EXPERIMENTAL MODELLING AND CONTROL OF LINEAR ACTUATOR FOR MANUFACTURING APPLICATIONS

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DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

Signed………………………………………………(Nurul Natasha Aiza binti Pozai)

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STATEMENT 1

This thesis is the result of my own investigations, except where otherwise stated. Other sources are acknowledged by giving explicit references.

Bibliography/references are appended.

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LIST OF SYMBOLS

%	Percentage
F	Force
$F_{average}$	Average force
Δt	Time
m	Mass
a	acceleration
g	g-force
g	Grams
G	Gravity
kg	Kilograms
m/s^2	Meter Per Second Squared
s	Second
sa	Data points
z_1	Acceleration in z-direction for set 1
z_2	Acceleration in z-direction for set 2
z_3	Acceleration in z-direction for set 3
$z_{average}$	Average acceleration in z-direction

LIST OF ABBREVIATION

ADC	Analog-To-Digital Converter
CPU	Central Processing Unit
DC	Direct Current
DMP	Digital Motion Processor
DSP	Digital Signal Processing
EMS	Emergency Stop Button
FFT	Fast Fourier Transform
FIFO	First In, First Out
Freq	Frequency
Hz	Hertz
IDE	Integrated Development Environment
IOC	Indicators Of Compromise
KHz	Kilohertz
LED	Light-Emitting Diodes
LMS	Learning Management System
MATLAB	Matrix Laboratory
MEMS	Micro Electro-Mechanical System
MPU	Memory Protection Unit
MQTT	MQ Telemetry Transport
PLX-DAQ	Parallax Microcontroller Data Acquisition Add-On Tool for Microsoft Excel
PSCAD	Power Systems Computer Aided Design
SD	Secure Digital
SMA	Simplified Memory-Bounded Algorithm
SMD	Surface-Mount Devices
USB	Universal Serial Bus
VI	Visual Instrument
WI-FI	Wireless Fidelity

PERMODELAN EKSPERIMEN DAN KAWALAN PENGGERAK LINEAR UNTUK APLIKASI PEMBUATAN

ABSTRAK

Kajian ini menerangkan mesin simulasi automatik yang dicipta untuk menggantikan proses manual pembuatan Kuih Loyang dan seterusnya meningkatkan pengeluaran Kuih Loyang. Silinder pneumatik dan Arduino UNO telah digunakan oleh mesin untuk mencapai sistem automatik. Mesin ini diprogramkan untuk melakukan peringkat mencelup, termasuk menggoncang bahagian kerangka acuan untuk mengeluarkan semua Kuih Loyang dari acuan. Ia didapati mampu menyelesaikan tugas yang dikodkan dalam IDE Arduino dengan betul. Penyelidikan ini membandingkan nilai getaran mesin simulasi dengan mesin manual di kilang dengan mengukur getaran yang dihasilkan oleh goncangan kerangka acuan. Hasilnya, sistem yang mampu mengukur pecutan kerangka acuan semasa goncangan telah dicipta untuk mengukur getaran dari segi pecutan. MPU6050 digunakan untuk mengukur pecutan dalam unit meter per saat kuasa dua. Peranti mengambil data mentah daripada MPU6050 yang dipasang pada bingkai acuan dan memprosesnya menggunakan pengawal Arduino UNO untuk mengira nilai graviti. Nilai graviti kemudiannya ditolak dengan nilai mengimbangi untuk mendapatkan data sebenar bagi pecutan dalam unit g. Seterusnya, gegaran mesin dianalisis dengan menentukan frekuensi dan amplitud kerangka acuan. Data daripada Arduino dihantar secara bersiri ke sistem pemantauan, di mana ia disimpan dalam fail excel. Kemudian, dalam Excel, Fast Fourier Transform (FFT) digunakan untuk menukar nilai G domain masa kepada domain frekuensi. Selepas melaksanakan Fast Fourier Transform (FFT), frekuensi dan amplitud diperolehi. Excel digunakan untuk mencipta graf pecutan berbanding masa dan kekerapan berbanding amplitud. Mengikut statistik, mesin simulasi bergegar tiga kali, menghasilkan pecutan maksimum 1.01g, 0.79g, dan 0.57g, manakala mesin manual di kilang bergegar sekali sahaja. Pecutan maksimum mesin manual di kilang ialah 1.03g. Frekuensi tertinggi mesin simulasi ialah 79 Hz diikuti 10 Hz, manakala frekuensi tertinggi mesin manual ialah 12 Hz diikuti 53 Hz. Ini menunjukkan bahawa mesin simulasi, seperti mesin manual, dapat mengeluarkan semua Kuih Loyang daripada acuan semasa peringkat mencelup. Kajian ini berjaya membuktikannya.

