AN EXPERIMENTAL STRENGTH OF COACH PEEL RIVETS JOINING SIMILAR AND DISSIMILAR SHEET MATERIALS

ROHANI BT DAUD

UNIVERSITI MALAYSIA PAHANG

AN EXPERIMENTAL STRENGTH OF COACH PEEL RIVETS JOINING SIMILAR AND DISSIMILAR SHEET MATERIALS

ROHANI BT DAUD

This thesis is submitted in partial fulfilment of the requirements
for the award of Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this project and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature : …………………………………….....
Supervisor : …………………………………….
Position : …………………………………….
Date : …………………………………….....

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Panel : …………………………………….
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STUDENT DECLARATION

I declare that this thesis entitled *an experimental strength of coach peel rivets joining similar and dissimilar sheet materials* is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	: ....
Name	: ROHANI BT DAUD
ID NUMBER	: MA05075
Date	: ……………………………………

Dedicated to my beloved

Daud bin Ibrahim

Raisiah bt Che Mat Ling

Youngest sisters

Youngest brothers

Friends

ACKNOWLEDGEMENTS

First I would like to express my grateful to ALLAH S.W.T. as for the blessing given that I can finish my project.

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My sincere also extends to all my beloved family especially my father Daud Bin Ibrahim and my mother Raisiah Bt Che Mat Ling because of if not their prayer and support I would not be here and done this thesis. More over I would like to thanks for all my colleagues and others who provides assistance at various occasions. Their view and tips are useful indeed in helping me to achieve doing this thesis.

ABSTRACT

The multi-materials structure has been applied as one of the methods in weight reduction especially in automotive industry. In this thesis, tensile test were performed in order to analyze the strength of similar and dissimilar sheet material joins connected rivets. It is used aluminum and steel sheet materials. Besides that, it is to study the fundamental phenomenon of tensile strength acted on coach peel riveted joints under similar and dissimilar sheet materials. Both materials are combined together to obtain the best comprise between weight reduction and the strength of the structure. The specimens of riveted joining was evaluated with tensile test in order to find the elastic of modulus (E), ultimate strength (σ_{ut}), yield strength (σ_y), proportional limit (σ_{pl}) and the fracture point (ε_f) from stress-strain diagram. The tensile strength for similar specimens is 22.25 MPa. While for the dissimilar sheet materials is 22.20 MPa. The percentage of difference between both specimens is very small, 0.22%.

ABSTRAK

Struktur multi-bahan telah diaplikasikan sebagai satu kaedah dalam pengurangan berat bahan terutama dalam industri automotif. Di dalam tesis ini, ujian tegangan telah dilaksanakan di atas arahan untuk menganalisis kekuatan sama jenis dan tidak sama jenis sambungan paku sumbat. Ia adalah mengunakan bahan kepingan aluminum dan besi. Selain daripada itu, ai adalah untuk mempelajari fenomena asas kekuatan tegangan yng bertindak ke atas sambungan paku sumbat pada sampel berbentuk L bagi sampel sama jenis dan tidak sama jenis kepingan bahan. Kedua-dua bahan adalah disambungkan bersama bertujuan untuk mendapatkan terrdiri daripada yang bagus diantara pengurangan berat bahan dan kekuatan struktur. Sampel sambungan paku sumbat telah dinilai dengan ujian tegangan di dalam arahan untuk mencari modulasi anjalan (E), kekuatan terakhir (σ_{ut}), kadar hasil kekuatan (σ_y), tahap keseimbangan (σ_{pl}) dan titik putus (ε_f) daripada gambar-rajah tegasan-tegangan. Kekuatan tegangan untuk sama jenis bahan sambungan paku sumbat adalah 22.25 MPa. Sementara itu, kekuatan tegangan tidak sama jenis bahan pula adalah sebayak 22.20 MPa. Peratusan perbezaan untuk kedua-dua bahan adalah sangat kecil iaitu 0.22%.

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LIST OF SYMBOLS

%	*Percentage*
F	*Force*
ε	*Total strain, Bandwidth parameter*
σ	*True stress, local stress*
σ_{ut} @ S_u	*Ultimate Tensile Strength*
F_t	*Capacity of the joint in tensile*
σ_{ta}	*Allowable stress in tension*
A_t	*Net tensile area*
w	*Width of plane*
N	*Number of holes at the section of interest*
D_{II}	*Hole diameter* ($D_{II} = D + 1/16$ *in* @ $D+1.6$ *mm*)
t	*Thickness of plate*
F_b	*Capacity of the joint in bearing*
σ_{ba}	*Allowable bearing stress*
A_b	*Bearing area*
L_t	*Total length*
L_g	*Grip to grip length*
L_h	*Length of horizontal section*
W	*Half plate width*
t_1	*Thickness of the plate at the rivet head side*

t_2	*Thickness of the plate at the rivet button side*
D	*Rivet hole diameter*
A_0	*Original cross-section area*
L_0	*Original gage length*
δ @ ΔL	*Elongation*
σ_y	*Yield Strength*
σ_{pl}	*Proportional Limit*
E	*Elastic of Modulus (Young's Modulus)*
ε_f	*Fracture Point or Breaking Point*

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Mechanical fastening is one of the major methods for joining structural components and its use will continue in the future despite a number of disadvantages and alternatives such as welding and bonding. (Calvin Rans, Paul V.Straznicky & Rene Alderliesten; 2007). With active pursuit of lightweight vehicle structures in the automotive industry, there is an increasing interest in developing new joining technology as a replacement for sport welding in lightweight metals such as aluminum alloys. Spot welding is primary method of joining steels body panels.

Although spot welding is considered a satisfactory joining method for aluminum body panels, the difficulty of sport welding thin aluminum sheet is well recognized. The reasons for difficulty of sport welding are due to its high thermal conductivity, low melting range and propensity to form oxide surface film(which contaminants the copper sport welding electrode tip and reduces the tip life).

Adhesive bonding, weld-bonding, riveting and clinching are some of the alternative joining techniques considered for aluminum alloys. Rivets are considered to be permanent fasteners. Riveted joints are therefore similar to welded and adhesive joints. When considering the strength of riveted joints similar calculations are used as for bolted joints (Maofeng Fu, P.K. Mallick; 2002).

Rivets have been used in many large scale applications including automotive industry, shipbuilding, boilers, pressure vessels, bridges, building. There are strict standard and codes for riveted joints in used for structural/ pressure vessels engineering but the standard are less rigorous for using riveted joints in general mechanical engineering.

A rivet is a cylindrical body a called a shank with head. It consists of smooth cylindrical shaft with a head on one end. The end opposite the head is called the buck-tail. On installation the rivet is placed in a pre-drilled hole. To distinguish between the two ends rivets, the original head is called the factory head and the deformed end is called shop head or buck-tail.

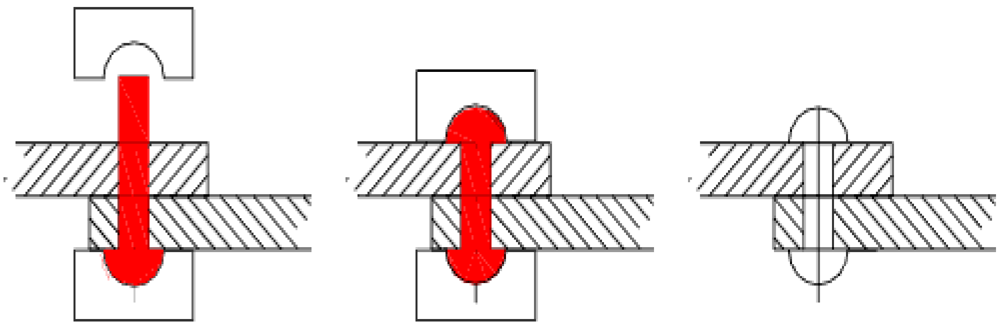


Figure 1.0: Process of rivets.

The selection of the number of rivets used for joint and the array is simply to ensure the maximum strength of the rivets and the plates. If ten small arrayed rivets on the lap joint were replaced by three large rivets across a plate the plate the plate section area (in tension) would clearly be significantly reduced.

