THE VIBRATION ANALYSIS OF KUIH LOYANG MOLD FRAME

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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.

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ANALISIS GETARAN DARI KERANGKA ACUAN KUIH LOYANG

ABSTRAK

Kuih Loyang adalah salah satu kuih yang permintaan orang ramai bagi pesta yang ada di Malaysia. Pengeluaran biskut yang perlahan telah menjadi salah satu masalah untuk memenuhi permintaan tersebut. Operator kilang kuih loyang hendaklah bekerja dengan lebih cepat dan berkesan untuk menyelesaikan masalah permintaan orang ramai. Tambahan pula, kerangka acuan yang berat telah memberi kesulitan kepada operator untuk menggoncang biskut untuk jatuh dari acuan. Untuk mengenal pasti gerakan yang sesuai untuk menggoncang semua biskut jatuh dari kerangka, getaran untuk kerangka acuan hendaklah dianalisis. Frekuensi semulajadi dan bentuk mod gerakan getaran harus diketahui. Dengan menggunakan simulasi analisis modal dan syarat sokongan tetap, 10 frekuensi semulajadi dan bentuk mod gerakan getaran dinilai. Linkungan frekuensi semulajadi adalah dari 165.97 Hz hingga 740.06 Hz. Bentuk mod terdiri daripada getaran lentur-torsional dan paksi. Kemudian, dengan ujian modal eksperimen, 10 frekuensi semulajadi dan bentuk mod getaran dinilai dan dibandingkan dengan simulasi. Eksperimen telah menghasilkan nilai amplitud tertinggi, 0.64 g / N pada frekuensi semulajadi, 244.4 Hz. Perbezaan peratusan antara kedua-dua keputusan mengikut amplitud tertinggi bagi bentuk mod nombor 3 ialah 5.07%. Hasil perbandingan untuk analisis dan eksperimen telah menunjukkan persetujuan yang baik dan nilai tersebut disahkan.

THE VIBRATION ANALYSIS OF KUIH LOYANG MOLD FRAME

ABSTRACT

Kuih Loyang is one of demand biscuits for most festival in Malaysia. The slow production of the biscuits has become as problem to meet the demand. The operator needs to work fast and effective to solve the problem of demand production. In addition, the heavy mold frame give some difficulty to operator to shake the biscuits fall off from the mold. In order to identify suitable motion to shake all the biscuits fall off from frame, the vibration motion of the mold frame was analyzed. The natural frequency and mode shape of the vibration motion should be known. By using modal analysis simulation and fixed support boundary conditions, the first 10 inherent natural frequencies and mode shapes of the vibration motion are evaluated. The natural frequencies are ranging from 165.97 Hz to 740.06 Hz. The mode shapes consists of lateral-torsional and axial bending vibration. Then, by experiment modal testing, the first 10 inheret natural frequencies and mode shapes of vibration motion are evaluated and compared with simulation.The experiment produced the highest amplitude, 0.64 g/N at natural frequency, 244.4 Hz. The percentage differences between both result according to highest amplitude for mode shapes number 3 is 5.07%. The comparing result for both analysis and testing shows a good agreement and its verified.

CHAPTER 1

INTRODUCTION

1.1 Overview

Part of the traditional food industry, the kuih Loyang industry is one of demand biscuits for most festival in Malaysia. Kuih Loyang is also known as kuih ros, kuih bunga durian, kuih cap, and kuih goyang. It is one type of Malay traditional biscuit which made of rice flour and egg mixture and fried in cooking oil. The biscuit that considered to be compatible with various ages has its own taste and appearance. This sweet fried biscuit is shaped like a rose complete with holes to represent layers of petals. Figure 1.1 shows a picture of Kuih Loyang which is ready to be eaten. This biscuit traditionally come originating from India, especially South India (Tamil Nadu and Kerala), where cookies known as 'Achu murukku' or 'Achappam', it was also sweet.

Figure 1.1 Ready-made Kuih Loyang

Generally, the whole process can be divided into few sections which are dipping process in the mixture and also in the frying oil and then finally put into biscuit container. In current technology, the mold is manually controlled by skillful operator. The operator use a metal bar to dipped the mold into cake mixture and transfer the mold to frying container for frying. The entire process is only depending on the operator. The operator able to create a unique motion of mold after the frying process that cause the cake to fall off from the mold rather than stick to the mold. Figure 1.2 shows a picture of the operator handling the mold during the production of the biscuit.

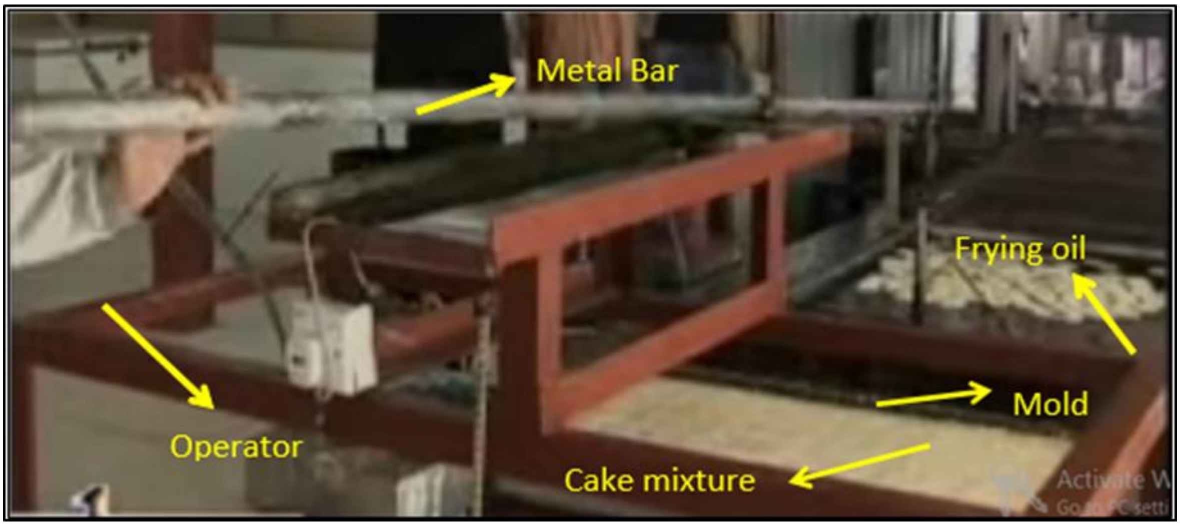

Figure 1.2 Operator handling the mold to produce Kuih Loyang.

The production of this cake is very slow as it has to be dipped and fried batch by batch. The company has to prepare the stock months earlier in order to fulfil the demand. There are some disadvantages if the stocks prepared so early. Sometimes, the Kuih Loyang might loses its tastiness and crunchy. As a solution for the slow production, a semi-automatic machine for dipping process of the biscuit is designed. Unfortunately, the designed machine does not work as effective as the traditional method. However, the vibration motion of the designed machine produced is not the same as the vibration motion produced when the mold handled by the operator.

1.2 Research background

The unique motion that produced by the mold handled by the operator is a kind of vibration motion. There are three types of vibration motion such as free vibration, forced vibration and damped vibration. Therefore, the vibration that might occurred to the kuih loyang frame is free vibration because the operator of the machine needed a little amount of vibration to fall off the biscuits into frying pan without any disturbances. Then, vibration analysis is important to identify its vibration motion because its use the units of displacement, velocity and acceleration as time waveform (TWF), and spectrum. There are different approaches that can be made to analyze vibration motion such as numerical, experiment and simulation [1]. Numerically, the vibration motion is analyzed by calculating parameters using equations or formulas. While experimentally, the analysis process is done by testing the subject normally, in situ testing is done on the site of the experiment. And for simulation, suitable software is used to analyze the vibration motion of sample.

