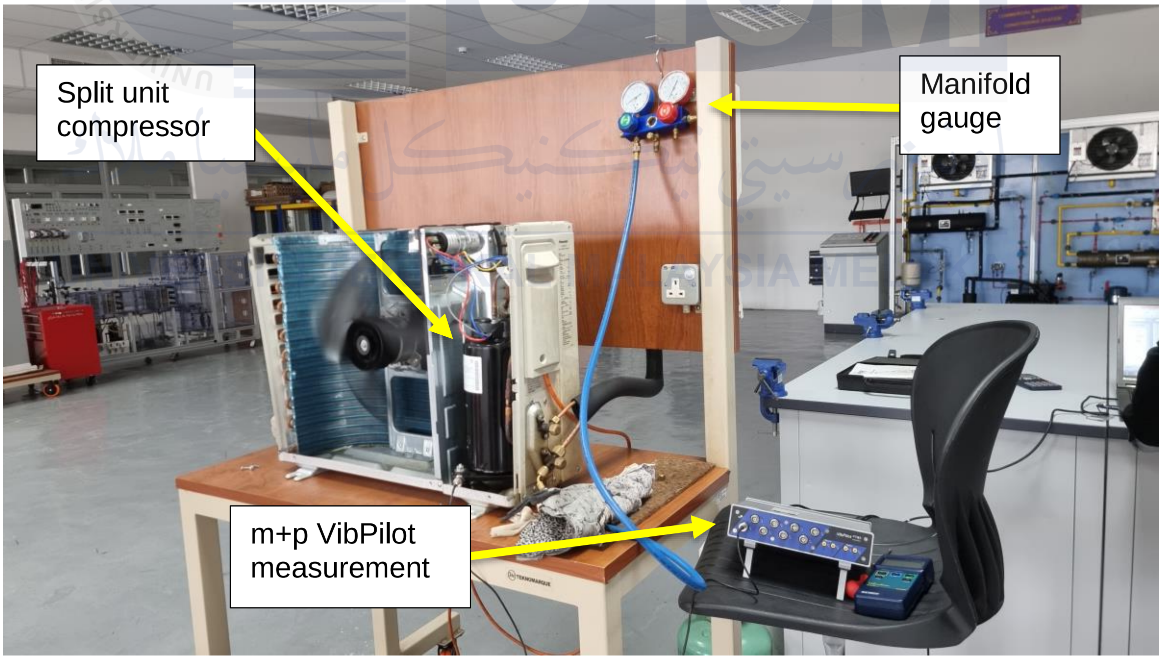

Figure 4.1 Experimental setup

Figure 4.2 Vibration sensor at the bottom of compressor (near to mounting)

Figure 4.3 Vibration sensor at the top of compressor (near to copper pipe)

4.2.1 Vibration Results Summary

The vibration results were measured using a vibration analyzer, with sensors placed strategically at the identified locations. The readings were recorded in units of velocity (mm/s), as per the analyzer's configuration. Table 4.1 below shows the results and average readings. The complete set of results, including detailed data and graphical plots generated by the software is provided in the appendices for further reference.

Table 4.1 Vibration reading during experiment

Mounting type	Sensor location on compressor	Vibration velocity RMS (mm/s)			
		Reading 1	Reading 2	Reading 3	Average
Original Rubber mounting	Bottom	9.467	9.576	9.791	9.611
	Top	8.083	8.163	8.193	8.146
New Rubber mounting	Bottom	5.864	5.656	5.680	5.733
	Top	4.923	4.179	4.135	4.412
Shock-Absorption Spring head mounting	Bottom	3.007	3.579	3.178	3.255
	Top	2.862	2.977	2.750	2.863

4.3 Data

In this section, the experimental data collected during the study is presented and analyzed in detail. The focus is on the vibration measurements recorded at two critical locations on the compressor, the bottom (near the mounting) and the top (near the copper pipe). The tests were conducted using three types of compressor mounting, the original rubber mounting, the new rubber mounting, and the shock absorption spring head mounting. Each test involved three readings to ensure consistency and reliability. Table 4.2 below shown the averange reading from the result at Table 4.1 above.

Table 4.2 Averange vibration reading for every type of mounting

Location of sensor at compressor	Vibration velocity RMS (mm/s)		
	Original rubber mounting	New rubber mounting	Shock absorption spring head mounting
Bottom	9.611	5.733	3.255
Top	8.146	4.412	2.863

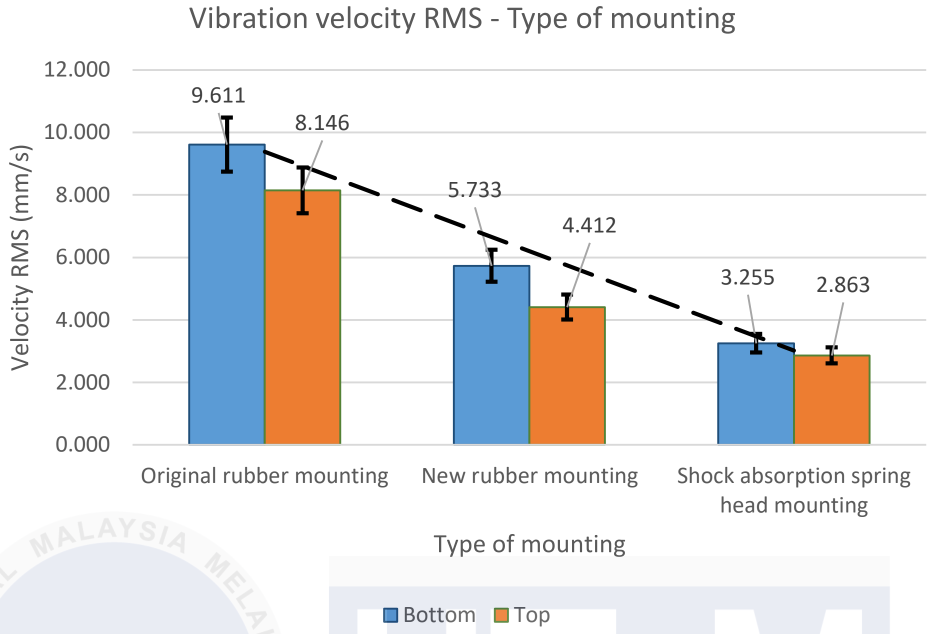

Figure 4.4 Vibration velocity – Type of mounting graph

4.4 Discussion

A comparative evaluation of the three mounting systems highlights their relative performance and their alignment with the study's objectives. The original rubber mounting, serving as the baseline for comparison, displayed the highest vibration levels, emphasizing its limitations in vibration isolation. Its inability to adequately reduce vibration transmission underscores the need for an improved mounting system.

The new rubber mounting presented a notable improvement over the original mounting, achieving significant reductions in vibration levels at both sensor locations. The 40.34% reduction in RMS vibration at the bottom location and the 45.84% reduction at the top location indicate that the new material and design modifications were effective. This improved performance demonstrates that the new rubber mounting is a cost effective solution for reducing vibrations, though it does not match the performance of the shock absorption spring head mounting.

The shock-absorption spring-head mounting emerged as the most effective mounting system in this study. It achieved the lowest vibration levels at both measurement points, with reductions of 66.13% at the bottom location and 64.84% at the top location compared to the original rubber mounting. These results highlight its advanced vibration isolation capabilities, making it the most suitable option for applications requiring high performance vibration damping. Its superior performance also aligns well with the study's objectives of improving vibration absorption in compressor mounting.

From a practical perspective, the findings suggest that while the new rubber mounting offers a cost effective improvement, the shock absorption spring head mounting delivers the most significant benefits in terms of vibration reduction. This mounting has the potential to enhance the longevity and reliability of critical compressor components by minimizing vibration induced wear and damage. However, its likely higher cost may limit its widespread application to scenarios where vibration isolation is critical. Overall, the results demonstrate that replacing the original rubber mounting with either the new rubber mounting or the spring head mounting can significantly enhance the performance of split unit air conditioning compressors, with the spring head mounting providing the most effective solution.

