UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DYNAMIC FATIGUE ANALYSIS FOR SPOT WELDED JOINT BASED ON NATURAL FREQUENCY DUE TO CYCLING LOADING

This report is submitted in accordance with the requirement of Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Manufacturing Engineering Technology (Process and Technology) with Honours.

by

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2016

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **Dynamic Fatigue Analysis for Spot Welded Joint Based On Natural Frequency Due to Cycling Loading**

SESI PENGAJIAN: **2015/16 Semester 2**

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfilment of the requirements for degree of Bachelor's Degree in Manufacturing Engineering Technology (Process and Technology) with Honours. The member of the supervisory is as follow:

………………………………………………

(Mr Mohammad Khalid Bin Wahid)

ABSTRAK

Analisis keletihan dinamik untuk tempat dikimpal bersama berdasarkan kekerapan semula jadi akibat kitaran adalah satu kajian tentang gabungan bahan menggunakan mesin kimpalan rintangan setempat dan telah menguji menggunakan ‘TM16 Universal Vibrational Apparatus’ yang merupakan mesin getaran. Punca keletihan terjadi apabila daya di mana digunakan pada bahan yang digabung. Masalahnya adalah untuk mengetahui apabila bahan digabung telah dikenakan tekanan, kekuatan pada tempat kimpalan sama ada boleh menahan daya dan lingkungan hidup getaran keletihan. Getaran ini akan menjadi hasil frekuensi semula jadi. Ini adalah sangat penting untuk mengetahui sama ada ia selamat untuk menggunakan penggabungan jenis ini terhadap bahan yang digunakan. Fokus kajian ini adalah untuk menggunakan ketebalan yang berbeza dan jenis bahan. Aluminium dan besi tergalvani dengan ketebalan 0.5mm dan 1mm setiap satu telah digunakan dalam eksperimen ini. Parameter mesin kimpalan tempat telah ditetapkan untuk setiap spesimen. Hasil frekuensi asli dan bacaan amplitud yang diperolehi daripada kajian ini telah diplotkan untuk setiap spesimen. Hasil kajian menunjukkan bahawa gabungan aluminium mempunyai lebih puncak amplitud daripada gabungan besi tergalvani. Hasil untuk gabungan aluminium untuk 1mm adalah 0.4mm puncak amplitud dan frekuensi semula jadi adalah 20.75Hz, 21.92Hz, 22.65Hz, 55.65Hz, 70.38Hz dan 80.79Hz. Hasil besi tergalvani adalah 0.4mm puncak amplitud dan frekuensi semula jadi adalah 180,55. Ini berlaku kerana aluminium mempunyai keadaan yang paling bergetar. Untuk gabungan ketebalan bahan berbeza 1mm setiap satu menunjukkan peningkatan pada kadar keadaan getaran dengan amplitud 0.4mm puncak dan frekuensi semula jadi adalah 75.65Hz. Ini menunjukkan bahawa penggabungan besi tergalvani adalah lebih baik dan bahan yang kuat daripada aluminium.

ABSTRACT

The dynamic fatigue analysis for spot welded joint based on natural frequency due to cycling loading is a study about the joining of material using resistance spot welding and been testing using TM16 Universal Vibration Apparatus which is vibration machine. The fatigue cause when the force where applied on the joined material. The problem is to know when the joined material were applied force, the strength on the weld nugget whether can withstand the force and the range of vibrations fatigue life. The vibrational will be result by its natural frequency. This is very important to know either it is safe to use this kind of joining on the material use. The focuses of this study is on using a different thickness and type of material. The aluminium and galvanized iron with thickness 0.5mm and 1mm each were applied in this experiment. The parameter of spot welding machine was set for each of the specimen. The result which is the natural frequency and amplitude reading obtained from the experiment were plotted for each specimen. The result shows that the aluminium joining has more amplitude peak than the galvanized iron joining. The result for aluminium joining for 1mm is 0.4mm peak amplitude and natural frequency is 20.75Hz, 21.92Hz, 22.65Hz, 55.65Hz, 70.38Hz and 80.79Hz. The galvanized iron result is 0.4mm peak amplitude and natural frequency is 180.55. This happen because the aluminium has a most vibrate condition. For joining dissimilar material thickness 1mm each shows the improvement on rate of vibration condition with 0.4mm peak amplitude and natural frequency is 75.65Hz. Its shows that the joining of galvanized iron are better and strong material than aluminium.

DEDICATION

To my beloved parent

Mr Mat Hassan Bin Saat & Mrs Rahimah Binti Harun

Thank you for support and believe

All the lecturers especially Mr. Mohammad Khalid Bin Wahid

All my friends and relative

Thousands of thanks and appreciate for your guidance, support, encouragement and understanding

ACKNOWLEDGEMENT

Bismillah ir-Rahman ir-Rahim,

Alhamdulillah thank to Allah SWT the Most Gracious and the most Merciful for His grace and permission to finish my Final Year Project successfully as required for fulfilment in my study of Bachelor's Degree in .Manufacturing Engineering Technology (Process and Technology) with Honours at Universiti Teknikal Malaysia Melaka (UTeM).

I would like to convey my thanks to Mr. Mohammad Khalid Bin Wahid for your guidance and advice that you gave to me throughout this Final Year Project and my studies. All knowledge and personality that you shows toward me will always been an inspiration and be a guideline for future life.

For my fellow classmate, lecturers and staff of Faculty of Engineering Technology that always support and give opinion for me to complete my Final Year Project, I would like to express my thanks to you all. Last but not least, thank to my parents and family for your support and always believe in me to complete this project. Thank you.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

SMAW	-	Shielded Metal Arc Welding
GTAW	-	Gas Tungsten Arc Welding
RSW	-	Resistance Spot Welding
RSEW	-	Resistance Seam Welding
ROW	-	Roll Welding
FRW	-	Friction Welding
mm	-	milimeter
kN	-	kilo Newton
N	-	Number of Cycle
MPa	-	Mega Pascal
kA	-	kilo Ampere
ms	-	millisecond
ω	-	Angular Frequency
f	-	Frequency
Hz	-	Hertz
rpm	-	rev per minutes

CHAPTER 1

INTRODUCTION

1.0 Introduction

Spot welding is a process of joining together two flat metal by using electric current through them. The electrodes were used to flow the electric current then the weld nugget will be created. The machine is widely used in automobiles industry. The strength of the spot weld is important to ensure the design of the automobile in perspective of safety and endurance. The mixture of stress lead high forces may cause the crack and fatigue failure on the weld nugget.

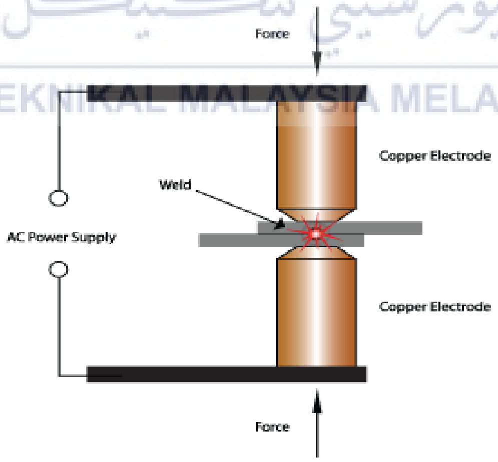

Figure 1.1: Spot weld process

(Sources: Spot Welding Services, 2016. Available: http://www.vista-industrial.com)

Fatigue known as a weakening of material because of the load or forces is applied on it. The loads or forces is applied at the material or specimens and will caused damage towards the mechanical properties of the material. The intensity of the forces under normal power and the imposition of a state alternately repeated will cause occurrence of fatigue failure. The failure of the material to resist stresses will cause the occurrence of fatigue cracks occur subsequent failure.

The frequency occurs when a vibration take places on the objects or materials. The system oscillates and the wave is form as a result of the object is known as natural frequency. The natural frequency were used to determine the result of the fatigue failure of the material through the vibration testing. The motive of this project is to find the fatigue failure based on the natural frequency test through vibration. It is also to know about fatigue in material combination and thickness when applying spot welding technique.

1.1 Problem Statement

The strength of the spot welded joint should be taken care to ensure the endurance of the part. The fatigue cause when the force where applied on the joined material. The problem is to know when the joined material were applied force, the strength on the weld nugget whether can withstand the force and the range of vibrations fatigue life.

Besides, the effect of the joining with different material and thickness also influence to support the vibrational condition. The vibrational will be result by its natural frequency. This is very important to know either it is safe to use this kind of joining on the material use.

1.2 Objective

The objective of this project are:

1. To compare the fatigue failure on the spot welded joint based on vibration analysis with conventional fatigue test.
2. To find natural frequency of spot welded joint.

