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MODAL ANALYSIS ON DIFFERENT TYPE OF ALUMINIUM, JOINED BY TIG WELDING

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BORANG PENGESAHAN STATUS TESIS

JUDUL: MODAL ANALYSIS ON DIFFERENT TYPE OF ALUMINIUM JOINED BY TIG WELDING

SESI PENGAJIAN: 2012/2013

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MODAL ANALYSIS ON DIFFERENT TYPE OF ALUMINIUM, JOINED BY TIG WELDING

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Report submitted in partial fulfilment of the requirements
for the award of Bachelor of Mechanical Engineering

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JUNE 2013

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FACULTY OF MECHANICAL ENGINEERING

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Date : 18 JUNE 2013

Dedicated to my father, Mr.Hazwan Abdullah, my beloved mother, Mrs. Whinah Awang, and last but not least to all my fellow friends

ACKNOWLEDGEMENTS

Praise is to Allah S.W.T, the Most Gracious, the Most Merciful for all the blessings and guidance upon me through my study. Thank you so much dear Allah forgiving me strength and answering my prayers.

This thesis would not have been possible without the guidance and the help of Several individuals who in one way or another contributed and extended their valuable assistance in the preparation and completion of this research.

First and foremost, I would like to record my sincere gratitude to my supervisor, Mr. Muhammad Hatifi bin Hj. Mansor for his supervision, advice and guidance from the very early stage of this research as well as giving me extraordinary experiences throughout the work. Above all and the most needed, he provides me unflinching encouragement and support in various ways. I am indebted to him more than she knows. One simply could not wish for a better or friendlier supervisor.

Many thanks go to all FKM laboratory instructor and technicians who are willingly landing their hands in laboratory and experimental work and all these staff of the Mechanical Engineering Department, UMP, who helped me in many ways and made my stay in UMP pleasant and unforgettable. Special thanks from me also go to My friends who are under same supervisor. I would like to acknowledge their comments and suggestions which were crucial for the successful completion of this study.

Where would I be without my family, my parents deserve special mention for their inseparable support and prayers. My father, Hazwan Abdullah, in the first place is the person who put the fundament by learning character, showing me the joy of intellectual pursuit ever since I was a child. My mother, Whinah Awang, is my special one who sincerely raised me with her caring and gentle love. Brothers and sisters, thanks for being supportive and caring siblings.

Finally, I would like to thank everybody who was important to the successful realization of this thesis, as well as expressing my apology that I couldn’t mention personally one by one.

ABSTRACT

Experimental Modal Analysis and Finite Element Analysis will be used to study the dynamic characteristic of a TIG welded joint between aluminium 1100 and aluminium 6061. The structural three-dimensional solid modelling of joining between aluminium 1100 and aluminium 6061 by TIG welding was developed using the SOLIDWORK drawing software. The finite element analysis was then performed in ALGOR software. The finite element model of the components was analyzed using the linear modal analysis approach and the experimental modal analysis was performed by using an Impact Hammer. Finally, an operating deflection shape analysis was carried out to investigate the dominant mode shape under a given operating condition. The natural frequency of the mode shape is determined and comparative study of modal analysis and finite element analysis was done from both method results. The comparison between natural frequencies of finite element modelling and model testing shows the closeness of the results. From the results, the percentage error had been determined. The percentage error is bit high because there are some errors occur during the experimental modal analysis. The experimental modal analysis is conducted with free boundary condition and the effect of damping which effect test rig by using sponge as a base of the plate is a factors as the higher percentage error. The result from the operating deflection shape analysis shows that mode two is the dominant mode shape with an operating frequency of 581 Hz.

ABSTRAK

Analsis modal secara eksperimen dan analisis elemen secara theory digunakan unuk mempelajari sifat dynamic terhadap sambungan kepingan antara aluminium 1100 dan aluminium 6061 oleh kimpalan. Pemodelan struktur tiga-dimensi dilukis menggunakan perisian melukis SOLIDWORK. Analisis elemen modal kemudian dijalankan dengan menggunakan perisian ALGOR 23.1. Analisis di dalam perisian ini menggunakan pendekatan analisis linier modal dan analisis modal secara eksperimen dilakukan dengan menggunakan kaedah kesan ketukan. Akhir sekali analisi bentuk pesongan operasi di jalankan untuk mendapatkan bentuk pesongan utama. Frekuensi dan bentuk mod ditentukan dan kajian perbandingan dilakukan dari kedua-dua keputusan kaedah. Perbandingan antara frekuensi dari pemodelan elemen secara teori dan ujian model secara eksperimen menunjukkan keputusan yang hampir sama. Peratus ralat agak tinggi kerana terdapat beberapa kesilapan berlaku semasa eksperimen. eksperimen dijalankan dengan keadaan tetap bagi sambungan kepingan-kepingan tersebut oleh kimpalan dengan menggunakan span sebagai pelapit kepingan dan memberi kesan redaman berlaku. Ia menyimpulkan bahawa dalam kaedah eksperimen, penggunaan span sebagai pelapit memberi kesan terhadap keputusan. Analisa bentuk pesongan operasi menentukan bahawa bentuk pesongan kedua adalah bentuk utama dengan frekuensi sebanyak 581 Hz.

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LIST OF ABBREVIATIONS

TIG	Tungsten Inert Gas
IMC	Intermetallic Compounds
GTA	Gas Tungsten Arc
NVH	Noide,Vibration And Hardness
FEA	Finite Element Analysis
FEM	Finite Element Method
DOF	Degree Of Freedom
SDOF	Single Degree Of Freedom
MDOF	Multi Degree Of Freedom
FRF	Frequency Response Function
DAS	Data Acquisition System
CAD	Computer Aided Diagram
IGES	Initial Graphics Exchange Specification
FFT	Fast Fourier Transform
ESAB	Elektriska Svetsnings-Aktiebolaget (English: Electric Welding Limited company)
2D	Two Dimensional
3D	Three Dimensional
ASCII	American Standard Code for Information Interchange
SI	International System of Units

CHAPTER 1

INTRODUCTION

1.1 GENERAL

Aluminium can be joined in many different ways and are highly suitable for many manufacturing applications. Aluminium is used for a wide range in automotive industry because it provides desired light-weighting structure. The joining method of aluminum includes the permanent method, which is welding. Fabricators find that an aluminium welded product is quicker and easier to be manufactured compared to steel fabrication and it offers more advantages but their welding characteristics need to be understood and the proper procedures employed. Aluminum and its alloys are routinely welded in the industry by a variety of methods.

Tungsten Inert Gas welding or TIG welding is one of the welding methods used in joining aluminium alloys. TIG welding can be defined as fusion of same or different material together, and the result of the welding is very strong and looks better and attractive too. This aluminium welding joint has its own natural frequency and vibration modes or mode shapes. These dynamic characteristics need to be analysed in order to avoid any damage or failure to the structure. It is an important element for any design to be analysed properly so that the structure can be redesign with better strength and stability.

In this project, student will investigate the dynamic properties of dissimilar aluminium joint by using TIG welding under an excitation force. It is important that the dynamic response of the aluminium joint to be analyse in order to determine the resonance whose characteristic frequency, damping and also mode shapes can be estimated from the analysis. Experimental Modal Analysis and Finite Element Analysis will be used in this research and the result from both analyses will be compared. In this project, the aluminium joint will be design in the Computer Aided Design (CAD) software which is Solidwork and to be analyse in the concept of modal analysis using Algor software. The experimental modal analysis will be done by using a roving impact hammer as the excitation force and the dynamic characteristic will be analyzed in the MEscope's software.

1.2 PROJECT BACKGROUND

Aluminium is now the most widely used metal in many structure. This is because aluminium has unique combination of properties. Among most important properties of aluminium are low weight, high strength, easy machining, excellent corrosion resistance and good thermal and electrical conductivity. The most common way of joining aluminium is by welding. Most alloys of aluminium are easy to be welded once a couple of factors are taken into consideration. Tungsten Inert Gas (TIG) welding is the process that will be used to join the different type of aluminium and it is a choice of welding process when high quality, precision welding is required.

Modal analysis is one of the ways in determining, improving, and optimizing dynamic characteristic of engineering structure. Experimental modal analysis is the best method to understand the characteristic of aluminium joint by determining the natural frequency and mode shapes of the aluminium joint.

Finite element analysis is a computer simulation technique for modeling and analyzing the effect of mechanical loads applied to a part in a system. ALGOR software will be used to find the natural frequency and also mode shape of the aluminium joint.

1.3 PROJECT OBJECTIVE

The purpose of this research is to study the dynamic properties and behavior of dissimilar aluminium joint by using TIG welding through the comparison of experimental modal analysis and the simulation in the finite element analysis.

1.4 PROJECT SCOPES

To achieve the mentioned objective, the project scopes in both experimental and simulation include:

a) Selection of different type of aluminium material that will be used in the welding process.
b) The type of joining that will be used for the dissimilar aluminium is TIG welding.
c) Performing the modeling process in Solidwork software based on specific design.
d) Performing Finite Element Analysis in Algor software.
e) Performing Experimental modal analysis in DASYlab by using an impact hammer.
f) Comparison between experimental and simulation analysis.
g) Performing Operating Deflection Shape Analysis to determine the dominant mode shape of the aluminium joint.

1.5 PROBLEM STATEMENT

Vibration is a frequent problem that affecting the result of joining dissimilar material between aluminium 1100 and aluminium 6061 by welding. The vibration problem occurs and affects the surface finish of joining plate. Analysis of vibration modes is an important criterion in any mechanical structure design, but is sometimes ignored and overlooked by some engineers. Every structural component or mechanical supports have its own vibration modes or mode shapes and natural frequency, which can shorten equipment life, and cause unwanted failure which will result in hazardous situations if they are not properly design and analysed.

One of the reasons for the failure is caused by the resonance frequency. The resonance frequency is the frequency at which any excitation produces an exaggerated response. This is important to know since excitation close to a structure's resonant frequency will often produce adverse effects. These generally involve excessive vibration leading to potential fatigue failures, damage to the more delicate parts of the structure or, in extreme cases, complete structural failure.

Therefore, one of the suitable methods to analyse the vibration modes and natural frequency of a structure is by performing an experimental modal analysis. Modal analysis will determine the fundamental vibration mode shapes and corresponding natural frequencies. These systems require accurate determination of natural frequencies and mode shapes thus, techniques such as Finite Element Analysis is also carried out.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter is to explain the fundamental of modal analysis and finite element analysis (FEA), regarding on the investigation of dynamic properties of the aluminium joint. It is important to study on the basic concept of both analysis because both result use to verified the computational result.

2.2 VIBRATION IN ENGINEERING STRUCTURE

According to Rao (2012), vibration is a repetitive, periodic, or oscillatory response of an engineering structure. The rate of the vibration cycles is termed “frequency”. Vibrations can naturally occur in an engineering structure and may be representative of its free and natural dynamic behavior. Vibrations may also be forced onto a structure through some form of excitation.

The excitation forces may be either generated internally within the dynamic system, or transmitted to the structure through an external source. When the frequency of the forcing excitation coincides with that of the natural motion, the structure will respond more vigorously with increased amplitude. This condition is known as resonance, and the associated frequency is called the resonant frequency. Natural, free vibration is a manifestation of the oscillatory behavior in engineering structures, as a result of repetitive interchange of kinetic and potential energies among components in the structure (Rao, 2012).

Resonant vibration is caused by an interaction between the inertial and elastic properties of the materials within a structure. Resonant vibration is often the cause of, or at least a contributing factor to many of the vibration related problems that occur in structures and operating machinery. To better understand any structural vibration problem, the resonances of a structure need to be identified and quantified. A common way of doing this is to define the structure's modal parameters (Schwarz and Richardson, 1999).

2.3 EXPERIMENTAL MODAL ANALYSIS

One common reason for doing an experimental modal analysis is for the verification or correction of the results of the analytical approach. Often, an analytical model does not exist and the modal parameters determined experimentally serve as the model for future evaluations such as structural modifications. Predominately, experimental modal analysis is used to explain a dynamics problem whose solution is not obvious from intuition, analytical models, or previous experience. After this many numerical methods are often adopted to predict the behavior of the dissimilar systems under dynamic loading conditions, both for scientific and practical applications (Havaldar, 2012)

Modal analysis is vital to understand and optimize the inherent dynamic behavior of structures, leading to lighter, stronger, and safer structures with better performance. Experimental modal analysis is based on determining the modal parameters by testing, unlike analytical modal analysis, where the modal parameters are derived from finite element models (FEMs). There are two ways of doing experimental modal analysis, which are classical modal analysis and operational modal analysis. When a modal test is performed on a test structure the objective is to measure data from which the modal parameters and modal frequencies can be estimated. (Havaldar, 2012)

The most typical data used for parameter estimation are frequency response functions (FRFs), which use excitation input and the corresponding output of the test structure. Transient excitation is an input of short duration relative to the measured time record in contrast to random or sine inputs. The versatility of transient excitation techniques allows for several advantages over typical vibration shaker input. Quick diagnostics of structures with short setup times are possible. The most commonly used method of transient excitation for modal testing is the impact hammer (Rao, 2012)

Figure 2.1: Impact hammer (Rao, 2012)

2.4 EXAMPLE OF EXPERIMENTAL MODAL ANALYSIS

2.4.1 Dynamic characteristics of the T-joint arc welded structure

An experimental modal analysis (EMA) was carried out by Chee (2007), to obtain the natural frequency and its associated mode shape for plates A and B that will be used to form a T-shape welded joint model. After these two plates were joined together using shield metal arc welding, EMA was conducted again on the welded joint model. The results from EMA were used as a comparison for FE results. Before the analysis can be carried out, plates A and B were divided into small grid points where at these points Frequency Response Function (FRF) was measured. 25 grid points were used to represent the plate shape since its geometry was simple. The plates A and B have weight of 452 gram and 637 gram, respectively. (Chee, 2007).

A Kistler Type 9722A500 impact hammer was used to produce the excitation force on the plate while a Kistler Type 8636C50 uni-axial accelerometer was fix mounted onto the plate at the area near to point 12 in plates A and B by using beeswax. The uni-axial accelerometer has sensitivity and mass of 100 mV/g and 5.5 gram, respectively. It is also important that the accelerometer should be placed away from the nodes of mode shapes. This is to ensure that the output signal from the accelerometer can be captured.

PAK MK II Muller BBM Analyzer was used to measure the signal from impact hammer and accelerometer and converts it into frequency response function, FRF. The frequency response functions were measured in the range of 0-6000 Hz. The plate was supported by a soft platform (sponge) in order to achieve free-free boundary conditions. Having measured all of the FRFs for 25 points curve fitting was produced using PAK MK II Analyzer in the Universal File Format (UFF). This file was then exported to ME Scope software to extract the modal parameter of a measured plate.