There are a number of types of rivets, designed to meet different cost, and strength requirements. These include solid rivets, blind rivets, multi-grip rivets, peel type blind rivets, self-pierce rivets, plastics rivets and tubular rivets.

1.2 IMPORTANCE OF RESEARCH.

This research is significant because:

1. It investigates the effects of materials combination in riveted joining that especially applied in automotive materials industry.

2. It provides to manufacturing engineers to the effects of different manufacturing parameters on the tensile strength for various rivet joining.

1.3 PROBLEM STATEMENT

With active pursuit of automobile materials industry, there are increasing interests in developing new technology as a replacement for spot welding lightweight metals such as steel and aluminum alloy. Rivet is some of the alternative joining techniques considered for these materials. Both materials are combined together to obtain the best comprise between weight reduction and the strength of the structure. With the trend to combine dissimilar materials in automotive industry, a reliable strength of the joining method must be developed and be evaluated. In this context, tensile test on the riveted joint under similar and dissimilar sheet material will be evaluated.

1.4 OBJECTIVES

The overall objectives for this project were:

- To analyze tensile strength of coach peel riveted joints under similar and dissimilar sheet materials which are aluminum and steel sheet materials.
- To study the fundamental phenomenon of tensile strength acted onto coach peel riveted joints under similar and dissimilar sheet materials (aluminum and steel sheet).

1.5 SCOPES OF RESEARCH

This project concentrates on the tensile strength of the rivets joining similar and dissimilar of sheet materials using coach peel specimens. The load (N), displacement (mm), stress (MPa) and strain (mm/mm) are main parameters in this experiment.

1.6 METHODOLOGY

The flow chart for this research:

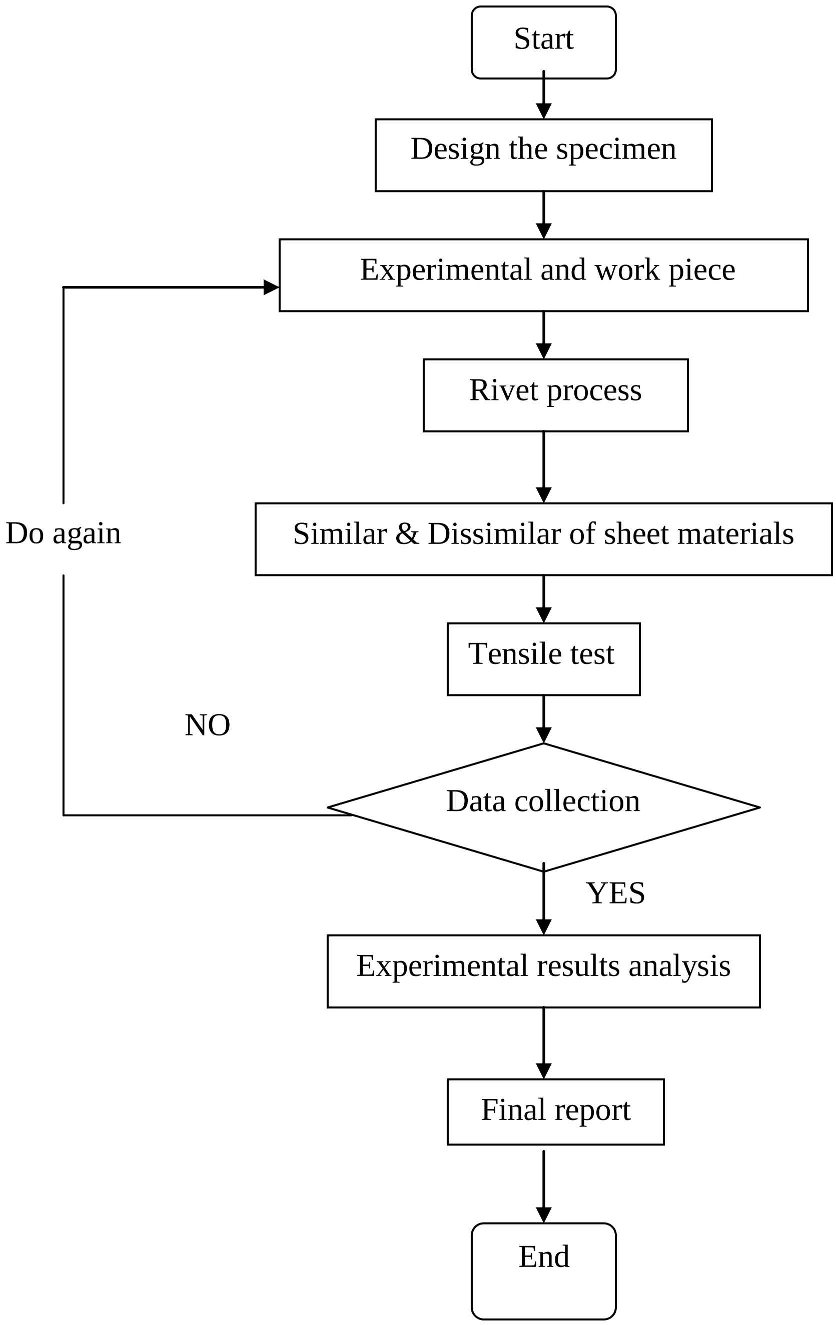


Figure 1.1: Flow chart of project.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter discussed some literatures that give information based on tensile test on riveted joints and shows how to investigate mechanical strength on riveted joins in similar and dissimilar sheet materials.

2.2 RIVET

Rivet is comes as a circular steel rod with forged head and the manufactured head, on one end. The length of rivet is the distance from the underside of the head to the end of the fresh rivet. The thickness of the material to be joined is called the grip of the rivet. Rivet requires holes to be made to receive them which reduce the net cross-section. These holes must be very accurately aligned and although rivets can be used in any orientation, enough clearance must be existed to set them properly.

Figure 2.0: Rivet nail

A riveted joint is quickly made and it is easy to aspect. A visual inspection and a few taps with ballast are all that is necessary. Rivets holes are not all bad. However, they are very effective crack properties and it left residual stresses around the hole that were usually alleviated by reaming hole to slightly larger diameter.

In rivet connection, the rivet joining is permanent. The connection may be subjected to tension tending to pull the members a part, or shear the members either axially or transversely. The connection may also resist moment, perhaps created by eccentric loads. Torsion, twisting or tearing forces may also be applied. It is essential to determine the forces that act on the connection, both under normal load and extraordinary circumstances and wonder about the types of failure they may cause. In most introductory treatments, rivet connection are assumed to be under simple tension.

Riveted connections subjected to forces unforeseen in design have to be add to the cracked plates and angles as the mechanical weak links most likely to produce the collapse of the beam. The purpose of this work is to find the failure criterion of the riveted beam shown in Fig 1, considering the cracked plate and the riveted joints as potential origins of the collapse.

2.2.1 FAILURE MODES IN RIVETED JOINTS

Failure modes of a riveted connection [6-7], it is assumed that the joined plates are not clamped together tightly enough to cause frictional forces between the plates to transmit loads. The method to analysis the failures that occur in rivet process:

1. **Shear Failure:**

   Where the rivet body is assumed to be in direct shear when tensile load is apply to a joint, provided that the line action of the load passes through the centroid of the pattern of rivets. It also assumed that the total applied load is sheared equally among all the rivets joints.

2. **Tensile Failure**

   A direct tensile force applied through the centroid of the rivet pattern would produce a tensile stress.

3. **Bearing Failure**

   When a cylindrical rivet bears against the wall of the hole in the plate non-uniform pressures exist between them. As a simplification of the actual stress distribution, it is assumed that area in bearing, A_b is rectangular area found by multiplying the plate thickness t by the diameter of the rivet which considered to e the projected area of the rivet hole.

   The allowable bearing stresses are based on the strength of the connected material, not the fastener. Where fasteners are locate near the edge of a sheet or a structural shape. In the minimum distance from the center of the fastener to the edge of the plate or shape is twice the nominal diameter of the fastener. There are may be many reasons for the bearing failure in the rivet process:

1. Heavier loading than has been anticipated.
2. Inadequate or unsuitable lubrication.
3. Careless handling and ineffective sealing or fit those are too tight.
4. With resultant insufficient internal bearing clearance.