EXPERIMENTAL MODELLING AND CONTROL OF LINEAR ACTUATOR FOR MANUFACTURING APPLICATIONS

ABSTRACT

This study describes an automated Kuih Loyang's simulation machine that was developed to replace the manual process and thereby boost Kuih Loyang production. The pneumatic cylinder and Arduino UNO were utilised by the machine to accomplish the automatic system. The machine is programmed to do the dipping stage, which includes shaking parts of the mould frame to remove all of the Kuih Loyang from the mould. It was discovered to be capable of properly completing the tasks coded in the Arduino IDE. This research compares the vibration value of the simulation machine to the manual machine in the factory by measuring the vibration produced by the shaking of the mould frame. As a result, a system capable of measuring the acceleration of the mould frame during shaking has been created to measure the vibration in terms of acceleration. The MPU6050 was used to measure the acceleration in terms of the metre per second squared. The device takes raw data from an accelerometer mounted on the mould frame and processes it using an Arduino UNO controller to compute gravitational values. The gravitational values then minus with the offset values to obtain the actual data for the acceleration in g unit. Next, the machine shaking is analysed by determining the frequency and amplitude of the mould frame. Data from the Arduino is serially delivered to the monitoring system, where it is saved in an excel file. Then, in Excel, the Fast Fourier Transform (FFT) is used to convert the time domain G-values to the frequency domain. After executing the Fast Fourier Transform (FFT), the frequency and amplitude are obtained. Excel was used to create a graph of acceleration versus time and frequency versus amplitude. According to the statistics, the simulation machine shakes three times, resulting in maximum accelerations of 1.01g, 0.79g, and 0.57g, while the manual machine at the factory shakes only once. The manual machine's maximum acceleration at the factory is 1.03g. The simulation machine's highest frequency is 79 Hz followed by 10 Hz, while the manual machine's highest frequency is 12 Hz followed by 53 Hz. This demonstrates that the simulation machine, like the manual machine, was able to remove all of the Kuih Loyang from the mould during the dipping stage. This study successfully demonstrates this.

CHAPTER 1

INTRODUCTION

1.1 Overview

There are several types of traditional Kuih which requires vibration to remove the Kuih from its mould. One of them are honeycomb cookies or another name for the traditional dish known as Kuih Loyang, which is also called Kuih Ros and Kuih goyang. Kuih Loyang is one of the biscuits that is in high demand at most celebrations in Malaysia, notably around the occasion of Eid Mubarak. Rice flour and an egg mixture are fried in cooking oil to create it, and the method calls for a specific iron or copper mould in order to make it. The flavour and texture of the biscuit that is considered to be age-appropriate are distinct from one another. This sweet fried biscuit is in the shape of a rose, and each layer of the rose's petals is represented by a hole in the biscuit.

In essence, the process can be broken down into three distinct phases: first, frying the biscuits in oil, second, dipping them in the mixture and third, storing them in the biscuit container. Moulds are manually operated by experienced operators in today's technology, which allows for greater precision. The operator will use a metal bar to immerse the cake mould into the batter for the cake, and then they will transfer the cake to the container for frying. Then, to release the biscuits from the main mould, it was necessary for people to manually shake the biscuits inside the mould. After the mould has been preheated in an oil bath, any leftover oil will be removed carefully by shaking the mould or absorbed by a piece of kitchen paper, depending on which method is chosen. After re-immersing the mould in the oil bath for 10 to 15 seconds after being dipped in the batter (which had been prepared in advance in accordance with the instructions), the finished product will be ready for consumption. Afterwards, it ought to be possible to slide the cookies out of the mould so that they may be baked. After that, the process is going to be repeated for the rest of the cookies or until all of the batter has been used up. The shaking step, which is part of the process for extracting the honeycomb biscuits, is the primary focus of this study. As a solution for the delayed production, a semi-automatic machine for the biscuit dipping process is built.

The development of machinery was conducted to minimize the load placed on human labour. Within the limitations of the machine's design requirements, the manufacturer can create a machine that is capable of being fully automated. In order for the machine to perform the motion in the same way as the robot, it needs to have the same degree of freedom. It is predicted that the automated system that will be constructed because of this study will have the capacity to carry out and handle all of the phases that have been described thus far by including particular processes into the system. This indicates that the machine can mimic the majority of the work done by human operators through the usage of suitable equipment and a suitable microcontroller. Because of this, it is possible to eliminate the possibility of human error and limitations.

Figure 1.1: The traditional Kuih Loyang mould

1.2 Project background

As previously indicated, honeycomb cookies are prepared in three steps. The first step is to make the batter to one's specifications, followed by heating the mould and removing excess oil. Cookies with thicker shells are produced using moulds at a higher temperature, and vice versa. The prepared mould will then be breaded and fried (Siti, 2019). Due to human effort, the outcome of traditional cookie baking may be uneven. This is because human error is more likely to occur during the period of excess oil removal. Additionally, it is extremely time-consuming and requires additional skill and attention to perfect the cookies. Consequently, automated solutions are more constant than human labour in situations requiring extreme regularity and precision.

The research will be conducted using the rectangular structure provided by Al-Ridhwee Holdings (M) Sdn Bhd. Initially, the technician in the food sector intended to design a semi-automated alternative to the previous system, which required human labour alone. After a period of testing, it was determined that the chosen machine was inconsistent in moving and shaking the mould frame. This analysis disregards the beginning phase of the process because it is assumed that the batter is made and stored in the batter chamber. Instead, the issue of inconsistency caused by the procedures will be investigated, the shaking during the dipping process will be focussed. The succeeding solutions will be supplied by the mechanism of motion. Presumably, a suitable device controlled by a compatible microcontroller will perform it semi-automatically. Consequently, decreasing human error and enhancing job efficiency.

Figure 1.2: The mould frame from Al-Ridhwee Holdings (M) Sdn Bhd

The unique motion generated by the operator's manipulation of the mould is a form of vibration. There are three different types of vibrational motion: free vibration, forced vibration, and damped vibration. Therefore, the vibration that may have occurred to the Kuih Loyang frame is free vibration since the machine operator required a small amount of vibration for the biscuits to fall into the frying pan without disruption.

There is a machine which has designed by the previous researcher, but the machine does not complete and need some improvements. The machine needs to be programmed by using the Arduino to enable the shaking of the machine. The picture of the machine is shown below:

Figure 1.3: The simulation machine before improvement

The vibration of the machine is terms of acceleration need to be measured. Hence, the current study focuses to programme the shaking of the machine and measure its acceleration using an MPU6050 sensor and an Arduino. Then, the PLX DAQ are utilized to send raw data from Arduino to Microsoft Excel. PLX-DAQ is an add-on for Microsoft Excel that collects data from Parallax microcontrollers. Connecting Arduino to MPU6050 enables the serial port of a PC to send data directly into Excel. After executing the Fast Fourier Transform in Excel, frequency and amplitude data are then obtained. The results of the experiment were compared and analysed with the results of manual shaking that have been done at Al-Ridhwee Holdings (M) Sdn Bhd to remove all Kuih Loyang.