1.3 Scope

The scope to be considered:

1. Type of joining material (galvanized iron and aluminium)
2. Thickness of joining materials
3. Vibration machine

1.4 Planning Flow Chart

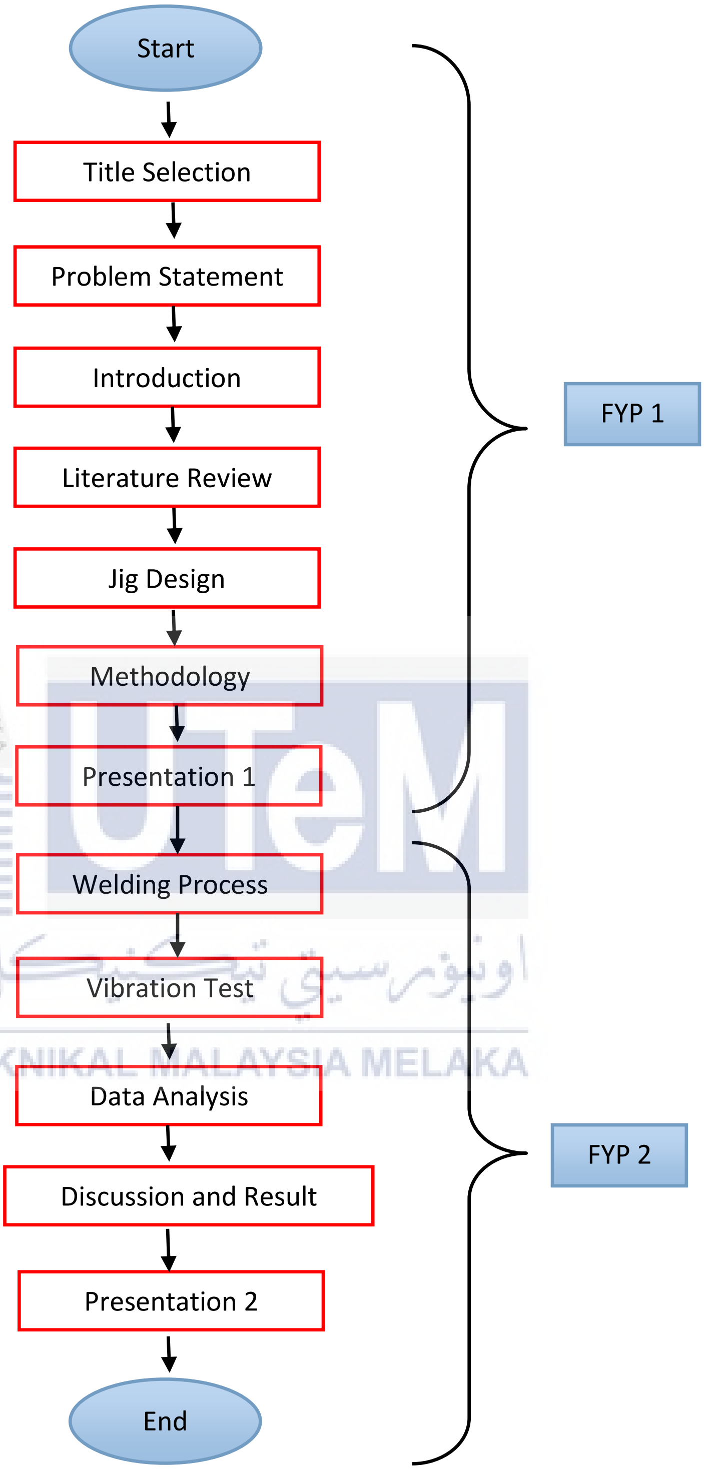

Figure 1.2: Flowchart

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

The research study need to be done is to gain information from the previous research that might help and use while conducting own study. This research need to focus on problem, idea and methodology. The previous research may help to improve the procedure and methodology on how this study should be done. The previous study also add some knowledge from its theoretical findings or by experiment researches.

2.1 Welding

2.1.1 Introduction

Welding can be defined as the ability to make durable and strong connections between materials. This fabrication process using heat, supplied by electrical or high energy to gain enough pressure and force for melting and coalescing materials. The materials are heated until reached its melting point, then it’s made a separate pieces of materials joined and combined together. The welding also can join metals or non-metals materials following the methods used.

2.1.2 Joining Process

Types of welding:

1. Electrical Arc Welding (SMAW, GTAW)
2. Resistance Welding (RSW, RSEW)
3. Brazing
4. Soldering
5. Thermal Welding (Gas , Thermite Welding)
6. Solid State Welding (ROW, FRW)

This type of welding need to be considered by both engineer and welder before the process or jobs takes place. Most of the welding process required a high degree of skill and technology. There are few things need to considered before choosing a process. First, the equipment and its quality. The equipment with a better quality is a very important factors to do a welding process to ensure the best result. Besides, the material also one of the factors. While choosing the process, the materials must meet the criteria that fulfill the process scope. Other than that, cost of materials. The cost must be reduced but it must be a quality types.

2.1.3 Safety

Safety must be considered by one of the important factors when conducting a welding process. Sign like 'Safety First' always be shown at the workplace. The workers or welder must obeyed the sign to make them safety. The first factor is the surroundings. When doing a welding, the surroundings must be comfortable to the welder. The ventilation system must be use to absorb smoke or dangerous air contaminants to prevent to welder from breathe the dangerous air.

Figure 2.1: Ventilation system

Other than that, the arc rays are dangerous to eyes and skin. So, eye protection must be wear to prevent the radiation exposure. The radiation can cause retinal burning and will interfere the vision. Eye protection such as goggles and face shield should be use to give better protection. The eye shield with special tinted can prevent the damage of the eye.

2.1.4 Welding Application

Welding is one of the largest fields that are widely used by the industries. With the modern technologies, there are many products or application that can be made. Ships, cars, and offshore mostly made and fabricated by welding. With new technologies, welding often to manufacture new product.

Welding also being used to manufacture domestic hardware, computer component, building construction, oil and gas piping system, medical instruments and other products. There's a lot of demand of welding technology in aerospace industry, electrical and electronic industry and automotive industry.

2.2 Material

2.2.1 Galvanized Iron

Galvanized iron forms by metallurgical bond between zinc and steel or iron, prevent itself from rusty. There is no effect on tensile, impact or bend properties when been manufactured and inspected. Only certain properties were effected when the steel had been cold worked prior to galvanizing.

The ductile properties can be lose and become embrittled cause by galvanizing and similar process. The cold working (punching, shearing and bending) may extent the embrittlement. The extent of embrittlement depends on the amount of strain, time at ageing temperature, and steel composition, particularly nitrogen content (useful in limiting the effects of strain ageing).

Other than that, the fatigue strength of the steels is not badly affected by galvanizing. The effect of galvanizing can be ignored based on the fatigue strength of welds. It is reduced by the presence of notches and weld beads, ignoring the effects of process involving a heating cycle.

2.2.2 Aluminium 1050A

Aluminium is most widely used material after iron. The properties of aluminium includes: low density (one third that of steel (2,700 kg/m^3) and copper) and lightweight, high strength, soft and malleable, non-toxic, has a high thermal conductivity, has excellent corrosion resistance and can be easily cast, machined and formed. It is also non-magnetic and non-sparking. (www.aluminumdesign.net)

Aluminium can be severely deformed without failure. This allows aluminium to be formed by rolling, drawing, machining and other mechanical processes. It can also be cast to a high tolerance. The tensile strength of aluminium 1050A is around 105MPa – 145MPa (Aalco Metals Ltd, 2016) but for some heat-treatable alloys this can be increased to over 690 MPa.

Aluminium naturally generating a protective oxide coating, aluminium is particularly useful for protection and conservation. It will not exposed to rusting. Aluminium also a good conductor of heat and electricity. Aluminium can be recycle with no deterioration in quality. It releasing no taste or toxins.

2.3 Resistance Spot Welding (RSW)

The resistance spot welding (RSW) applied the forces to surfaces which the heat is produced by the flow of electric current through electric resistance to these surfaces. The electrodes which produced the heat formed a weld nugget in the plates or workpiece then a structure of joining was created. The nugget can be seen but the process to create it is invisible to saw.