Fatigue is result of shear stress cyclically appearing immediately below the load carrying surface. The riveted connections to transmit forces normal to the rivet axis also can fail by any one of the mechanisms shown below:

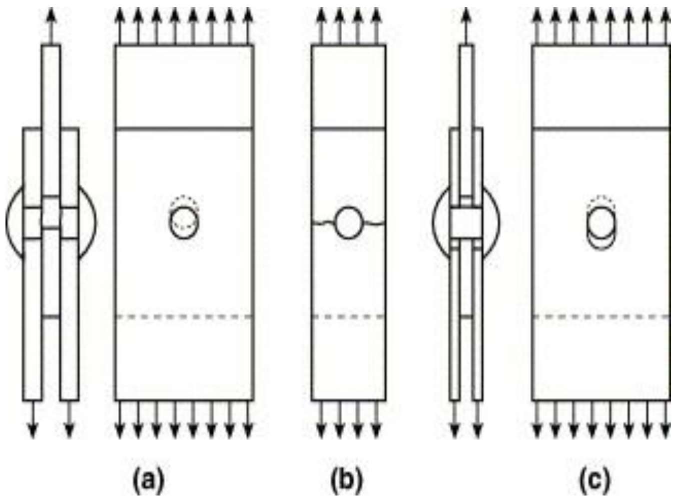


Figure.2.1: Failure modes of a riveted joint.

Source: A. Valiente, J. Moreno; 2006

(a) Shearing of the rivet shank
(b) Tensile necking of the cross-sections weakened by the connection holes.

The rivet joint efficiency is simply described as follows

$$\text{Efficiency} = \frac{\text{Max Allowable Force applied to Rivet Joint}}{\text{Plate Strength with not holes}}$$

The joint efficiency is increased by having multiple rows of rivets. It is also clear that the efficiency can never be 100%. The maximum allowable force is the smallest of the allowable shear, tensile or bearing forces.

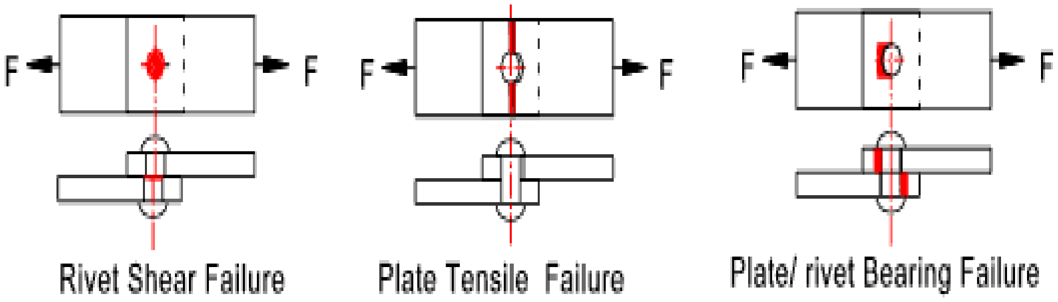


Figure 2.2: Type of Failure

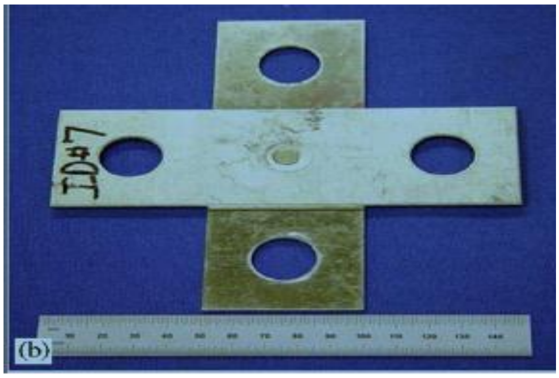
2.2.2 CONNECTION DESIGN

The usual tension connection fails by tearing between rivet holes, by shearing of a rivet, or by crushing of either the rivet or the similar and dissimilar of sheet material joined. Tearing between rivet holes is a failure of the similar and dissimilar sheet of materials joined, not the rivet failure. Shearing of rivet is a failure of the rivet itself. Crushing can be failure of either the similar and dissimilar of sheet material joined or the rivet.

2.2.3 SAMPLES RIVET JOINT DESIGN

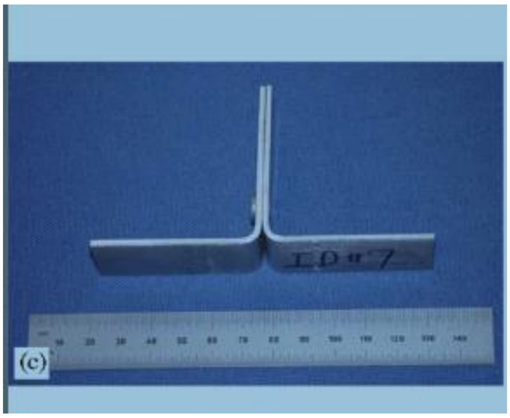
In riveted joint, a few type of coupon configuration often used on riveted joint in aluminium plate for static loading, they are lap-shear sample, cross-section sample, coach peel sample and U-shape sample by using similar and dissimilar sheet material (Figure 4).

(a) Lap-shear rivet sample.



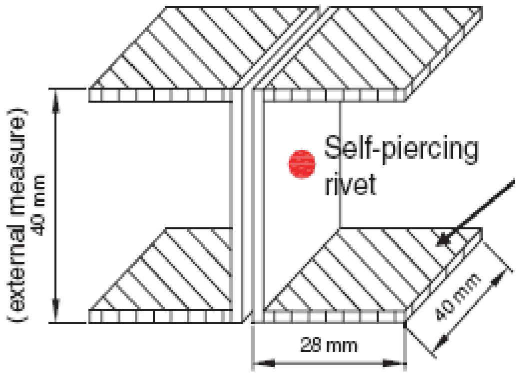
(b) Cross-tension rivet sample

Source: Sun at el; 2007



(c) Coach peel rivet sample.

Source: Sun at el; 2007



(d) U-shape rivet sample.

Source: R. Porcaro at el; 2006

Figure 2.3: Sample of rivet joint.

2.3 TENSILE TEST

In order to evaluate the static strength of coach peel riveted joint on similar and dissimilar sheet materials, tensile test are studies in this research.

2.3.1 WHAT IS TENSILE TESTING

A tensile test, also known as tension test, is probably the most fundamental type of mechanical test that can be performing on material. Tensile tests are simple, relatively inexpensive, and fully standardized. By pulling on something, the material will react to forces being applied in tension can be determined. As the material is being pulled, the strength along it's with how much it will elongate can be find.

Tensile strength, σ_{UTS} or S_U is the stress at which a material breaks or permanently deforms. Tensile strength is an intensive property and consequently, does not depend on the size of the test specimen. However it is dependent on the preparation of the specimen's materials. Tensile strength, along with elastic modulus and corrosion resistance, is an important parameter of engineering materials that used in structure and mechanical devices.

When load is applied to the riveted joint in specimen's plate, deformation will be results. The resulting stress concentrations would degrade the static strength of the riveted joint in specimens either for similar and dissimilar of sheet materials. The riveting process also introduces residuals and hoop stress at edges of the hole. There is a frictional force occurs between contact surfaces in the joint. When the riveted joints are subjected to tensile load, all contacting surfaces can move relative to each other and a contact damage process.

The factor generally causes cracks to form at the rivet hole edges and/or in the plate at the rivet head edge. These cracks then grow across the plate width and through the plate thickness, leading to failure of the joint. Tensile failure can occur by tearing of the joined members (base metal failure), pulling out the rivet (base metal failure), or breaking of the rivet shank (rivet failure).

2.3.2 TENSILE FAILURE

A direct tensile force applied through the centroid of the rivet pattern would produce a tensile stress. Then the capacity of the joint in tension would be:

$$F_t = \sigma_{ta} A_t \qquad (1)$$

Where

F_t = capacity of the joint in tensile

σ_{ta} = allowable stress in tension

A_t = net tensile area.