4.5 Verification

Validation of experimental results is essential to ensure reliability and adherence to industry standards. Each vibration reading was recorded three times for each mounting type and sensor location to minimize random error and ensure repeatability. The average of these readings was used to accurately represent the vibration level. The experimental setup was designed for stability by shielding the compressor to prevent unwanted movement, maintaining consistent sensor placement at the bottom (near the mounting) and top (near the copper pipe), and ensuring controlled conditions with R22 refrigerant pressure maintained consistently at 65 psi.

Statistical validation was conducted to verify the consistency and reliability of the data. Calculation of the standard deviation for the readings showed low variability, reinforcing the repeatability of the results. Margins of error were assessed to ensure that the differences observed between mounting types were statistically significant. In addition, the vibration analyzer was calibrated before the testing, and the sensors were validated under known conditions to verify their accuracy and reliability.

Figure 4.5 below shown vibration severity per ISO 10816, the results were evaluated based on that regulation which provides a standard for assessing the severity of vibrations in rotating machinery. According to ISO 10816, vibration levels below 4.5 mm/s are generally considered acceptable for small machinery such as compressors. Both the new rubber mounting and the shock-absorbing spring head mounting achieved vibration levels well within this range, confirming compliance with the standard. The original rubber mounting, however, exceeded this limit, highlighting its inadequacy as an effective damping solution.

These findings were compared with existing studies on vibration isolation, and the observed performance trends were in line with established knowledge, further validating the results. The improvements demonstrated by the new rubber mounting and the shock absorbing spring head mounting not only met but exceeded industry standards for vibration isolation, confirming their suitability as a significant advancement in improving compressor performance.

VIBRATION SEVERITY PER ISO 10816

MACHINE			CLASS I	CLASS II	CLASS III	CLASS IV
	in/s	mm/s	Small < 3.7kW-5HP	Medium < 373kW-500HP	Large rigid foundation	Large soft foundation
Vibration Velocity Vrms	0.01	0.28		Excellent		
	0.02	0.45				
	0.03	0.71				
	0.04	1.12		Good		
	0.07	1.80				
	0.11	2.80		Satisfactory		
	0.18	4.50				
	0.28	7.10		Unsatisfactory		
	0.44	11.2				
	0.71	18.0				
	1.10	28.0		Unacceptable		
	1.77	45.0				

Figure 4.5 Mechanical vibration ISO 10816

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This study analyzed the effect of changing mounting types on the vibration characteristics of a 1 HP split unit air conditioning compressor. The results showed that the original rubber mounting was the least effective, with the highest vibration levels at both sensor locations. The new rubber mounting reduced vibration by approximately 40-45%, while the shock absorption spring head mounting achieved reductions of over 64%, making it the most effective. Both the new rubber and spring head mounting performed within acceptable limits as per ISO 10816 standards. These improvements significantly enhance the compressor's reliability, efficiency, and lifespan, offering practical solutions for vibration management in air conditioning systems.

5.2 Limitation

This study has several limitations. The experiments were conducted in controlled laboratory settings, which may not fully replicate real-world operational conditions. The research focused exclusively on a 1 HP split unit compressor, limiting the applicability of the findings to compressors of other capacities or designs. External factors, such as system load variations and refrigerant types, were not included in the analysis, which may also influence vibration levels. Furthermore, while equipment calibration was thorough, minor measurement inaccuracies may still exist. These limitations highlight the need for caution when applying these findings beyond the specific conditions studied.

5.3 Recommendation

Future research should investigate the effects of mounting type changes on compressors of varying capacities and configurations. Expanding the study to include external factors, such as load variations and refrigerant types, could provide a more comprehensive understanding of vibration management. Field testing in real-world operational environments is also recommended to validate the findings under practical conditions. Additionally, cost benefit analyses of different mounting systems, focusing on maintenance costs and energy efficiency, would aid decision-making. Exploring advanced materials and innovative designs for mounting systems could further enhance vibration isolation and improve overall system performance.

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APPENDICES

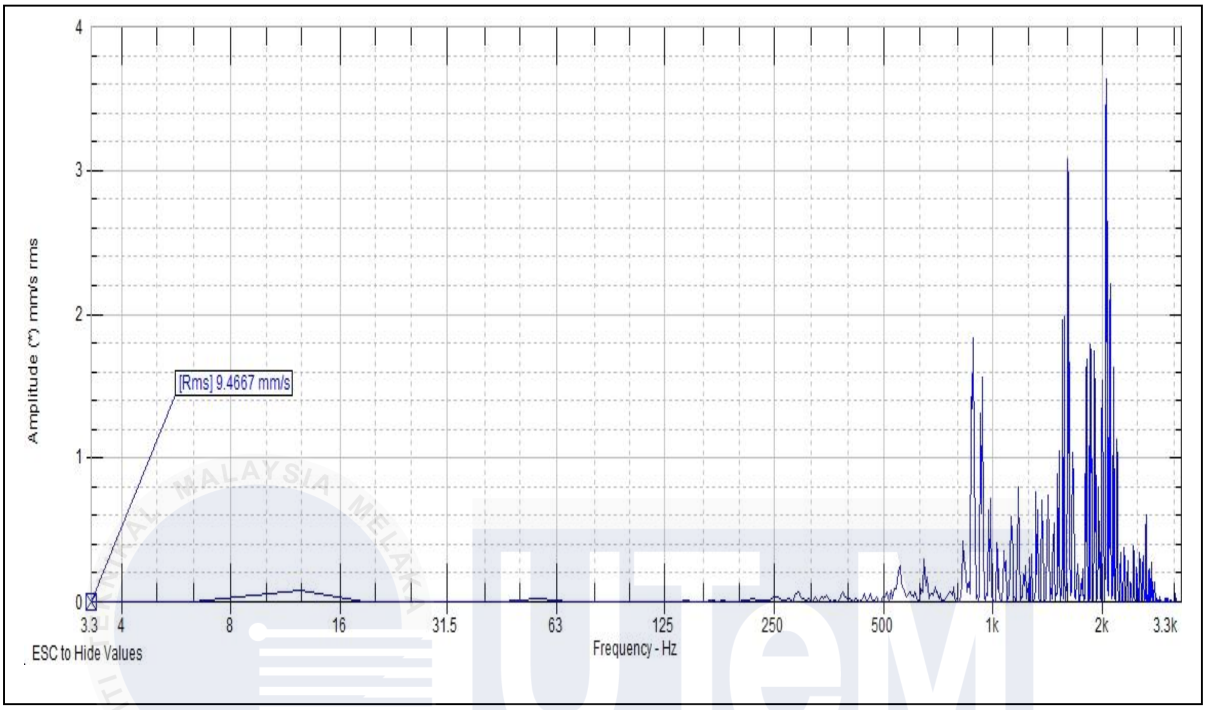
ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	WEEKS													
					1	2	3	4	5	6	7	8	9	10	11	12	13	14
Title Selection	1	1	1	1														
Planning and Research	2	2	2	2														
CHAPTER 1																		
Background, Problem Statement	2	2	2	3														
Objective, Scope	2	2	2	3														
CHAPTER 2																		
Literature Review	3	6	3	10														
Research Gap	9	2	11	2														
CHAPTER 3																		
Introduction	6	1	8	1														
Research Design	6	2	8	3														
Flow Chart	8	2	9	2														
Proposed Methodology	10	2	10	3														
Parameters and Equipment	10	3	11	2														
Limitation	12	1	13	1														
CHAPTER 4																		
Expected Result	12	1	13	1														
Others																		
Elog Book Weekly	1	12	1	13														
Report Progression	1	12	1	13														
Submission	12	1	13	1														