This welding process is very complicated as it involves interaction of electrical, thermal and mechanical phenomena. The nugget formed in workpiece plays a crucial role in joining structure. As the nugget of spot welding is enclosed in joining structure, the process of nugget growth is invisible and difficult to test. (Luo et al., 2016)

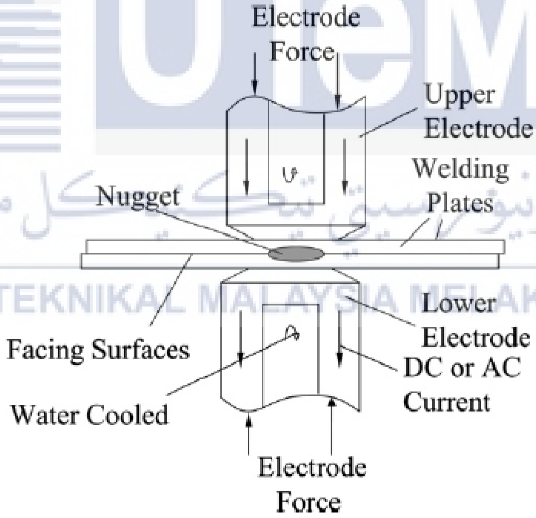

Figure 2.2: Spot welding system (Zhao et al., 2013)

There were a sequence of event that happen in this process. There are:

1. The squeeze time

   This is the time that the workpiece is clamp and the electrode was align with the pressure ready to applied.

2. The weld time

   The current flow from the electrodes through the workpiece and generate heat.

3. The hold time

   The pressure is maintained without the presence of electric current.

4. The off time

   The electrode were lift up and the pressure is off.

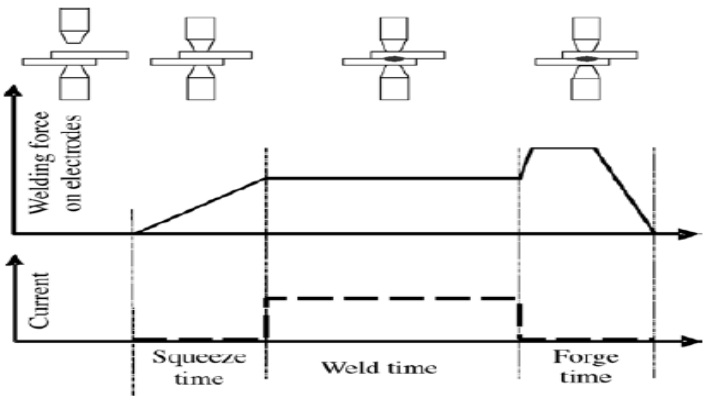

Figure 2.3: Spot weld cycle (Pereira et al., 2010)

In both automotive production and crash repair, resistance spot welding is the primary process for joining thin sheet steel. Resistance spot welding is a very fast and reliable process that is readily automated and does not require much operator skill. The greatest technical requirement of resistance spot welding is to ensure that the process is correctly set-up in the first instance. Because of its simplicity, resistance spot welding is influenced by many factors, characteristics of the machine and geometry of the component and there is no universal parameters needs to apply to make a combination.

If the thickness of the elements and/or the thermal conductivity of the materials are different, the distribution of the current and of heat build up may be non-symmetric, causing the nugget to be lop-sided and possibly unacceptable. Unequal thickness of the workpiece are spot welded together may become unbalance heating and cause physical, mechanical and metallurgical issues. Thickness 6mm for uncoated steel and 4mm for coated steels is better to producing a joint of resistance spot welding.

The methods of resistance spot welding low initial cost and adaptability for automation in high-rate production of sheet metal assemblies. There are famous in making the sheet joints. However, the resistance is a highly temperature dependent variable and will change significantly during weld process. It can be noted that the resistivity of both aluminium and galvanized steel is larger than copper electrodes. Thus, the heat generated in the work piece is greater than that in the electrodes, which enables welding.

Resistance welding is a useful way for joining galvanized steel sheets. The zinc coating layer stays in place when the electrode contact point touched the edge of the weld between the contact surfaces when making lap joints. It is better than other welding technique because using others technique will make the zinc layer melts and directed away from the weld.

Resistance spot welding is used to join two or more metal sheets together for examples, automotive industry. The fact that, in the European vehicle industry alone, more than 100 million spot welding joints are made daily tells something about the popularity of the method. (TWI World Centre for Materials Joining Technology, 2003) The spot welded joined quality is defined by the diameter of welding spot. The diameters can be monitored by using destructive and ultrasonic testing. In destructive testing, the joint is torn apart and the diameters of the spot are inspected. In ultrasound testing, the diameters are estimated by using additional sensors. (Laurinen et al.)

2.3.1 Parameter

a. Electrode force

Requires large force to get better weld quality. The force must not large because it will cause spatter between electrode and sheet and cause electrode to stick to the sheet.

If the force is too big, the electrical resistance will decrease at the contact surface and decreasing heat generation and not melting enough material. It also cause conduction heat away from the weld area, which is undesirable for nugget formation. (Oscar Andersson, 2013)

b. Squeeze time and hold time

Squeeze time is the time that the electrode force adjusting to desired level. The hold time is after the welding, the electrode still on the workpiece to allow solidification to the weld nugget.

c. Weld current and weld time

Too low current will not provide sufficient heat to create a nugget while too high current will result in expulsion and even temperatures above the boiling point. (Oscar Andersson, 2013)

Welding time the period which welding current is applied on workpiece. Shorter weld time would be better. The diameter of weld nugget also depends on weld time.

Sheet thickness, t [mm]	Electrode force, F [kN]	Weld current, I [A]	Weld time [cycles]	Hold time [cycles]	Electrode diameter, d [mm]
0.63 + 0.63	2.00	8 500	6	1	6
0.71 + 0.71	2.12	8 750	7	1	6
0.80 + 0.80	2.24	9 000	8	2	6
0.90 + 0.90	2.36	9 250	9	2	6
1.00 + 1.00	2.50	9 500	10	2	6
1.12 + 1.12	2.80	9 750	11	2	6
1.25 + 1.25	3.15	10 000	13	3	6 7
1.40 + 1.40	3.55	10 300	14	3	6 7
1.50 + 1.50	3.65	10 450	15	3	6 7
1.60 + 1.60	4.00	10 600	16	3	6 7
1.80 + 1.80	4.50	10 900	18	3	6 7
2.00 + 2.00	5.00	11 200	3x7+2	4	7 8
2.24 + 2.24	5.30	11 500	3x8+2	4	7 8
2.50 + 2.50	5.60	11 800	3x9+3	5	8
2.80 + 2.80	6.00	12 200	4x8+2	6	8
3.00 + 3.00	6.15	12 350	4x9+2	6	8
3.15 + 3.15	6.30	12 500	4x9+2	6	8

Figure 2.4: Welding parameter

(Sources: Spot Welding Parameter. Available: http://www.robot-welding.com)

2.4 Fatigue Testing

There are several ways to measures the quality of the product which is physical, mechanical properties and fatigue failure. Fatigue testing are done to investigate the fatigue life of the workpiece. It also a method that determine the behaviour of materials that react under certain load or force. In the industry, to guarantee durability of the product design, it is necessary to measure the fatigue life.

When the cyclic loads applied for a long time, with the damage force in each cycle that gathered in the structure until reached it fatigue point, than the fatigue failure happens. Česnik and Slavič, (2014) *s*tate that "The fatigue failure can occur even if the structure is loaded with a low-amplitude cyclic loads when the load is applied for a longer period of time. Each cycle represents a certain amount of fatigue damage that is being accumulated by the structure; when the accumulated fatigue damage at the given point on the structure reaches a certain value (usually defined as unity), the fatigue failure occurs."

There are stages in fatigue failure which is initiation, propagation and final rapture. Initiation happen when repetitive shear stresses acted and caused the change which is irreversible in the metal. There are several factors that can affect the pressure resulting in failure of which the part geometry, stress and the environment.