The experiment of the vibration motion can be done by modal testing is the form of vibration testing of an object whereby the natural (modal) frequencies, modal masses, modal damping ratios and mode shapes of the object under test are determined [14] .E. Alexandr and I. Alexandr [2] said that FEA method is widely used to solve problems that involve an estimation of natural frequencies of all elements of turbines. ANYSY software is one of the software that suitable to use to analyze the vibration motion of the sample. ANSYS software has high potential in analysis varies in structural, thermal, magnetic and vibration analysis [3]. While SOLIDWORK software can provides good solid modelling. Solid model is prepared by using SOLIDWORK software before transferred to ANSYS software for analysis. By analyzing the natural frequencies and mode shapes of the motion, the data will be compared with experiment data to identify the vibration motion of the frame.

1.3 Problem Statement

The main problem of kuih loyang mold frame is during the machine performance, the frame provides heavy loads as it makes it difficult for operator shake it properly to fall off all the biscuits and it can damage the form of biscuits. Its need appopriate vibration technic to get all biscuit to fall off from it mold frame.

1.4 Objectives

To analyze the vibration of the kuih loyang mold frame that exist from loyang machine to shake the biscuits fall off from the mold.

1.5 Scope of Research

The method that used by operator to fall off the biscuits is by shaking the mold. In order to analyze the motion, observation must be made on the whole process of making kuih loyang. Identify the steps included in the whole process, type of movement and equipment used to produce the biscuits. The company required that all the biscuits should be able to fall off from the mold perfectly without any damaging to its. The whole motion during the production by using the kuih loyang machine is observed and studied.

The important parameters such as the weight and the material type of their mold is determined for future improvement for the machine. The measurement of the mold frame is taken for simulation. Natural frequencies and mode shapes are important parameters that should be simulated to analyze the vibration motion. Simulation is done by using ANSYS software but the solid modelling for the whole frame is done by using SOLIDWORK software. The simulation was analyzed and compared with experiment data.

The experiment was done by using modal testing analysis to get its mode shapes and natural frequencies. Modal testing is done by using impact hammer testing because it has an ideal impact to a structure that can cause a constant amplitude in frequency domain. The experiment is set up and the frame get an impact few times from the hammer and the accelerometer get its vibration motion. The collected experiment data is analyzed and compared with the simulation data. The both data is analyze together to achieve the vibration motion and natural frequencies that provide by kuih loyang frame.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter will discuss on the methods that exist to analyze a vibration motion that include in experimental, numerical and simulation analysis. The vibration motion produced during the whole process will be elaborated more in this chapter.

2.2 Vibration motion

Vibration is a mechanical phenomenon of oscillation that occur about a point. There are 2 types of vibration which are free and forced vibration. Free vibration is when the object is put in a rest condition and allowed to move without any restraint. While forced vibration is when the system is added with external force while moving which lead to resonance. Resonance is a phenomenon in which the external force frequencies approach the natural frequencies of the system. Resonance can cause the natural frequencies of the system to excite higher, lower or destroyed. Resonance can cause a poor working condition and gave impact on the strength and stability of a system [4]. Vibration can give a desirable and non-desirable effect on the system. Usually, the direct cause of damaged of a mechanical structure is from vibration [5].

Commonly, vibration has 2 measureable quantities which are amplitude and frequency. Amplitude of a vibration represent the strength of the vibration in term of displacement. Frequency of a vibration represent the speed of the oscillation from the stationary point. The number of cycles that vibrating object completes in one second is called frequency. There are many wave forms of displayed that used as an illustration for easier understanding of vibration. The most common used is in time domain and frequency domain. Figure 2.1 shows the comparison of a time domain and frequency domain. Time domain graph consist of the amplitude of the vibration in Y-axis versus the time in second in X-axis. While frequency domain consists of the amplitude of the vibration in Y-axis versus the frequency in X-axis.

Natural frequencies and mode shapes are important parameters that should be known in order to study the vibration motion and avoid failure [3]. Each natural frequencies is associated with specific mode shapes. Mode shape is a unique pattern of motion in which part vibrating with fixed natural frequency.

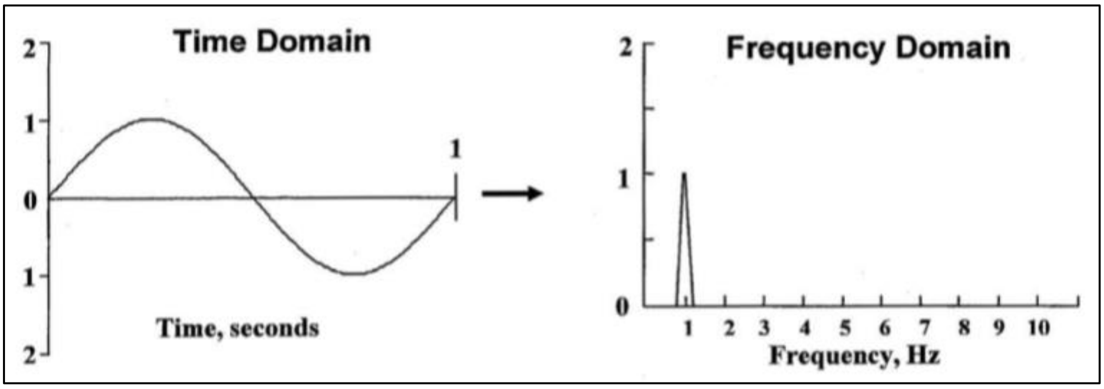

Figure 2.1 Example of a time domain graph and frequency domain graph

2.3 Numerical analysis of vibration

There are 3 different approaches that can be made to study vibration and one of them is by using numerical approach. Nikkah Bahrami, Khoshbayani Arani and Rasekh Saleh presented a modified wave approach in calculating natural frequencies and mode shapes of a non-uniform beams [1]. They claimed that analytical solution for the vibration with variable cross-sections are complex and in many cases are impossible. By using a modified wave approach, the non-uniform beam is divided into several continuous segments for which there exists an exact analytical solution when each segment has uniform cross-section. The method presented has higher accuracy because it has a benefit of calculating natural frequencies and mode shapes compared to other approximate method which has limited in number of natural frequencies that can be calculated. Therefore, natural frequency also can be calculated by using modal analysis equation due to its own model weight [15].

$$Wn = \sqrt{\frac{k}{m}} = \sqrt{\frac{g}{\delta}}$$

Where, k and m stand for stiffness and mass respectively. Wn is the natural frequency.

In complex structures, non-uniform beams are likely to be used in effort to achieve a better strength and weight distribution and sometimes to satisfy special architectural and functional requirements. A systematic theoretical development of the vibration response of non-uniform beam is presented with a general elastically restrained boundary condition [6]. They discovered the relations between the fundamental solutions of the governing fourth order differential equation with variable coefficients, the characteristic equations for the free vibration and Green function for the forced dynamic response. If the exact closed form fundamental solutions of the system are available, then the natural frequency and forced dynamic response can be shown in exact closed form. But if vice versa, a simple and efficient numerical method can be used to find the approximate fundamental solutions and the dynamic response of the system. The present analysis can also be applied to the vibrational analysis of beam with viscous and hysteretic damping.