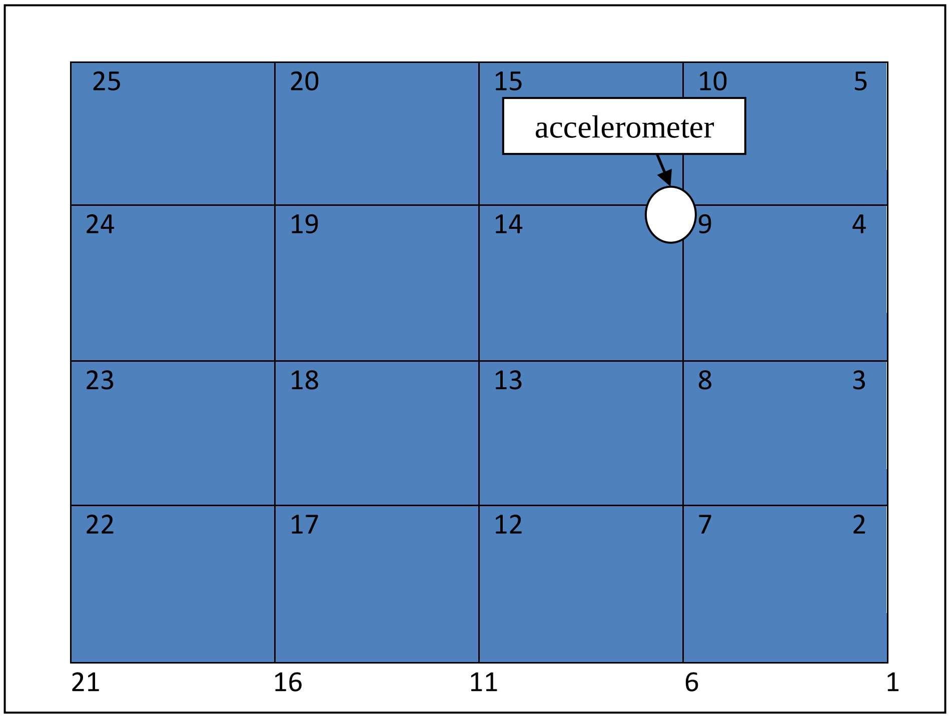


Figure 2.2: Element grid for plate A and B (Chee, 2007)

The procedures to carry out the Experimental Modal Analysis test for this T-shape welded joint are similar to single plate procedures. This model was divided into 50 small grid points and accelerometer was fix-mounted. Again, the impact hammer method was applied to produce the excitation force on the model. PAK MK II analyzer converted the signal from impact hammer and accelerometer and transferred it to ME scope software to generate natural frequency and its associated mode shape (Chee, 2007).

2.4.2 Dynamic parameters of adhesively bonded steel and aluminum plates

Experiment is conducted with a roving hammer test where the accelerometer is fixed at a location as in figure 2.3. Where there is maximum displacement and the structure is impacted to define the mode shapes of the structure. Post-processing is done to obtain the required frequency response function, FRFs. By these FRFs natural frequencies, mode shapes and damping ratio were obtained. Experimental and finite element analysis values were then compared. This software is a complete, integrated solution for tested-based engineering, combining high speed multiple-channel data acquisition with a suite of integrated testing, analysis and report-generation tools. (Havaldar, 2012).

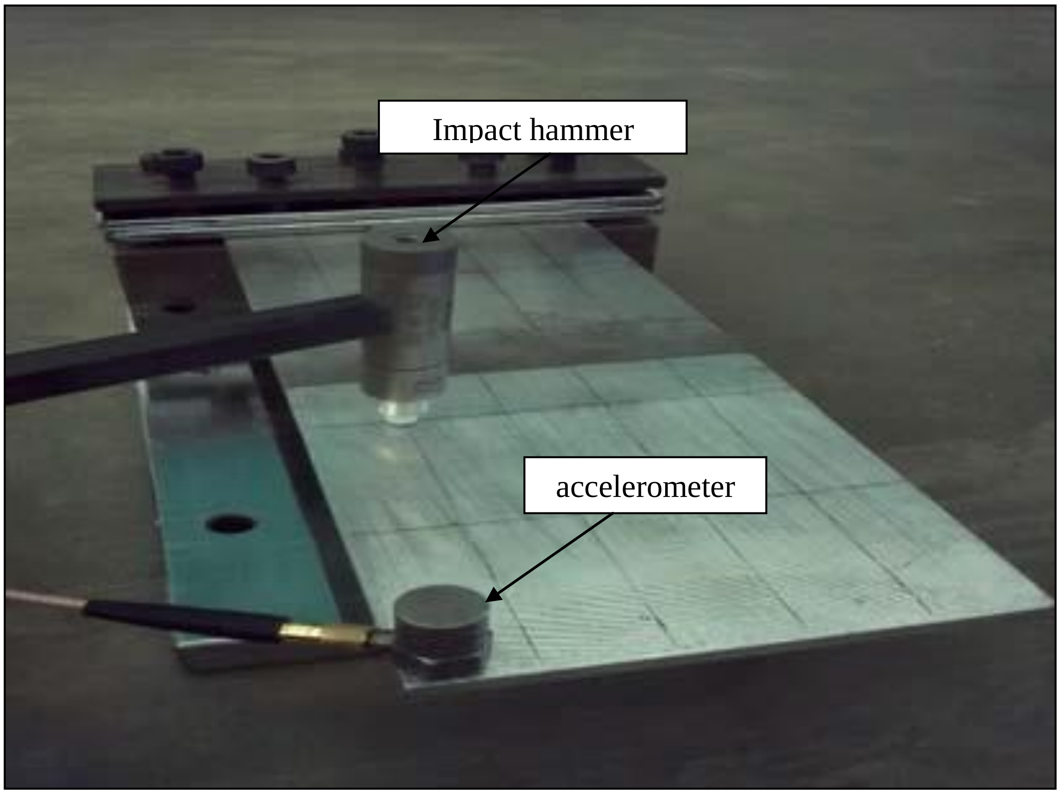


Figure 2.3: Impact hammer and accelerometer is fixed at a location (Havaldar, 2012)

2.5 FINITE ELEMENT ANALYSIS

Finite Element Analysis (FEA) was first developed in 1943 by R. Courant, who utilized the Ritz method of numerical analysis and minimization of variation calculus to obtain approximate solutions to vibration systems. Shortly thereafter, a paper published by Turner (1956) established a broader definition of numerical analysis. The paper centered on the "stiffness and deflection of complex structures". FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. A company is able to verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction.

Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition. There are generally two types of analysis that are used in industry: 2-D modeling, and 3-D modeling. While 2-D modeling conserves simplicity and allows the analysis to be run on a relatively normal computer, it tends to yield less accurate results. 3-D modeling, however, produces more accurate results while sacrificing the ability to run on all but the fastest computers effectively. Within each of these modeling schemes, the programmer can insert numerous algorithms which may make the system behave linearly or non-linearly. Linear systems are far less complex and generally do not take into account plastic deformation (Hotwai, 2009).

2.6 EXAMPLE OF FINITE ELEMENT ANALYSIS

2.6.1 Finite element analysis on adhesively bonded aluminium and steel plates.

In Havaldar (2012) research, plates are modeled using commercially available finite element package ANSYS in order to obtain the dynamic parameters such as natural frequencies and corresponding mode shapes. The plates are meshed using SOLID186 element available in the elements library. The element is defined by 20 nodes having three degrees of freedom per node, translations in the nodal x, y, and z directions. Plate dimensions maintained throughout the analysis was 250 x 100 x 5mm. Figure 2.4 depicts the meshed model of joined plates with cantilever boundary conditions.

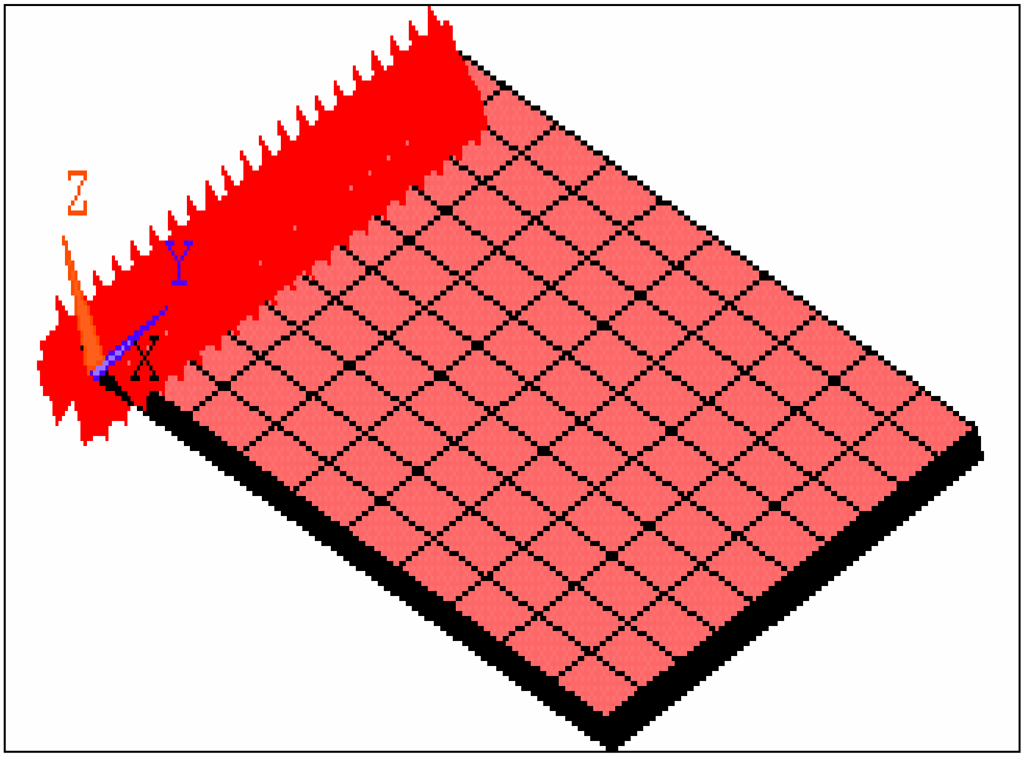


Figure 2.4: Finite Element meshing of the plate (Havaldar, 2012)

2.6.2 Finite Element Analysis on a T-Shape Welded Joint Model

A 3-dimensional Finite Element model of the plates was developed using this ABAQUS/CAE (Computer Aided Engineering). Material properties were assigned to the plates A and B. Linear perturbation frequency was used as analysis step to modal analysis on the plate. In this analysis, algorithm was used to analyze the plate because the element size on plate is fine and consists of many degrees of freedom (DOF).

The minimum frequency was set at 1 Hz to avoid the solver from calculating the six rigid body motions which have the frequency of 0 Hz. No constraints and loads were assigned in an attempt to simulate the free-free boundary condition.

In ABAQUS, there are two modeling elements used to represent the 3- dimensional model, which are solid element and shell element. A solid element consists of hexahedral (Hex), tetrahedral (Tet) and wedge elements while a shell element consists of quadrilateral (Quad) and triangular (Tri) elements.

All of the 3D element type above were used to model Plate A and B to define the most suitable modeling method on single plate. Global element size that assigned on each type of element is 4 mm which enough to represent the actual model. A 3-dimensional Finite Element model of the T-shaped welded joint was generated using ABAQUS/CAE. The model which used solid element to model plates A and B was called Solid Based Model while the model using shell element to model plates A and B was called Shell Based Model. Global element size that was assigned on each type of element is 5 mm which enough to represent the actual model (Chee, 2007)

2.6.3 Dynamic analysis of beam structure using finite element method in Algor program .

Modal analysis in Algor software used the Natural Frequency (Modal) analysis type to determines the natural frequencies for the structure. For modal analysis the authors define a new analyze scenario with the same characteristics that are already define in static analysis.

Utilizing the computed aided design programs and finite element method analysis is very easy to calculate structure deformations, stresses and displacements in different sections and characteristic points of the structure, as well as size determination and structural elements construction. (Tomey, 2008)

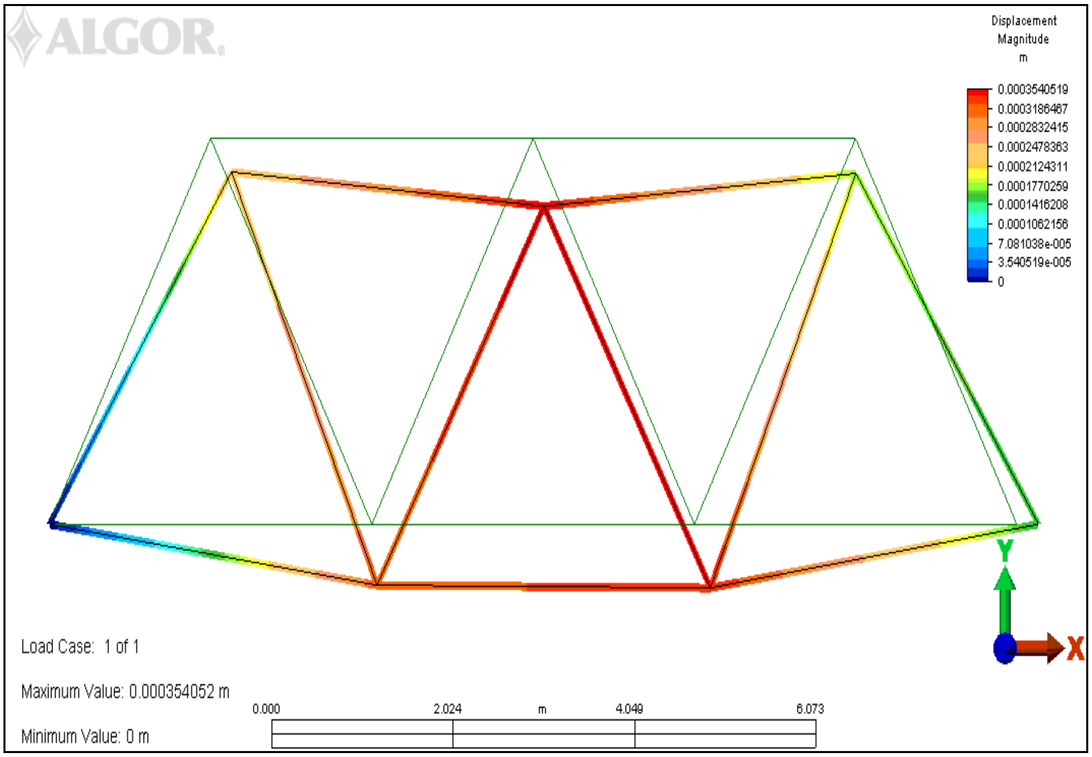


Figure 2.6: Displacement magnitude of the beam using Algor software (Tomey, 2008)

2.7 TUNGSTEN INERT GAS (TIG) WELDING

The Tungsten Inert Gas (TIG) welding process is one of the ways to join aluminium materials. In some case the TIG welding is used to join different type and thinner section of materials for example aluminium alloys and stainless steel material. In this research, student used different type of aluminium which is aluminium 1100 and aluminium 6061 to be weld. There are many factors and criteria than should be taken into consideration before performing this welding process in order to achieve high quality of welding results. There are also important procedures that need to follow and give special attention the type of tungsten electrode, size of welding nozzle, gas type, and gas flow rates.