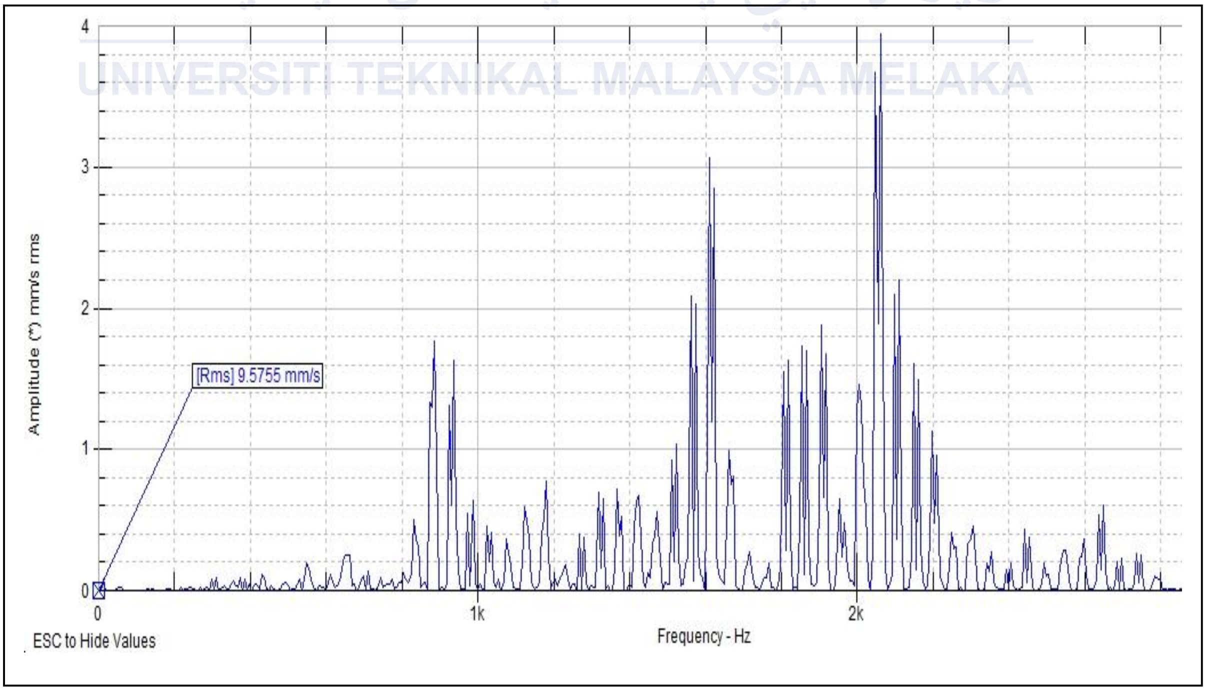
Appendix A Gantt Chart BDP 1

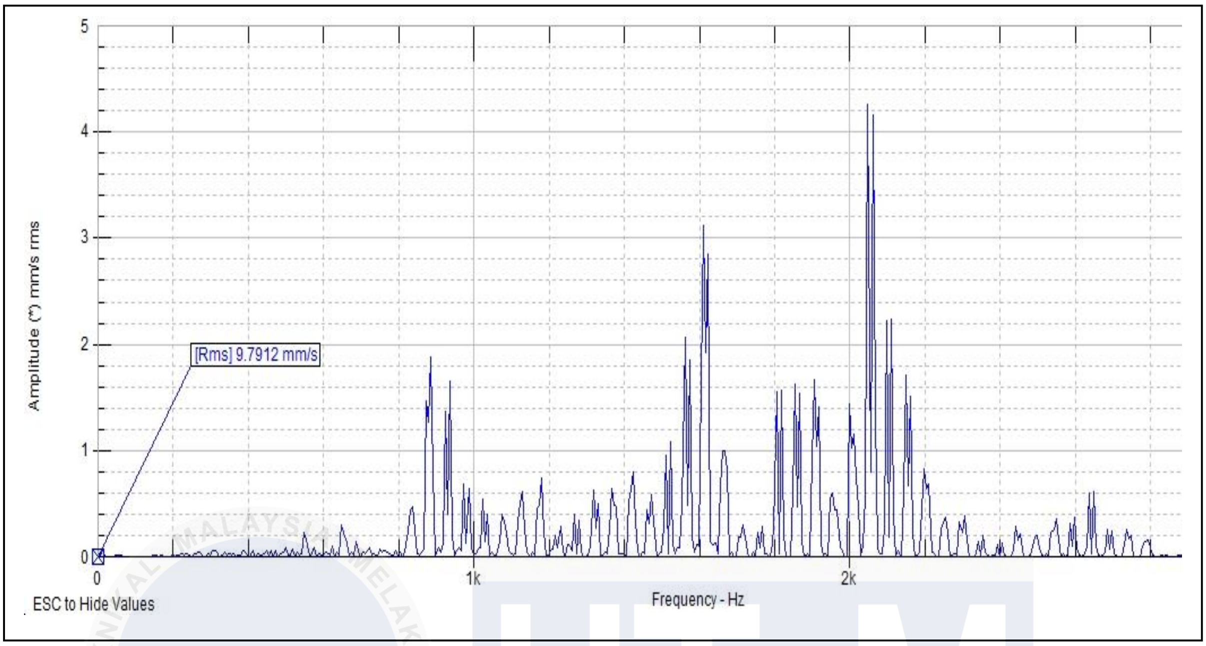
ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	WEEKS													
					1	2	3	4	5	6	7	8	9	10	11	12	13	14
Conduct experiment	2	2	3	4														
CHAPTER 4																		
Introduction	1	1	1	2														
Result	3	2	5	3														
Data	4	2	6	3														
Discussion	5	1	8	1														
Verification	6	1	9	2														
CHAPTER 5																		
Conclusion	7	1	10	1														
Limitation	8	1	10	2														
Recommendation	9	1	11	1														
Others																		
E-log book	1	13	1	13														
Report progession	1	10	1	12														
Technical report progression	10	2	11	3														
Submission	13	1	13	1														

Appendix B Gantt Chart BDP 2

Appendix C Experiment graphical graph







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3
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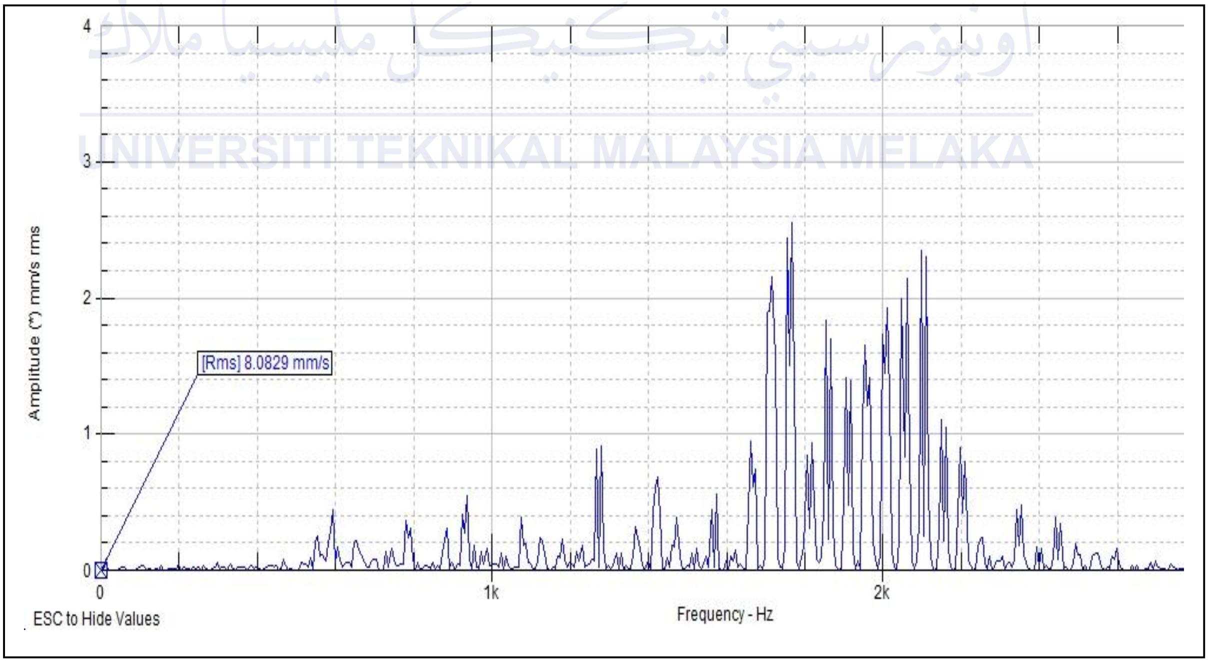
2k
Frequency - Hz
ESC to Hide Values