1.3 Problem statement

The present mould frame shakes the biscuits manually to remove them from the mould. The manual shaking might be inconsistent in every cycle. Due to inconsistent shaking of the mould, several Kuih Loyang mould unplugged from the mould frame hence this study purposely to eliminate the unplugged mould. Thus, an automated machine that used the linear actuator to control the process and the shaking of the machine will be created. The linear actuator will be controlled by the microcontroller named Arduino UNO.

1.4 Objectives

The goals of this project are:

1. To control the linear actuator by using the Arduino and then examine the mechanical vibration in terms of acceleration during the shaking of the machine.
2. To obtain and compare the frequency and the amplitude of the simulation machine and the factory’s machine.

1.5 Scope of work

The operator shakes the mould to get the biscuits to fall out. Since the linear actuator and pneumatic cylinder utilized in the previous Kuih Loyang machine were not compatible with the new honeycomb cookie production commands, the machine was retrofitted. Extracting and retracting motions might be utilized to emulate dipping process motions, as well as the shaking of the mould frame that will be employed to remove excess oil from the mould during the excess oil removal phase of this project. An 8 kg rectangular piece of steel will be utilized as a study sample.

There are a few accelerometers that can be used to measure the shaking in terms of acceleration, and these sensors will be investigated in order to determine which one is best for the system's needs. As a next step, a sequence of orders for measuring acceleration in a honeycomb cookie making process will be written into the computer code. A controller (Arduino UNO) processes accelerometer data collected by the system to obtain gravitational values. Serially transmitted data from the Arduino is stored in an Excel file by the monitoring system. After applying the Fast Fourier Transform, these are the resulting amplitudes and frequencies. Excel was used to visualise the amplitudes and frequencies. It's possible to see the amplitudes at various frequencies. This information is then compared to that obtained by manually shaking the product in the factory.

CHAPTER 2

LITERATURE REVIEW

This chapter will discuss the relevant technologies that have been introduced and implemented in society by a variety of companies and organizations, in addition to the previous research on the market-available microcontrollers' adaptiveness and the devices' suitability for system applications. These topics will be covered in this chapter.

2.1 Invented machine

Traditional honeycomb cookies are created one by one, which is time-consuming and only suitable for household consumption, not large production. AEC Machinery designed a manually operated machine to produce a big quantity of Kuih Loyang. The machine is distinctive because it features an adjustable mould frame. It uses gas to heat and can make 6000 pieces per hour. It contains 20 moulds and is 2000 x 430 x 750 mm and 58 kg (Halim, 2021).

Figure 2.1: Kuih Loyang machine from AEC Machinery

Even though a machine that is capable of producing honeycomb biscuits on a large scale was developed, there has been an ongoing increase in demand for these cookies. Because the manually operated equipment is dependent on the physical stamina of the human operator, it is unable to satisfy the demand. Then, the Malaysian Agricultural Research and Development Institute (MARDI) has developed a solution that is only semi-automated, as can be seen in the following figure (Figure 2.2). It is claimed that it is capable of improving production efficiency by first decreasing the involvement of human labour at the pick and place station from the previous level of 3–4 operators to a maximum of 2 per production line (Zulkifly A. Rahman, 2011), while simultaneously increasing the production output from the previous level of 150–200 pieces per hour to 1200–1500 pieces per hour after having the mechanical system implemented. The device featured a chamber for making the batter, another chamber for frying the food, and a designated mould frame that could move freely between the chambers. The mould frame could hold anywhere from 18 to 25 individual moulds. The dipping portion of the process takes about twenty to thirty seconds to finish, and the shaping of the cookies in the fryer takes approximately two minutes (Hamzah & Abdul Wahid, 2016). In this scenario, the production of 25 honeycomb cookie pieces may be completed in a maximum of 150 seconds, demonstrating once again that the semi-automated system is a solution that is both faster and more exact than other approaches to coping with the overwhelming demand from customers.

Figure 2.2: Kuih Loyang Machine by MARDI

Next, the machine created by the Muhammad Hasraff, 2017 can produce four pieces of Kuih Loyang in one time. This machine is created for his final year project and it is semi-automatic machine as represented in Figure 2.3. . The roller is used to move from one location to another location. There are two processes involved which are the first one, the mould immerse into the batter then the second process is the mould immerse in the oil to fry the Kuih Loyang. This machine does not shake but it will stay in the oil until the Kuih Loyang flower and then the mould is removed from the oil.

Figure 2.3: Kuih Loyang machine's by Hasraff

Figure 2.4 currently a new semi-automatic rose cake machine that can dip, shape, and cook rose cakes. Using only one or two people, this machine can produce 800 to 900 pieces each hour (Saadah, 2015).

Figure 2.4: Semi-automatic rose cake machine

Then, there is a semi-automatic machine created by Zul Design and it made of stainless steel. It can produce 20 pieces of Kuih Loyang at one time (Zul, 2020). However, it still need several human labour to handle the machine. Figure 2.5 display the Kuih Loyang machine and the worker who assigned to pick up manually the cooked Kuih Loyang from the oil into the container.

Figure 2.5: Semi-automatic machine by Zul Design

Then, the company named Al-Ridhwee Holdings (M) Sdn. Bhd has created the machine that can produce 100 pieces of Kuih Loyang in one time. The average production of the Kuih Loyang is 12 000 pieces per day. However, they still need the human labour to shake the mould because the machine is not fully automated (Irfan, 2022). The picture shown below. Hence, this project focus to improve the existing machine by programmed a code to make the machine fully automatic but have the sufficient vibration to remove all of the biscuits during dipping phase hence the quality of works can be improved.