The evaluation of area A_t requires the subtraction of the diameter of all the holes from the width of the plates being joined.

Then:

$$A_t = (w - ND_{II})t \qquad (2)$$

Where;

w = width of plane

N = number of holes at the section of interest.

D_{II} = hole diameter (D_{II} = D+ 1/16 in @ D+1.6 mm)

t = thickness of plate.

2.3.3 BEARING FAILURE

When a cylindrical rivet bears against the wall of the hole in the plate, a nonuniform pressure exists between them. As a simplification of the actual stress distribution, it is assumed that area in bearing A_b is rectangular area found by multiplying the plate thickness t by diameter of the rivet D. this can be considered as the projected area of the rivet hole. Then the bearing capacity of a joint is;

$$F_b = \sigma_{ba} A_b \tag{3}$$

Where;

F_b = capacity of the joint in bearing.

σ_{ba} = allowable bearing stress.

A_b = bearing area = N_b D_t

t = thickness.

The allowable bearing stresses are based on the strength of the connected material, not fastener. Where the fastener are located near the edge of a sheet or a structure shape, the minimum distance from the center of the fastener to the edge of the plate or shape is twice the nominal diameter of the fastener.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter discusses the steps of making riveted joints and tensile test on riveted joints specimen plate. The methodology is shown by flow chart and followed by the Gantt chart.

3.2 JUSTIFICATION

In this research, steel metal and aluminium metal are the materials that have been chosen to be used for similar and dissimilar specimen in riveted joint during tensile test. Steel and aluminium sheets are materials that have been chosen because it is easy to be fabricated and the cost material in producing the specimens is low. Besides that, steel and aluminium are lightweight metal and it is use currently for the mass production in automotive industry. Both materials are combined together to obtain the best compromise between weight reduction and strength of the body.

3.3 METHODOLOGY

The methodology describes the process of this study and it is illustrated in the figure 3.0 below:

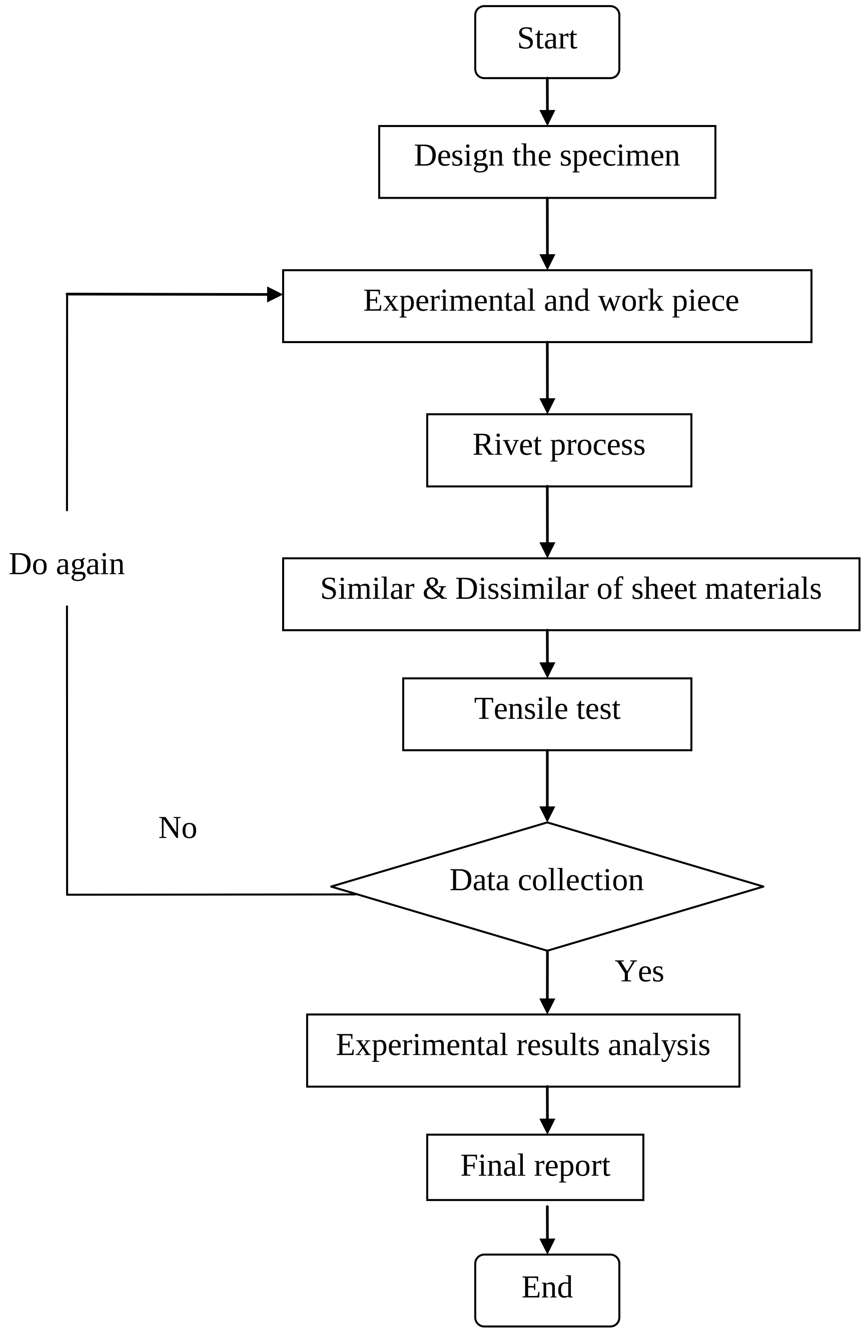


Figure 3.0: Flow Chart of Methodology

The project is starts by doing the literature review on finding about all information, knowledge and another type of researches about the riveted joints by reading and surfing the internet. This literature review could give a lot of idea about background of this study.

After doing literature review, the idea will be generated by doing the design of specimens for the experiment. Next, after get all the information needed in this study, the problems statement, objectives, and scopes of study could be written. It is meaning that, in this project the important part is the selection of method of how the project will run. The selection of the parameters for tensile test in riveted joints under similar and dissimilar sheet materials is being made. The selected parameters is related to be main characteristics for tensile riveted joint that is load, displacement, stress, strain, ultimate strength, yield strength, proportional limit, breaking or fracture point and failure location in riveted joint.

There are four types of joining in riveted joint that can be chosen: (1) Lap-shear samples, (2) Cross-section samples, (3) U-shaped samples, (4) Peeling Samples. In this study, design of specimen that chosen is peeling sample because of it more suitable to use on fatigue test in riveted joint. Coach peel specimens have been used to evaluate fatigue strengths of the riveted joints subjected to shear loading.

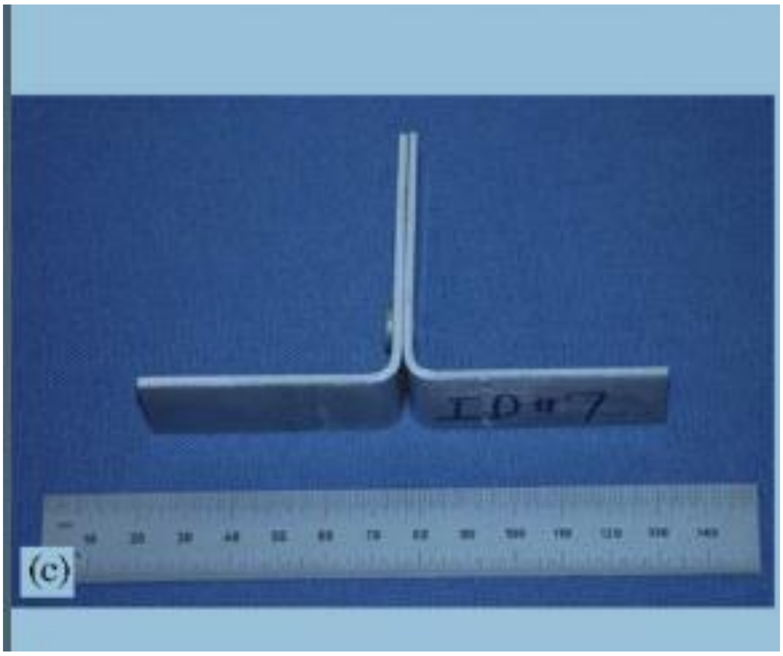


Figure 3.1: Coach Peel: Selection specimen for this project. Source: Sun at el; 2007

3.4 RIVET PROCESS

In riveting process, the rivet body is inserted in aligned pre-drilled holes in the plates to be jointed. The mandrel of the rivet is then pulled in the rivet joint. The riveted specimen was joined using a 5mm diameter blind rivet that consists of a rivet head, a rivet sleeve and a rivet mandrel.