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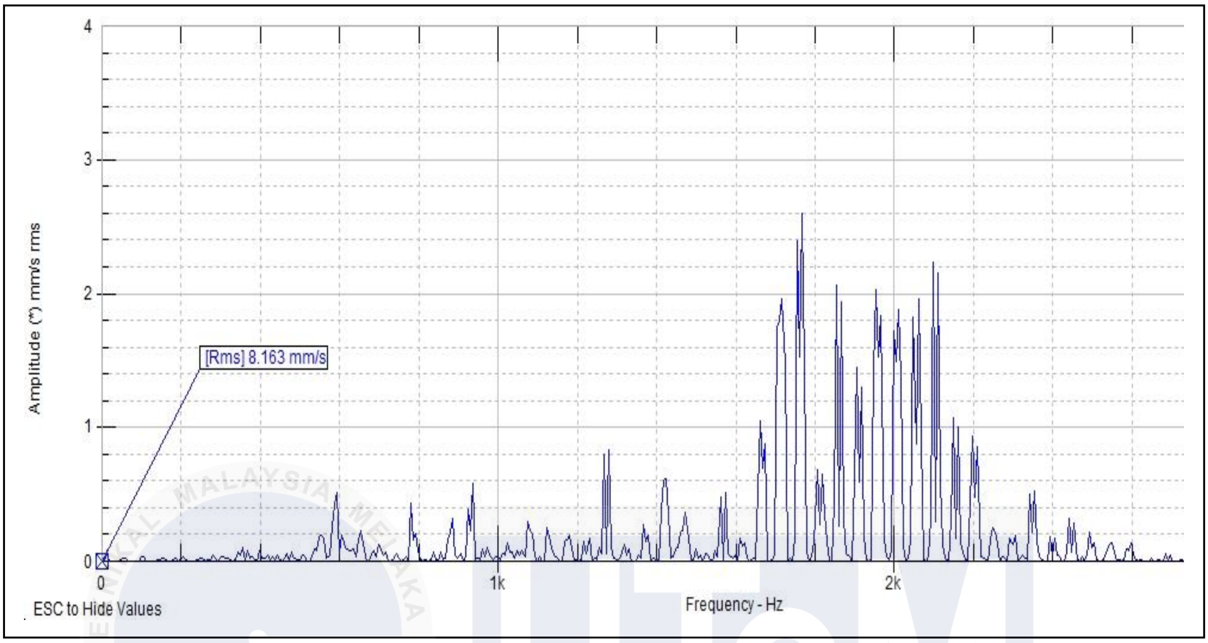

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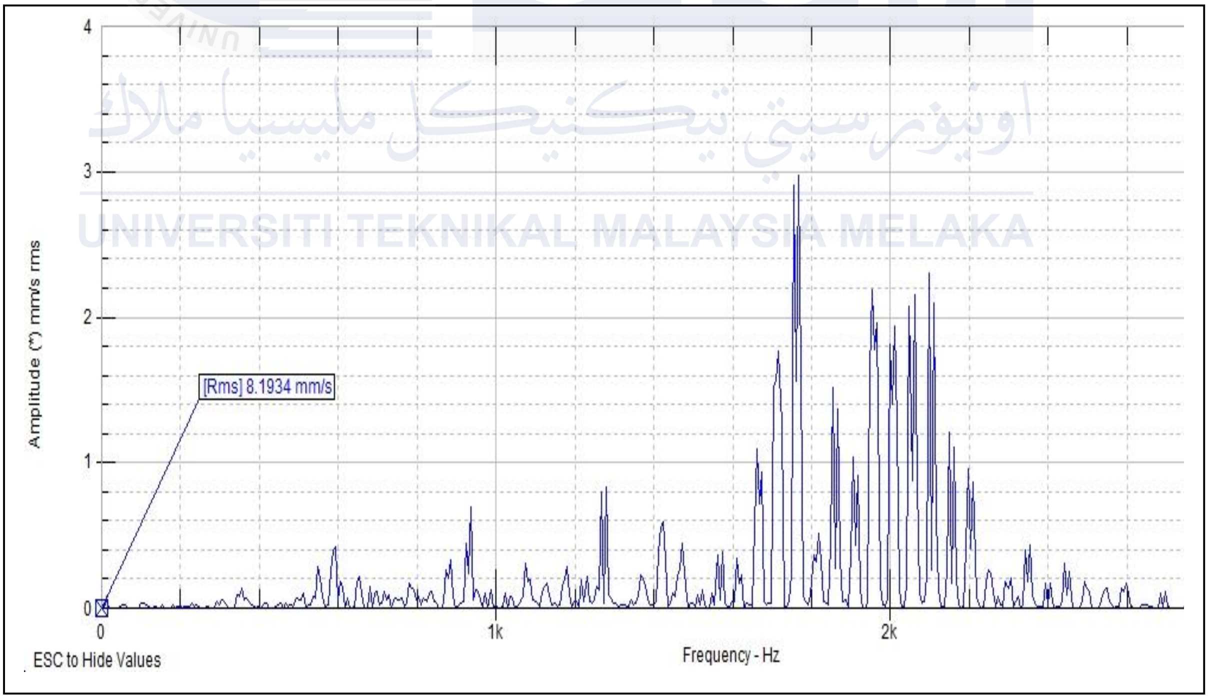
ESC to Hide Values



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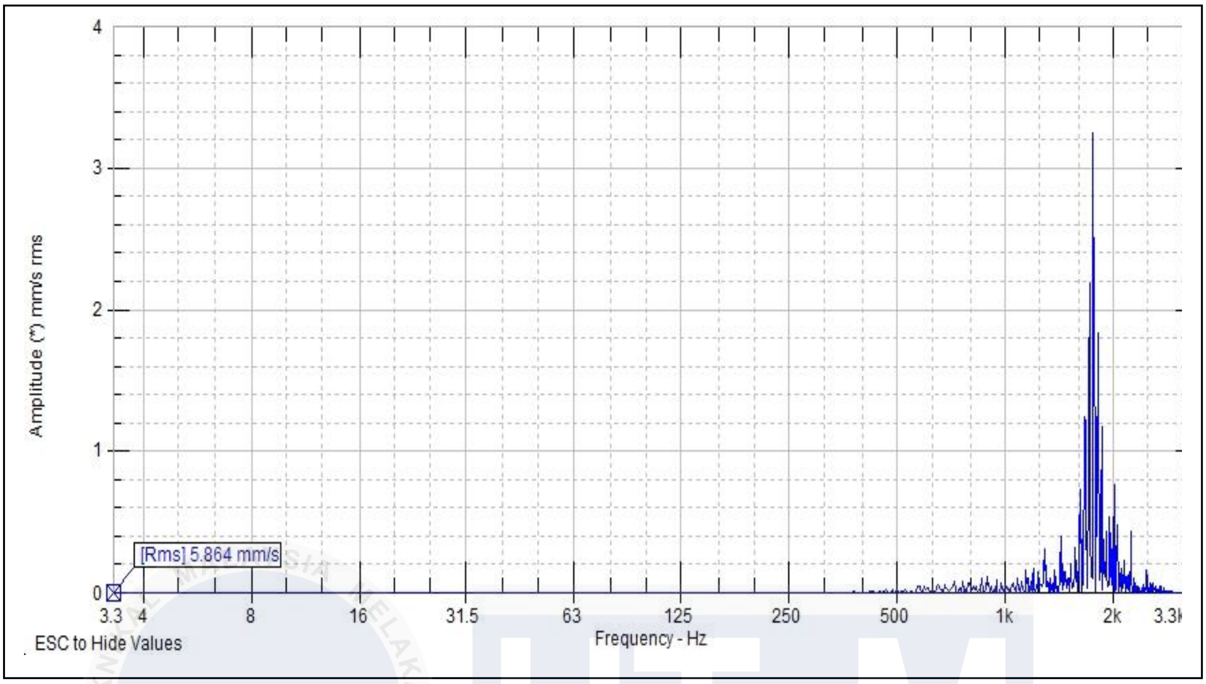