2.7.1 TIG Welding Aluminum Joint design.

According to Waine (2010), the joint designs shown in figure 2.7 are applicable to the gas tungsten-arc welding process with minor exceptions. Inexperienced welders who cannot maintain a very short arc may require a wider edge preparation, included angle, or joint spacing. Joints may be fused with this process without the addition of filler metal if the base metal alloy also makes a satisfactory filler alloy. Edge and corner welds are rapidly made without addition of filler metal and have a good appearance, but a very close fit is essential.

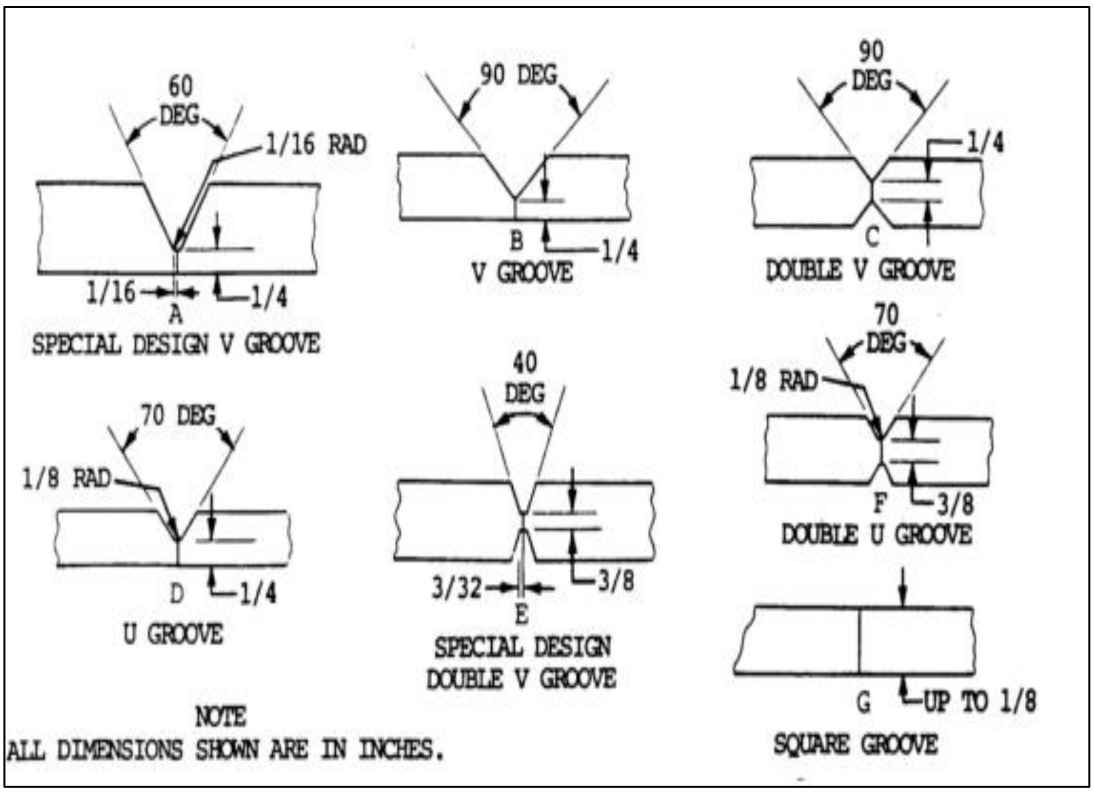


Figure 2.7: Joint design for aluminium plates (Waine, 2010)

2.8 OPERATING DEFLECTION SHAPES (ODS)

Operating Deflection Shapes (ODS) are used for visualization of the vibration pattern of a structure under real life operating conditions. Vibration measurements are performed at different points and directions on the structure known as degrees of freedom (DOFs) and the vibration pattern can be shown in a number of formats including an animated geometry model of the structure. Figure 2.8 shows an example of a geometry model before animation. Unlike modal analysis techniques which only help visualize the inherent resonant characteristics of a product, ODS is a very powerful tool that can solve problems related to forced vibrations. (Heaton, 2006)

Traditionally, ODS have been defined as the deflection of a structure at a particular frequency. However, ODS can be defined more generally as any forced motion of two or more DOFs on a structure. An operating deflection shape contains the overall vibration for two or more DOFs on a structure. An ODS therefore contains both forced and resonant vibration components whereas a mode shape characterizes only the resonant vibration at two or more DOFs. (Schwarz, 1999)

2.8.1 ODS Analysis of a Steel Bar Fixed At One End

In Heaton (2006) research the steel bar is tapped repeatedly close to the free end and the FFT from one of the closest transducers is recorded. The resulting FFT is displayed in Figure 9 and shows three dominant peaks corresponding to the first three modes of the bar. The frequencies of the modes are shown to be 52Hz, 355Hz and 916Hz.

The steel bar is driven in turn at each of the three frequencies and a single measurement set is recorded. The data is then exported into the display software where the ODS are viewed. The geometry model is interpolated and viewed at the modal frequency. Interpolation involves the computation of points or values between the ones that have been measured, using the data from the surrounding points or values.

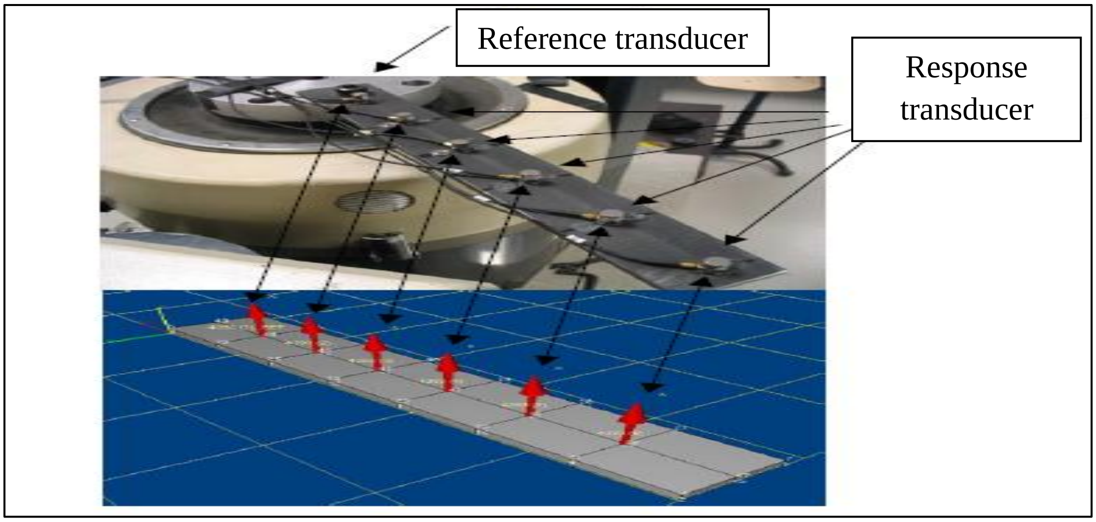


Figure 2.8: steel bar and geometry model of the bar (Heaton, 2006)

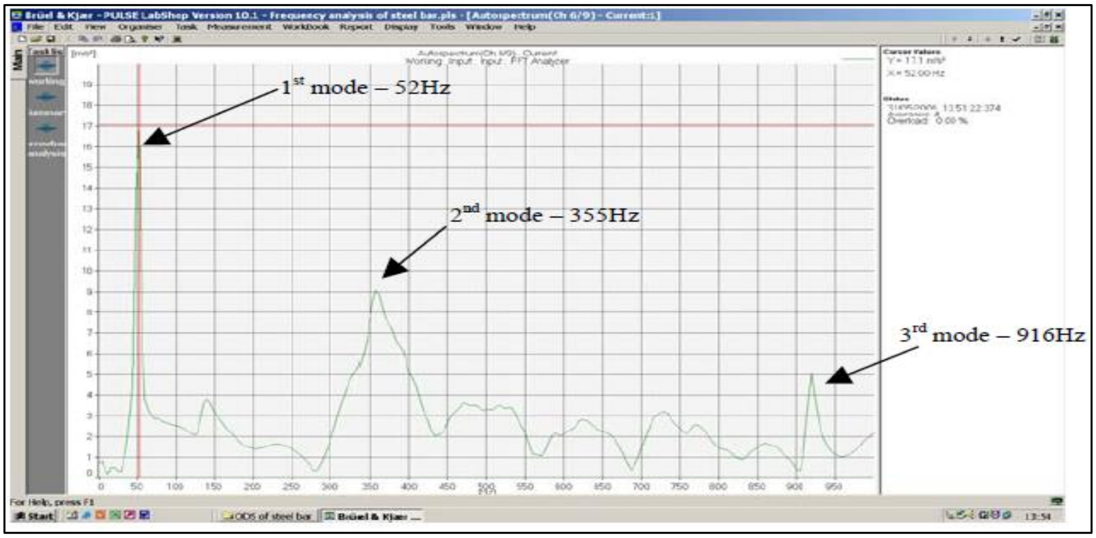


Figure 2.9: The FFT showing the first three modes (Heaton, 2006)

CHAPTER 3

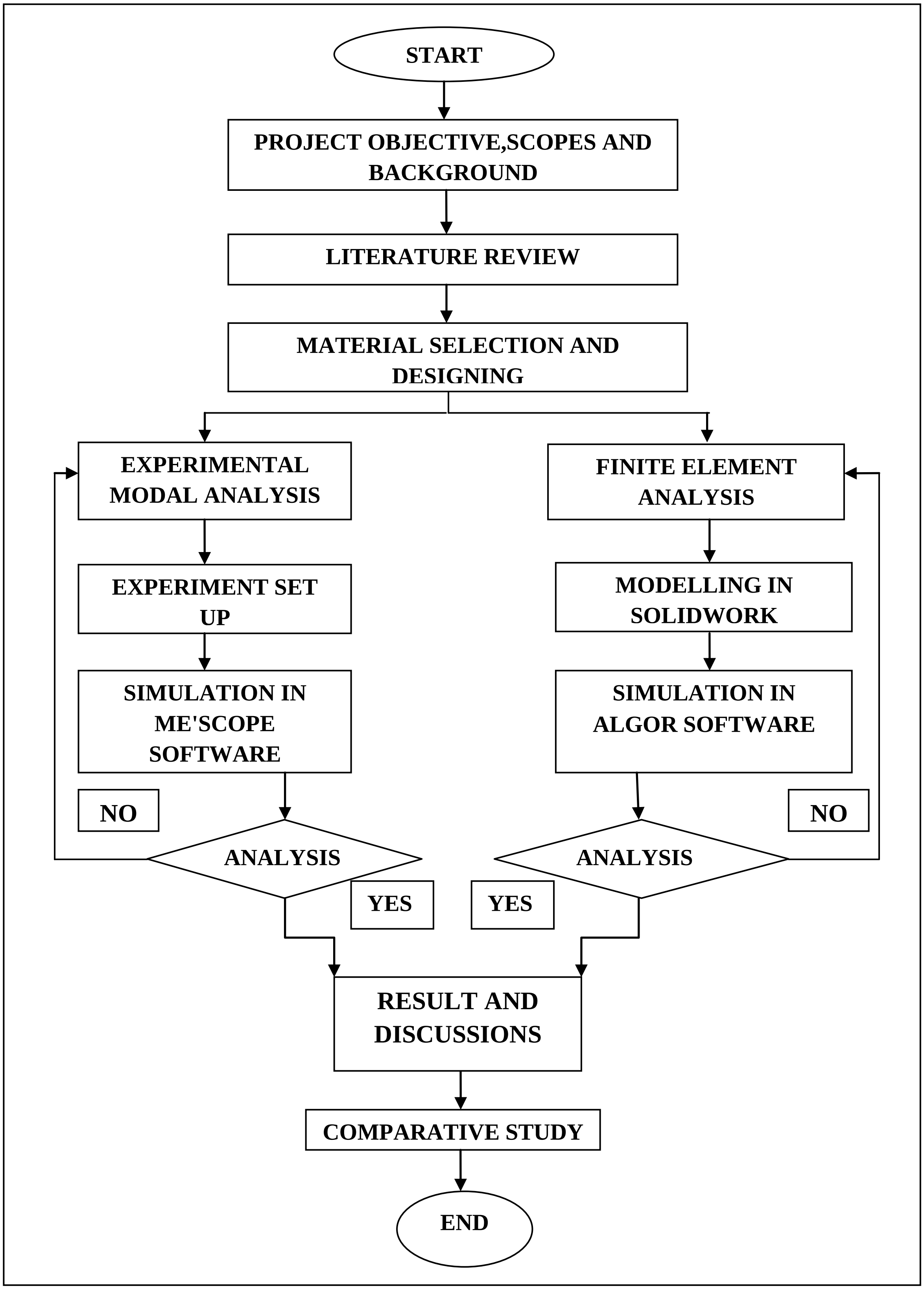
METHODOLOGY

3.1 INTRODUCTION

This chapter is about the about how the research is carried out. The research is to study about the dynamic properties and behavior of different types of aluminium joint by TIG welding using the experimental modal analysis and performing Finite Element Analysis by using ALGOR software. All the result and data from the ALGOR will be compared with the data collected from the experimental modal analysis.

The flow chart of the methodology is as shown below. This study begins with the problem statement, determine the project objectives and scopes, literature review on previous work and theoretical study on joining by metal inert gas, TIG welding and modal analysis. After doing the literature review, the model of aluminium sheet metal joining by MIG welding is sketched using SOLIDWORK software. Then a simulation is conducted to observe the dynamic properties such as natural frequency and mode shapes. Lastly, after gathering information and data from both results, a comparative study will be done and discussed on the performance of the aluminium sheet metal joining by TIG welding.

3.2 FLOW CHART



3.3 MATERIAL SELECTION

It is important that we know the main physical and chemical characteristics of the aluminium before we do the final material selection. For example, there are a number of important differences between aluminium and steel which influence the welding behavior, which are their melting point and their oxides. The oxides of iron all melt close to or below the melting point of the metal, aluminium oxide melts at 2060°C, some 1400°C above the melting point of aluminium. This has important implications for the welding process, since it is essential to remove and disperse this oxide film before and during welding in order to achieve the required weld quality.

The Materials that was selected were aluminium alloy 1100 in 3.0 mm thickness and aluminium alloy 6061 plates in 2.0 mm thickness. The two types of aluminium plates have been cut to Size 150 mm x 100mm, and the surface was cleaned by abrasive paper and acetone before the experiment. A single-V groove has been opened on the plate, with a bevel angle of 45° in both aluminium alloy side.