Both researcher, E. Alexandr and I. Alexandr presented an approach to solve the problems in calculating natural frequencies and mode shapes of a Francis turbine by using coupled of finite and boundary elements method [2]. Methods of estimation of natural frequencies of all elements are very important in designing a turbine. Numerical approaches are made to determine the natural frequencies and mode shapes of the turbine in 2 conditions which are in air and water. The developed method also used for comparison of numerical and experimental parameters of natural vibration for different types of hydraulic machine which is in this case is Kaplan turbine. The results of calculation and comparison for both Francis and Kaplan turbine showed good agreement with experimental data.

2.4 Experimental analysis of vibration

Another approaches that can be made in analyzing a vibration is by using an experimental analysis. To understand the characteristics of the vibration, a device named accelerometer is used. Accelerometer is a device used to measure the acceleration forces. The collected data is analyzed with a software that performs the fast transform (FFT) analysis. The accelerometer is attached to the observed part, data are collected over time and digitally store as acceleration values in the computer. The analysis of the raw data using the Logger Pro Software is performed to get a set of sine wave frequencies and respective amplitude that create the raw data

[7]. Figure 2.2 shows the time domain data collected for speaker of a single frequency source and Figure 2.3 shows the data transformed into frequency spectrum.

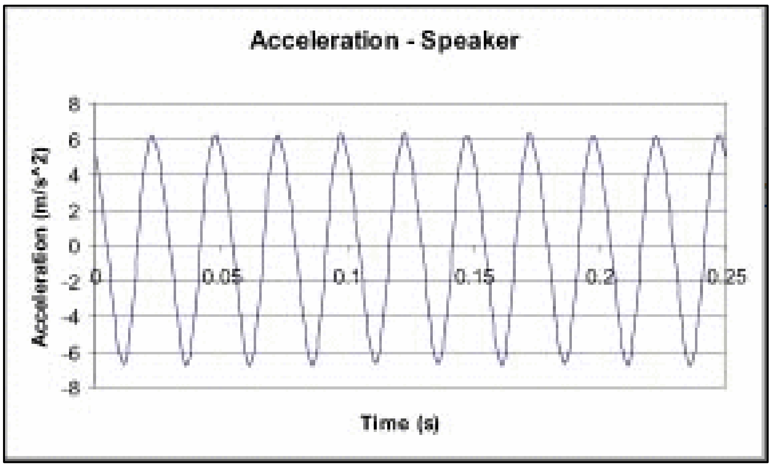

Figure 2.2 Example data for acceleration-time data for speaker of a single frequency source

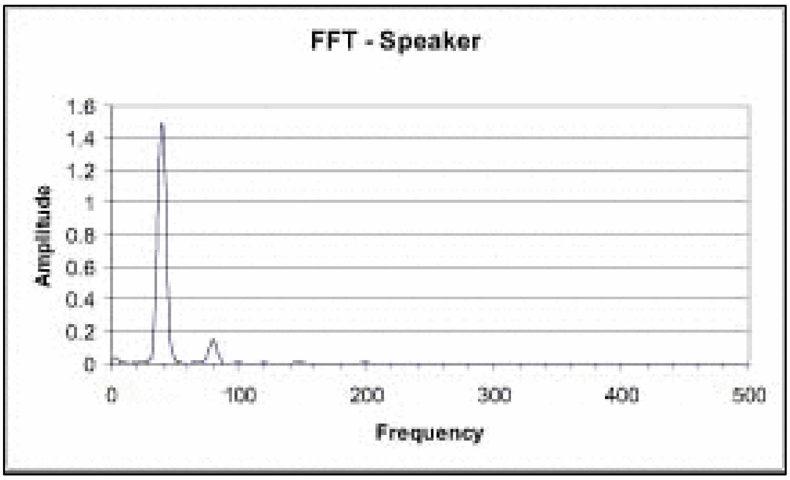

Figure 2.3 Example results of the FFT analysis of the acceleration-time data for speaker of a single frequency source

Accelerometer is widely used in an effort to study vibration and reduce damages of a mechanical structure. Accelerometers are used to do modal testing on the offshore rock lighthouses around the British Isles [8]. Some conventional techniques of forced and ambient vibration testing were used along with some unusual excitation methods. For a big structure like lighthouses, a small hammer is not suitable to produce an excitation forced. Shaker is needed to produce an excitation forced so that the vibration characteristics can be studied. Often, shaker is related with logistic challenges due to the need to deploy heavy shakers that also need mains power or heavy battery capacity.

The main aim is to reduce the logistics complexity of such modal tests, the study is aiming to evaluate the capacity of lightweight portable wireless MEMS accelerometer for synchronous acceleration measurements at multiple locations on a footbridge and of force generated by a human jumping to generate dynamic response [9]. Instead of using a heavy shaker, a wireless inertial measurement units (IMUs) is carefully located on footbridges and successful to recover ground reaction force (GRFs) in open space conditions on full-scale structures. The developed procedure is useful for testing footbridges with modal frequencies in the range of the first and second harmonics of jumping and which likely to suffer from vibration serviceability problems.

In 2017, Brownjohn, Au and Li et al improved the design of vibration field tests and structural health monitoring projects so that they can produce optimally reliable modal parameters data with pre-defined precision and uncertainty [10]. Forced vibration testing provides the best modal parameters estimate but is technically unfeasible for long span and tall structure which have to rely on less reliable modal parameters from ambient vibration tests. The study showed that with good planning, good results of field vibration testing can be obtained even though with a small set of sensors not of the best quality.

2.4.1 Modal Testing of Vibration Motion

Besides that, for the modal testing structure have two types of testing such as impact hammer testing and shaker modal testing (shown in figure 2.4). This method permits the produce experimental value of natural frequencies, modal damping ratios and deflection shapes (including harmonics), for each mode of interest, as function of the vibration level [16]. One of the testing might not be use because of the limited size of structure to analyze. For example, the impact hammer test need small lightweight structures to test, if the size its bigger can occur poor signal to noise ratio. The frequency analysis range that detected is from 0Hz to 1000Hz was evaluated [17].

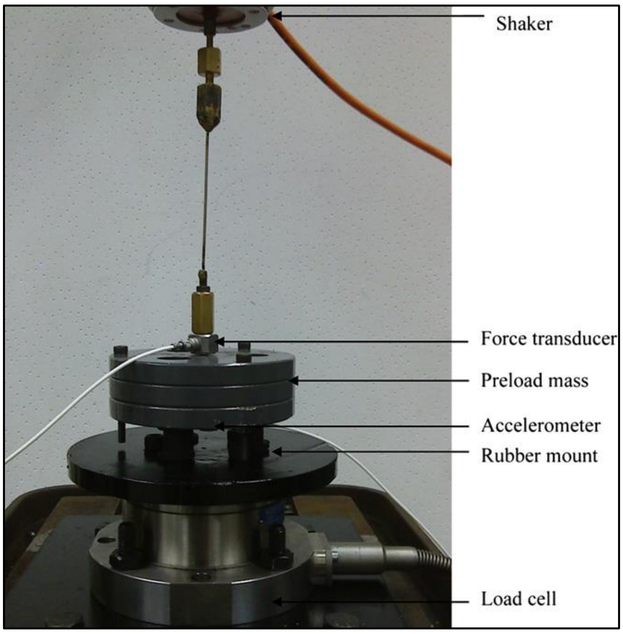

Figure 2.4 Example setup for dynamic stiffness measurement by shaker

2.5 Simulation analysis of vibration

Furthermore, the simulation approach also another way of analyzing vibration and it is the most widely used to solve vibration problems [2]. Kumar, Jaiswal, Pandey and Patil [3] had analyzed a vibration motion of a truck transmission housing by using ANSYS 14.5 software based on Finite Element Analysis (FEA) method. They claimed that noise and vibration are the main reason for transmission housing failure. In order to prevent failure, they required to reduce the level of noise and vibration which also required them to find the natural frequency and natural mode shapes. The transmission housing motion is constrained by fixed-fixed motion supported by boundary conditions which lead them constraining the displacement of bolt holes. The analysis results shows that the transmission housing is subjected to axial bending vibration, torsional vibration and axial bending with torsional vibration.