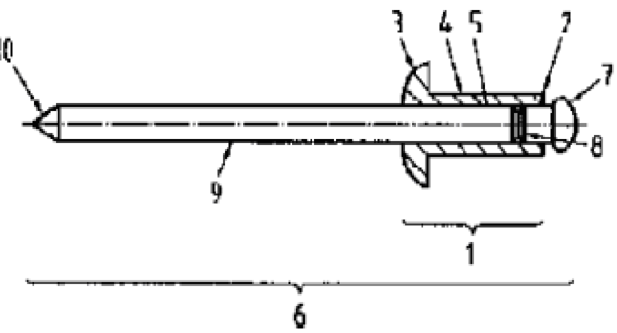


Figure 3.2: Rivet structure

1. Blind rivet body　　　　6. Mandrel

2. Blind rivet end 7. Mandrel head

3. Blind rivet head 8. Break area

4. Blind rivet shank 9. Mandrel shank

5. Blind rivet core 10. Mandrel end

There are two types set specimens that used which same configurations and dimensions. The joined must be done in similar and dissimilar sheet materials using steel and aluminium plate which aluminium plate was arranged at the rivet head side for dissimilar joint. The plates used were for similar specimens; (1) Aluminium-Aluminium and for dissimilar; (2) Aluminium-Steel.

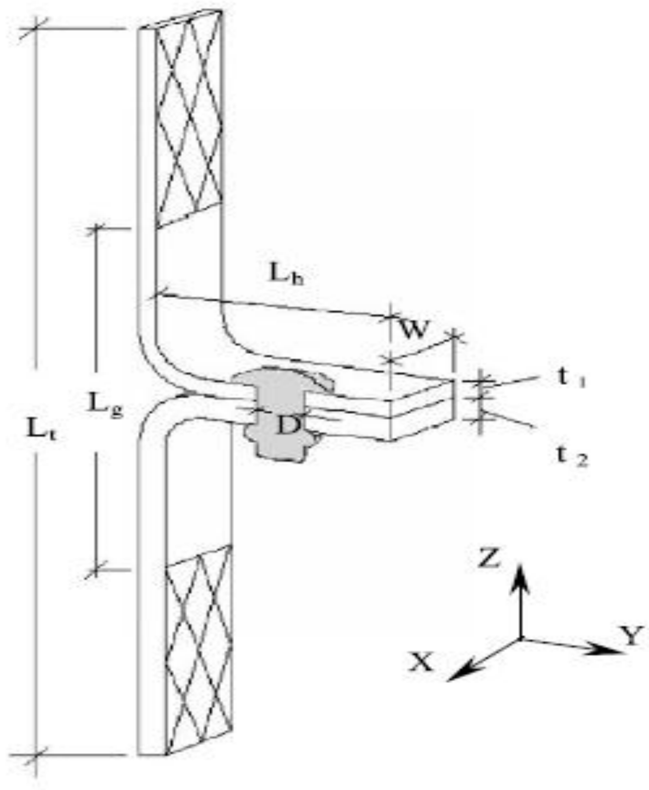


Figure 3.3: Coach peeling specimen. Source: A.Fatemi, B. Li; 2004

Configuration and dimensions of a coach peel rivet specimen, L_t: total length (100mm); L_g: grip to grip length (50mm); L_h: length of horizontal section (25mm); W: half plate width (12.5mm); t_1: thickness of the plate at the rivet head side (1.5mm); t_2: thickness of the plate at the rivet button side (1.5mm); D: rivet hole diameter (5mm).

3.5 TENSILE TEST

3.5.1 TENSILE TESTING

The rivet hole could be considered as notches and the resulting stress concentrations would degrade the static and fatigue strength of the rivet joint. The riveting process also introduces residual and hoop stresses at the edges of the hole. There is a frictional force between contact surfaces in the joints.

When such rivet joints are subjected to tension loads, all contacting surfaces can move relative to each other and contact damage process (i.e. fretting) may arise. The combination of these factors generally causes cracks to form at the rivet hole edges and/or in the plate at the rivet head edge plate. These cracks then grow across the plate width and through the plate thickness leading to the failure of the joint.

The tensile strength of a driven rivet depend on the mechanical properties of rivets materials before driving and other factors related to the installation process. Most tension test driven rivets showed a tendency to decrease in strength as the grip length was increased. Two factors contribute to this observation. First, there is a greater "upsetting" effect, since the driving energy per volume for short rivets is favorable. Second, strength figures are based on the full hole area, which applies that the driven rivet completely fills the hole.

All tensile tests were performed by using displacement control, similar to that in a conventional plate specimen tensile test. The upper end of the specimens was fixed and quasi-static upward displacement was applied to the lower end. The displacement rate is 0.1mm/min was chosen initially until the displacement reached a pre-determined displacement level, depending on the type of materials specimens. Displacement was then increased by a factor of tension load and the time to fracture.

3.6 DATA COLLECTION

Since each specimen must be tested to failure to obtain the data to be use for compare the riveted joints between similar and dissimilar sheet materials. The data from the tensile test such as displacement (mm), stress (MPa) and strain (mm/mm) were taken by the load was setting and then applied to the specimens.

a) Table 3.1: Similar sheet material: Aluminum-Aluminum

No of specimen	Load (N)	Displacement (mm)	Stress (MPa)	Strain (mm/mm)
1				
2				
3				
4				
5				
6				

b) Table 3.2: Dissimilar sheet material: Steel- Aluminum

No of specimen	Load (N)	Displacement (mm)	Stress (MPa)	Strain (mm/mm)
1				
2				
3				
4				
5				
6				

3.7 RESULTS ANALYSIS

By using the recorded data, the nominal or engineering stress is found by dividing the applied load to P (N) by specimen's original cross-section area A_{0}.

$$\sigma = \frac{P}{A_0} \tag{4}$$

The nominal or engineering strain is also found by dividing the change in the specimen's gage length, δ ($\delta = L - L_0$) by the specimen's original gage length L_0.

$$\varepsilon = \frac{\delta}{L_0} \tag{5}$$

From the data of tension test, it is possible to compute various stress and corresponding strain in the specimen and then plotted the result. The resulti9ng curve is called stress-strain diagram. The yield strength, ultimate tensile strength, breaking strength or fracture point, and elastic or Young's Modulus of the specimens can all be determined from this curve. The curve that shown, is typical of metallic behavior. At small strain values (the elastic region), the relationship between stress-strain is nearly linear. Within the region, the slope of the stress-strain curve defined as the elastic modulus.

Since many of materials lack a sharp yield point, sudden observable transition between the elastic region and the plastic region, the yield point is often defined as the stress that give rise to 0.2% permanent plastic strain. By this convection, a line is drawn is parallel to elastic region of the specimens, starting at a strain level 0.2% strain (or 0.002mm/mm). The point at which this line intersects the curve called the yield point or yield stress. The ultimate tensile strength, in contrast, is found by determining the maximum stress reached by the specimens. The graphs that will be obtained are in figure 3.4.