3.3.1 Characteristic of aluminium

a) The oxide film on aluminium is durable, highly tenacious and self healing. This gives the aluminium alloys excellent corrosion resistance, enabling them to be used in exposed applications without additional protection. This corrosion resistance can be improved further by anodizing which is the formation of an oxide film of a controlled thickness.
b) The coefficient of thermal expansion of aluminium is approximately twice that of steel which can mean unacceptable buckling and distortion during welding.
c) The coefficient of thermal conductivity of aluminium is six times that of steel. The result of this is that the heat source for welding aluminium needs to be far more intense and concentrated than that for steel. This is particularly so for thick sections, where the fusion welding processes can produce lack of fusion defects if heat is lost too rapidly.

d) The specific heat of aluminium which is the amount of heat required to raise the temperature of a substance, is twice that of steel. Aluminium has high electrical conductivity, only three-quarters that of copper but six times that of steel. This is a disadvantage when resistance spot welding where the heat for welding must be produced by electrical resistance.
e) Aluminium does not change color as its temperature rises, unlike steel. This can make it difficult for the welder to judge when melting is about to occur, making it imperative that adequate retraining of the welder takes place when converting from steel to aluminium welding. Aluminium is non-magnetic which means that arc blow is eliminated as a welding problem. Aluminium has a modulus of elasticity three times that of steel which means that it deflects three times as much as steel under load but can absorb more energy on impact loading.

3.3.3 Aluminium alloy 1100

Aluminium alloy 1100 contains at least 99% aluminium. Aluminium alloy 1100 filler metal easily welded with commercial techniques such as electrical resistance, arc inert gas, inert gas arc welding-protected option. If welding of aluminium alloy Al 1100 alloy is higher, such 6063 or 5052, then the filler rod should be aluminium alloy 4043.Aluminium 1100 has excellent corrosion resistance and satisfactory anodizing and conversion coating finishing characteristics. It is unmatched by any other commercial aluminum alloy in workability. Readily to welding, brazing, and soldering. Machinability is poor and tends to be "gummy". Non-heat treatable. Typical applications include chemical storage, processing equipment, kitchen utensils, and general sheet metal work.

3.3.4 Aluminium alloy 6061

This is the most versatile of the heat treatable aluminum alloys. It has most of the good qualities of aluminum, and it offers a wide range of mechanical properties and corrosion resistance. It can be fabricated by many of the commonly used techniques. In the annealed condition, it has good formability. Aluminium alloy 6061 normally used for a wide variety of products and applications from truck bodies and frames to screw machine parts and structural components. Also it is used where appearance and better corrosion resistance with good strength are required.

3.4 MODELLING

3.4.1 Modeling Method

After the materials is selected and design, the next activity is to model the part, using Computer Aided Design (CAD) software which is SOLIDWORK. The design of the model is shown in figure. The assemble part consist of 2 part that is an aluminium alloy 1100 which have the thickness of 3mm and aluminium alloy 6061 that have the thickness of 2mm. These two parts are assembled to the weld bead.

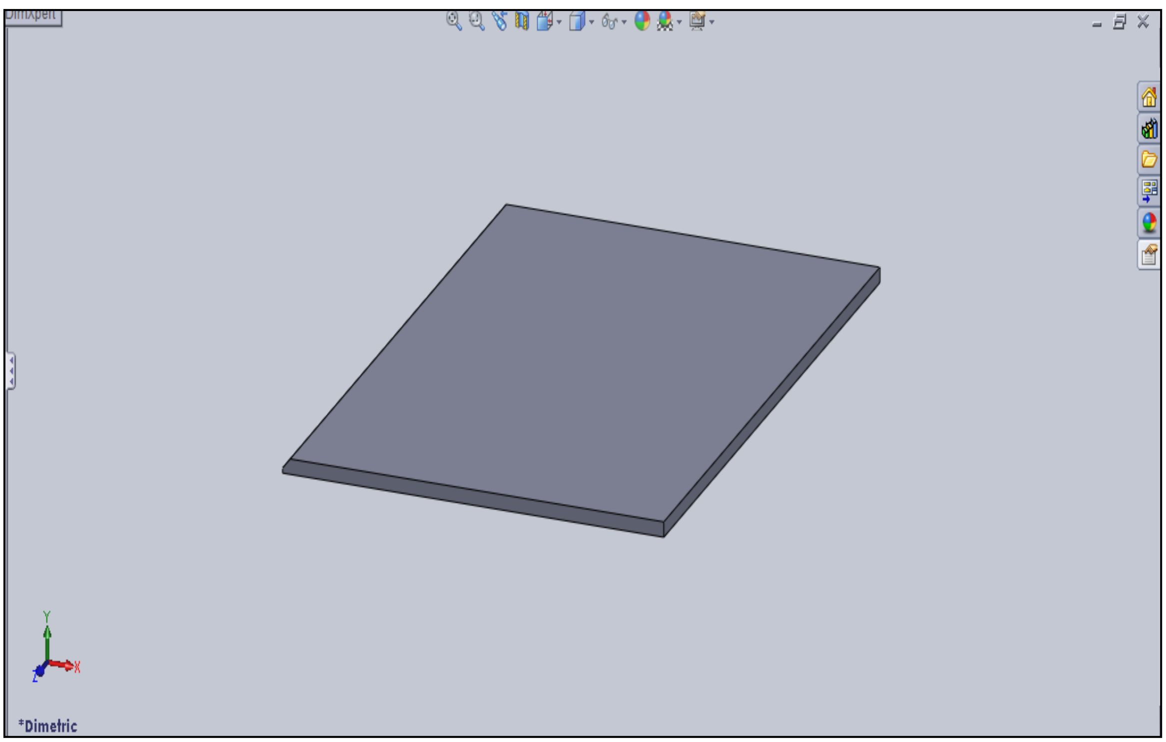


Figure 3.1: Isometric view of aluminium alloy 1100

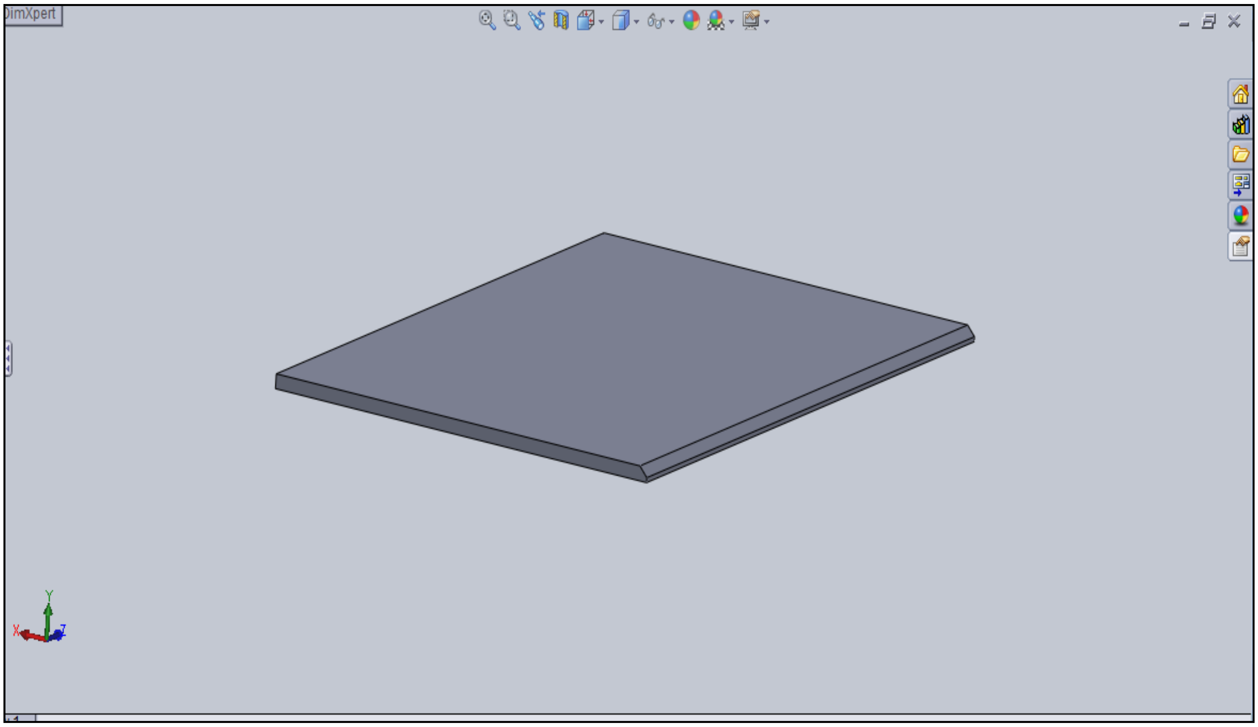


Figure 3.2: Isometric view of aluminium alloy 6061

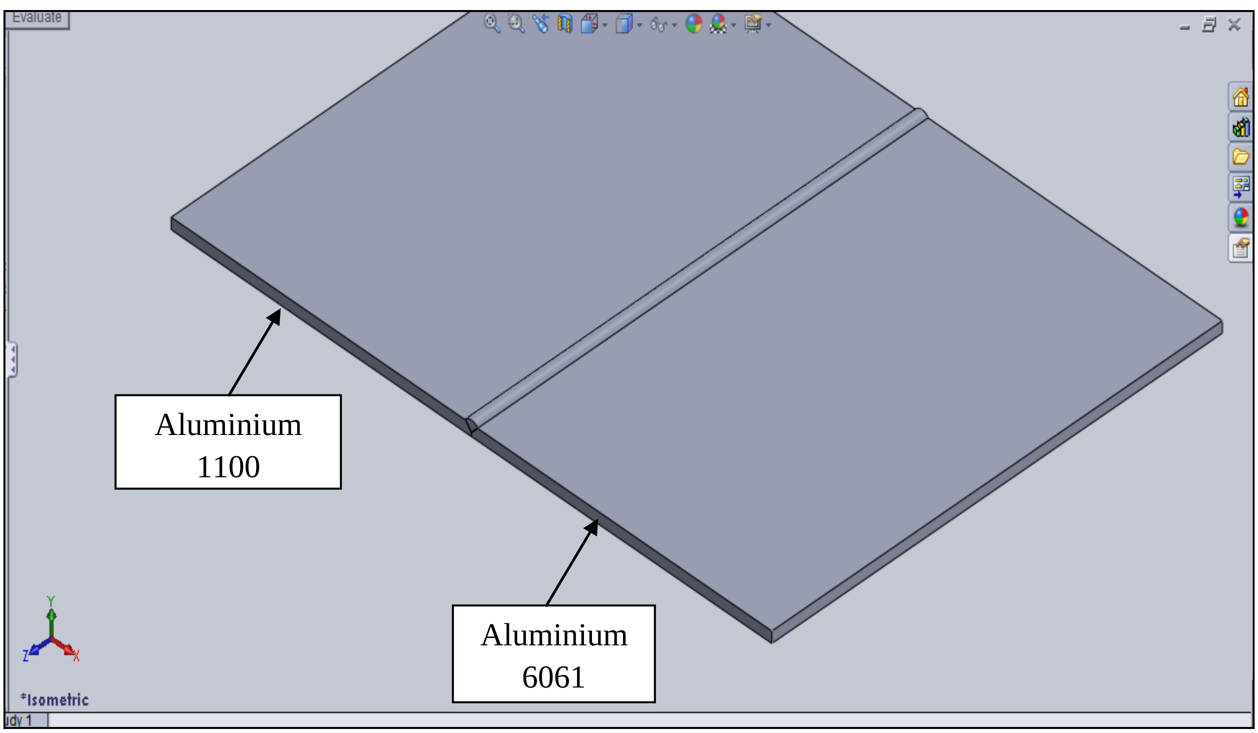


Figure 3.3: Isometric view of welded aluminium 1100 and 6061

3.5 SIMULATION

3.5.1 Simulation method

The finite element analysis is carried out is using Autodesk ALGOR simulation. ALGOR is capable of generating meshes automatically because its support for multi-CAD environment and also an extensive finite element modeling tool that help manufacturers study initial design intent and accurately predict product performance. It also allows user to validate and optimize designs before manufacturing which can increase efficiency, minimizing reliance on physical prototypes, reducing costs, and decreasing errors. It also allows complex geometries to be generated easily and support mesh types of 2D and 3D simulation.

Autodesk ALGOR simulation software is used to conduct the analyzing of the joining aluminium alloy with weld bead. ALGOR Finite Element Analysis (FEA) uses a complex system of point called nodes which make grid called mesh. Natural frequency (modal analysis) in ALGOR determined a part's natural frequencies and mode shape to avoid frequencies that are disruptive or harmful in the design.

3.5.2 Transferring model

The 3D model of joining both aluminium alloy 1100 and 6061 with weld bead by SOLIDWORK is transferred into the ALGOR software in type of IGS file. IGS file is a 2D/3D vector graphics format based on the Initial Graphics Exchange Specification (IGES) used by many CAD programs as a standard ASCII text- based format for saving and exporting vector data which can store wireframe models, surface or solid object representation, circuit diagram and other object. The IGES format was introduced in 1979 and has since become a standard for transferring three dimensional models between CAD programs.

For this experiment, 5 mode shapes were analysed and there are no loading and boundary condition were imposed on the test specimen. The free boundary condition is simulated by supporting the structure with soft material such as sponge. The mesh structure for joining of both aluminium alloys with weld bead is shown in figure 3.4. The simulation is done part by part so then it can be compared to the experimental analysis later.

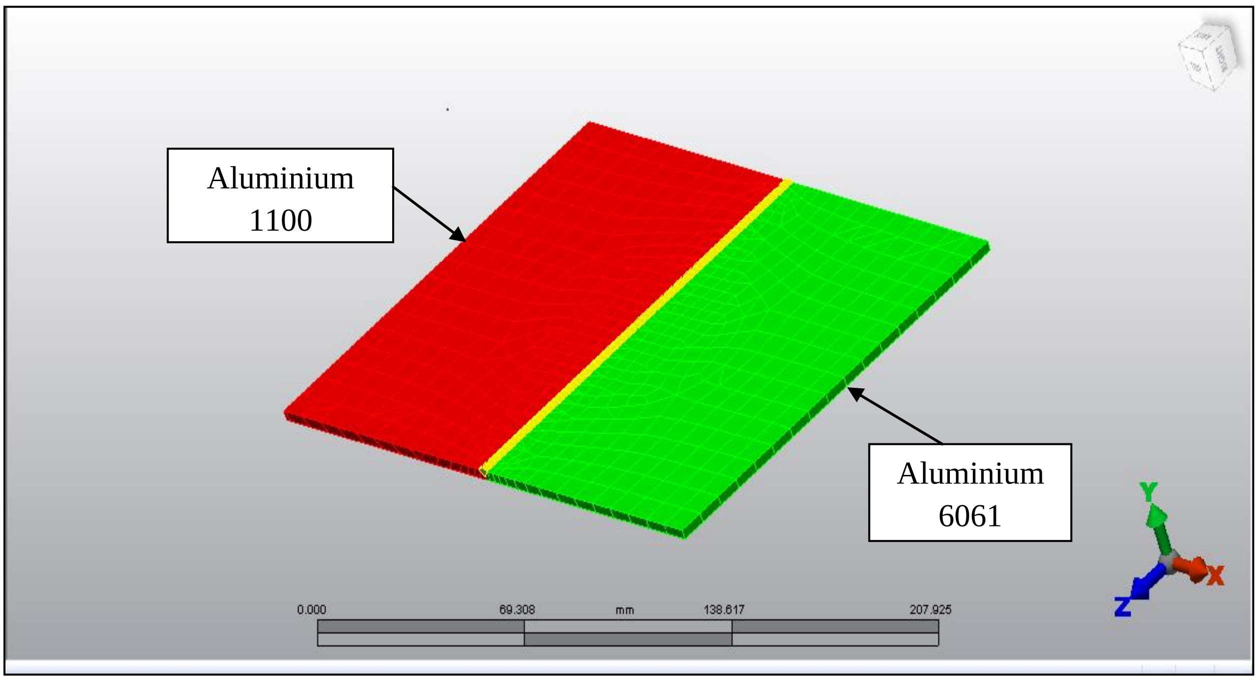


Figure 3.4: Mesh diagram of assembled part

3.6 EXPERIMENTAL MODAL ANALYSIS

3.6.1 Impact hammer

Impact hammer is used as the excitation force for the experimental modal analysis. The hammer will impacts an excitation force to the device and will produce a wide range of frequency for the Data Acquisition System (DAS) to read and measure the vibration of the device along the frequency range. In this project PCB piezotronics impact hammer was used to excite the force. Testing with impact hammer has some very distinct advantages. The input spectrum from the impact is flat out to the roll off frequency with no holes in the spectrum. The technique can be very efficient and portable compared to the aligning and moving of shakers and their associated control systems.