To differentiate the effect of fixed and unfixed constraint, [11] study the relation between dynamic vibrations of transmission and fixed constraint of vehicle frame. The simulation is done for two conditions and each condition material property and boundary condition was same. One condition is set for zero displacement of all bolt holes and another one condition is set for one bolt loosened or unconstraint condition. Simulation results shows that one bolt unconstraint condition reduce the natural frequency.

Other than constraint, different type of materials also give effect on the vibration of a mechanical structures. Kumar, Jaiswal and Jain et al [12] study the effect of mechanical properties of materials on natural frequency and mode shapes of heavy vehicle gearbox transmission casing. A fixed constrain based boundary condition was used by constraining the connecting bolts hole but different materials which are grey cast iron, structural steel, aluminum alloy and magnesium alloy are taken into discretion. Mechanical properties that are taken into considerations for the modal analysis are elastic modulus, poisons ratio and material density. In the end, they found out that the mechanical properties taken into considerations are directly related with natural frequency and vibration mode shapes.

From all above three research [3,11,12], the step taken in order to study the vibration motion are all the same. The only different is the boundary condition of the simulation. Finite Element Analysis (FEA) methods are widely used in estimating the natural frequencies and mode shapes of the vibration. ANSYS software is used for simulation and a solid modelling software such as SOLIDEDGE is used for modelling. Modal analysis is a technique used to determine, improve and optimize dynamic characteristics of engineering structures [13].

Although, there also the dynamic analysis is carried out by the finite element method simulation thereby predicting failure modes of the vehicle frame under vibration analysis [15]. This work investigates the vibration characteristics of the frame including the natural frequencies and mode shapes. The frame is simulated by ANSyS software to detect the uniaxial element with tension-compression, torsion, and bending capabilities. The results states that vibration of the vehicles frame occurred at different nodal points. Since, the installation of other components and accessories will be mounted, which can increase the mass, the vibration will be reduce. Figure 2.5 and 2.6 shows the simulation of the different mode shape of the vibration by using ANSyS software.

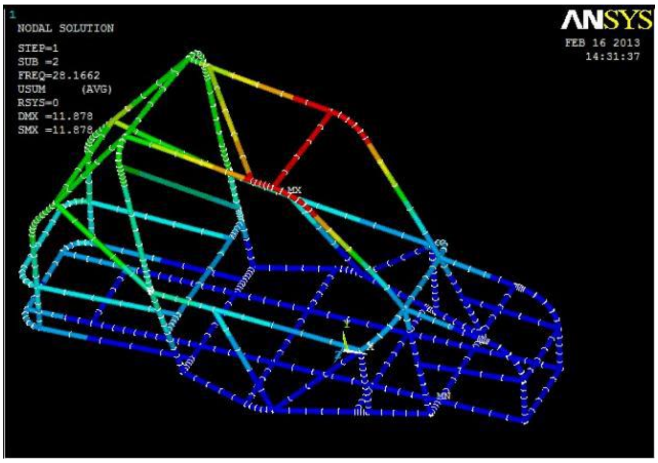

Figure 2.5 Example of second mode shape of vibration using ANSyS software

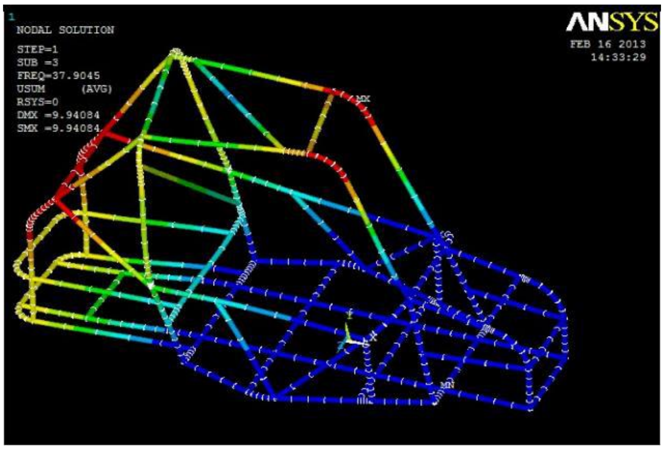

Figure 2.6 Example of third mode shape of vibration using ANSyS software

2.6 Verification of data

When finalize the data, the verification is an important step to ensure the research done is right and the boundary conditions taken into consideration are not wrong. Most of the research are verifying their data by comparing with an experimental data. For an example of numerical analysis, the results of calculations for Francis turbine and Kaplan turbine showed good agreement with the experimental data [2]. For simulation analysis, in [13] modal analysis using experimental approach is planned to be done in order to verify their study [13,15]. Other than comparing with an experimental approach data, comparison with available literature results is also another way in verifying research data. It can be observed in the simulation results with available literature results and the simulation results were verified with the experimental result available in literature [11,12].

2.7 Summary of literature review

Based on the literature review, there are 3 available approaches in analyzing a vibration motion which are numerical, experimental and simulation analysis. Simulation approaches are the one widely used in solving problems involving vibration motion [2,15]. Numerical approaches are hard to be done since many boundary conditions that had to be taken into considerations. While experimental analysis involved logistics challenges in conducting the experiment varying from the tools and location requirement [9]. By using simulation, modal analysis type of simulation based on FEA methods are suitable in analyzing a vibration motion. Natural frequencies and mode shapes are important parameters in order to study the vibration motion [3]. ANSYS software is the most common used software for the simulation and any suitable solid modelling software can be used for solid modelling of the mechanical structures. The collected data must be verified either by comparing with experimental data or any literature results available.

CHAPTER 3

METHODOLOGY

3.1 Overview

The methodology is fully done based on the knowledge gained from the literature study and some research. Generally, the analysis of the vibration motion of honey Kuih Loyang mold frame will be simulate by using ANSYS software. The mechanical properties of the mold frame will be varied to study the effect of mechanical properties on the vibration motion. Besides that, the experiment by using impact hammer modal testing will be set up to find its vibration motion. Figure 3.1 shows the flow process of the whole steps taken for the simulation and experiment of the mold frame to the verification of the data.