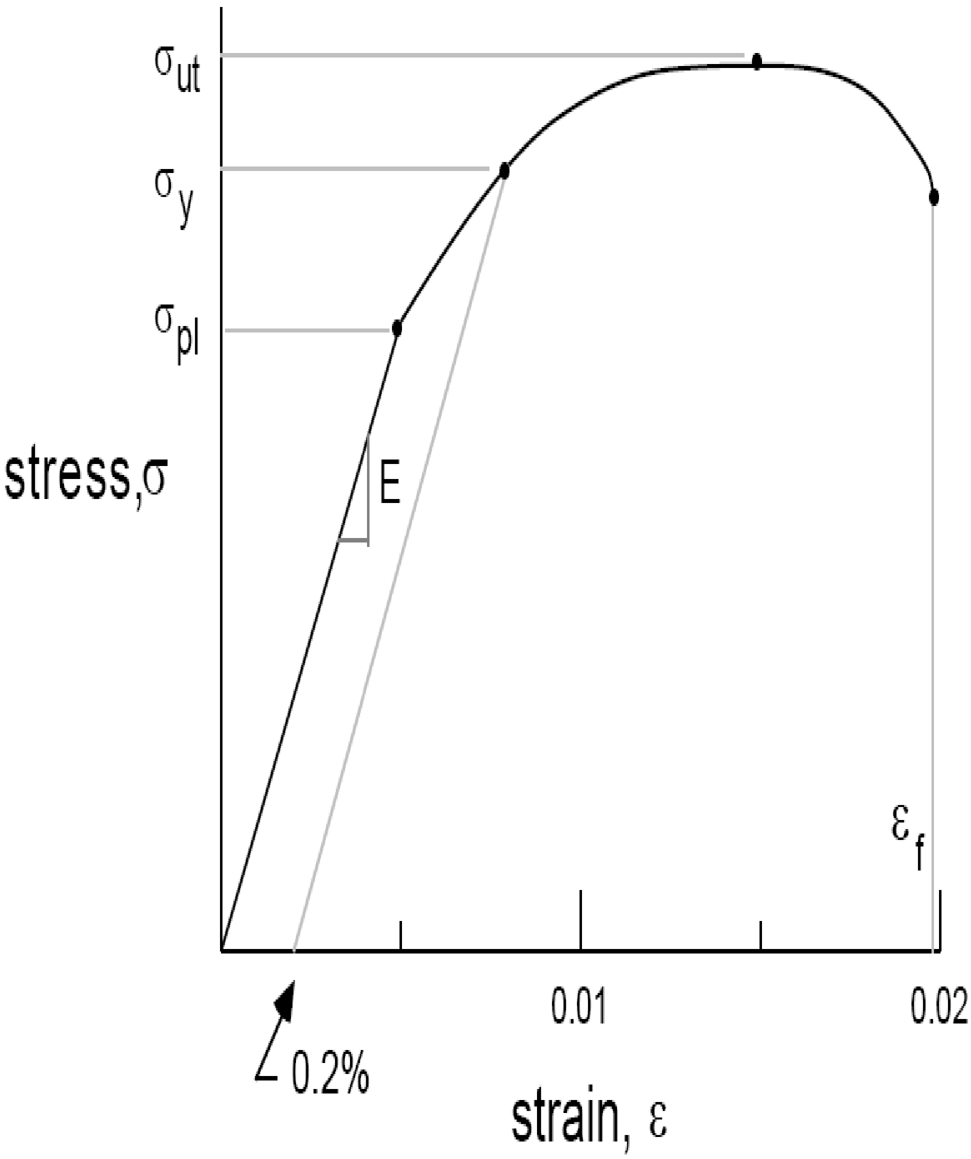


Figure 3.4: Stress-strain diagram

Description:

(1) σ_{ut} = Ultimate Tensile Strength

(2) σ_y = Yield Strength

(3) σ_{pl} = Proportional Limit

(4) E = Elastic of Modulus (Young's Modulus)

(5) εf = Fracture Point or Breaking Point

CHAPTER 4

RESULTS AND DISCUSSIONS

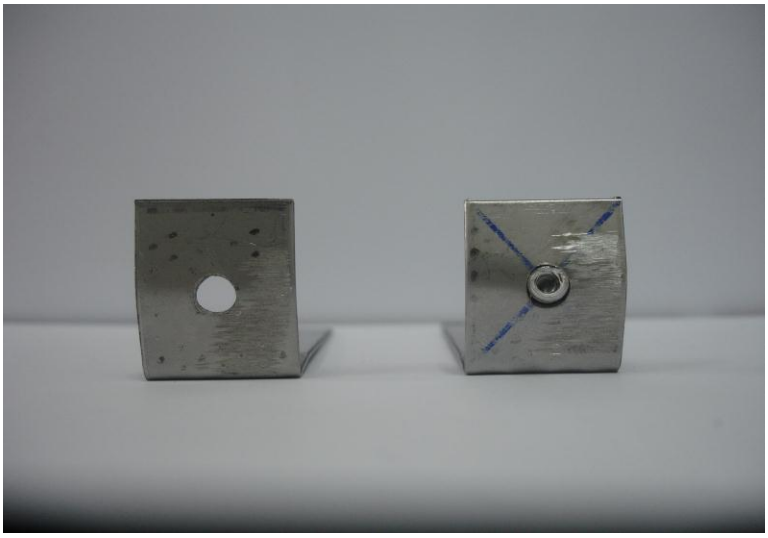
4.1 INTRODUCTION

The purpose of this chapter is to discuss the result that has been obtained after doing the experiment. Furthermore, this chapter may give further discussion for every analysis for the specimen's material. The analysis given is based on tensile test experimental.

The tensile test is done to investigate the strength of rivets joining similar and dissimilar sheet materials. Besides that, this test is executed under displacement on specimens in order to characterize the static behavior of the joints and to estimate the ultimate tensile strength dissimilar sheet materials.

4.2 ANALYZING THE SIMILAR SHEET MATERIALS

The specimen was joint using rivet in coach peel design and tensile test is done to evaluate the strength of rivet in this joining. This test uses 10 specimens to get the accurate results about the strength of rivet under similar sheet material joining. During the experiment, the joining failure location are investigated either the specimens' failure or rivet failure.



(a)

(b)

Figure 4.0: (a) and (b) Location Rivet Head Failure

From figure 4.0: (a) and (b) shows the failure location that occurred at the rivet head during the experiment. While at the hole of drill location, the bearing failure occurs because of tension force that was shown in figure 4.1. It is occurs because of the actual stress distribution.

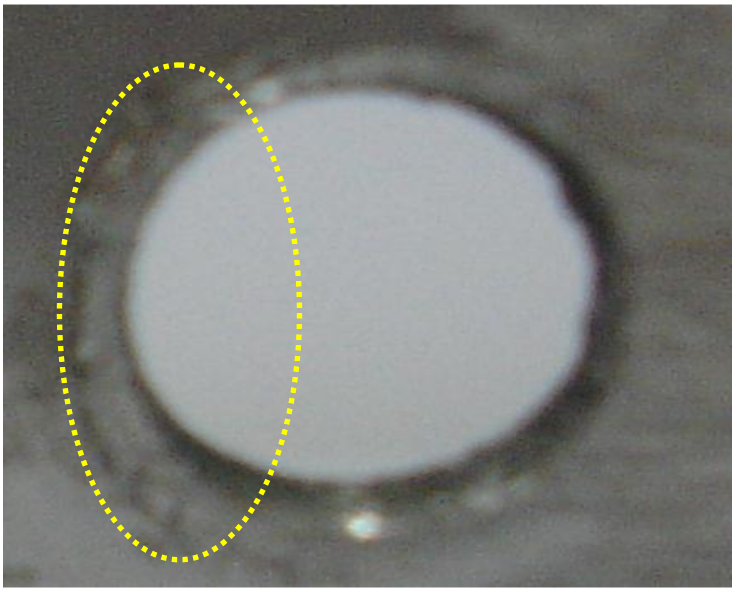


Figure 4.1: Bearing Failure

When a cylindrical rivet bears against the wall of a hole in the plate, a nonuniform pressure exists between rivet and palate. As the simplification of the actual stress distribution, it is assumed that the area in bearing. Where it is the rectangular area found by multiplying the plate thickness by diameter of the rivet. This can be considered to be the projected area of the rivet hole. The allowable bearing stresses are based on the strength of the connected material, not the fasteners. Where the fasteners were located near the edge of the plate or shape is twice the nominal diameter of the fastener.

Beside that, the also tensile failure was occurred at the joining. Which a direct tensile force applied through centroid of the rivet pattern would produce a tensile stress was shown in figure 4.2.