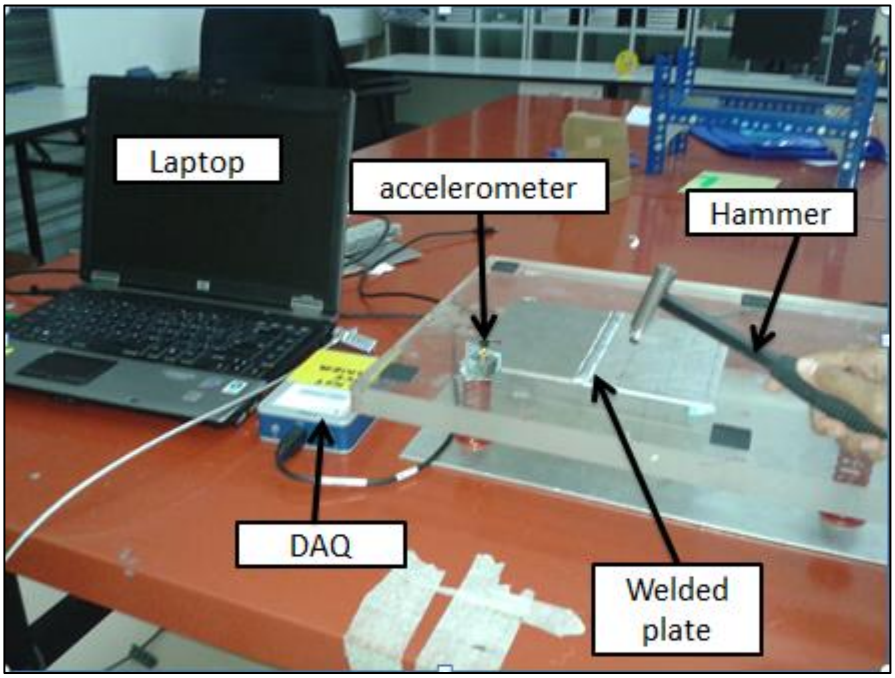


Figure 3.5: Experimental modal analysis system

3.6.2 Accelerometer

Accelerometer is used as the sensor to connect with the Data Acquisition System, DAS. Type of accelerometer used is tri-axial accelerometer and was mounted onto the plate from one point to another after the impact hammer knocks the plate for five times to get the average result. The accelerometer is a device for measuring vibration of a structure, producing an output signal proportional to acceleration. Engineers must properly place vibration sensors, known as accelerometers, on a structure to record the vibration response of a structure due to a known excitation by either a shaker system or an impulse hammer. These excitation systems are necessary to properly excite the modes of the system that reveal the modes of the structure. The accelerometers must have the frequency range, dynamic range, signal-to-noise ratio, and sensitivity needed for the specific test scenario.

3.6.3 Data Acquisition System (DAS)

Specialized data acquisition hardware is needed to properly acquire these vibration signals. NI offers dynamic signal analyzers (DSAs) that can simultaneously acquire each channel with 24-bit high-resolution delta-sigma analog-to-digital converters (ADCs). These DSA products have antialiasing filters to prevent aliasing and noise from affecting the measurement quality.

3.6.4 Modal analysis procedures

The sensitivity of the accelerometer and hammer must be set up in the measurement & automation software. This value is in the units you specify with the sensitivity unit's input. Refer to the sensor documentation to determine this value. The sensitivity of the hammer is 2.24 mvolts/g and sensitivity of the accelerometer is 5 mvolts/g. The setting of the sensitivity is shown in figure 3.6. The graph displays the analog signals acquired or generated by the device. After setting up the sensitivity, run the software and safe the setting.

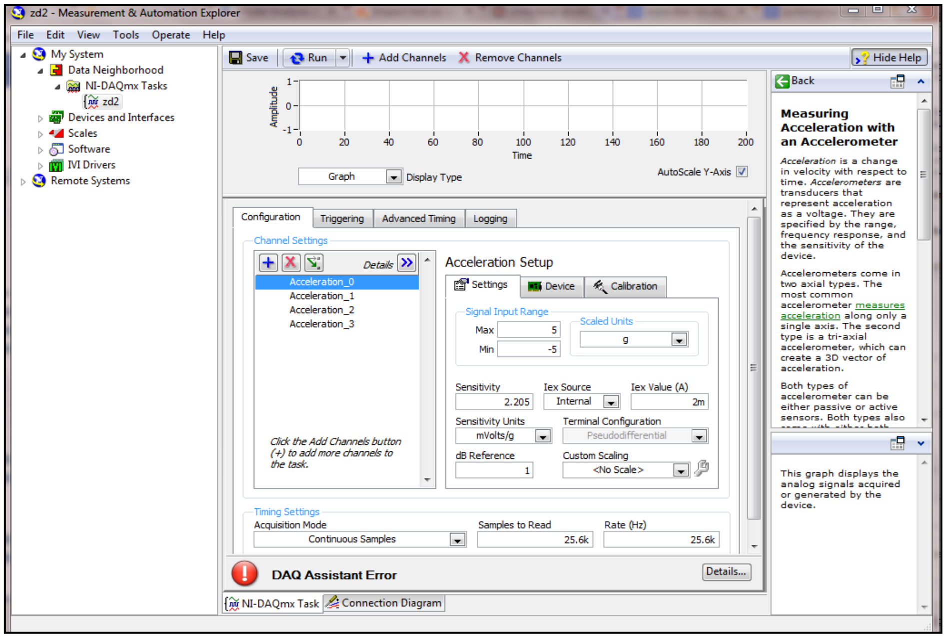


Figure 3.6: Setting the sensitivity of accelerometer and hammer

The experimental modal analysis is carried out using DASYlab 10.0 software. Figure 3.7 shows the schematic diagram of modules in the DASYlab software.

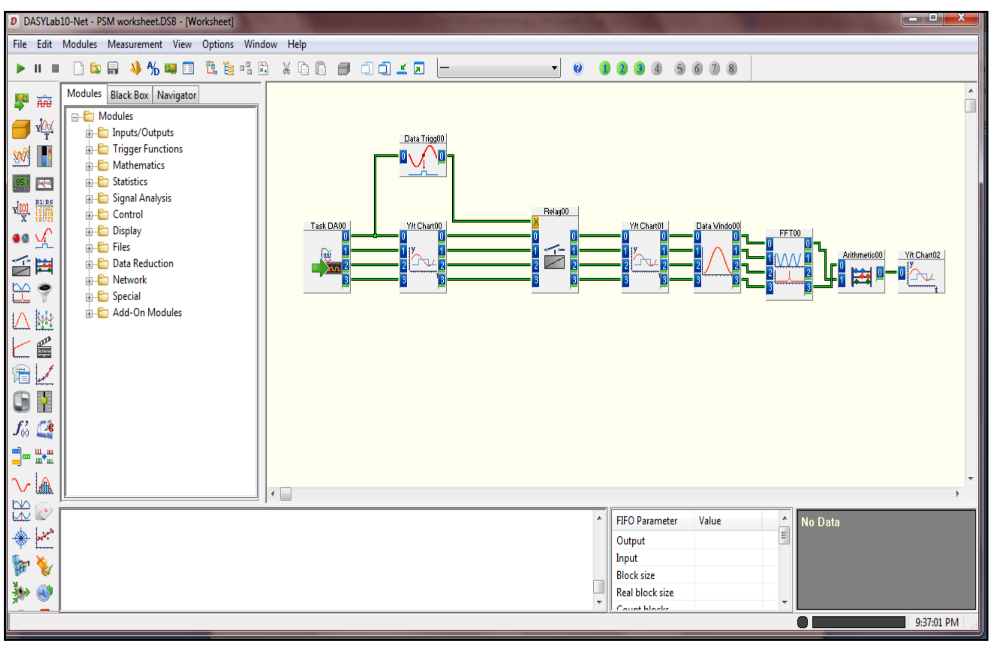


Figure 3.7: Schematic diagram of modules in DASYlab

The data experimental modal analysis from DASYlab 10.0 is carried out is using ME’scope software. 3D models with simple are easily built in ME’scopeVES by using the Drawing Assistant. More complex models can be built by repeatedly using the Drawing Assistant to model the structure using several simpler Substructures. A plate with a dimension of 100mm × 150mm × 3mm for both aluminium 1100 and aluminium 6061 was drawn in the ME’scope software. The analysis in the ME’scope software was carried out in two situation which is before and after the plates were welded. 24 and 20 points were assigned to aluminium 1100 and aluminium 6061 respectively. While the welded plate was assigned with 35 points.

In order to get the result of natural frequency and mode shapes in the ME’scope software, curve fitting is carried out for all plates. The figure 3.8 below shows the curves fitting process for five number of modes.

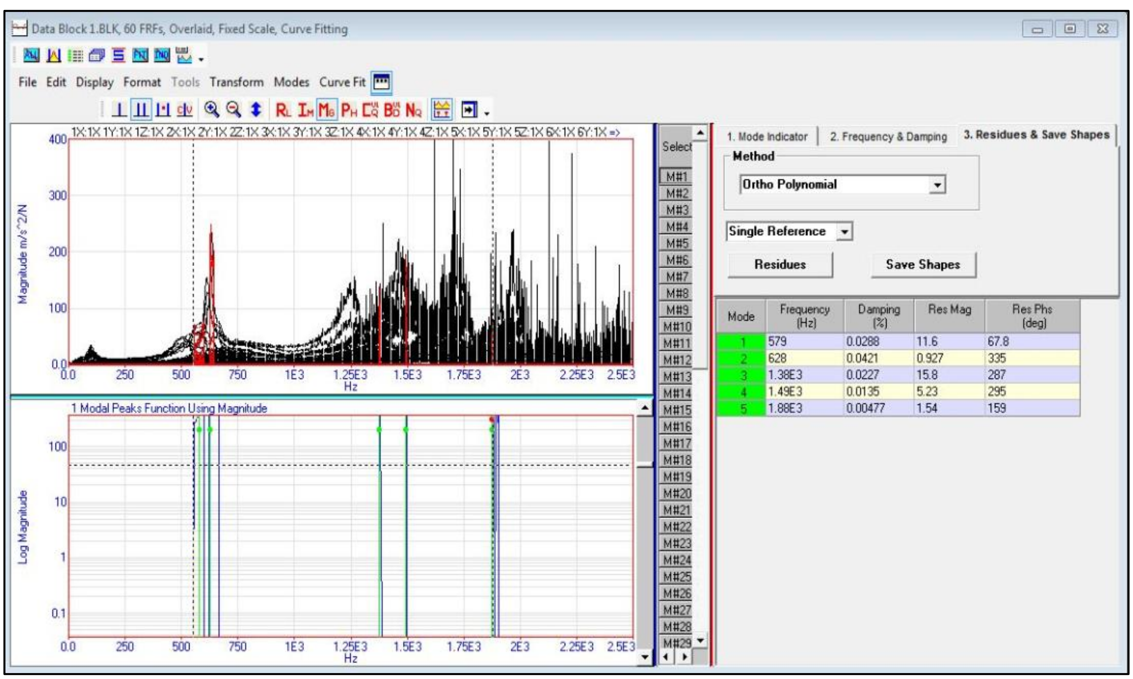


Figure 3.8: Curve fitting in ME'scope software

3.7 OPERATING DFLECTION SHAPE (ODS)

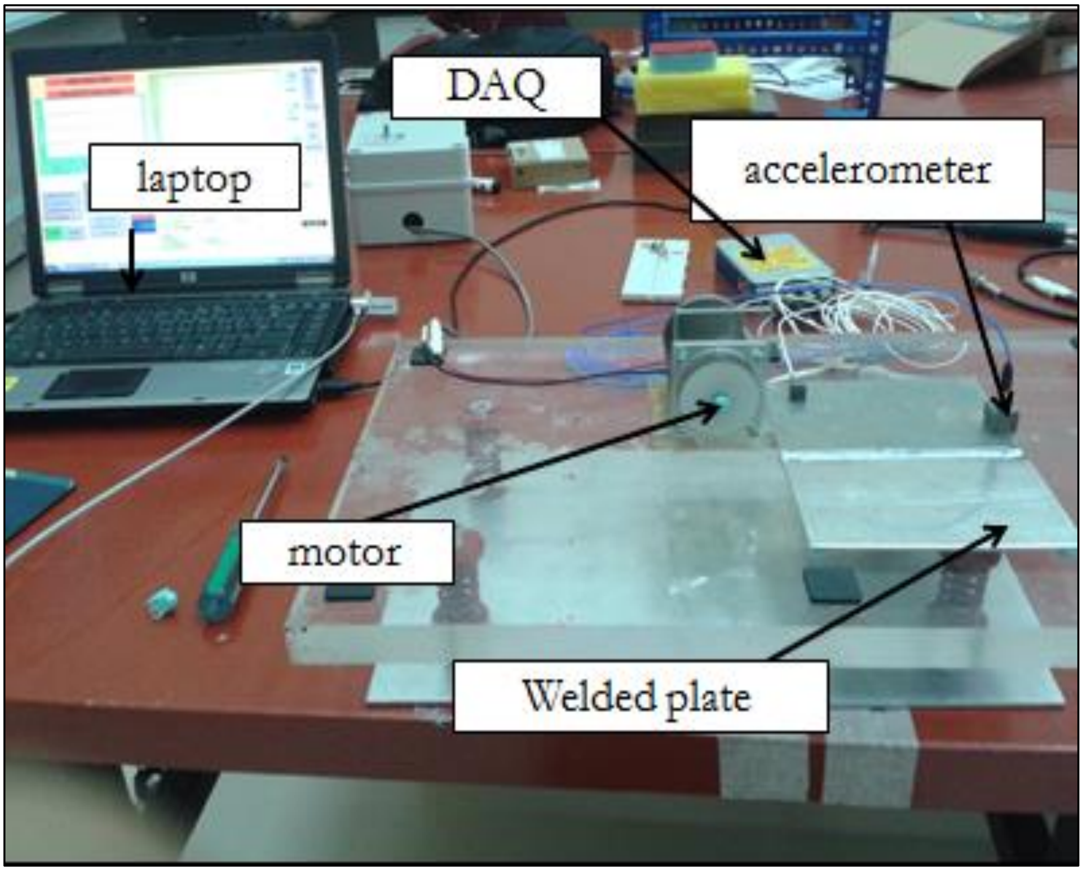


Figure 3.9: Experimental setup for ODS analysis

Figure 3.9 shows the experimental setup for the ODS analysis. A motor with a maximum speed of 3200 rpm or 53.6 Hz is used as the excitation frequency for the TIG welded aluminium plate. Same as in the experimental modal analysis, 34 points was assigned to the welded aluminium plate, and a tri-axial accelerometer is also used as the output sensor and a single axis accelerometer is used as reference.