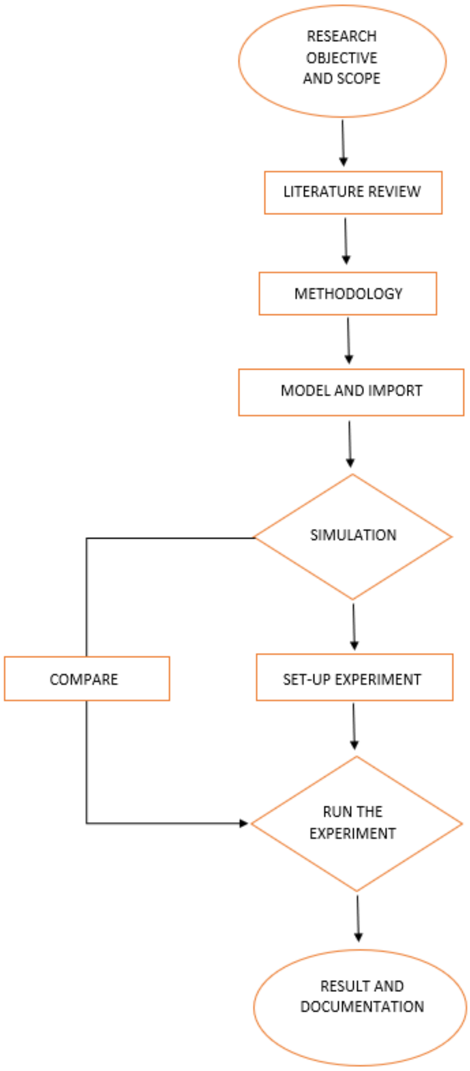

Figure 3.1 Flow process for the whole vibration analysis of the honey Kuih Loyang mold frame

3.2 Building of 3D model

The kuih Loyang mold frame model was constructed by using SOLIDWORKS (2018) software. SOLIDWORKS software have good modelling features so it is selected for solid modelling of the frame. Before modelling the kuih Loyang mold frame through software, the measurements of the whole part of frame is taken. The design model of the mold frame of honey Kuih Loyang is a complex design which consists of the main frame, 100 rose-shaped molds, frame support and holding bar. Firstly, the main frame must be sketch with dimension that be measure earlier and make a 3D model by extrude boss and extrude cut features in SOLIDWORKS. Then, add the holder and rose-shaped mold by sketch the part and extrude on the main frame. To produce 100 rose-shaped molds is use the linear pattern features in SOLIDWORKS on the main frame that being build. Finally, the fixed support will be added to complete the whole kuih Loyang mold frame. The figures below show the establishment steps of the frame model by steps.

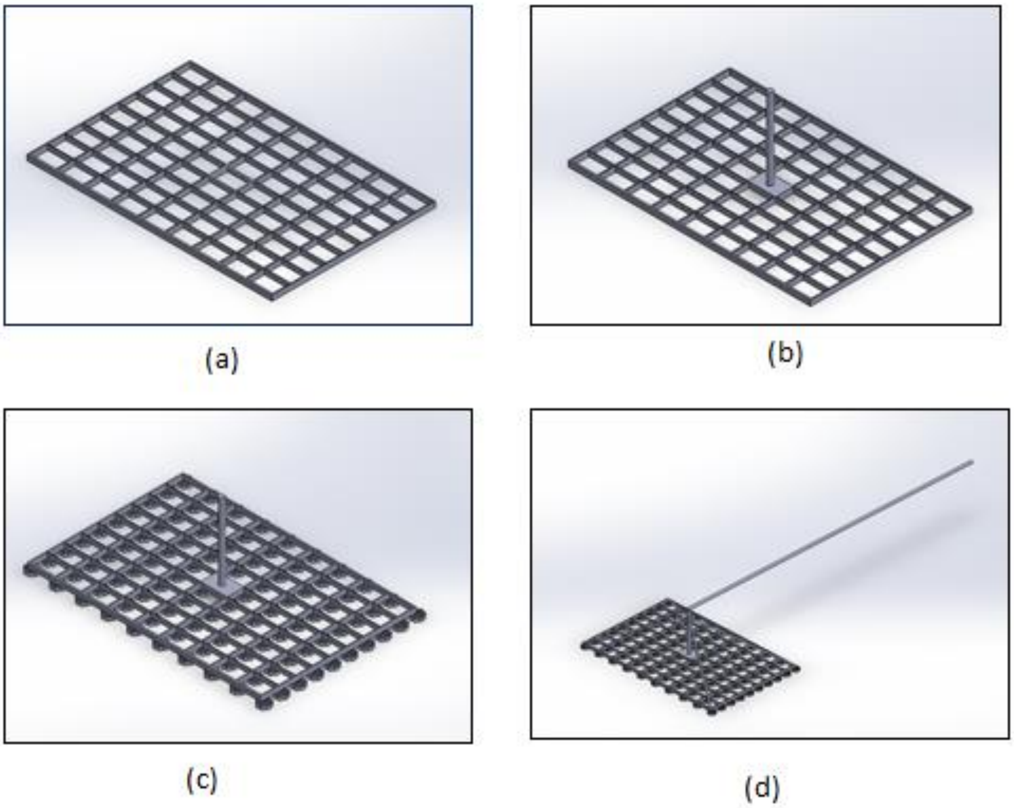

Figure 3.2 Kuih loyang mold frame a) Main frame b) Main frame with holder c) Frame with 100 rose-shaped molds d) Frame without fixed support

The complex model required a lot of time and powerful Random Access Memory (RAM) of computing device during simulation which leads to a limitation for the simulation process to be done. So necessary simplification is inevitable for the model [5]. To make the results less differ from the actual, the simulation needs to do from simple part to complex model to overcome limitations during the simulation. Figure 3.3 shows the complete model of the frame.

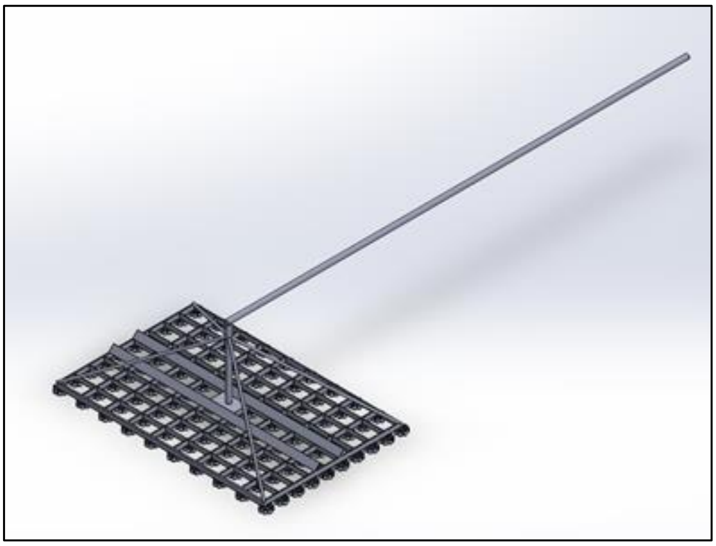

Figure 3.3 Complete Kuih Loyang frame

3.3 Modal analysis of mold frame

For the free vibration analysis, this study used a large commercial finite element software ANSYS to establish the simulation of the model. ANSYS software is a FEA based analysis tool for structures which works on nodes and elements concept. Elements are connected at a point known as node. This process is known as meshing. The fine meshing ensures more accurate results but increases calculation time [11]. Modal type of simulation is chosen for the simulation in order to see the natural frequencies and mode shapes that exist for the free vibration of the mold frame. The solid mold frame model in Initial Graphics Exchange Specification (IGES) file is imported to ANSYS software.

3.3.1 Meshing and fixed support

The complete mesh of the solid model is obtained by using automatic mesh generation with fine size. Figure 3.4 shows the complete mesh of the solid model in ANSYS software which have 325445 nodes and 150489 elements. Modal simulation required to define and apply the boundary conditions. All the support and the holding bar are set as fixed support while the main mold frame and the rose-shaped mold are left for free vibrating. The maximum number of the mode shapes is set to be 10. To simulate the mold frame, fixed support constrain based boundary condition was used. Figure 3.5 shows the fixed support constrain based boundary condition. The blue color shows the fixed support constraint condition.