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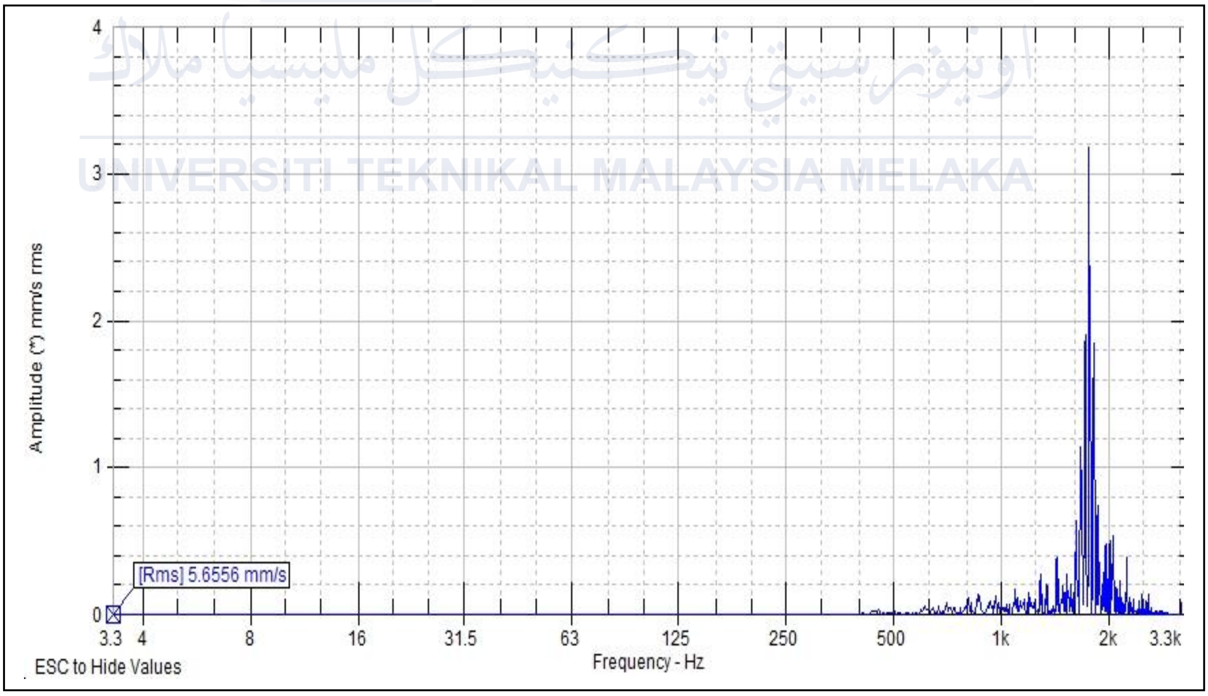

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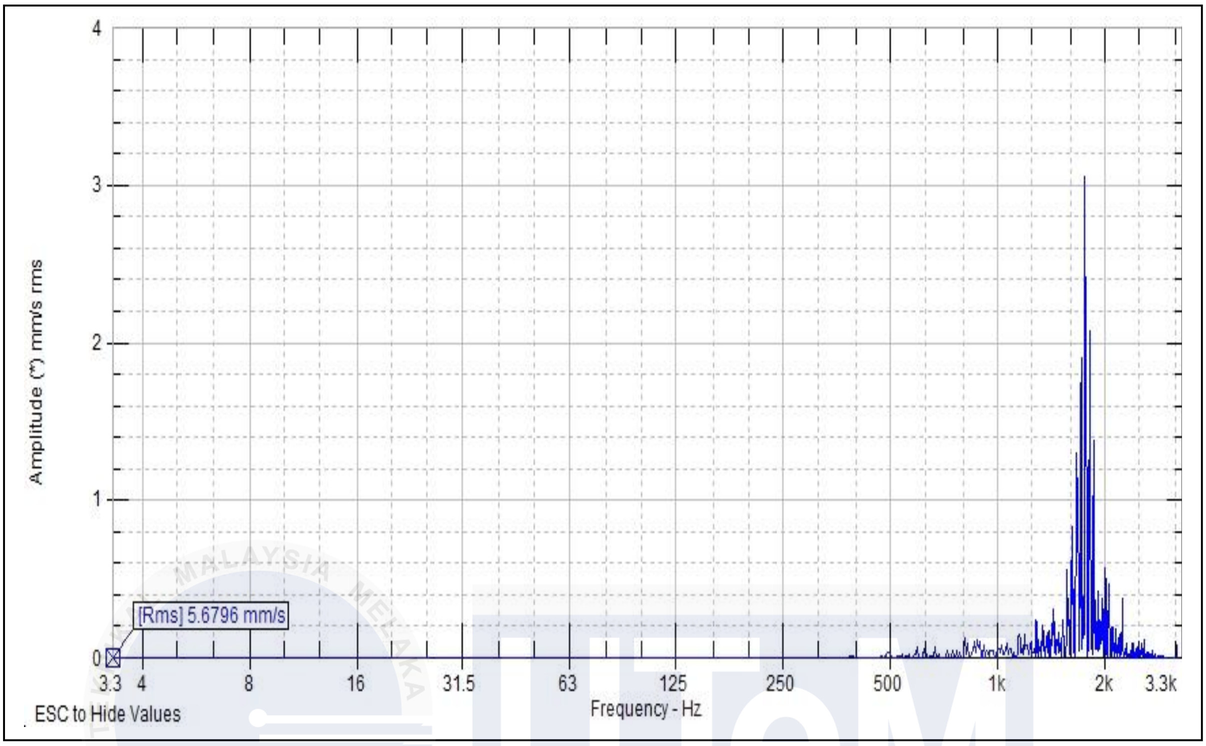

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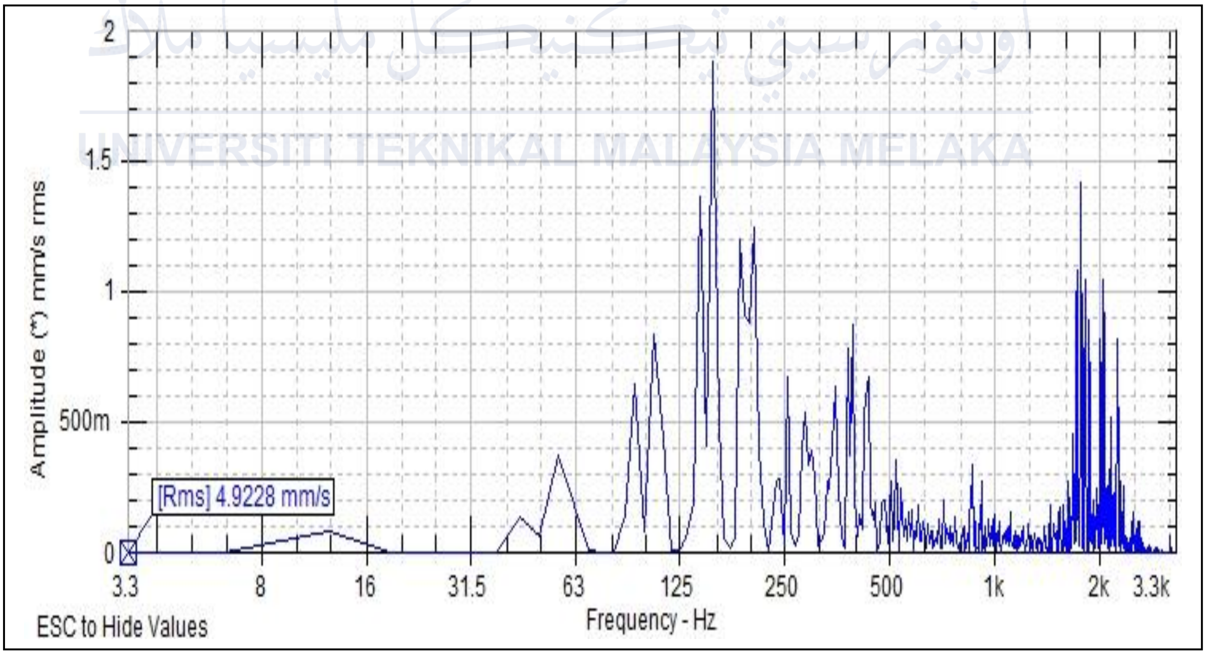