After the data is collected in the DASYlab software, the data is input in the ME’scope software to get the ODS results. Four mode shapes are analyzed, with four operating frequency. The drawing of the plate is done in the ME’scope software with 34 points on the plate. Curve fitting is carried out in order to get the mode shapes of the welded plate.

The data from the ME'scope software is then collected and was input into Microsoft Excel to calculate and draw the mode shape of the plate.

CHAPTER 4

RESULT AND DISCUSSIONS

4.1 INTRODUCTION

In this chapter, the result from both analysis will be presented and discussed. The result of the TIG welding of aluminium 1100 and aluminium 6061 will also be discussed. The simulation result will be compared with the result of modal testing with an impact hammer. The details about the dynamic properties and the comparative study of the aluminium joint will be discussed.

4.2 RESULT OF JOINING BETWEEN ALUMINIUM 1100 AND ALUMINIUM 6061 BY USING TIG WELDING

Joining between aluminium 1100 and aluminium 6061 is done by using TIG welding before the experimental modal analysis is carried out. During the welding process, aluminium 4043 was used as the filler to join the aluminium plates. The result of TIG welding for both plates can be seen in figure 4.1.

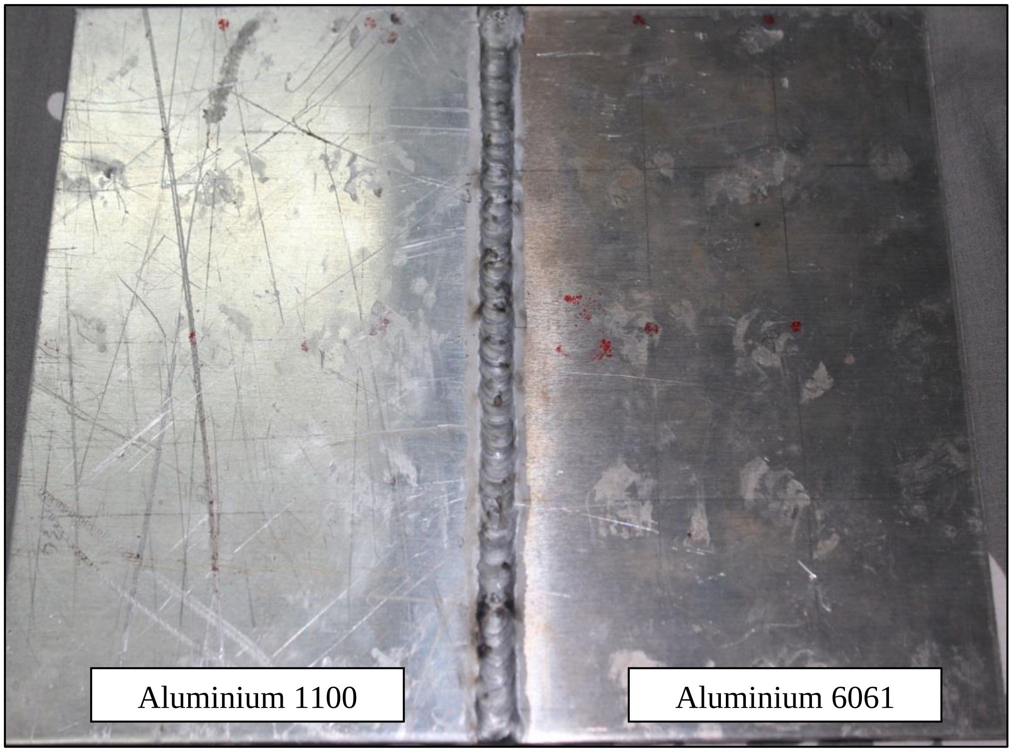


Figure 4.1: Top view for the welded plates of aluminium 1100 and 6061

Figure 4.2: Side view for the welded plates of aluminiun 1100 and 6061

Figure 4.1 and Figure 4.2 shows the result of TIG welding of different type of aluminium. Both plates are welded by using the technique of butt join and no brazing occured during the welding process because both aluminium plates melt and the gap between the aluminium is then filled with the aluminium 4043 filler to form fusion area as shown in Figure 4.2. The filler spread fully on both surface to form a firm joint. Based on observation in Figure 4.1, the joint has a good front and no crack appears on the welded plates.

4.3 RESULT OF NATURAL FREQUENCY

From the simulation in the Algor software, the result that will be compare to the experimental modal analysis is the natural frequency and the respective mode shapes. Natural frequency is the frequency at which a structure or a system vibrates when it is not disturbed by any force. While mode shape is a pattern of motion in which all part of the system move.

4.3.1 Natural Frequency From Finite Element Analysis

The finite element analysis was carried out in Algor software. Modal analysis was chosen to be the type of analysis in the simulation process of the different type of welded aluminium plate which is aluminium 1100 and also aluminium 6061. Firstly the aluminium 1100 was analysed and the result of the natural frequency with the maximum and minimum displacement for each mode is presented in Table 4.1. While the result of natural frequency with its maximum and minimum displacement for each mode of aluminium 6061 is presented in Table 4.2. Lastly, the result of natural frequency with its maximum and minimum displacement for the welded plate is presented in Table 4.3. The range of frequency in this study is between 500 Hz until 2500 Hz, and the number of mode is five.

Table 4.1: Frequency and displacement for aluminium 1100 (FEM)

Mode	Frequency (Hz)	Max. Displacement (Mm)	Min. Displacement (Mm)
1	609	255.45	4.190
2	672	187.39	0.281
3	1499	190.43	8.783
4	1562	295.66	0.666
5	1929	237.92	4.378

Table 4.2: Frequency and displacement for aluminium 6061 (FEM)

Mode	Frequency (Hz)	Max. Displacement (Mm)	Min. Displacement (Mm)
1	613	257.80	4.666
2	669	188.04	4.648
3	1475	187.86	8.619
4	1558	296.73	1.528
5	1912	234.63	5.028

Table 4.3: Frequency and displacement for welded aluminium 1100 and 6061 (FEM)

Mode	Frequency (Hz)	Max. Displacement (Mm)	Min. Displacement (Mm)
1	816	229.09	1.515
2	836	206.21	1.368
3	1049	176.82	0.566
4	1178	207.46	0.752
5	1857	179.17	1.361

4.3.2 Natural Frequency Form Experimental Modal Analysis

Experimental modal analysis is done by using an impact hammer as the excitation force to determine natural frequency and mode shape of the TIG welded aluminium 1100 and aluminium 6061 plates. From the experimental modal analysis, a set data is collected during the impact hammer testing. The testing is made for three condition which for the aluminium plate 1100, followed by aluminium plate 6061 and lastly for the welded aluminium plates. 24 and 20 points were assigned to aluminium 1100 and aluminium 6061 respectively. While the welded plate was assigned with 35 points. The experimental modal analysis is carried out by moving the tri-axial accelerometer from one point to another, and the knocking of the impact hammer is done for five times before moving on to the next point to get the average result. The result for the three condition is presented in Table 4.4, Table 4.5 and Table 4.6 respectively.

Table 4.4: Frequency and displacement for aluminium 1100 (EMA)

Mode	Frequency (Hz)	Max. Displacement (Mm)	Min. Displacement (Mm)
1	509	123	0.000
2	637	473	0.000
3	1410	787	0.000
4	1500	197	0.000
5	1940	964	0.000

Table 4.5: Frequency and displacement for aluminium 6061 (EMA)

Mode	Frequency (Hz)	Max. Displacement (Mm)	Min. Displacement (Mm)
1	579	146	0.000
2	628	228	0.000
3	1380	629	0.000
4	1490	940	0.000
5	1880	483	0.000

Table 4.6: Frequency and displacement for welded aluminium 1100 and 6061 (EMA)

Mode	Frequency (Hz)	Max. Displacement (Mm)	Min. Displacement (Mm)
1	760	0.196	0.000
2	796	0.625	0.000
3	954	0.142	0.000
4	1130	1.67	0.000
5	1810	0.458	0.000

4.3.3 Comparison of Natural Frequency Between FEA and Experimental Modal Analysis

Table 4.7 shows natural frequencies obtained from the finite element analysis and experimental modal analysis of the aluminium 1100. Based on the calculation of errors in percentage, mode shape 1 had the highest percentage error which is 16.42 % while mode 5 had the lowest percentage of error which is 2.12 %. As for Figure 4.3, the graph represents the comparison of error between the two results which is from the FEM analysis and also EMA.

Table 4.7: Comparison in natural frequency for aluminium 1100

Mode Shape	Finite Element Analysis	Experimental Modal Analysis	Error (%)
1	609	509	16.42
2	672	637	5.20
3	1499	1410	5.93
4	1562	1500	3.96
5	1929	1940	2.12

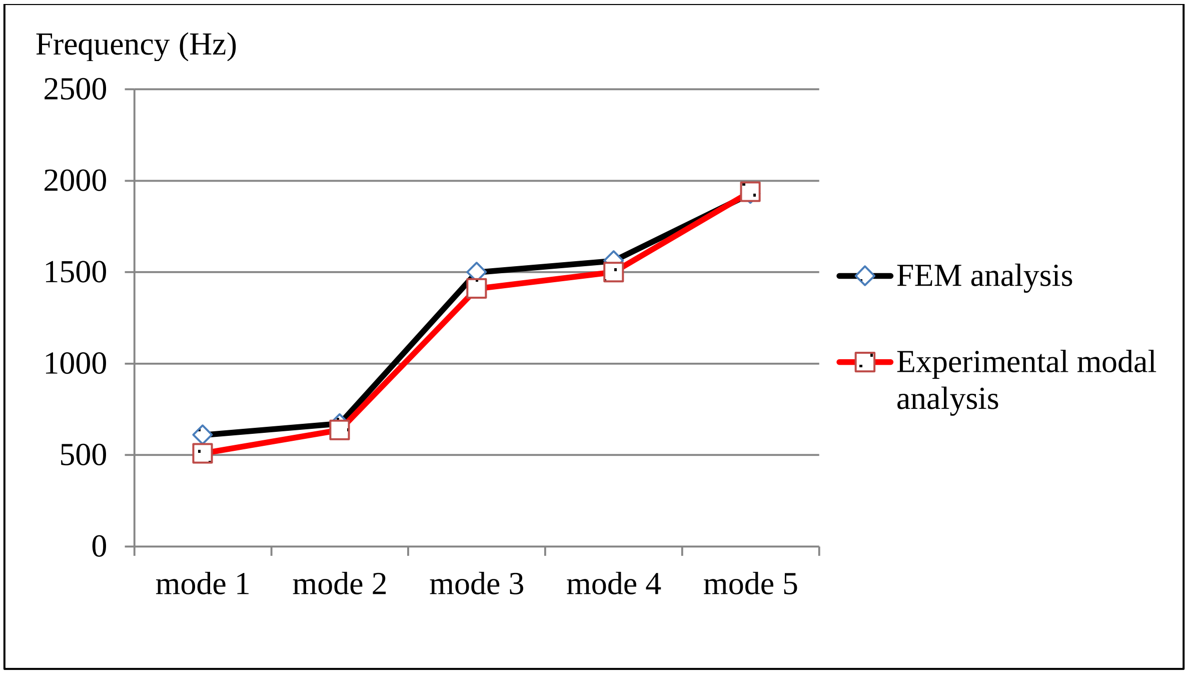


Figure 4.3: Graph comparison in natural frequency of aluminium 1100

Table 4.8 shows natural frequencies obtained from the finite element analysis and experimental modal analysis of the aluminium 6061. Based on the calculation of errors in percentage, mode shape 3 had the highest percentage error which is 6.44 % while mode 5 had the lowest percentage of error which is 1.67 %. As for Figure 4.4, the graph represents the comparison of error between the two results which is from the FEM analysis and also EMA.

Table 4.8: Comparison in natural frequency for aluminium 6061

Mode Shape	Finite Element Analysis	Experimental Modal Analysis	Error (%)
1	613	579	5.54
2	669	628	6.12
3	1475	1380	6.44
4	1558	1490	4.36
5	1912	1880	1.67

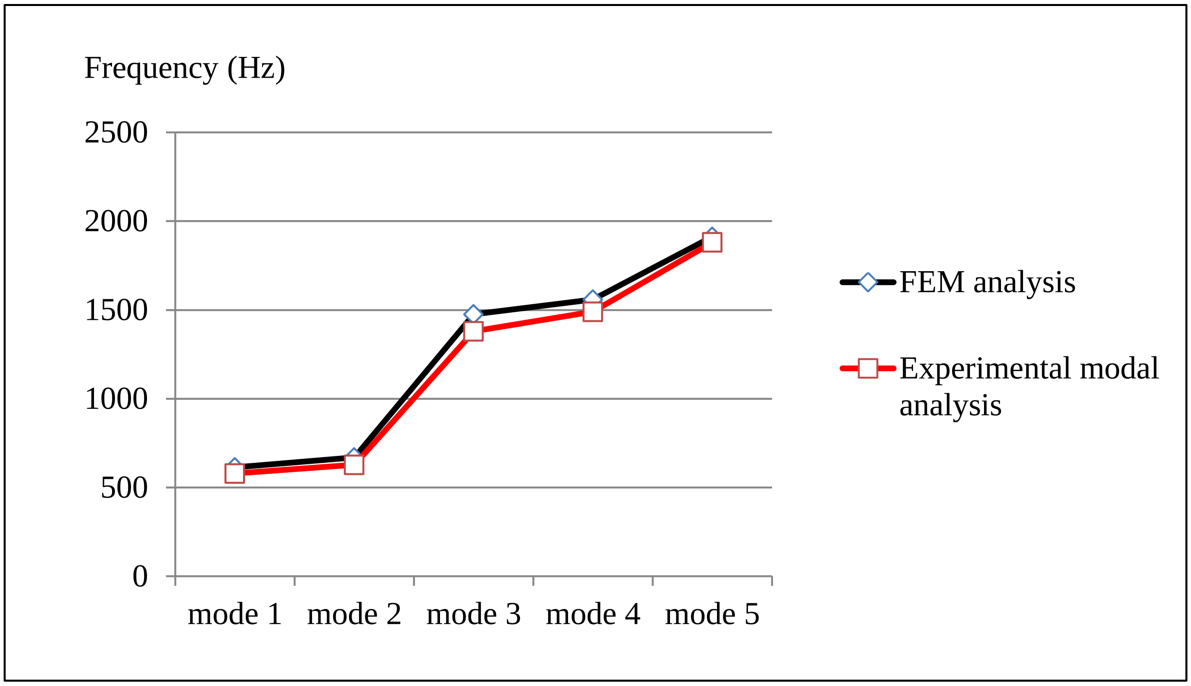


Figure 4.4: Graph comparison in natural frequency of aluminium 6061

Table 4.9 shows natural frequencies obtained from the finite element analysis and experimental modal analysis of the TIG welded aluminium plate 1100 and 6061. Based on the calculation of errors in percentage, mode shape 3 had the highest percentage error which is 9.05 % while mode 5 had the lowest percentage of error which is 2.53 %. As for Figure 4.5, the graph represents the comparison of error between the two results which is from the FEM analysis and also EMA.