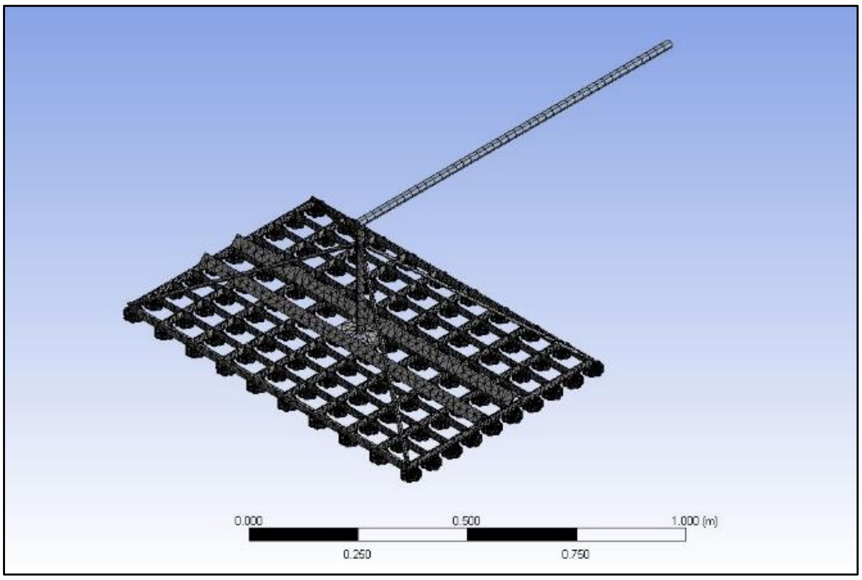

Figure 3.4 The complete meshed of the solid model in ANSYS software

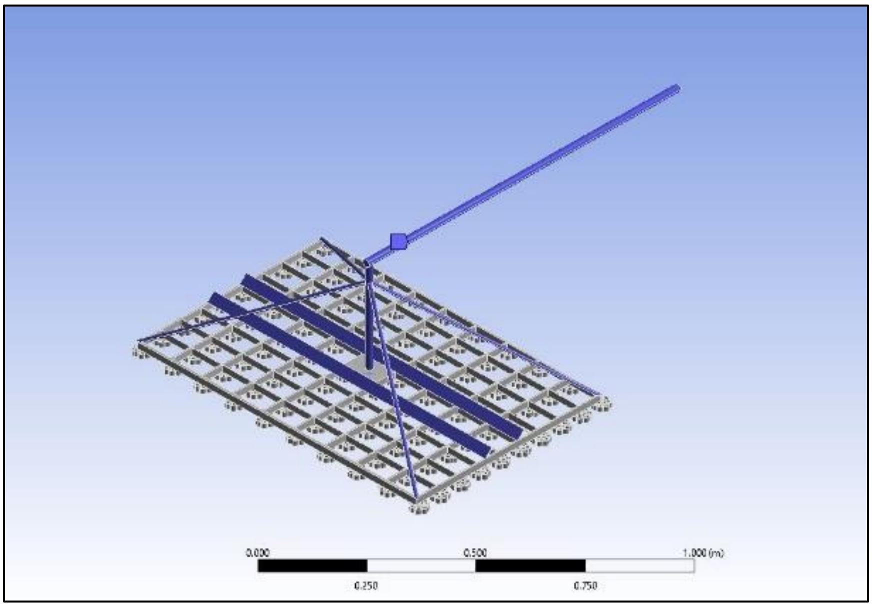

Figure 3.5 Fixed support constraint boundary condition

3.3.2 Mechanical Properties

The materials that chosen for mold frame is structural steel because of it strength and durability to take shaking process for long term use. For the modal analysis, the mechanical properties is important to include because it directly related with natural frequency of the vibration. Mechanical properties of materials used for the modal analysis are elastic modulus, poisons ratio and material density. Table 1 shows the mechanical properties of the materials for structural steel.

Table 1 Mechanical properties of the materials for structural steel

MATERIALS	MECHANICAL PROPERTIES		
	Young's Modulus (Pa)	Poisson's ratio	Density (kgm^-3)
Structural Steel	2.00E+11	0.3	7850

3.4 Modal testing of mold frame

The modal testing is the common method of the characterizing the vibrations of a structure by imparting a known force and measuring the response of the structure. The transfer function (or frequency response function (FRF)) is often curve fitted to estimate the modal parameter from the testing. The chosen of method to do the modal testing is impact hammer modal testing because it can cause uniform amplitude in the frequency domain and it can excite the structure.

3.4.1 Impact Hammer Modal Testing

Impact hammer modal testing can identify the mode shapes and natural frequencies by transferring the impact vibration from accelerometer to the LMS test lab software. The modal testing is set up by preparing all the apparatus needed in the experiment such as accelerometer, impact hammer, dynamic signal analyzer and high-speed cable to transfer all data to be analyze.

3.4.1(a) The apparatus and equipment

The accelerometer needed to be use because its response sensitive enough to detect the ringing of the structure. Dynamic signal analyzer is an instrument that can measures the magnitude and phase input signal frequency that can be useful to the experiment. The needed of the high-speed cable is to transfer all information from accelerometer to the software. The figure 3.6 below show the all equipment and apparatus that being used in the modal testing.

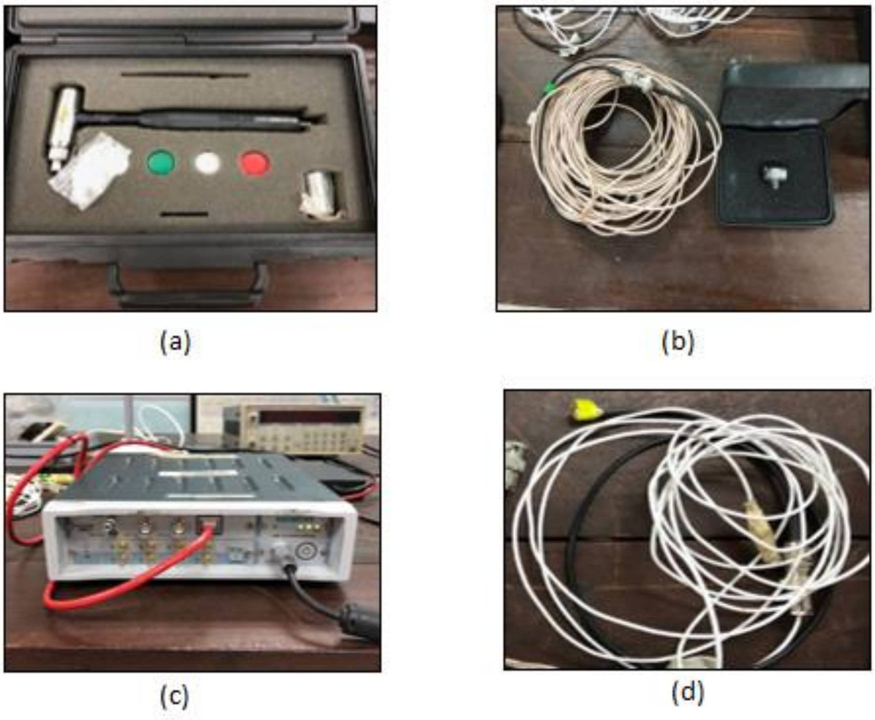

Figure 3.6 Equipment and apparatus a) Impact Hammer b) Accelerometer c) Digital Analyzer Signal d) High-speed cable

3.4.1(b) The procedure of modal testing

The procedure of the impact testing is firstly, the frame will hang up to the stand being tide up with rubber band and make sure the frame not moving or rotating as shown in figure 3.7 (a). Then, the accelerometer is attached to the frame because it will receive the vibration motion during impact hammer giving some force to frame. The output of the impact hammer and accelerometer are used to calculate the frequency response functions (FRFs) across the structure. Then, the selection of impact locations need carefully plan and document it locations. The accelerometer is connected to dynamic signal analyzer and the digital analyzer is connected to laptop for transfer the data. Besides that, this modal testing has to repeat several times to get tally data with simulation data. Then, the frequency response function (FRFs) graph is plotted in the LMS test lab software as it shown in Figure 3.8. The graph will be analyze and compare with simulation data. Figure 3.7 (b) shows the set-up of impact hammer testing to identify the modal analysis. Figure 3.9 shows the detail layout for modal testing system.