Next stage is propagation. The crack changes its direction and perpendicularly flourish to tensile stress. There are the easiest spot to fatigue fracture. The last stage is final rupture. The cross-sectional area decreased to a small area and weakens the part then occur the complete fracture. The complete fracture depends on the part itself which is ductile or brittle. (Stage of Fatigue Failure, 2016, https://www.tec-eurolab.com/eu-en/stages-of-fatigue-failure.aspx)

Thickness of specimen (mm)	Shear Force, F (kN)	Number of Cycle, N	Fatigue Stress, S (MPa)
0.5 and 0.5	0.62	500	16.58
1 and 1	0.20	61	6.22
1 and 0.5	0.1	58	2.71

Table 2.1: Comparison result for aluminium (Mohd Nabil Bin Mohd Sufian, 2016)

Thickness of specimen (mm)	Shear Force, F (kN)	Number of Cycle, N	Fatigue Stress, S (MPa)
0.5 and 0.5	0.4	46	9.25
1 and 1	2.50	1500	57.8
1 and 0.5	0.1	8409	2.28

Table 2.2: Comparison result for galvanized iron (Mohd Nabil Bin Mohd Sufian, 2016)

The data shows the fatigue stress that occurs when joining a similar material with different thickness. Joining the different thickness had been prove that it was easy to failure and it effect the strength of spot welded joint. Every material has it fatigue limit. (Mohd Nabil Bin Mohd Sufian, 2016)

2.5 Vibration Fatigue

The vibrational fatigue occurs when it meet the factors such as natural frequency changes and also damping loss and lead to varying amplitude of stress load cycle. Česnik et al., (2012) stated that the vibrational test based on specimen dynamic response. The natural frequency were used to determine the fatigue failure of specimens. Changes in natural frequency of the specimen also change the actual load stress from its desired load stress. Fatigue damage to spot-welded joints may result in the degradation of structural and noise performance under dynamic loading conditions. (Shang et al., 2003)

The object that is not disturbed by external forces and it vibrates in a certain rate known as natural frequency. Natural frequency is a system where the number of times of oscillations during the transition from the original position until the displaced position. If an object is forced at its natural frequency, resonance will occur and large amplitude vibrations will be observe. Resonance is vibrating system responds with maximum amplitude to a force. Resonance occurs when value of force is same with one of natural frequencies.

The incident of Tacoma Narrows Bridge which collapse in 1940 also been linked with the vibration fatigue and natural frequency. The theory from the investigation found that the bridge bears with the forces (wind velocity) than cause the vibration on the material of the bridge. The force were applied at a natural frequency of the bridge. The amplitude increased and cannot withstand the force when it meets the resonance frequency, so the bridge collapsed. (Fuller, 2000)

In this project, fatigue testing based on natural frequency have been chosen to test the joining of spot welded joint. The automotive industries uses the spot welded joint to make part body. The natural frequencies for an automotive body are likely within the frequency range of the dynamic load that originates from load surfaces. (Han et al., 2013) The damage of spot welded joint or crack growth make changes in frequency response of structure.

The factor that need to be considered on welding dissimilar material is material properties. The heat transfer were influenced by thermal conductivity and heat capacity. Besides, hardness of material influence the contact resistance. Other than that, geometry and dimensions of electrode and workpiece. The distribution of the current density were influenced by this geometry and dimensions. (Soundarrajan et al., 2015)

CHAPTER 3

METHODOLOGY

3.0 Introduction

The process of this project will be present in this chapter. The sequence of overall process from the beginning until the last process are shown in the flowchart. The flowchart were used as a guidelines to conduct the project smoothly.

3.1 Flowchart

Flowchart were used to show the processing method. It is the references in completing the project. If the problem occurs while doing the project, the flow chart also can be used as a guideline to finish the project.

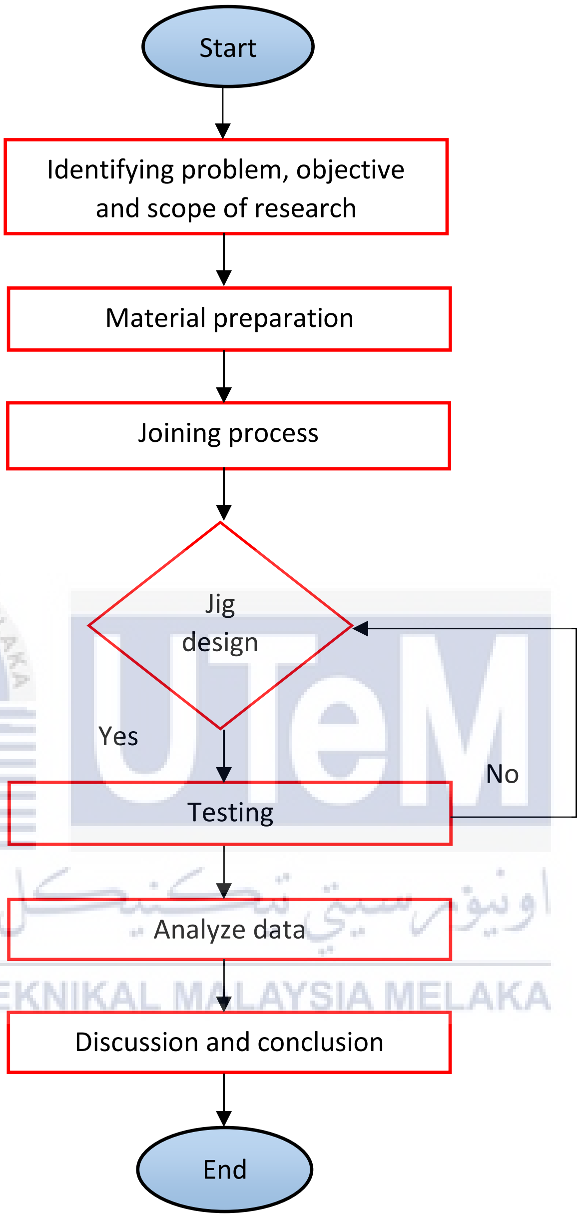

Figure 3.1: Flowchart

3.2 Material Preparation

Aluminium and galvanized iron are the two type of material that been used in this project. This material are suitable for resistance spot welding joining. The thickness of the material are 0.5mm and 1mm.

3.2.1 Cutting Material

To cut the material, the shear machine is use followed by its suitable dimension. The shape are followed by the joining technique which is lap joint. The foot shear machine use to cut the material because it suitable with the thickness.

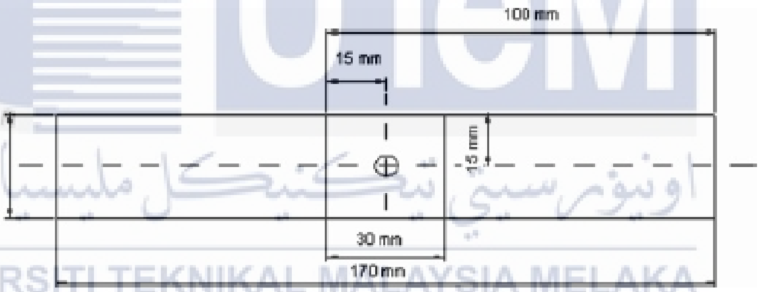

Figure 3.2: Specimens dimension (Aslanlar et al., 2007)

Figure 3.3: Foot shear machine

3.3 Joining Process

Resistance spot welding were used to join the material together. The parameter use must suitable with the type of material. Different thickness of material which is for aluminium joint and galvanized iron joint are 1mm and 0.5mm. Other than that, for aluminium-galvanized iron joint is 1mm thickness.

The material which is lap joint were clamp at the electrode. The set up current flow from electrode through the specimen. The diameter of electrode influence the current flow. The weld nugget formed and hold time take place. The electrode than release itself after finish.

Material	Thickness (mm)	Welding Current (kA)	Welding Time (ms)
Galvanized Iron	0.5 + 0.5	8.0	300
	1 + 1	9.0	500
	1 + 0.5	8.5	340
Aluminium	0.5 + 0.5	8.0	280
	1 + 1	9.0	480
	1 + 0.5	8.5	320
Aluminium + Galvanized Iron	1 + 1	9.0	500