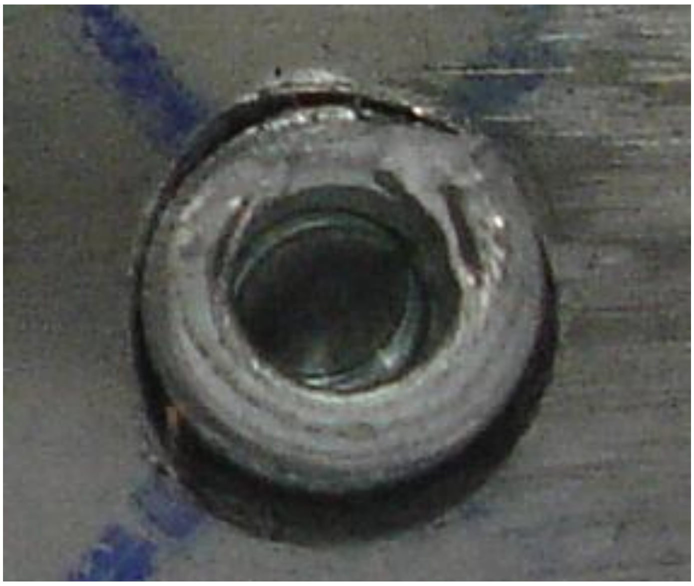


Figure 4.2: Tensile failure

4.3 ANALYZING THE DISSIMILAR SHEET MATERIALS

The specimens of dissimilar sheet material also were joint using rivet in coach peel design and tensile test is done to evaluate the strength of rivet in this joining. In this specimen the mild steel was located at bottom part in joining like shown in figure 4.3. Besides that, this test also using 10 specimens to get accurate results about the strength of rivet under dissimilar sheet material joining. During this experiment the locations of the joining failure occur are investigated either the specimens' failure or rivet failure same as similar joining.

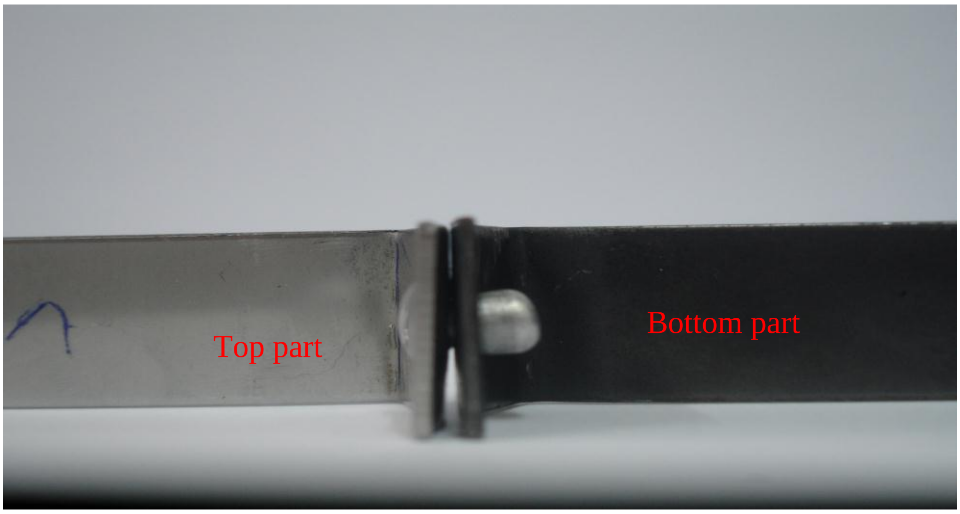


Figure 4.3: **Dissimilar Joining**

During the experimental process, the location of failure was occurred at rivet head. The failure is the same at similar sheet material specimens which bearing failure and tensile failure occurs in the joining as shown in figure 4.4 (a) and (b).

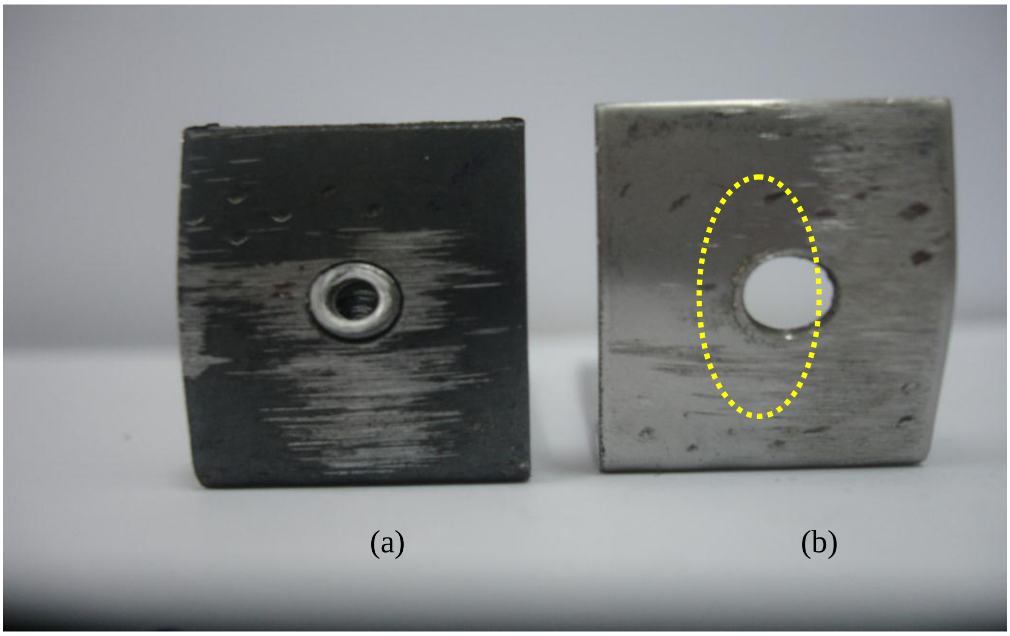


Figure 4.4: (a) Tensile Failure. (b) Bearing Failure

From the observation that was done during experiments, the location of failure was same location for both specimens which at rivets head. This shows first expression that the strength of rivets joining for both specimens was equal. These proved was fixed with data collection during tensile test and analyze the data.

4.4 RESULT

During running the experiment for both specimens, some data has been taken such as load (N), displacement (mm), stress (MPa) and strain (mm/mm). This data was important to be investigated and compare the strength of rivets joining similar and dissimilar sheet materials.

4.4.1 SIMILAR SHEET MATERIAL

Table 4.1: Result for Similar Sheet Material

No of specimen	Load (N)	Displacement (mm)	Stress (MPa)	Strain (mm/mm)
1	200	0.714	16.67	0.0620
2	400	1.430	20.81	0.1020
3	600	2.143	23.94	0.1512
4	800	3.286	25.21	0.1766
5	1000	4.143	26.60	0.2005
6	1200	5.143	27.55	0.2278
7	1400	6.000	27.90	0.2478
8	1600	7.430	26.48	0.2728
9	1800	10.000	24.45	0.2941
10	2000	15.770	22.25	0.3229

4.4.2 DISSIMILAR SHEET MATERIAL

Table 4.2: Result for Dissimilar Sheet Material

No of specimen	Load (N)	Displacement (mm)	Stress (MPa)	Strain (mm/mm)
1	200	1.000	14.78	0.0571
2	400	2.429	19.10	0.0947
3	600	3.286	21.30	0.1367
4	800	4.143	23.10	0.1700
5	1000	5.286	24.00	0.1889
6	1200	6.571	24.60	0.2020
7	1400	7.757	25.40	0.2160
8	1600	9.143	26.20	0.2387
9	1800	11.857	25.14	0.2620
10	2000	16.530	22.20	0.3084

4.5 DISCUSSIONS

From experimental data, the strength of rivets joins between both specimens could be investigate and made comparison. Firstly, the displacement of both specimens was being investigated and compared. When the values of load that applying increases, the values of displacement of both specimens also increased. The increases of displacement were not constantly due to constant increases of the load. This could be see through graph 1, where the displacement for dissimilar sheet material is higher than similar sheet material which difference displacement between both specimens is only about 7.11%.