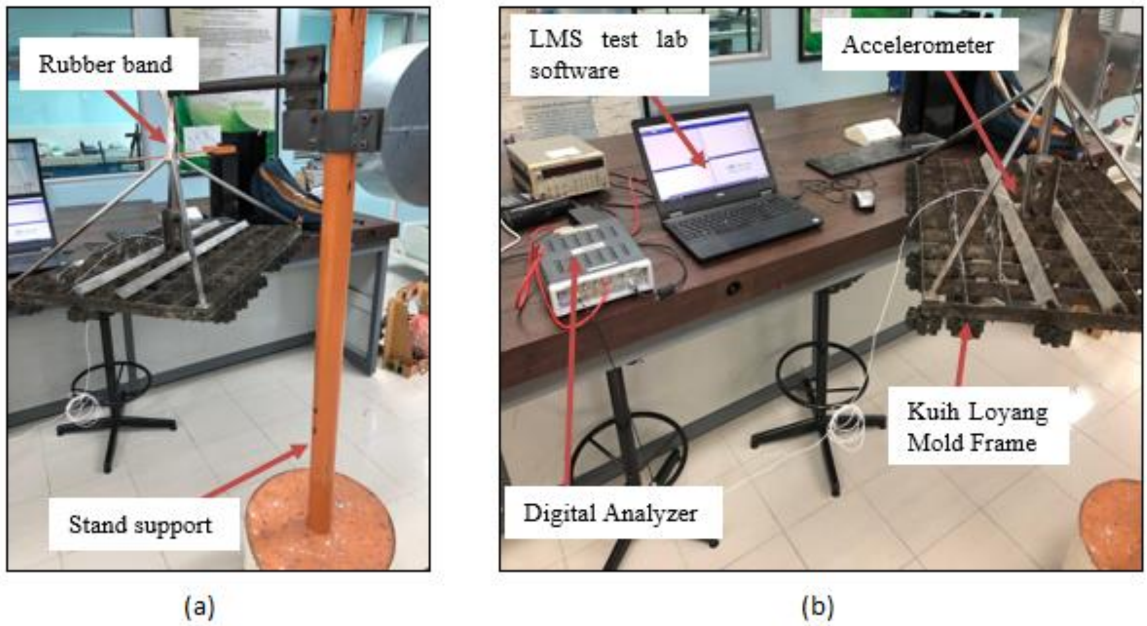

Figure 3.7 Experiment set-up view a) Mold frame with the stand b) Whole set-up experiment