Table 3.1: Spot weld parameter

Figure 3.4: Inventor AS-25 Resistance Spot Welding

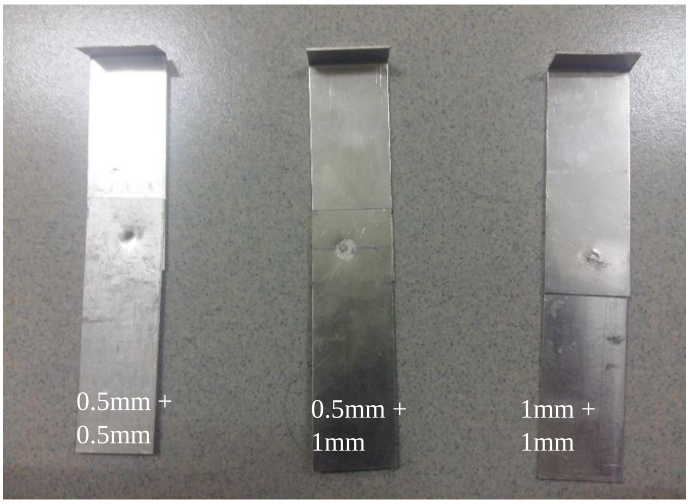

Figure 3.5: Aluminium joint

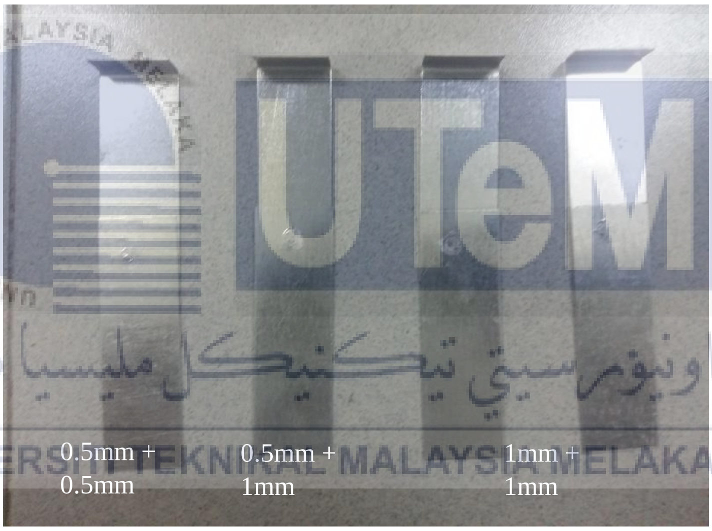

Figure 3.6: Galvanized iron joint and aluminium-galvanized iron joint

3.4 Jig Design

The jig must be design and fabricate to hold the specimens when attach on a vibration testing machine which is TM16 Universal Vibration Apparatus. The jig are fabricate according to the thickness of the specimens. It must be a good holder when the specimen are attach.

Figure 3.7: Actual jig

The holder were create using two pieces of mild steel plates with the dimension 100mm x 50mm x 3mm. The plates than were drilled at the middle following the size of the screw thread at the testing machine. The function of the holder was to hold the one end of the specimen. Other than that, the holder also clamp and hold the contactor that were connect to the stroboscope. The contactor was a sensor routed to the spot weld nugget.

Figure 3.8: Plate holder

Figure 3.9: Hold specimen and contactor

For the other end of the specimen, the stainless steel hose clamps were used. The device used to prevent the end of the specimen from moving while the testing runs. The specimen were clamped up and down. The specimen were bends to make sure it had a better grip.

Figure 3.10: Hose clamp

Figure 3.11: Hose clamping

3.5 Testing

Vibration testing will be applied in this project. The specimens will be clamp at the jig that were designed at the TM16 Universal Vibration Apparatus. The range of the experiments can be use using this machine. The main purpose of this machine is to suppress the primary resonance vibrations of the specimens tested.

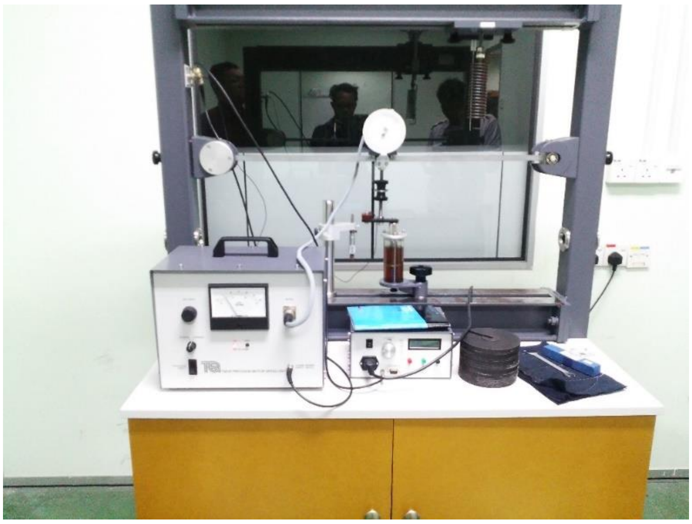

Figure 3.12: TM16 Universal Vibration Apparatus

The motor speed was adjusted to form the vibration on the specimens that attach at the jig. Once it touch the contactor (sensor), the flash light appears. The frequency reading then will be taken at the stroboscope. The micrometer were used to get the amplitude of the specimen. The amplitude were taken until the specimen did not touch the micrometer. The final result should be taken when it reach the maximum speed of motor or the specimen crack.

Figure 3.13: TM16 Precision motor speed unit

Figure 3.14: Stroboscope (frequency reading)

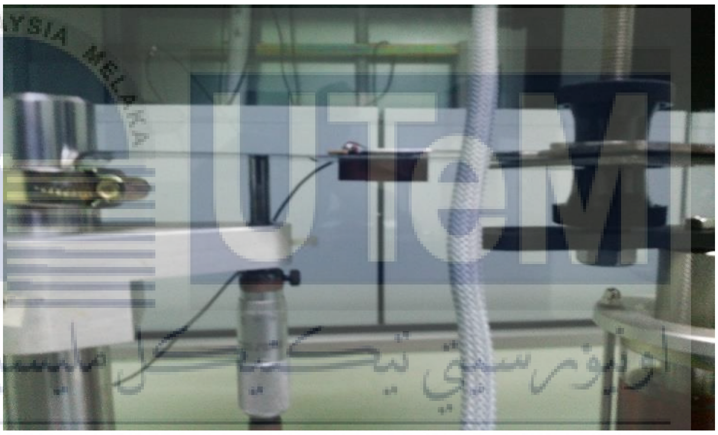

Figure 3.15: Testing

The result that obtain in this project was the natural frequency reading of the specimens that occurs in maximum speed or when the fatigue or crack happen. The reading was based on frequency that was running by motor speed. The speed of the motor up until 3000 rpm. The specimens vibrates until it touch the contactor (sensor) causing the flashlight at the stroboscope (frequency reading).

CHAPTER 4

RESULT AND DISCUSSION

4.0 Data Collection

The result can be collected from the stroboscope (frequency reading). The data was analyzed and the graphs were plotted. The frequency obtain by the vibration of the motor speed were noted.

4.1 Frequency Calculation

Natural frequency can be theoretically calculate by using formula

$$\omega = \frac{2\pi N}{60} \qquad f = \frac{\omega}{2\pi}\text{; Unit Hz}$$

The angular frequency is rate of change of speed respect to time. N is a number of speed (rpm) of the motor rotating.

4.2 Result

Each specimens were attach at the machine using the same method and procedure for vibration testing. The motor speed start from 500 rpm, however each of the specimens started to vibrate clearly was on 1100 rpm. The natural frequency reading than appear at the stroboscope. The data shows in figure below.