Figure 2.6: Kuih Loyang machine by Al-Ridhwee Holdings (M) Sdn. Bhd

2.2 Vibration motion

Vibration is a point-centred mechanical oscillation. Free and forced vibrations exist. When an object is at rest and permitted to move freely, it vibrates freely. While forced vibration adds external force to a moving system, causing resonance. External force frequencies approach the system's inherent frequencies during resonance. Resonance can raise, reduce, or destroy system frequencies. Resonance can impair system strength and stability (Yu et al., 2017). Vibration can be good or bad for a system. Vibration usually causes mechanical building damage (Bai et al., 2012).

Amplitude and frequency measure vibration. Amplitude is a vibration's displacement strength. Frequency is the oscillation speed from a stationary point. Frequency is the number of vibration cycles per second. Waveforms are used to illustrate vibration. Time and frequency domains are the most popular. Figure 2.7 compares time and frequency domains. Time-domain graphs show vibration amplitude on Y-axis versus time in seconds on X-axis. Y-axis vibration amplitude vs X-axis frequency is the frequency domain.

Natural frequencies and mode shapes are vital for studying vibration and avoiding failure (Kumar et al., 2014). Natural frequencies have unique mode shapes. Mode form is a unique motion pattern with set natural frequency.

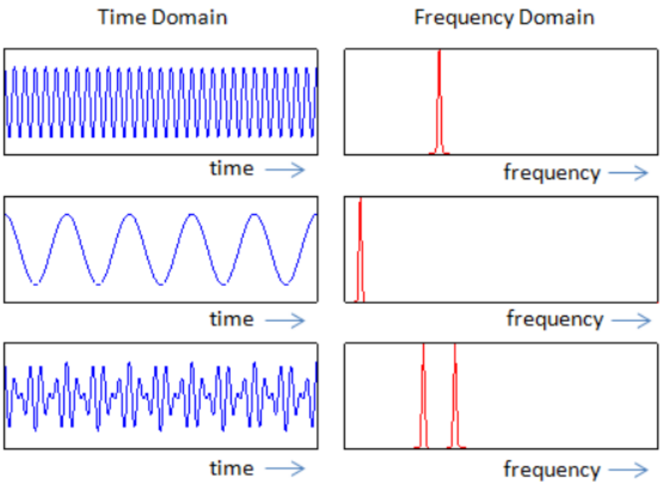


Figure 2.7: Time domain and frequency domain

2.3 Mechanical vibration measurement

Considering the findings of the study, an explanation of how a Micro Electro-Mechanical System (MEMS) accelerometer can be used to assess mechanical vibration has been provided. It has been demonstrated that a number of sensors, including the ADXL-335, the ADXL-345 sensor, and the MPU-6050 sensor, are capable of accurately measuring vibrations.

There are two studies that have been carried out, the first of which is the calibration of the ADXL-335. This is accomplished by comparing the signals received from the ADXL-335 to those obtained from a standard accelerometer by means of a vibration exciter. In the second experiment, a comparison is done between the readings obtained from MEMS accelerometers and those obtained from a sensor that has a better degree of precision in a three-degrees-of-freedom shear construction that was triggered by an imbalanced DC motor. As a consequence of this, the ADXL-335 accelerometer can be utilized as a vibration sensor with a level of precision that is satisfactory in low-frequency applications. According to the findings of this experiment, the sensitivity of the ADXL-335 decreases as the frequency of excitation rises, which leads to an increase in the associated error with the amplitude measurements. These findings were acquired by doing the experiment. However, the inaccuracy that was provided by the measurements was minimal when dealing with low frequencies. This demonstrates that the ADXL-335 is an instrument that should be utilized for measuring amplitudes in circumstances that involve low frequencies. The signals that were measured with the MEMS sensors gave positive results in the time domain by displaying a low level of noise. Because the measurements of the natural frequencies of the structure given by the MEMS accelerometers were very close to the one given by the DeltaTron and the analytical value, the results also showed that the sensors can be used in modal analysis with a certain degree of precision in the frequency domain. This was demonstrated by the fact that the measurements of the natural frequencies of the structure given by the MEMS accelerometers. In addition, the wavelet coherence demonstrated that the MEMS sensors are capable of measuring a frequency range that is approximately between 5 and 45 Hz. This demonstrates that these sensors are suitable for usage in low-frequency applications. (Varanis et al., 2018).

Following that, an investigation was carried out to measure the mechanical vibrations by utilising software such as Arduino, MATLAB, and EPICS, as well as hardware such as Arduino, an accelerometer, and a serial adapter. The operating vacuum pump is selected so that the system can be tested on an unidentified input source. They take readings of the frequencies that are sent from the pump to the floor. The accelerometer is positioned near the pump, and another is placed on the floor in the immediate area. Both the frequency domain of the waveforms and the transfer function are created at this step. As a consequence of this, all frequencies with a value lower than one are affected, whilst the frequencies with a value more than one are amplified. This demonstrates that it is possible to carry out a trustworthy data capture and analysis utilising hardware and software that is not only inexpensive but also readily available (Hjort & Holmberg, 2015).

This study describes the development of a low-cost accelerometer-based system for monitoring the structural health of bridges. Find the bridge's natural frequency using a low-cost accelerometer to determine the bridge's health (MPU6050). In order to obtain gravitational values, a controller (Arduino UNO) is used to analyse raw accelerometer data (Saurav Tiwari, et al, 2022).