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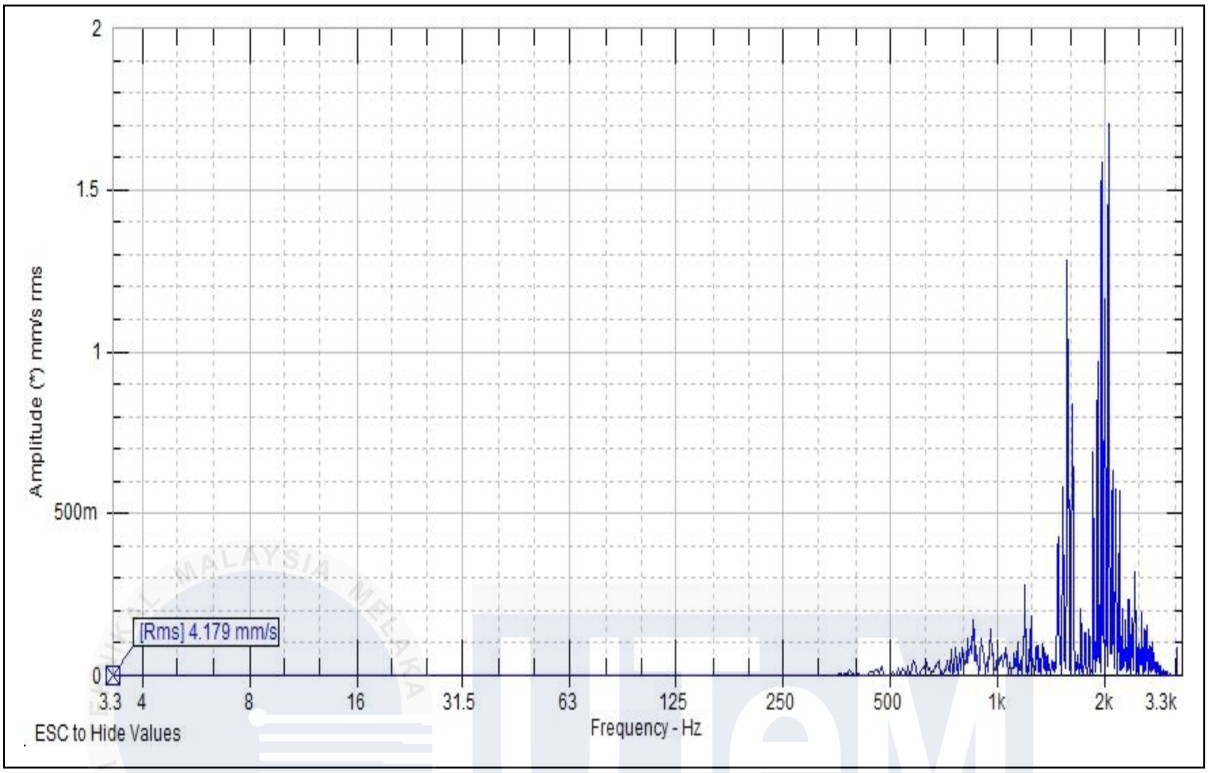
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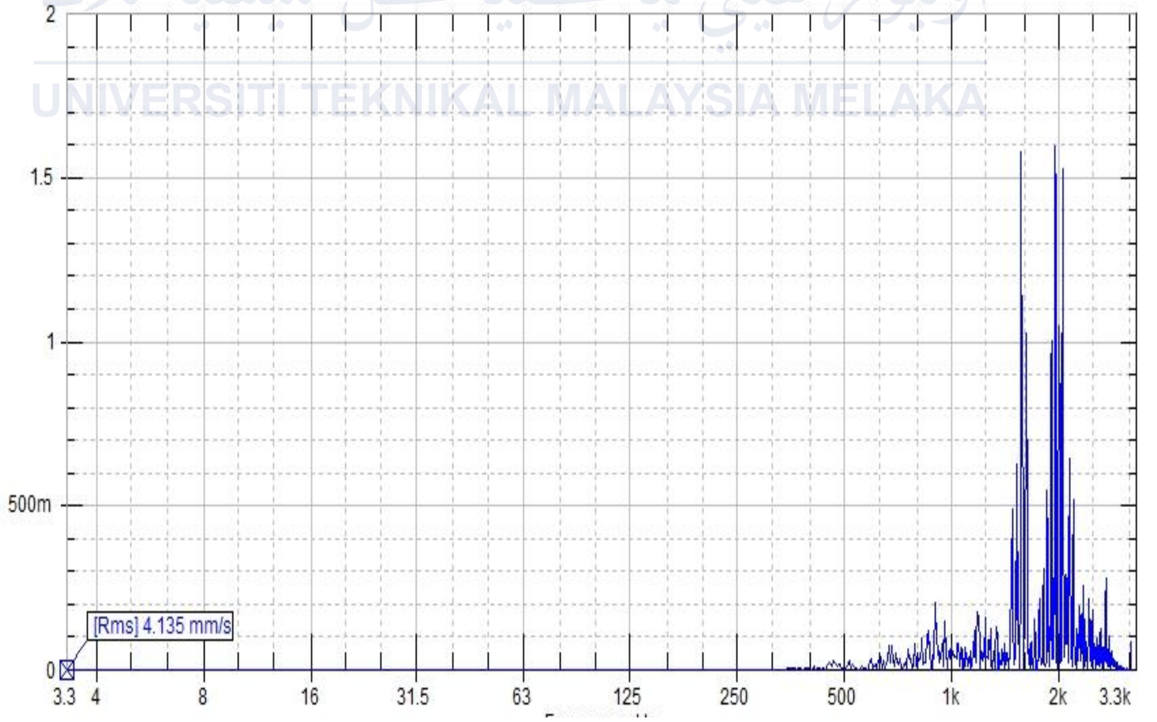
31.5
63
125
250
500
1k
2k
3.3k
Frequency - Hz
ESC to Hide Values