I. Joining thickness 0.5mm + 0.5mm

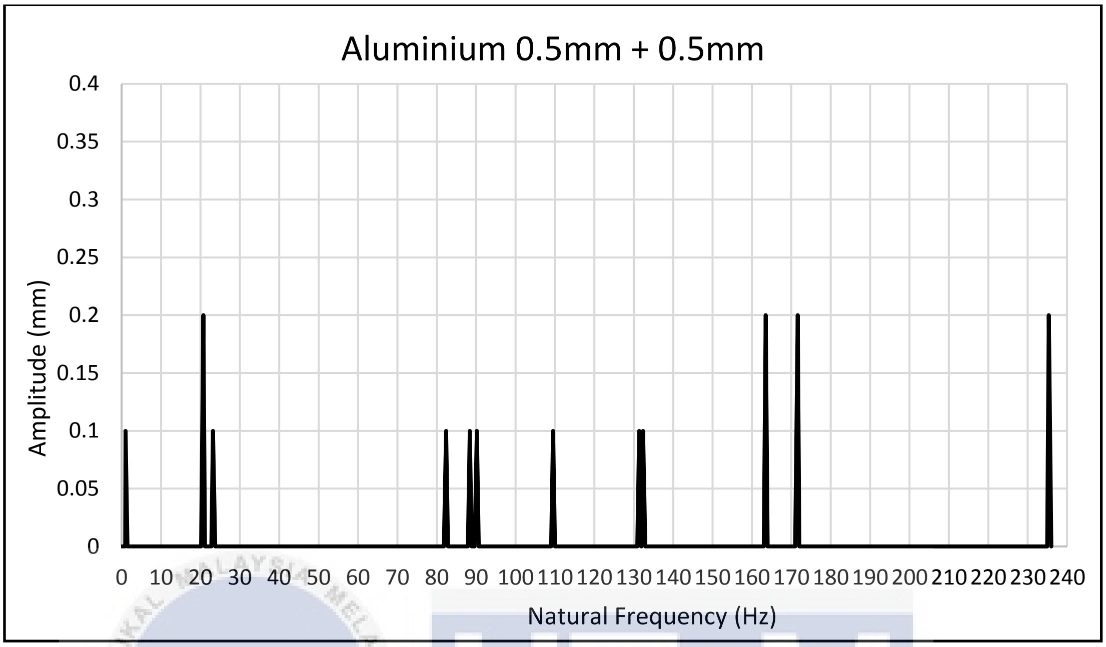

Figure 4.1: Result of aluminium 0.5mm and 0.5mm

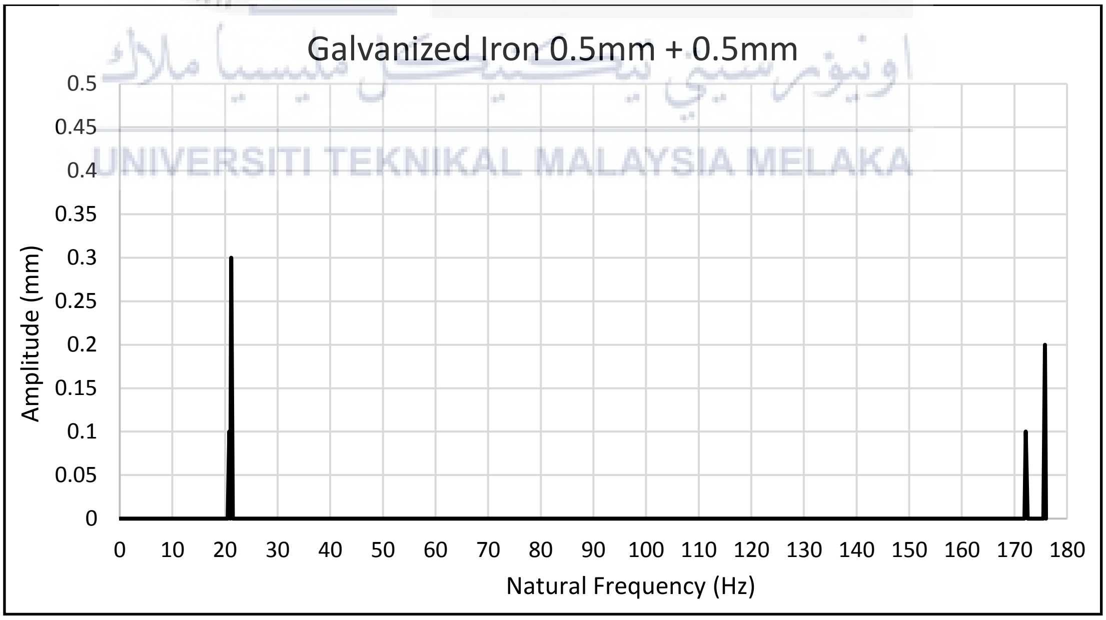

Figure 4.2: Result of galvanized iron 0.5mm and 0.5mm

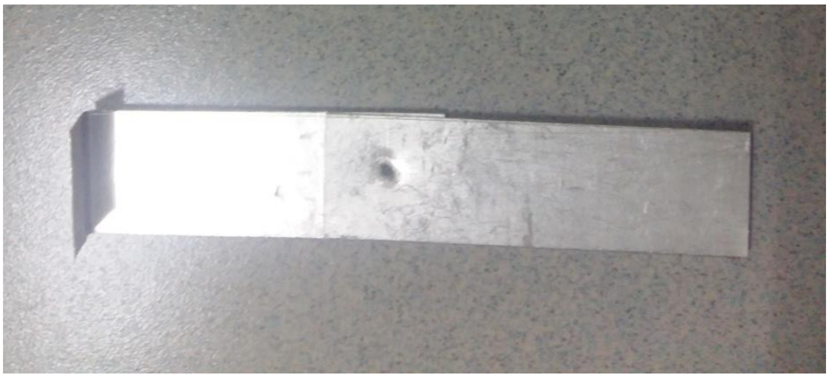

Figure 4.3: Aluminium 0.5mm and 0.5mm

Figure 4.4: Galvanized iron 0.5mm and 0.5mm

The result above shows the joining thickness of 0.5mm and 0.5mm for aluminium and galvanized iron. The result shows for aluminium joining, the highest amplitude peak was 0.2mm and its natural frequency was 20.77 Hz, 163.53 Hz, 171.64 Hz, and 235.4 Hz. While the other joining which is galvanized iron, the highest amplitude peak was 0.3mm and its natural frequency was 21.2 Hz.

The highest amplitude peak is where the resonance happened. This because at that time, the most vibration condition occurs. This shows that the galvanized iron 0.5mm and 0.5mm are stronger than aluminium 0.5mm and 0.5mm because the galvanized iron had less vibration.

The maximum resonance happen at maximum amplitude peak. Hence, natural frequency values form of vibration fatigue condition for aluminum joining can be predict and expectations for the failure was easier to be expected. While for galvanized iron, the form of vibration fatigue condition was smaller and prediction of the failure is expected to be limited.