This study discusses vibration-based electric fault diagnostics. Detecting and diagnosing incipient defects improves product quality and operational efficiency of electrical equipment running off the mains. This study focuses on transformers, dc, three-phase, and single-phase induction motors. For diagnosis, piezoelectric accelerometer vibration data are evaluated. This equipment's frame has an accelerometer. Signals are FFT'd. Healthy and faulty electrical equipment have different vibration spectrums. High-frequency vibration spectrum analysis detects equipment flaws. Most vibration sensors are piezoelectric. This sort of sensor's electric charge output is proportional to force. We see an increase in the damaged transformer's vibration amplitude. Experimental findings have proven the technique of analysing electrical equipment quality using FFT of transformer, dc motor, and induction motor vibration. (Lorgulescu et al., 2010).

The proposed approach detects electrical and mechanical induction motor problems. MEMS accelerometers detect mechanical defects. Machine vibration from voltage harmonics justifies the adjustment. This helps discover induction motor electrical faults. MEMS accelerometer-measured vibration. Induction motor MEMS accelerometer. Sensor and controller communicated. The vibration data obtained in terms of acceleration in all 3-axes is then recorded in a micro SD card and retrieved using a card reader. Insert the card into the computer's USB. PSCAD can create electrical problems and plot the FFT spectrum. MEMS Accelerometers provide a low-cost vibration detecting solution. Vibration analysis found mechanical and electrical induction motor issues. Misalignment and slack installation cause additional amplitude and frequency modulations (Raj et al., 2013).

MEMS Accelerometer-based vibration analysis has many advantages over traditional methods. MEMS Accelerometers are non-contact, hazard-free, low-cost, dependable, compact, lightweight, and low-power (Maruthi & Panduranga Vittal, 2022).

2.4 Data transferring from Arduino

2.4.1 PLX DAQ

PLX-DAQ is an add-on tool for Microsoft Excel that allows for the gathering of data from Parallax microcontrollers. Any one of our microcontrollers that is connected to a sensor and the serial port of a personal computer is now able to transfer data directly into Excel. Add-in for Microsoft Excel (PLX-DAQ) programme can acquire up to 26 channels of data from any Parallax micro controllers and drop the values in columns as they arrive. Field data can be easily analysed with spreadsheets, sensors can be analysed in the lab, and equipment can be monitored in real-time (Patrick, 2018).

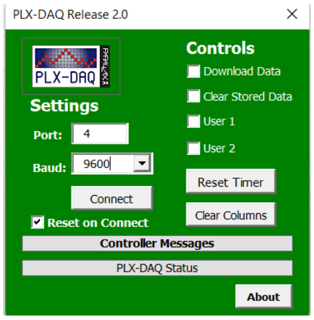


Figure 2.8: PLX-DAQ Dialog box

Arduino IDE and PLX-DAQ programming tools are the two software platforms that were utilized in the process of developing a wireless monitoring system for batteries. Arduino IDE is used to write the code, and then the code is uploaded to an Arduino board. The parallax data acquisition is an additional software tool that is available for use in Microsoft Excel. The data collecting software package provided by parallax includes a function that allows for the analysis of data gathered from sensors using spreadsheeting.

Data from the port can be received in the laptop once the Bluetooth has been initialised. The data that was received is processed by the parallax tool, and then it is recorded in the Excel sheet (Sreenivas Rao & Shivakumar, 2019). The current and voltage measuring sensors that are included in the solar panel performance monitoring system are those that have been incorporated into an Excel Spreadsheet by way of the PLX-DAQ application programme. These sensors are designed to be a part of the system. (Murfianah et al., 2021).

2.5 Data analysis

2.5.1 Fast Fourier Transform (FFT) In Excel

The Fourier transform transforms time domain functions into frequency domain representations and is defined as

$$X(f) = \boldsymbol{F}\{x(t)\} = \int_{-\infty}^{\infty} x(t)\, e^{-j2\pi ft}\, dt \tag{1}$$

x(t) is the time domain signal, and
X(f) is its Fourier Transform.

To graphically display the results of the FFT, wire the output arrays to the Waveform Graph, as shown below. Remember that FFT output is complex and, consequently, two graphs are necessary to display all the information (K. Fahy, 2014).

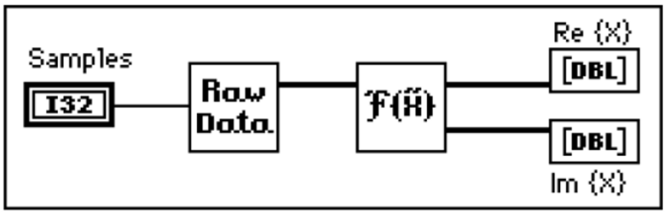
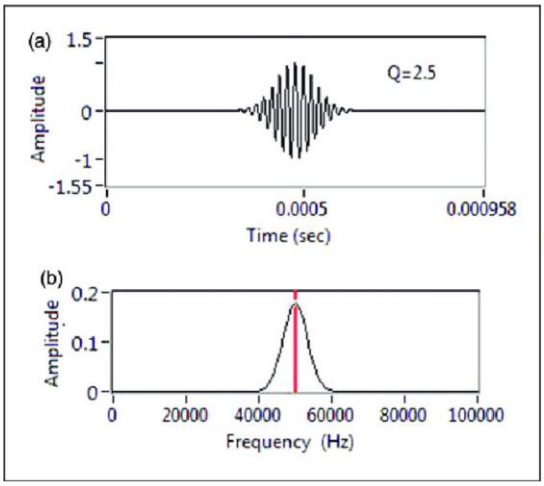


Figure 2.9: Block diagram to display the standard output

Time domain signal processing separates unwanted signals from the target signal, identifies tainted signals. Using a frequency domain simplifies system analysis technically. The example of time domain and frequency domain display in Figure 2.10.



Signal of Q ¼ 2:5: (a) Time domain signal and (b) frequency domain signal.