Table 4.9: Comparison in natural frequency for welded aluminium 1100 and 6061

Mode Shape	**Finite Element Analysis**	**Experimental Modal Analysis**	**Error (%)**
1	816	760	6.86
2	836	796	4.78
3	1049	954	9.05
4	1178	1130	4.07
5	1857	1810	2.53

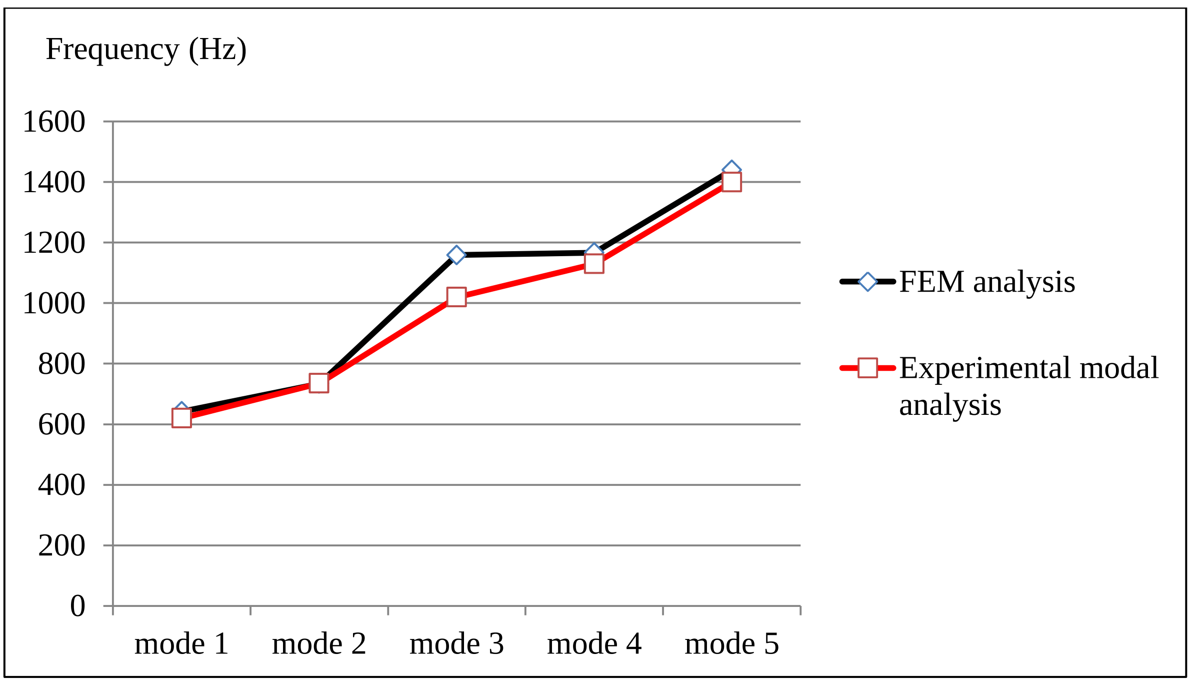


Figure 4.5: Graph comparison in natural frequency of welded aluminium 1100 and 6061

4.4 RESULT OF MODE SHAPES

Mode shapes were the deformation or patterns at any resonant frequencies. At these resonant frequencies there are a variety of different shapes depending on the excitation force frequency. These deformation patterns are referred to as the structure's mode shapes.

Modal analysis is done by using ALGOR finite element analysis (FEA) to determine the mode shape of the TIG welded aluminium plate 1100 and 606. From the natural frequencies each will represent different mode shapes. In this study, only five mode shapes were studied from the Algor software. After the meshing process is carried out in the software, the result of mode shapes for each natural frequency is recorded. The mode shape from FEA will then be compared the results of mode shape from the experimental modal analysis.

From the experimental modal analysis, a set data is collected during the impact hammer testing. The result of mode shapes can be obtained from the ME'scope software. The data from the DASYlab is collected and transferred to the ME'scope software. Then curve fitting process is carried out in order to get the mode shapes.

4.4.1 Comparison of Mode Shapes Between Finite Element Analysis (FEA) and Experimental Modal Analysis (EMA)

The results of mode shape from FEA and EMA were compared, and the comparison of mode shapes for the aluminium plate 1100, aluminium plate 6061 and also for the TIG welded aluminium plate 1100 and 6061 are shown in Table 4.10, Table 4.11 and Table 4.12 respectively.

Table 4.10 represent the comparison of mode shape for aluminium plate 1100. As shown in the table, the first bending deformation can be seen at the first mode shape. There is a bending deformation occur on the left side of the plate. The frequency for the first mode shape is 609 Hz and 509 Hz for the FEA and EMA result respectively. The maximum displacement for the plate is 255mm for the FEA and 123mm for the EMA. The second bending deformation can be seen in the second mode shape where the plate bend upwards, while the third bending deformation can be seen in the third mode shape where the plate bend downwards. The frequency for the second mode from the FEA and EMA results is 672 Hz and 637 Hz, while the maximum displacement is 187mm and 473mm respectively. The third mode shape occurs at the frequency of 1499 Hz from FEA and 1410 Hz from the EMA.

For the fourth and fifth mode shape, the deformation is twisting. The deformation for the fourth mode occurred at a frequency of 1562Hz for FEA and 1500 Hz for the EMA. The maximum displacement during the deformation is 295mm for the FEA and 197mm for the EMA. The deformation for the fifth mode occurred at the frequency of 1929 Hz and 1940 Hz for the FEA and EMA respectively. The maximum displacement during the deformation is 237mm for the FEA and 964mm for the EMA. Mode 3 and mode 5 did not show the same deformation pattern in both FEA and EMA.

Table 4.10: Comparison of mode shape for aluminium 1100

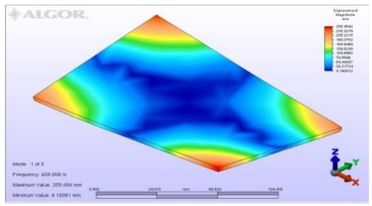
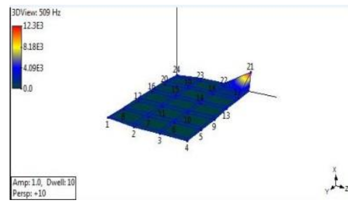
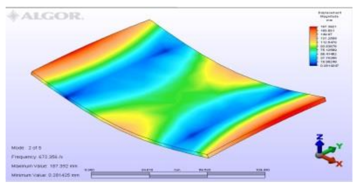
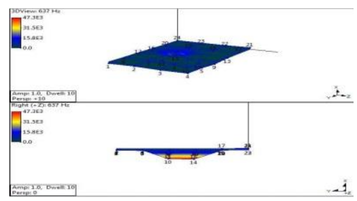
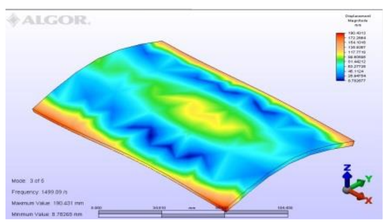
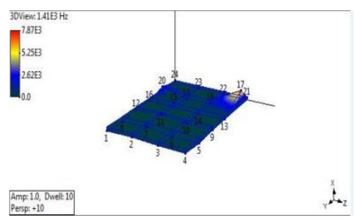
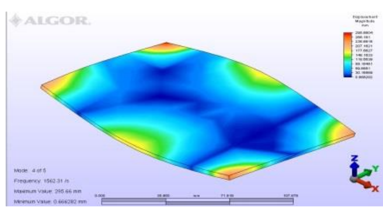
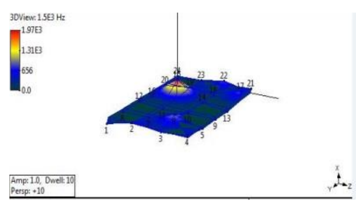
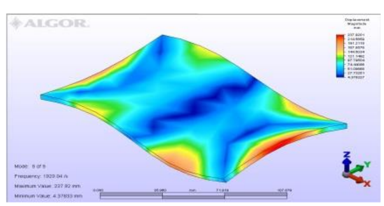
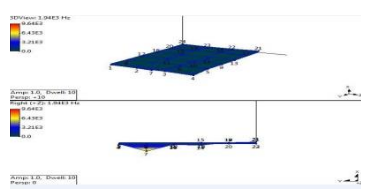
Mode Shape	**Finite Element Analysis**	**Experimental Modal Analysis**
1		
2		
3		
4		
5		

Table 4.11 represent the comparison of mode shape for aluminium 6061. As shown in the table, the first mode shape shows the first bending deformation of the plate. The frequency for the first mode shape is 613 Hz and 579 Hz for the FEA and EMA result respectively. The maximum displacement for the plate is 229.09 mm for the FEA and 146 mm for the EMA.

The second and third bending mode also represented by the second and third mode shape in the table which they bend upwards and downwards respectively. The frequency for the second mode from the FEA and EMA results is 669 Hz and 628 Hz, while the maximum displacement is 188.04mm and 228mm respectively. The third mode shape occurs at the frequency of 1475 Hz from FEA and 1380 Hz from the EMA.

For the fourth mode shape, the deformation is twisting. The deformation for the fourth mode occurred at the frequency of 1178 Hz for FEA and 1130 Hz for the EMA. The maximum displacement during the deformation is 296.73mm for the FEA and 940mm for the EMA. The deformation for the fifth mode is also a twisting deformation. The deformation occurred at the frequency of 1912 Hz and 1880 Hz for the FEA and EMA respectively. The maximum displacement during the deformation is 234.6mm for the FEA and 483mm for the EMA.

Table 4.11: Comparison of mode shapes for aluminium 6061

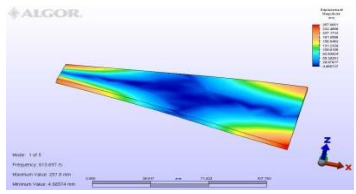
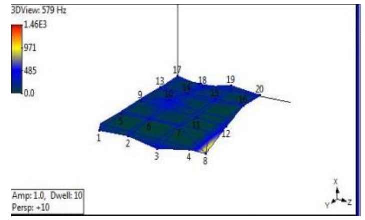
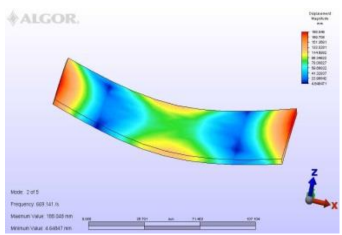
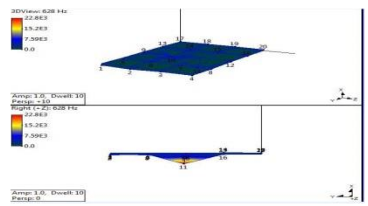
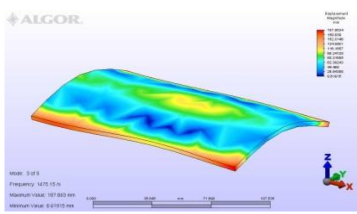
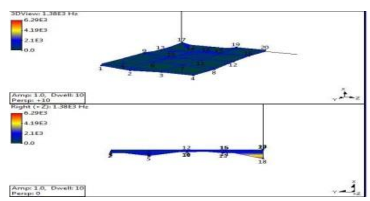
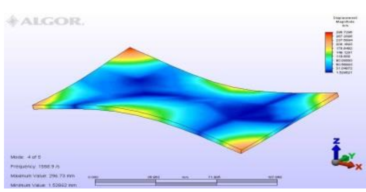
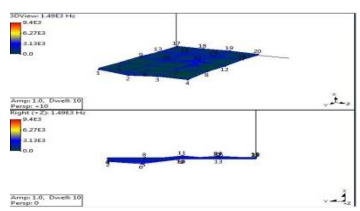
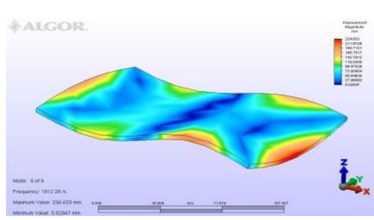
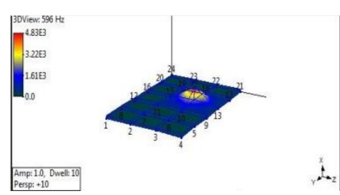
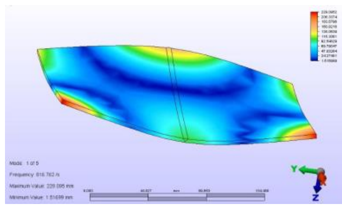
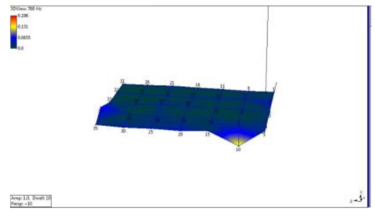
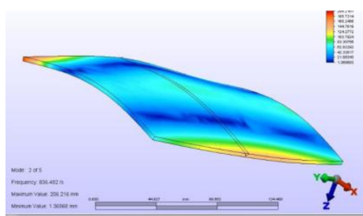
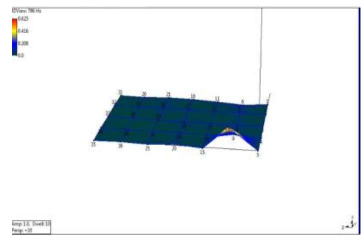
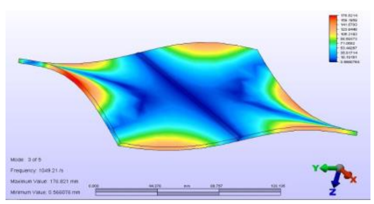
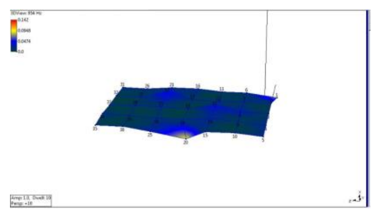
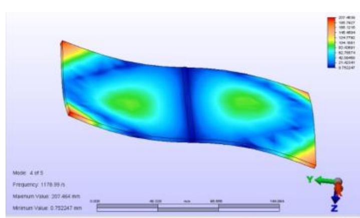
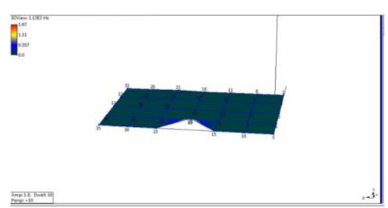
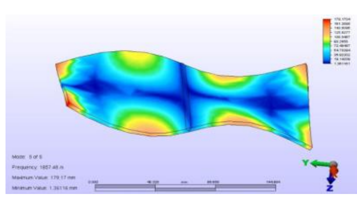
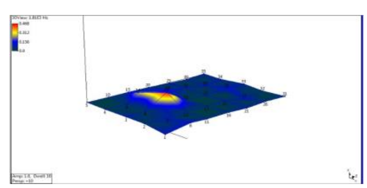
Finite Element Analysis	Experimental Modal Analysis
	
	
	
	
	

Table 4.12 represent the comparison of mode shape for the TIG welded aluminium 1100 and 6061. As shown in the table, the first mode shape shows the first bending deformation of the welded plate. The frequency for the first mode shape is 816 Hz and 760 Hz from the FEA and EMA result respectively. The maximum displacement for the plate is 257.80mm from the FEA result and 0.196 mm from the EMA result.