1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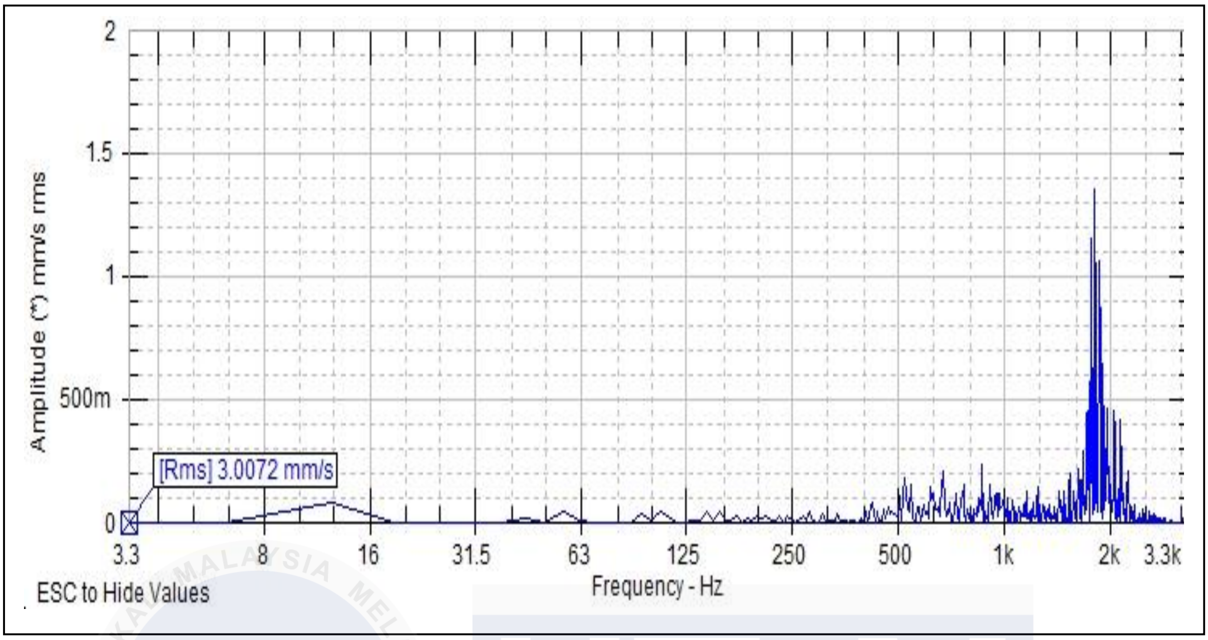
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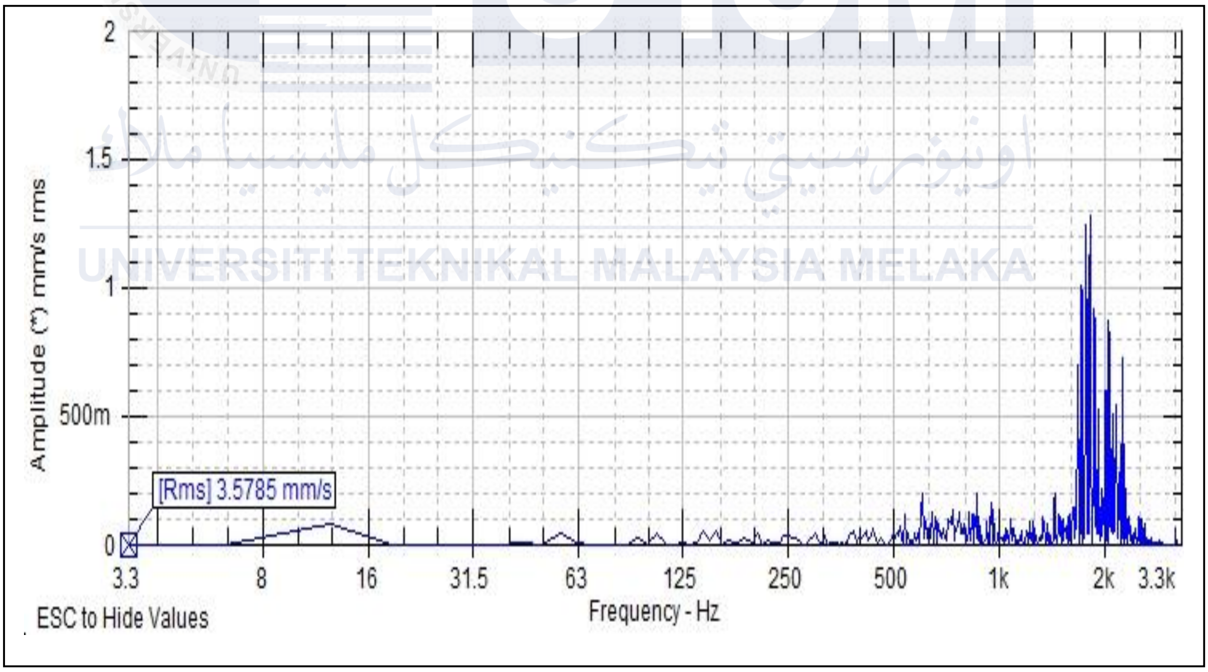
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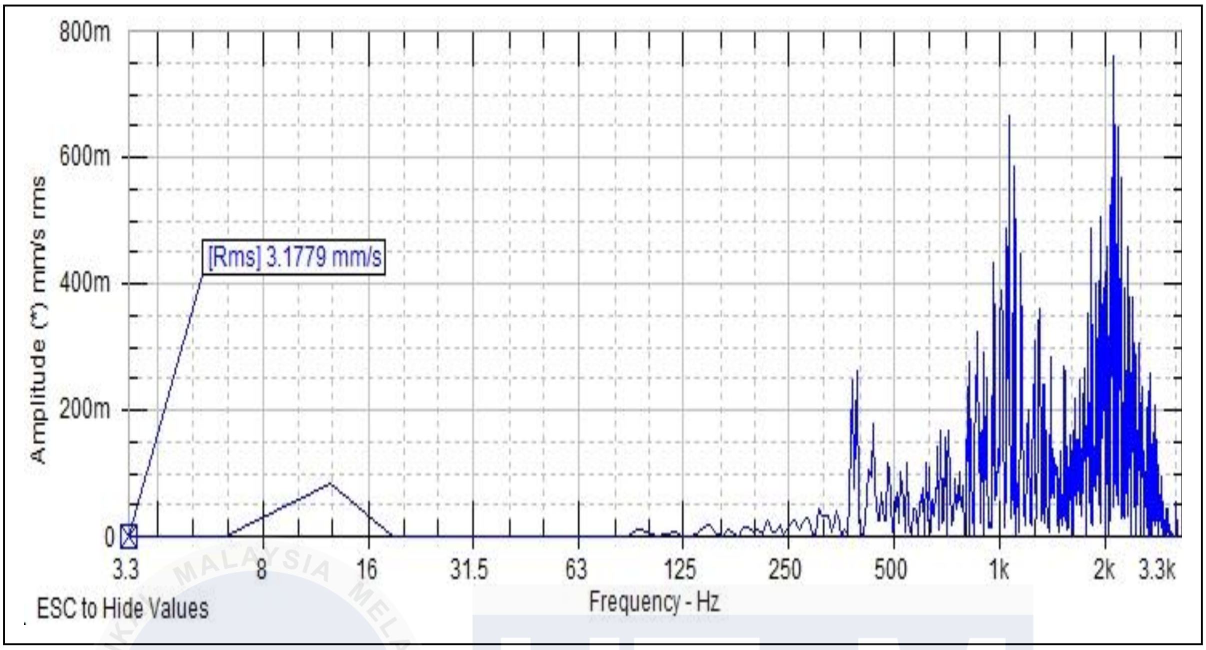
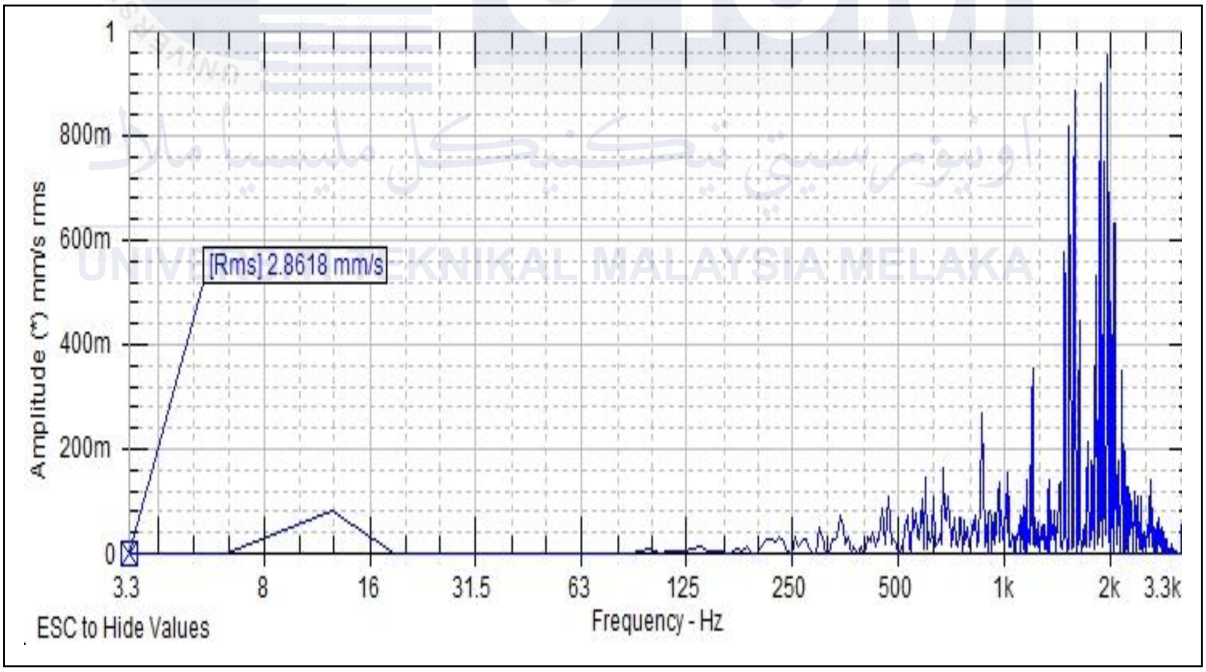
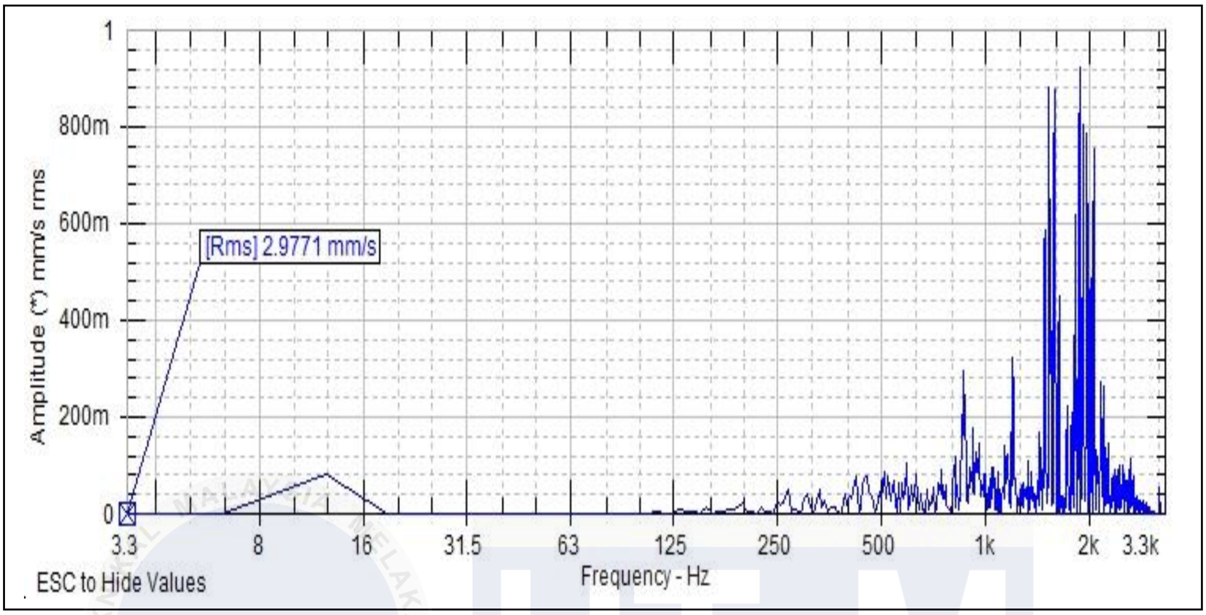
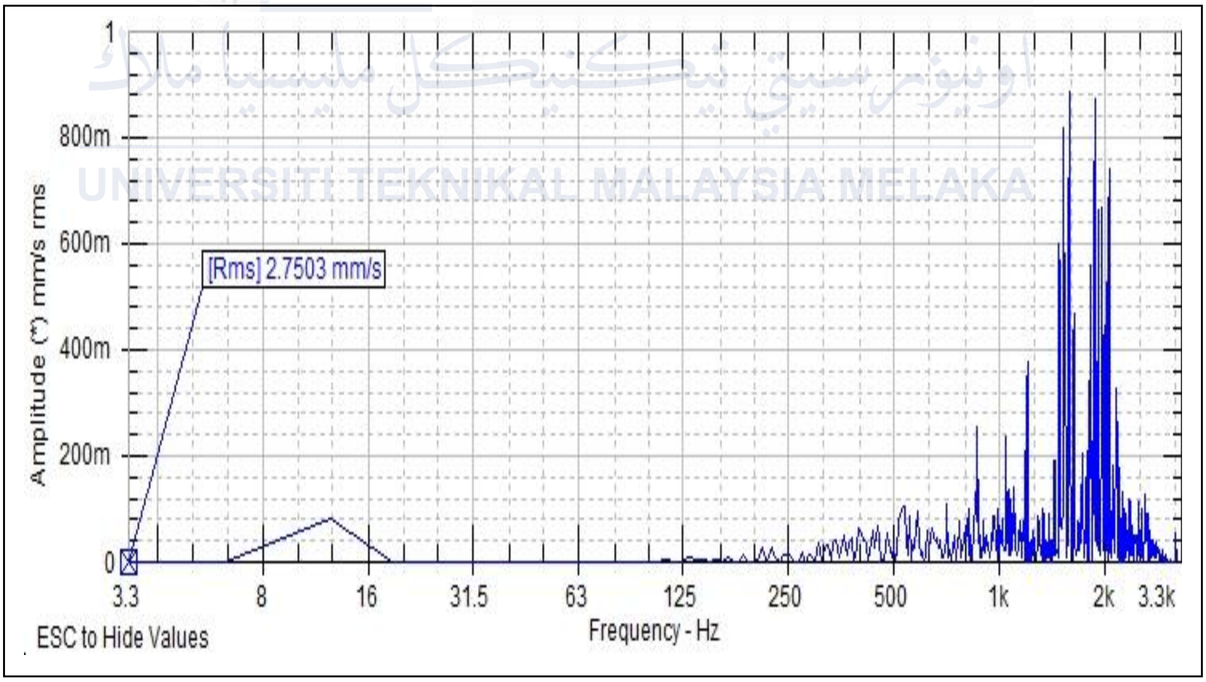


800m
600m
400m
200m
0
Amplitude (*) mm/s rms
[Rms] 3.1779 mm/s
3.3
8
16
31.5
63
125
250
500
1k
2k
3.3k
Frequency - Hz
ESC to Hide Values



1
800m
600m
400m
200m
0
Amplitude (*) mm/s rms
[Rms] 2.8618 mm/s
3.3
8
16
31.5
63
125
250
500
1k
2k
3.3k
Frequency - Hz
ESC to Hide Values


[Rms] 2.9771 mm/s
Amplitude (*) mm/s rms
1
800m
600m
400m
200m
0
3.3
8
16
31.5
63
125
250
500
1k
2k
3.3k
Frequency - Hz
ESC to Hide Values


[Rms] 2.7503 mm/s
Amplitude (*) mm/s rms
1
800m
600m
400m
200m
0
3.3
8
16
31.5
63
125
250
500
1k
2k
3.3k
Frequency - Hz
ESC to Hide Values