Figure 2.10: The example of time domain to frequency domain

A time-domain graph shows how a signal changes over time, but a frequency-domain graph shows how much of the signal exists inside a certain frequency band throughout a range of frequencies. The Excel data analysis package includes a Fourier analysis procedure that computes the complex coefficients, from time series data. The amount of samples in the time series data must be a power of two (2^n). The steps to perform the Fast Fourier Transform (FFT) is shown below:

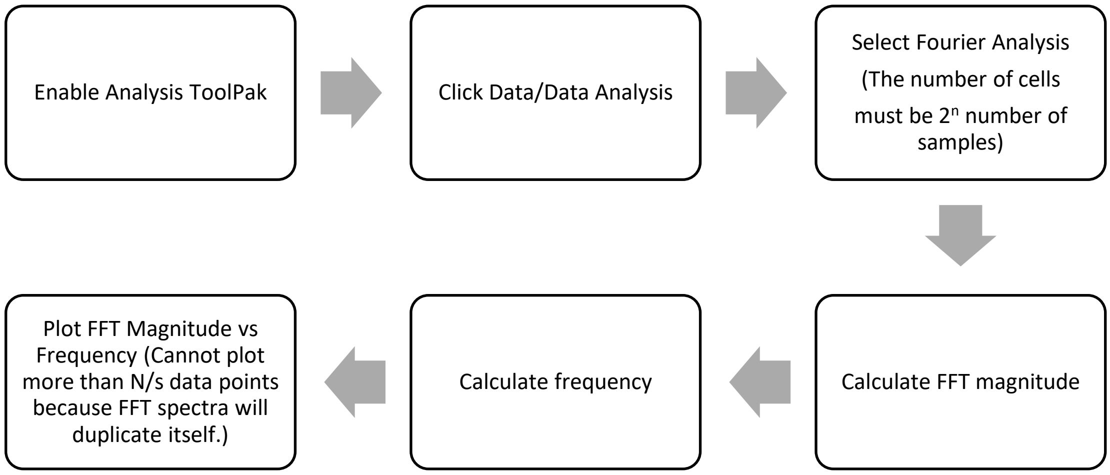


Figure 2.11: Steps to perform FFT in Excel

2.5.2 Fast Fourier Transform in LabView

A look at LabVIEW's findings Fourier and spectrum analysis can be performed with the VI library's comprehensive set of tools. All DSP outputs, including the Fast Fourier Transform and Power Spectrum VIs, are in the standard DSP format. Digital filtering applied mechanics and acoustics, medical imaging, mode analysis and numerical analysis, seismography and instrumentation are only few of the domains where the FFT can be used.

The LabVIEW analysis VIs, which can be found on the Signal Processing palette, increase the speed of FFT-related applications. The FFT results of real-valued input sequences can be displayed in three common formats: standard, double-sided, and single-sided (K. Fahy,2014). This study used the Arduino then the Arduino serial data is saved in Excel by a monitoring system. LabVIEW reads the spreadsheet file. LabVIEW's FFT uses graphical programming. An accelerometer's time domain G-Values are FFT'd to provide frequency domain output. FFT gives amplitudes and frequencies. LabVIEW graphs amplitudes and frequencies. Amplitudes depend on frequency. Top frequency peak is most essential. Internet of Things allows remote access to G-Values (IoT). IOT additionally stores G-Values and Natural Frequency. Node MCU communication used MCU and MQTT protocols (Saurav Tiwari, et al, 2022).

2.6 Summary of literature review

Based on the literature review, there is no fully automated machine which has been created. Hence, this project focus to improve the existing machine by programmed a code to make the machine fully automatic but have the sufficient vibration to remove all of the biscuits during dipping phase hence the quality of works can be improved. The machine will be programmed using the Arduino then to measure the vibration of the machine, a system that can measure the vibration need to be set up. There are several sensors that can be used but need to decide which one to use depends on its functionality and other parameters. The data that got from the sensor need to be converted into the Gravitational value because the raw data is acceleration in terms of m/s^2 . Then the G-value will be minus with the offset to get the actual data. The Arduino is connected to a chosen sensor and the serial port of a personal computer is now able to transfer data directly into Excel by using the PLX-DAQ software. Then, the data need to be analysed by perform the Fast Fourier Transform (FFT) in Excel to get its frequency and amplitude. Commonly, the LabView software will be used to perform the FFT but in this research, I have decided to perform the FFT in Excel. The data from the sensor need to be compared with the manual data from the factory.

CHAPTER 3

METHODOLOGY

This chapter will discuss all of the potential devices, components, and control methods that can be utilized in the research and will clearly state where methods of comparisons will also be shown accordingly. This is the flowchart for the methodology of this research:

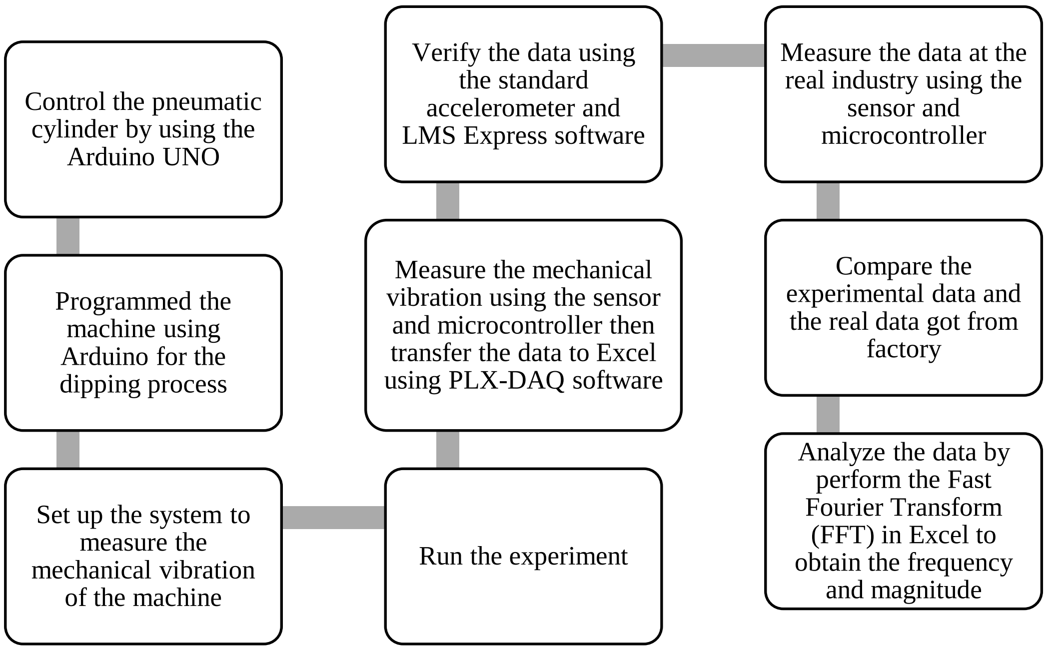


Figure 3.1: Flowchart of the research's methdology

3.1 The control of pneumatic cylinder by using the Arduino UNO

Figure 3.2 shows the final look of the machine. The sliding mechanism are created by attaching a unique part with sliding rollers to the machine's U-rail tracks. The machine also has two degrees of freedom, a control panel, and an indicator system. Two linear actuators will power the machine's motion system. Two solid bars will be fitted to the rectangular block as dampers to reduce vibration during the shaking phase.

The indication system placed here uses three various colours of light-emitting diodes (LED) to indicate the machine's status to users. The control panel will be responsible for manipulating machine status based on the platform's coding. This machine is designed with two positions which are position 1 and position 2 (in the middle of the machine) as labels in Figure 3.2.

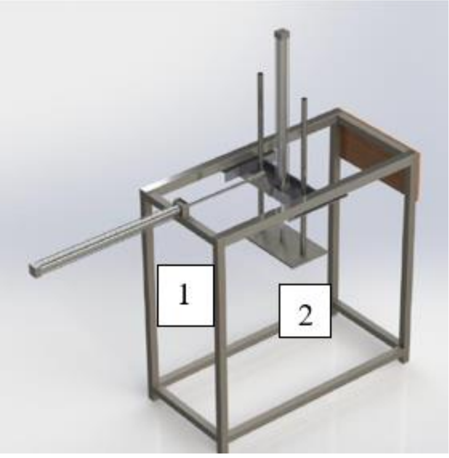


Figure 3.2: The final look of the machine

The improvement is attaching the mould frame to the machine. The bolt and nut are used to attach the 8kg mould frame under the metal plate of the machine. The mould needs to be attached before measuring the value the of machine’s vibration in terms of acceleration because mass of the mould will affect the acceleration value.

Figure 3.3: Mould frame

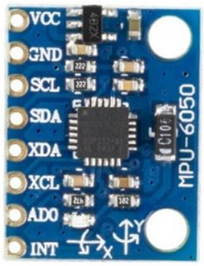
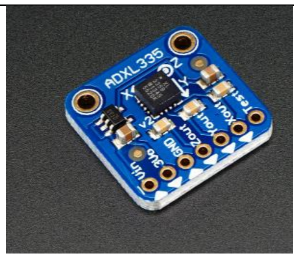
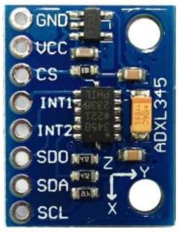
This is because the Newton's second law of motion describes the behavior of objects for whom all of the current forces are not balanced. This law applies to situations in which all of the forces are not equal. According to the second law of motion, the rate of acceleration of an object is determined by two different factors: the total force that is acting upon the object and the mass of the object itself. An object's acceleration is determined in a manner that is directly proportional to the total force that is acting upon the object while also being inversely proportional to the item's mass. When there is a greater amount of force exerted upon an item, that object will experience a greater amount of acceleration. When an object's mass is increased, the object's acceleration will decrease because of the increased mass. The formula is shown below:

Acceleration, $a = \frac{F}{m}$ F: Force (2)
m: mass
a: acceleration

3.2 Acceleration measurement systems

There are three types of accelerometers which are capacitive MEMS accelerometer, piezoelectric accelerometer, and piezo resistance accelerometer. Accelerometers that use capacitance changes in a seismic mass under acceleration are known as capacitive MEMS accelerometers. Capacitive MEMS accelerometers are frequently available as surface-mount devices (SMDs) that can be attached directly to printed circuit boards due to their low cost and compact size (PCBs). It is ideal to use DC-coupled capacitive MEMS accelerometers, which have a good signal-to-noise ratio but have limited bandwidth for sensing low-frequency vibration, motion, and steady-state acceleration. Capacitive MEMS accelerometers can only measure modest acceleration levels (less than 200g). Capacitive MEMS accelerometers, which are inexpensive and easy to use, have grown increasingly popular (Hanly, 2022). A piezoelectric accelerometer sends an electrical signal when accelerated suddenly. A seismic weight is linked to a piezoelectric accelerometer's detecting crystal. The sensor's weight accelerates the crystal. The piezoelectric crystal translates force into electrical signals that detect acceleration. Piezoelectric accelerometers measure shocks and vibrations accurately. Piezo resistance or Piezoresistive accelerometers change resistance dependent on acceleration. An accelerometer sensor can be used to measure the changes in acceleration. Piezoresistive accelerometers measure low-frequency impacts less accurately than piezoelectric accelerometers. They perform well at large amplitudes for vehicle crash testing and weapon testing. Capacitive sensors change capacitance dependent on acceleration. Two capacitive plates and a diaphragm make them up. As the sensor accelerates, the diaphragm moves, changing the capacitive plates' spacing. This changes the sensor's capacitance, which may be measured and converted to acceleration. However, in this research, the capacitive MEMS accelerometer will be used due to the lower cost and for education purposes only.There are a few types of capacitive MEMS accelerometers. The comparison has been made in Table 3.1.