The second mode shape also represents the second bending deformation, which the welded plate bends upwards. The frequency for the second mode shape from the FEA and EMA results is 836 Hz and 796 Hz, while their maximum displacements is 206.21 mm and 0.625 mm respectively. The third mode shape represents the first twisting deformation which occurred at the frequency of 1049 Hz and 954 Hz from FEA result and EMA result respectively. Their maximum displacement is 176.82 mm from the FEA result and 0.142 mm from the EMA result.

The fourth mode shape shows the third bending deformation. The deformation for the fourth mode occurred at a frequency of 1558 Hz for FEA and 1490 Hz for the EMA. The maximum displacement during the deformation is 207.46 mm for the FEA and 1.67 mm for the EMA. The deformation for the fifth mode is also a twisting deformation. The deformation occurred at the frequency of 1857 Hz from the FEA result and 1810 Hz for the EMA result. The maximum displacement during the deformation is 179.17 mm for the FEA and 0.458 mm for the EMA.

Table 4.12: Comparison of mode shapes for welded aluminium 1100 and 6061

Mode Shape	Finite Element Analysis	Experimental Modal Analysis
1		
2		
3		
4		
5		

4.5 RESULT OF OPERATING DEFLECTION SHAPE ANALYSIS

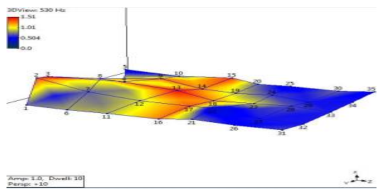
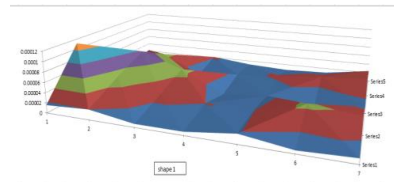
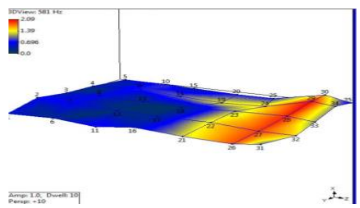
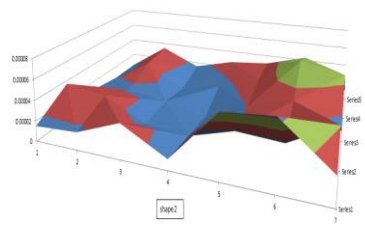
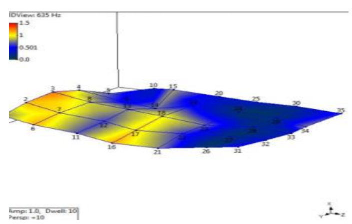
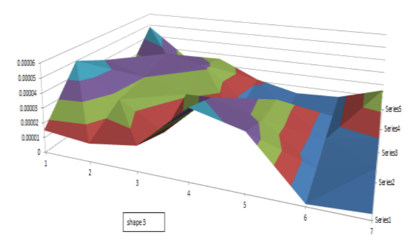
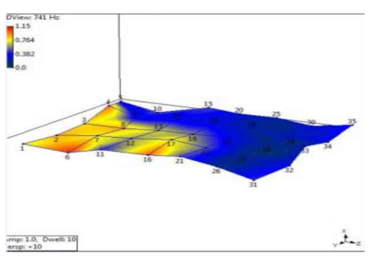
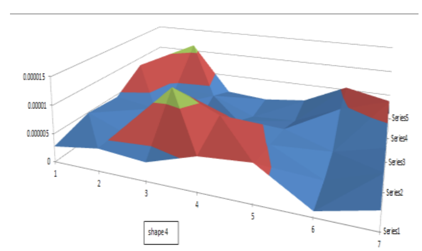
Operating Deflection shape analysis is done by using a motor with the speed of 3200 rpm and the data is collected in the DASYlab software to determine the mode shape of the TIG welded aluminium plate 1100 and 606. In this study, only four mode shapes were studied from the DASYlab software and the result of mode shapes for each operating frequency is analysed in the ME'scope software. Based on the result obtained, the dominant mode shape under given operating frequency is determined. The mode shape of the welded plate is determined by using ME'scope software and also by using Microsoft Excel software.

4.5.1 Result Of Mode Shapes From ME'scope Software And Microsoft Excel Software

The result from the ME'scope software is collected and transferred to Microsoft Excel software to calculate the response and mode shape of the welded aluminium plates. Table 14 shows the data that have been transferred to the Microsoft Excel software. From the collected data, the response of the welded aluminium plate is calculated and four mode shapes which are the response are then recorded and tabulated in Table 4.13. Based on the result of mode shapes from Table 4.13, the dominant mode shape is mode 2, with an operating frequency of 581 Hz and a maximum displacement of 2.09 mm.

From Table 4.13, the first mode shape shows the first deformation pattern an operating frequency of 530 Hz has the maximum displacement of 1.51 mm. the second mode shape shows the second deformation pattern and also the dominant mode, with an operating frequency of 581 Hz and a maximum displacement of 2.09mm. The third mode shape shows the third deformation pattern with an operating frequency of 635 Hz and a maximum deflection of 1.5mm. The last mode shape which is the fourth mode shape shows the fourth deformation pattern, with an operating frequency of 741 Hz and a maximum deflection of 1.15mm.

Table 4.13: result of mode shape from ODS analysis

	FROM ME SCOPE	FROM EXCEL
MODE 1: 530 Hz, max dis: 1.51mm		
MODE 2: 581 Hz, max dis: 2.09mm		
MODE 3: 635 Hz, max dis: 1.5mm		
MODE 4: 741 Hz, max dis: 1.15mm		

4.6 DISCUSSION OF COMPARISON

4.6.1 Differences in the Result Obtain From FEA and EMA

Based on the comparison result obtained from Finite Element Analysis and Experimental Modal Analysis, there are some differences can be seen in terms of natural frequency and mode shape of the aluminium plates. Differences that exist between the FEA model and EMA model have attributed to the error in the experimental data.

One of the reasons for the differences in the correlation of the result is because of the weight differences in the design model in the FEA and the real model for the EMA. Also in the ALGOR software, it is assumed that the stiffness for the joining plate is ideal, and then applied that rigidity joining plate during virtual model. The actual joining plate stiffness is different from this assumed stiffness, and it is actually not constant throughout the plate.

In a research project conducted by Koudri (2012), the boundary condition in the experiment must be considered in order to achieve correlation of the FEA and EMA results. The percentage of error form the correlation of the FEA and EMA results are mostly within the accepted range and the high error in some of them might be referred to the boundary condition specification, because it is not easy to simulate the realistic boundary condition and in his research, the boundary condition is a free-free boundary condition. It is impossible to imitate the perfect free boundary condition in the experiment.

Another reason that may be causing the high percentage error levels in the comparative study is because in the experimental modal analysis there is the effect of damping due to the test rig by using a sponge as a base of the plate while in simulation, the plate was free condition and no effect of damping. Since the condition is different, there will be a slight error in the result. While doing the experiment, the room is also not completely silent. Even though the room is soundproofed, but the door is left open and there will be noise come from the outside by accident and affect the result of the experiment.

4.6.2 Differences In The Result Of Before And After The Aluminium Plates Are Welded.

The purpose of studying the dynamic parameter of before and after the aluminium plates are welded is to identify the influence of the welding to the structure. Based on the result obtained, the dynamic parameters which are the natural frequencies and mode shapes are totally different. This is because of the influence of welding to the aluminium plates. In a research project conducted by Lebahn (2004), the pre-examinations has shown that the dynamic behavior of a welded structure is strongly influenced by residual stresses due to welding. In his research, welding stresses are measured to investigate their influence on the dynamic behavior of the welded structures. It was observed that the natural frequencies are shifted up to 50 % between a structure with residual stresses and the same structure stress relieved.

CHAPTER 5

CONCLUSION AND FUTURE REFERENCE

5.1 INRODUCTION

This chapter will conclude the project and briefly discussed about the recommendation that can be applied in the future work. The conclusion obtained according to the result from chapter 4.

5.2 CONCLUSION

The objective of this project is to determine the dynamic properties and behaviour of different type of TIG welded aluminium plate 1100 and 6061 by using experimental modal analysis and comparison with the finite element analysis (FEA).

The dynamic characteristic for the TIG welded aluminium 1100 and aluminium 6061 has been determined. Both analyses gave the natural frequency and mode shape of before and after the aluminium plates are welded. The comparison of natural frequency from both FEM and modal analysis shows almost the same result with an acceptable percentage of error.

The joining of aluminium plate 1100 and aluminium plate 6061 by using TIG welding process gave different dynamic properties to the structure. The welding process gave effect to dynamic properties which are the mode shape and natural frequency of the plates.

The objective of the Operating Deflection Shape is to analyse the vibration pattern of a structure under an operating conditions. From the ODS analysis, the dominant mode shape has been determine, which is mode 2 with an operating frequency of 581 Hz.

5.3 FUTURE RECOMMENDATION

There are few improvements need to be done for the future research. This is to improve the accuracy of the predicted dynamic properties of TIG welded aluminium 1100 and 6061. Some of the recommendations are:

i. The research is carried out in a completely soundproofed room and only the person doing the experiment is allowed to be in the room while doing the experiment.
ii. Use joining between aluminium 1100 and aluminium 6061 by metal inert gas (MIG) welding as model of modal analysis.
iii. Change filler wire aluminium 4043 two aluminium 5356

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APPENDIX

Table 1: Data collected from ME'scope software (ODS analysis)

	shape 1	shape2	shape3	shape4
1x	0.196	0.221	0.253	0.133
2x	1.39	0.545	0.839	0.235
3x	0.647	0.16	0.663	0.213
4x	0.164	0.0872	0.351	0.401
5x	0.281	0.0875	0.808	0.348
6x	0.251	0.254	0.2	0.189
7x	0.64	0.46	0.448	0.0836
8x	0.973	0.257	0.503	0.157
9x	0.576	0.448	0.628	0.205
10x	0.109	0.504	0.419	0.54
11x	0.082	0.504	0.277	0.154
12x	0.326	0.14	0.14	0.582
13x	0.588	0.168	0.356	0.0458
14x	0.0831	0.0816	0.537	0.174
15x	0.267	0.226	0.433	0.0529
16x	0.0844	0.153	0.761	0.28
17x	0.252	0.0825	0.628	0.403
18x	0.0269	0.0215	0.215	0.161
19x	0.189	0.226	0.0976	0.0145
20x	0.14	0.392	0.192	0.0219
21x	0.23	0.884	0.617	0.31
22x	0.243	0.278	0.465	0.224
23x	0.142	0.303	0.449	0.153
24x	0.277	0.417	0.0452	0.0361
25x	0.0851	0.453	0.0677	0.0689
26x	0.0741	0.943	0.0253	0.0471
27x	0.558	0.238	0.0385	0.0132
28x	0.0226	0.492	0.0644	0.0199
29x	0.384	0.83	0.0786	0.217
30x	0.128	0.641	0.0923	0.263
31x	0.124	0.385	0.0607	0.149
32x	0.443	0.6	0.158	0.156
33x	0.174	0.162	0.165	0.127
34x	0.464	0.692	0.486	0.351
35x	0.3	0.148	0.236	0.0445

Table 1: Respond, X fro each points on the plate (ODS analysis)

Mode 1	Mode 2	Mode 3	Mode 4
1.56965E-05	1.49116E-05	1.51146E-05	2.77856E-06
0.000111317	3.67729E-05	5.01233E-05	4.90949E-06
5.18145E-05	1.07957E-05	3.96087E-05	4.44988E-06
1.31338E-05	5.88366E-06	2.09693E-05	8.37748E-06
2.25037E-05	5.90391E-06	4.82713E-05	7.27023E-06
2.01011E-05	1.71382E-05	1.19483E-05	3.94849E-06
5.12539E-05	3.10377E-05	2.67643E-05	1.74653E-06
7.7922E-05	1.73406E-05	3.00501E-05	3.27996E-06
4.61285E-05	3.0228E-05	3.75178E-05	4.28275E-06
8.72918E-06	3.40065E-05	2.50318E-05	1.12814E-05
6.56691E-06	3.40065E-05	1.65484E-05	3.21729E-06
2.61075E-05	9.44625E-06	8.36384E-06	1.21588E-05
4.70895E-05	1.13355E-05	2.1268E-05	9.56829E-07
6.655E-06	5.50581E-06	3.20813E-05	3.63511E-06
2.13825E-05	1.52489E-05	2.58682E-05	1.10516E-06
6.75911E-06	1.03234E-05	4.54634E-05	5.84961E-06
2.01812E-05	5.56654E-06	3.75178E-05	8.41926E-06
2.15427E-06	1.45067E-06	1.28445E-05	3.36353E-06
1.51359E-05	1.52489E-05	5.83079E-06	3.02926E-07
1.12118E-05	2.64495E-05	1.14704E-05	4.57523E-07
1.84194E-05	5.96463E-05	3.68606E-05	6.47635E-06
1.94605E-05	1.87575E-05	2.77799E-05	4.67969E-06
1.1372E-05	2.04444E-05	2.6824E-05	3.19639E-06
2.21833E-05	2.81363E-05	2.70032E-06	7.54182E-07
6.81517E-06	3.05654E-05	4.04451E-06	1.43942E-06
5.93424E-06	6.36272E-05	1.51146E-06	9.83988E-07
4.4687E-05	1.60586E-05	2.30006E-06	2.75767E-07
1.8099E-06	3.31968E-05	3.84737E-06	4.1574E-07
3.07523E-05	5.60028E-05	4.6957E-06	4.53345E-06
1.02508E-05	4.32503E-05	5.51416E-06	5.49446E-06
9.93044E-06	2.59772E-05	3.62632E-06	3.11283E-06
3.54773E-05	4.04839E-05	9.43919E-06	3.25907E-06
1.39347E-05	1.09307E-05	9.85738E-06	2.65322E-06
3.71591E-05	4.66915E-05	2.90345E-05	7.3329E-06
2.40253E-05	9.98603E-06	1.4099E-05	9.2967E-07