II. Joining thickness 0.5mm + 1mm

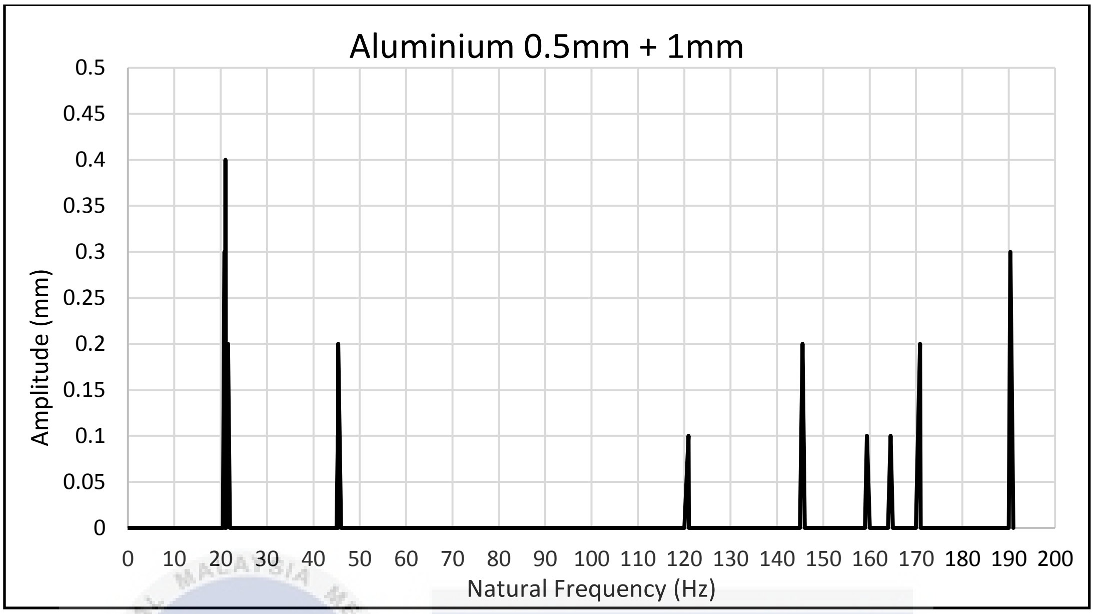

Figure 4.5: Result of aluminium 0.5mm and 1mm

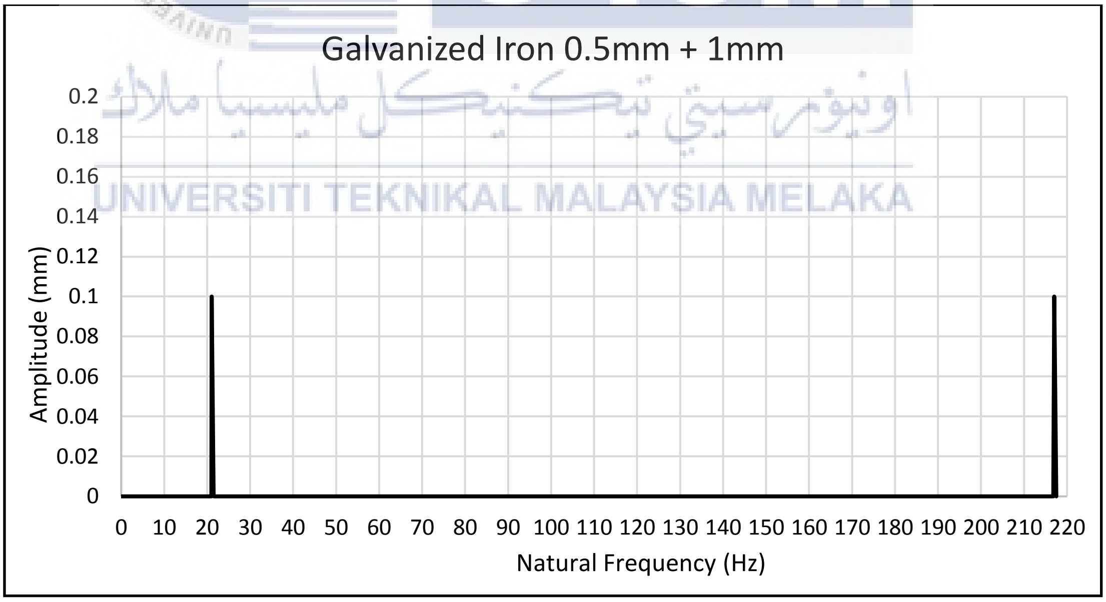

Figure 4.6: Result of galvanized iron 0.5mm and 1mm

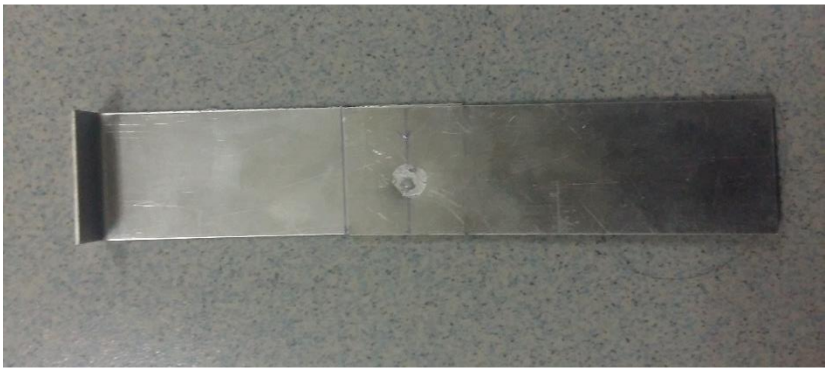

Figure 4.7: Aluminium 0.5mm and 1mm

Figure 4.8: Galvanized iron 0.5mm and 1mm

The results above show the joining thickness of 0.5mm and 1mm for aluminium and galvanized iron. From the result, it shows that aluminium highest amplitude peak was 0.4mm and its natural frequency was 21.06 Hz. For galvanized iron, the highest amplitude peak was 0.1mm and its natural frequency was 21.06 Hz and 217.01 Hz. The aluminium joining had many amplitude reading than the galvanized iron.

The highest amplitude peak is where the resonance happened which is for aluminium joining was at 0.4mm while for galvanized iron at 0.1mm. This because at that time, the most vibration condition occurs. This shows that the galvanized iron 0.5mm and 1mm are stronger than aluminium 0.5mm and 1mm because the galvanized iron also had less vibration.

III. Joining thickness 1mm and 1mm

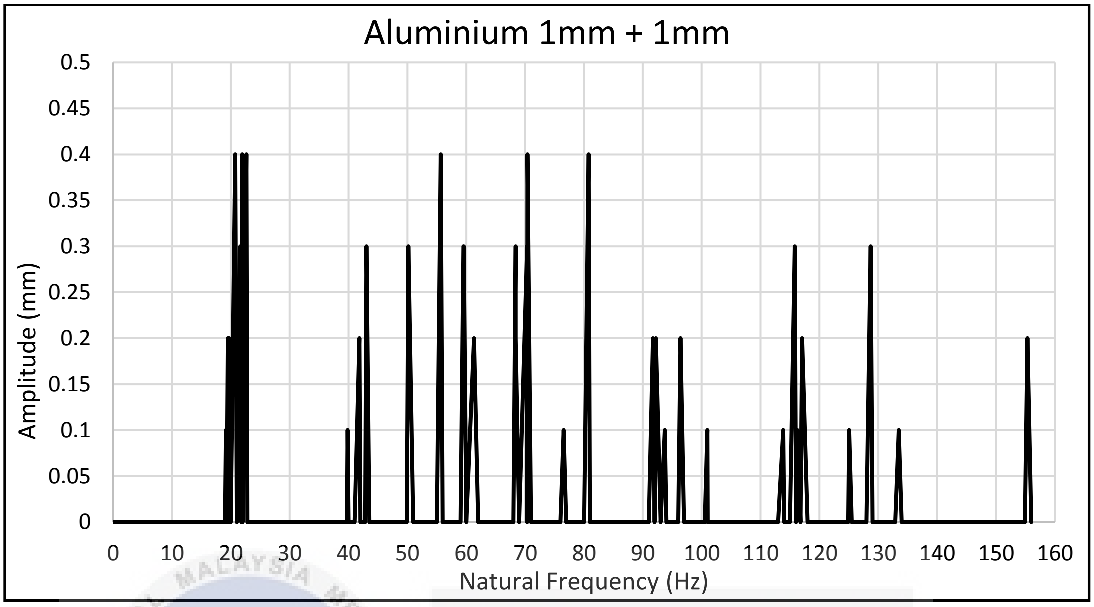

Figure 4.9: Result of aluminium 1mm and 1mm

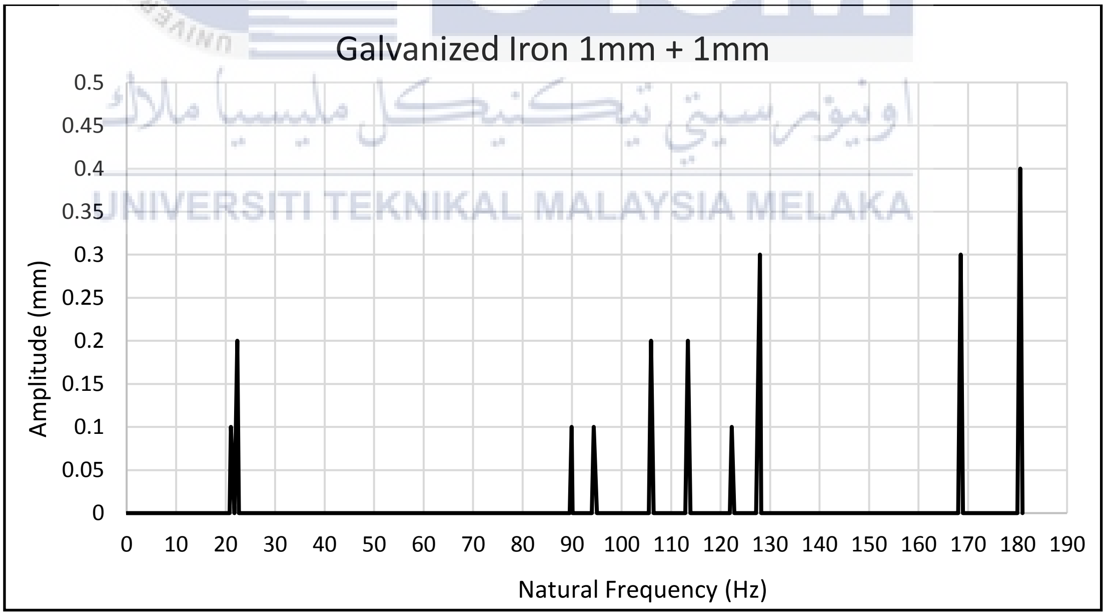

Figure 4.10: Result of galvanized iron 1mm and 1mm

Figure 4.11: Aluminium 1mm and 1mm

Figure 4.12 Galvanized iron 1mm and 1mm

The result above shows the joining thickness 1mm and 1mm for aluminium and galvanized iron. The result shows that the highest amplitude peak for aluminium joining was 0.4mm and its natural frequency was 20.75 Hz, 21.92 Hz, 22.65 Hz, 55.65 Hz, 70.38 Hz and 80.79 Hz. For galvanized iron joining, the highest amplitude peak was 0.4mm and its natural frequency was 180.55 Hz. The result also shows that the aluminium joining had many amplitude reading than galvanized iron joining.