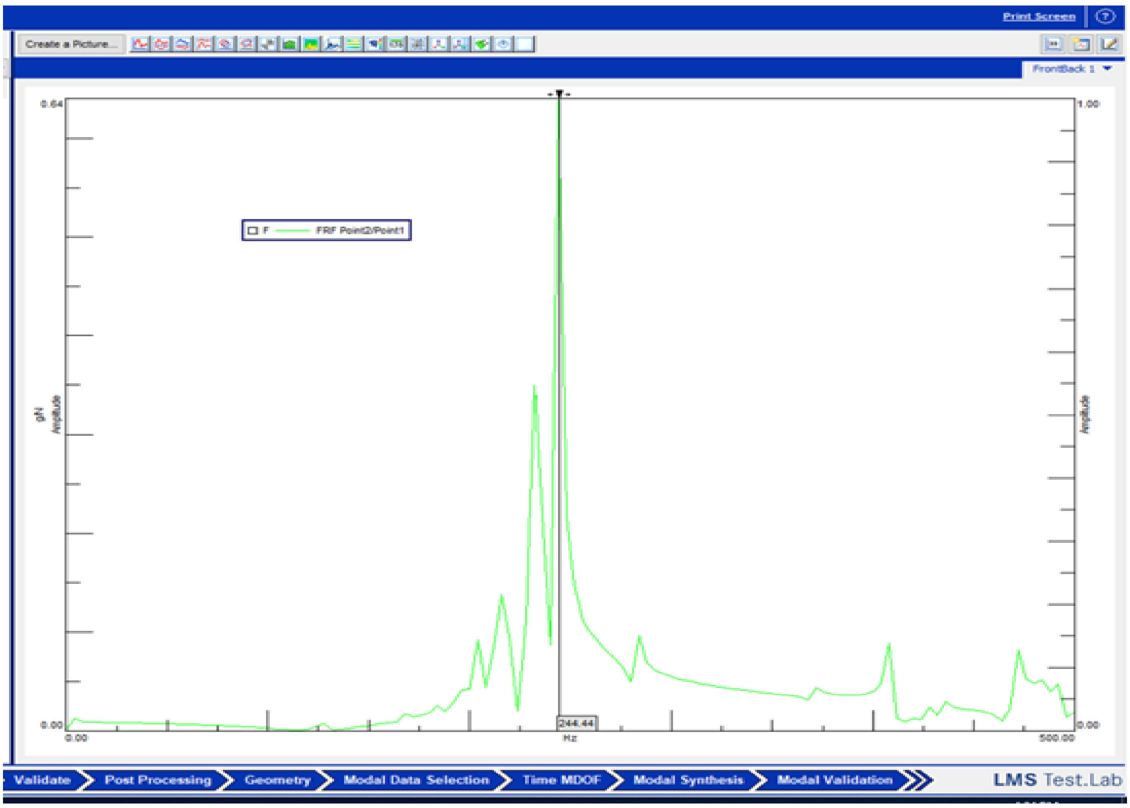

Figure 3.8 The frequency response function graph from LMS software

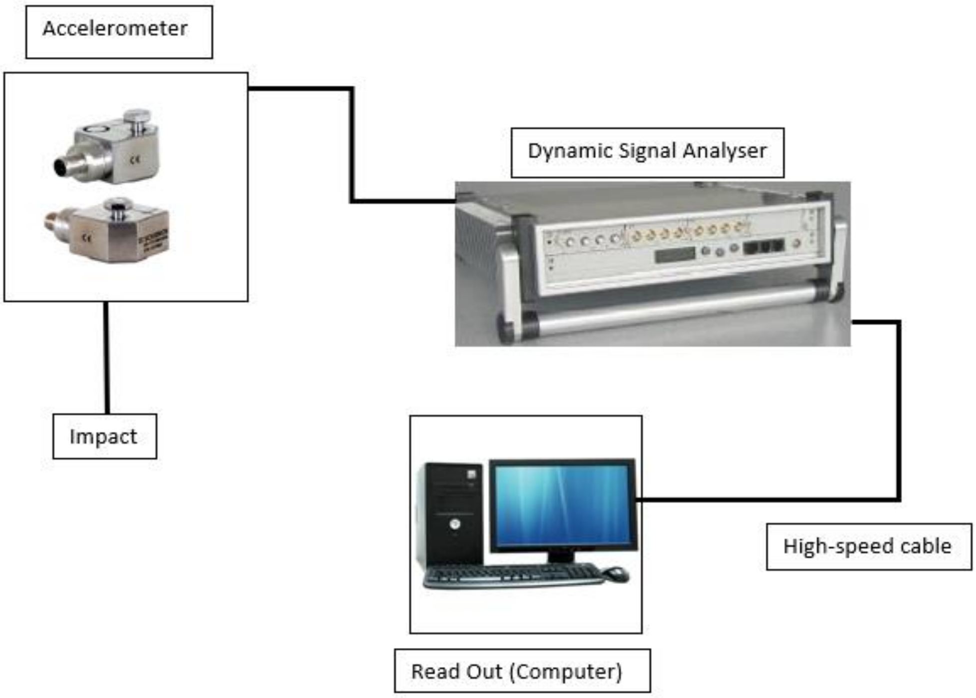

Figure 3. 9 Layout for modal testing system

3.5 Verification of data

This paper concern with the vibration motion of the mold frame. This act of analysis is to verify whether experiment or simulation that obtain the value natural frequency due to its mode shapes in the same pattern or not. Other than that, the act of comparing the natural frequencies collected on simulation and experiment is as an alternative to verify its analysis. The simulation is verified by compare it with available literature results in [12]. The experiment result is important to know which natural frequency need to be achieve by identify its mode shapes.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Simulation of free vibration analysis of structural steel mold frame

In modal analysis the load is applied by the program automatically [11], by applying the suitable boundary conditions. The simulation was done for structural steel material and for fixed support boundary condition. The FEM based software ANSYS provides the first 10 natural frequencies and mode shapes. The results obtained from the simulation were tabulated. Table 2 represents the first 10 natural frequencies and deformation effects for the structural steel mold frame according to their mode shapes. The natural frequencies are ranging from 160Hz to 740Hz. Figure 4.1 shows the pattern of the natural frequencies of the structural steel mold frame against the mode number. The natural frequencies increase as the mode number increase. For mode 9 there is an abrupt increase in frequency value of structural steel mold frame. Figure 4.2 shows the deformation pattern of structural steel mold frame according to their mode number.

Table 2 The natural frequency and deformation effects according to their mode number for structural steel mold frame

MODE	NATURAL FREQUENCY (Hz)	DEFORMATION (m)
1	165.97	0.036836
2	173.74	0.034408
3	256.8	0.033244
4	285.07	0.030849
5	384.84	0.023609
6	439.3	0.031726
7	442.17	0.024799
8	492.38	0.028861
9	671.13	0.026431
10	740.06	0.025023

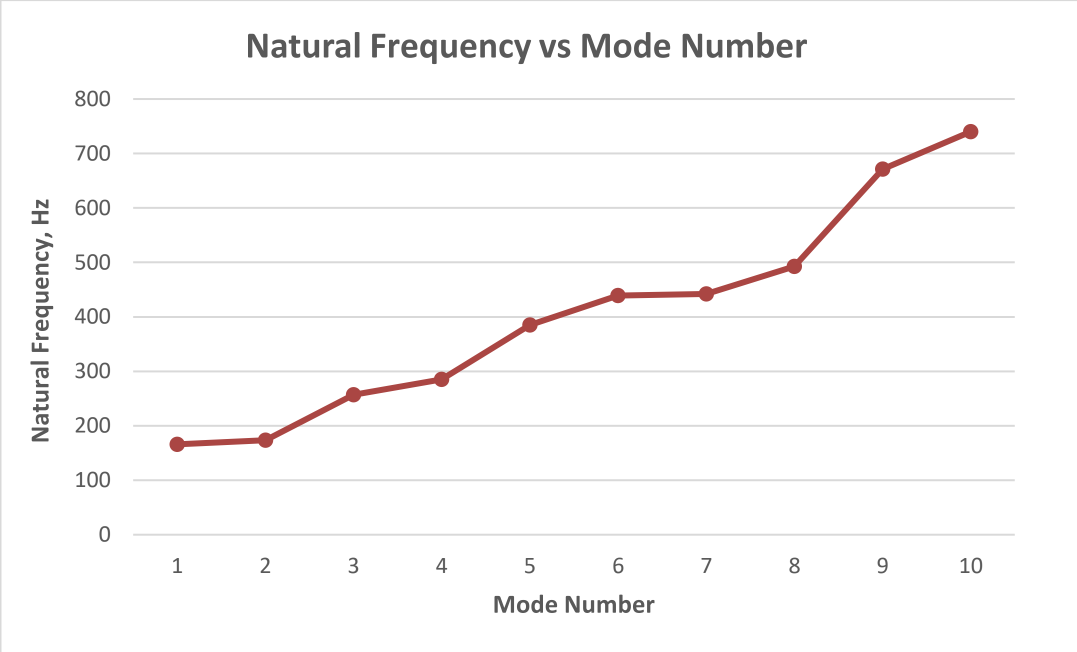

Figure 4.1 The pattern of the natural frequencies of structural steel mold frame corresponding to their mode shapes

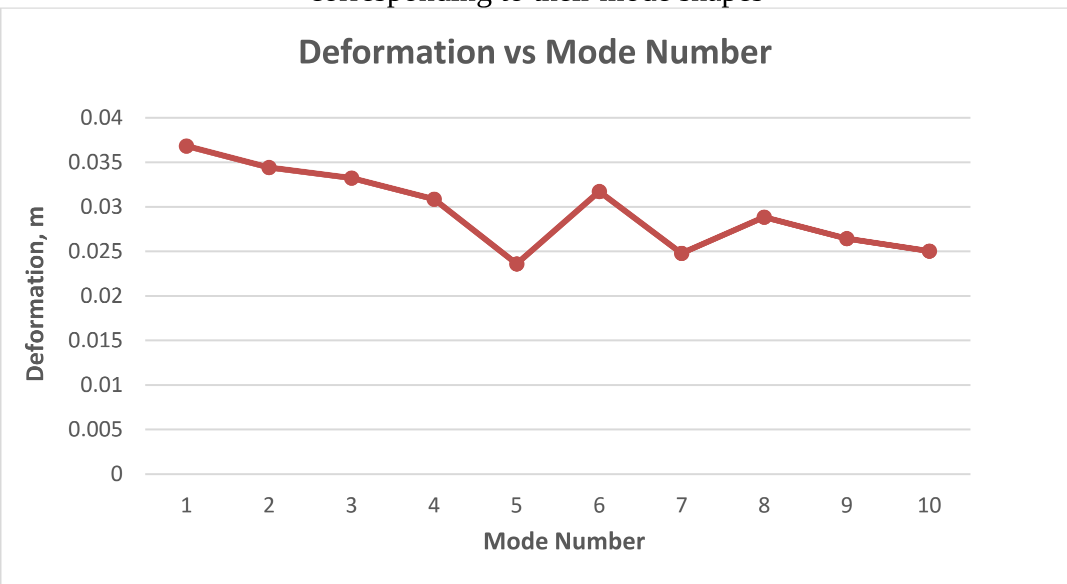

Figure 4.2 The deformation pattern of structural steel mold frame according to its mode number

Every corresponding natural frequency are followed by mode shapes. Mode shapes are unique pattern of movement that represent how the mechanical structures move with specific natural frequencies during vibrating. From the simulation, the deformation effect of the mold frame is decreasing as the natural frequencies increase except for mode 5 and 7. Mode 1 shows the highest deformation effect with 0.036836mm while mode 5 shows the lowest deformation effect with 0.023609mm. From figure 4.3, the mode shapes of the mold frame consist of lateral-torsional and