Table 3.1: Comparison between three accelerometers

Sensor	Alternative 1: MPU6050	Alternative 2: ADXL335	Alternative 3: ADXL345
			
Data output X, Y, and Z-axis	Digital (1024 byte FIFO buffer)	Analogue	Digital
Measurement range	Up to ±16g	±3g	Up to ±16g
Analog to Digital Converter (ADC)	16-bit (internal sensor converter)	8 to 10-bit (microcontroller converter)	16-bit
Sensitivity	Up to 16, 384 LSB/g	3.9 mg/LSB	3.9 mg/LSB
Temperature range	-40 to 85°C with an accuracy of ±1°C.	−40 to +85°C	-40°C ~ 85°C
Sensing axis	6 axis (3 accelerometers, 3 gyrometer)	3 axis	3 axis

3.3 Working principle of the sensors

3.3.1 MPU6050

MPU6050 tracks 6-axis motion using MEMS. On-chip gyroscope, accelerometer, and temperature sensor. Digital MPU6050. This module is tiny, accurate, has high repeatability, high shock tolerance, application-specific performance programmability, and affordable consumer prices. MPU6050 interfaces readily with magnetometers and microcontrollers. The gyroscope measures rotational velocity (rad/s) along the X, Y, and Z axes (roll, pitch, and yaw). This determines an object's orientation. Accelerometers measure velocity change. It detects static and dynamic forces like gravity (9.8m/s2) and vibrations. MPU-6050 measures X, Y, and Z acceleration. In a static object, Z-axis acceleration should equal gravitational force and be zero on X and Y.

3.3.2 ADXL 335

ADXL 335 accelerometer measures object acceleration. It monitors acceleration in three dimensions (X, Y, Z) using analogue inputs. Low-noise, low-power gadget. For acceleration measurement, it's interfaced with a microprocessor like Arduino. It's employed in construction machinery including drilling, driving piles, and demolition, as well as jogging, walking, dancing, and skipping machines. It's in stores and online. Because the ADXL335 accelerometer is an analog model, its operation is based on capacitive sensing as its underlying principle. The capacitance of an accelerometer that uses capacitive sensing will fluctuate as the accelerometer is moved in any direction. The analog voltages of this capacitance shift whenever there is a change, and such shifts are detected by the controller that handles its interface.

3.3.3 ADXL 345

ADXL345 is a 3-axis accelerometer that measures static and dynamic acceleration (due to motion or shock). It can detect free fall or tilt. It's a MEMS accelerometer with a micromachined polysilicon structure on a wafer. Capacitive accelerometer. Polysilicon springs support the proof mass, and differential capacitors record acceleration. Any axis acceleration deflects the proof mass and unbalances the differential capacitor, causing a proportional sensor response. Phase-sensitive demodulation determines the acceleration's magnitude and polarity.

3.4 Comparison between the controlling platforms to measure the acceleration.

There are two choices of the controlling platforms which are NodeMCU and Arduino UNO that can be used to set up the system that able to measure the acceleration. NodeMCU is a microcontroller that has built-in Wi-Fi capability while the Arduino

UNO uses the ATMega328P microcontroller. The other comparison is listed in Table 3.2.

Figure 3.4: NodeMCU versus Arduino UNO

Table 3.2: Comparison between microcontrollers

	Alternative 1: NodeMCU	**Alternative 2: Arduino UNO**
Microcontroller	ESP 8266	ATmega328p
Operating voltage	3.3V	5V
Input voltage	4.5V – 10V	7V – 12V
Digital I/0 Pins	16	14
EEPROM	512 Bytes	1024 Bytes
Length	58mm	69mm
Width	31mm	53mm
WIFI	Yes	No
USB connection	Micro-USB	USB type-B
SRAM	64KB	32KB
Current consumption	15µA – 400mA	45Ma -80mA
Requirement of supportive components	Breadboard Jumper wires (male-female wires)	Breadboard Jumper wires (male-female wires)
Advantages	• Better processor and memory (comes with 80MHz of clock speed and 4MB of flash memory) • Built-in TCP/IP Stack (contains a Wifi connection and can connect through Wifi) • Cheaper • Breadboard friendly and compact (can be easily inserted into	• Extensive support because the Arduino UNO has a very good content online liableble and many people participate in this community • Easy interface with sensors and actuators because it supports both 3.3V and 5V modules • Voltage handling capability (can

	the breadboard and test various designs)	handle the voltage of 20V)
Disadvantages	• Need to learn how to program the new functionalities • Analog pins (has only one Analog pin input) • Lower voltage level	• Memory and Processor limitations • More expensive compared to NodeMCU • Non-breadboard friendly (cannot be inserted into the breadboard)

The alternatives will be placed side by side once again for contrast in terms of the several aspects as revealed:

I. Reliability on functionality

This element will be rated based on the performance of the devices to measure the mechanical vibration by looking into the sensitivity and other criteria.

II. Efficiency

The other rating for the controlling platform will be based on reviewing its working efficiency in terms of its capacity to command the necessary coded sequence in a manner that is both constructive and sustainable while simultaneously processing at a high speed.

III. Feasibility

In this section, the devices and platforms will both be evaluated based on how well they perform and how well they apply to certain situations.

IV. Stock availability

The purpose of this standard is to establish whether or not the products already available on the market are ready for the stock by the technical requirements that are necessary for this study.