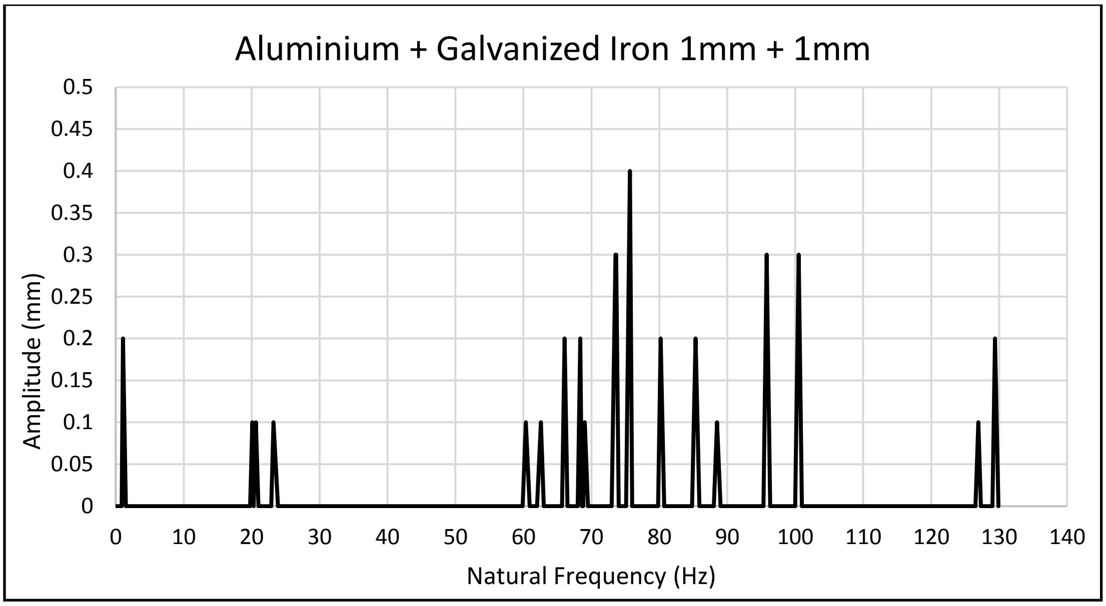

Figure 4.13: Result of aluminium and galvanized iron 1mm and 1mm

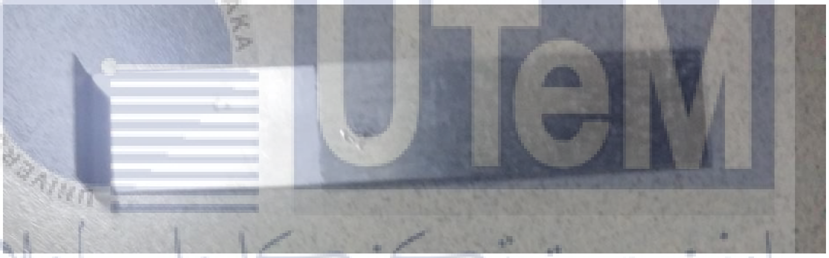

Figure 4.14: Aluminium and galvanized iron 1mm and 1mm

The result shows the joining of aluminium and galvanized iron with same thickness which is 1mm each. The result shows that the highest amplitude peak was 0.4mm and its natural frequency was 75.65 Hz. The number of amplitude peak for this joining decrease than the aluminium joining and increase for galvanized iron joining.

The highest amplitude peak is 0.4mm, where the resonance happened. This because at that time, the most vibration condition for the joining occurs. This shows that the galvanized iron 1mm and 1mm are stronger than aluminium 1mm and 1mm because the galvanized iron had less vibration. While for the aluminium – galvanized iron 1mm and 1mm, it's had more vibrations occurs than galvanized iron 1mm and 1mm because following the graph, its shown there are more highest peak than galvanized iron 1mm and 1mm.

For joining 1mm and 1mm, the aluminium joining had shown six maximum value. While for galvanized iron joining, it only show single maximum value and the aluminium – galvanized iron joining also show single maximum value. The maximum amplitude peak was 0.4mm with its natural frequency readings.

The amplitude peak for all joining thickness 1mm and 1mm, the highest amplitude peak was 0.4mm. The natural frequency for aluminium joining and aluminium - galvanized iron joining were around 70.38 Hz to 75.65 Hz. This shows the natural frequency at that reading were the highest amplitude peak that can be obtain. While for galvanized iron joining was 180.55 Hz. This is because the influenced of the material itself because galvanized iron was a hard materials.

The joining of aluminium and galvanized iron shows the improvement by the number of amplitude peak. The high peak and lower peak were more balance than aluminium joining and galvanized iron joining. The vibration rate for aluminium joining are high while for galvanized iron are low.

During the spot welding process, the heat unbalance occur in sheet metal and which had different material properties. The aluminium material has higher melting temperature while melt temperature for the galvanized iron is lower. For aluminium, the spot weld nugget not completely freeze, the welding electrodes have been withdrawn. This also influenced by the thickness of material.

Following all the result above, the aluminium joining have more amplitude peak than the galvanized iron joining. This trend happen because aluminium are soft material. The trend did not change even the thickness of material changes. The galvanized iron are better material which is hard material. The material also had a high cycle and high fatigue strength.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.0 Conclusion

The experiment focuses on the study fatigue failure on spot welded joint based on natural frequency. This experiment using the different thickness and material which had been used in the testing. The problem statement had been identified and then comes out with the experiment objectives. The progressing of this project were scheduled and been planned completely. The working procedure were followed.

The objective of this project were achieved continuously. The first objective is to compare the fatigue failure on spot welded joint based on vibration analysis with the conventional fatigue. Using the conventional fatigue, the specimen comes to the failure because of the force of the machine influenced the joining process of the material. At the certain force, it will fail.

Besides that, the vibration analysis used the same material and thickness to find its fatigue failure. The specimens were not fail because the specimen did not reach the cycle level limits. On the other hand, the specimen were test not by force but by the speed of motor. The speed of the motor may not enough to get the result. At the time fatigue happen, the prediction of fatigue strength can be know.

Next objective is to find the natural frequency of the spot welded joint. The aluminium joining with thickness 1mm and 1mm had the highest peak amplitude which is 0.4 at frequency 20.75 Hz, 21.92 Hz, 22.65 Hz, 55.65 Hz, 70.38 Hz and 80.79 Hz. However, the galvanized iron reading had highest peak amplitude which is 0.4 at frequency 180.55 Hz. This means the type of material and thickness give a big influenced on identified the natural frequency reading.

5.1 Recommendation

As a recommendation, a study will be done after this can continue the study that has been conducted to achieve the cycle of failure and get the fatigue failure. On the other hand, the researcher also can re-study this experiment but without using a damper or under damped. In addition, the use of different materials can also be done in this study with better technology. A researcher also can study the effect of fatigue failure using a spot welded joint for a product.

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APPENDICES

Specimen	Natural Frequency (Hz)	Amplitude (mm)
Aluminium 0.5mm + 0.5mm	1.02	0.1
	20.77	0.2
	23.2	0.1
	82.39	0.1
	88.36	0.1
	90.19	0.1
	109.52	0.1
	131.4	0.1
	132.4	0.1
	163.53	0.2
	171.64	0.2
	235.4	0.2

Specimen	Natural frequency (Hz)	Amplitude (mm)
Galvanized Iron 0.5mm + 0.5mm	20.79	0.1
	21.2	0.2
	21.2	0.3
	172.18	0.1
	175.81	0.1
	175.81	0.2

Specimen	Natural frequency (Hz)	Amplitude
Aluminium 0.5mm + 1mm	20.86	0.3
	21.06	0.4
	21.56	0.2
	45.31	0.1
	45.38	0.2
	120.95	0.1
	145.55	0.2
	159.42	0.1
	164.53	0.1
	170.9	0.2
	190.35	0.3

Specimen	Natural Frequency (Hz)	Amplitude (mm)
Galvanized Iron 0.5mm + 1mm	21.06	0.1
	217.01	0.1

Specimen	Natural Frequency (Hz)	Amplitude (mm)
Aluminium 1mm + 1mm	19.18	0.1
	19.47	0.2
	19.7	0.2
	19.86	0.1
	20.75	0.4
	21.62	0.3
	21.92	0.4
	22.65	0.4
	39.84	0.1
	41.86	0.2
	43.05	0.3
	50.15	0.3
	55.65	0.4
	59.5	0.3
	59.57	0.3
	61.3	0.2
	68.36	0.3
	68.37	0.2
	70.35	0.3
	70.38	0.4
	76.53	0.1
	80.79	0.4
	91.71	0.2
	92.18	0.2
	93.72	0.1
	96.38	0.2
	100.97	0.1
	113.86	0.1
	115.79	0.3
	116.23	0.1
	117.08	0.2
	125.08	0.1
	128.71	0.3
	133.46	0.1
	155.33	0.2

Specimen	Natural Frequency (Hz)	Amplitude (mm)
Galvanized Iron 1mm + 1mm	21.06	0.1
	22.39	0.2
	89.93	0.1
	94.38	0.1
	105.93	0.2
	113.38	0.2
	122.28	0.1
	127.94	0.3
	168.55	0.3
	180.55	0.4

Specimen	Natural Frequency (Hz)	Amplitude (mm)
Galvanized Iron and Aluminium 1mm + 1mm	1.09	0.2
	20.13	0.1
	20.64	0.1
	23.2	0.1
	60.36	0.1
	62.59	0.1
	66.08	0.2
	68.39	0.2
	69.05	0.1
	73.55	0.3
	73.65	0.3
	75.65	0.4
	80.21	0.2
	85.34	0.2
	88.51	0.1
	95.8	0.3
	100.52	0.3
	126.94	0.1
	129.4	0.2