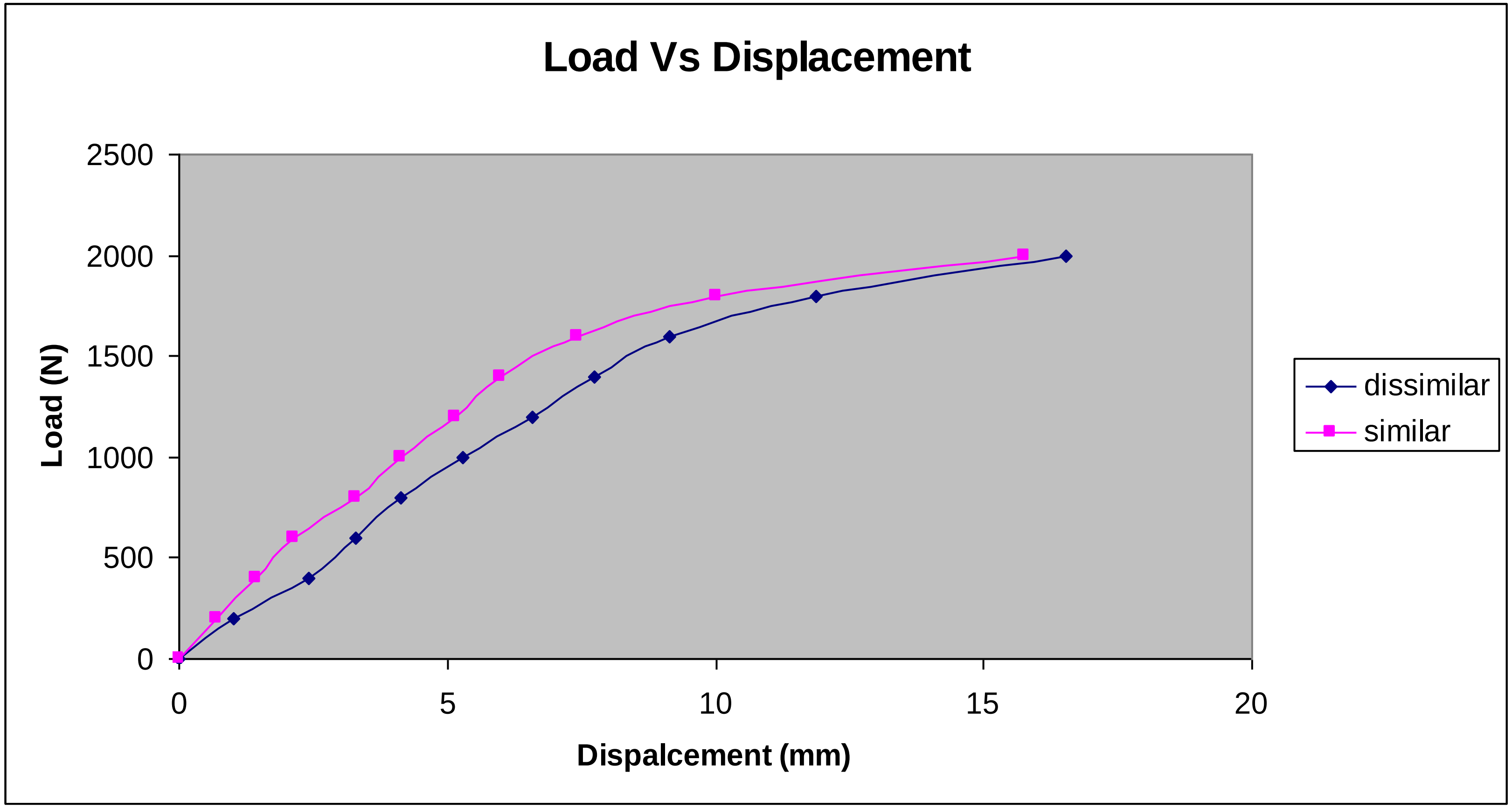


Figure 4.5: Graph 1: Load (N) Versus Displacement (mm)

Tensile strength is the stress of which a material breaks or permanently deforms. Tensile strength is an intensive property and consequently, does not depend on the size on the size of specimens. Tensile strength, along with elastic and corrosion resistance, is important parameters in engineering materials. Graph 2 was been use to investigate more detail the strength of rivets joining for both specimens, Elastic or Young's modulus (E), yield strength (σ_y), ultimate strength (σ_{ut}), proportional limit (σ_{pl}) and breaking strength (ε_f) has been investigating .

When a load is applied to specimens, deformation will be results. The deformation is elastic if it completely recovered immediately after load is removed. Purely elastic deformation is associated with stretching of the primary bonds in specimens. Stress is the force per unit area.

$$\sigma = F/A \tag{6}$$

Strain is elongation per unit length:

$$\varepsilon = \Delta L / L \tag{7}$$

The stress and elastic strain are directly proportional and related by Modulus of Elastic (or Young's Modulus) which is related to potential energy well of the interatomic bonds. Hooke's law relates these parameters,

$$\sigma = E\ \varepsilon \tag{8}$$

Where E is Young's Modulus. It is implicit here that only axial stresses and strains of the interest. It is assumed $\sigma = 0$ when $\varepsilon = 0$ so that the $\sigma = E\ \varepsilon$ represent the first part of the load displacement curve, a straight line that passes through the origin with E is slope of graph.

From graph 2, the slope (E) for similar sheet material is 285.71 MPa which higher about 3.91% compare with slope (E) for dissimilar sheet material which it slope (E) is 269.23 MPa.

Yield strength (σ_y) is the stress at which strain change from elastic deformation to plastic deformation, causing it to deform permanently. The value of yield strength of similar specimen is 20.81 MPa. While the yield strength for a dissimilar specimen is 19.10 MPa. The value of yield strength for similar sheet material is higher than dissimilar sheet material is about 8.2 % which less than 10%.

After the yield point, the specimens will undergo a period of strain hardening in which the stress increases again with increasing strain up to ultimate strength. If the specimens are unloaded at this point, stress- strain curve will be parallel to that portion of the curve between origin and the yield point. If it is re-loaded it will be follow the unloading curve up again the ultimate strength, which has become the new yield strength.

The ultimate strength (σ_{ut}) is the maximum stress specimen can withstand when subjected to tension, compressing or shearing. The value of ultimate strength (σ_{ut}) for similar sheet materials is 27.90 MPa. While the value of ultimate strength (σ_{ut}) for dissimilar sheet material is 26.20 MPa. The difference ultimate strength (σ_{ut}) is about 6.09% which, ultimate strength (σ_{ut}) for similar sheet material is higher compare with ultimate strength (σ_{ut}) for dissimilar sheet material.

Proportional limit for similar sheet material is 16.67 MPa while for dissimilar sheet material is 14.78 MPa. The difference of proportional limit (σ_{pl}) between both specimens is about 11.34%. Proportional limit of specimens is the point on the stress-strain graph where the curve becomes nonlinear. The proportional limit stress is the value of stress is the value of stress corresponding to the elastic limit of the materials. For strain levels below the elastic limit strain, Hooke's law was used to relate stress to strain. The proportional limit commonly assumed to coincide with yield point.
Fracture point or breaking strength is the stress coordinates on the stress-strain curve at the point rapture. The fracture point of similar sheet material is 0.3229 mm. while

the fracture point of dissimilar specimens is 0.3084 mm. the differences between this values is about 4.70%. After a period of the necking, the specimen will rapture and the stored elastic energy is released as noise and heat. The stress on the material at the time of the rapture is the tensile strength. The tensile strength for similar specimen is 22.25 MPa. While for dissimilar sheet material is 22.20 MPa.

Table 4.3: Stress- Strain

Properties	Similar	Dissimilar	Percentage (%)
Modulus elasticity (E); [E=σ/ε]	285.71 MPa	269.23 MPa	3.91
Yield Strength (σy)	20.81 MPa	19.10 MPa	8.20
Proportional Limit (σpl)	16.67 MPa	14.78 MPa	11.34
Ultimate strength (max stress)(σut)	27.90 MPa	26.20 MPa	6.09
Fracture point (ε_f)	0.3229	0.3084	4.70

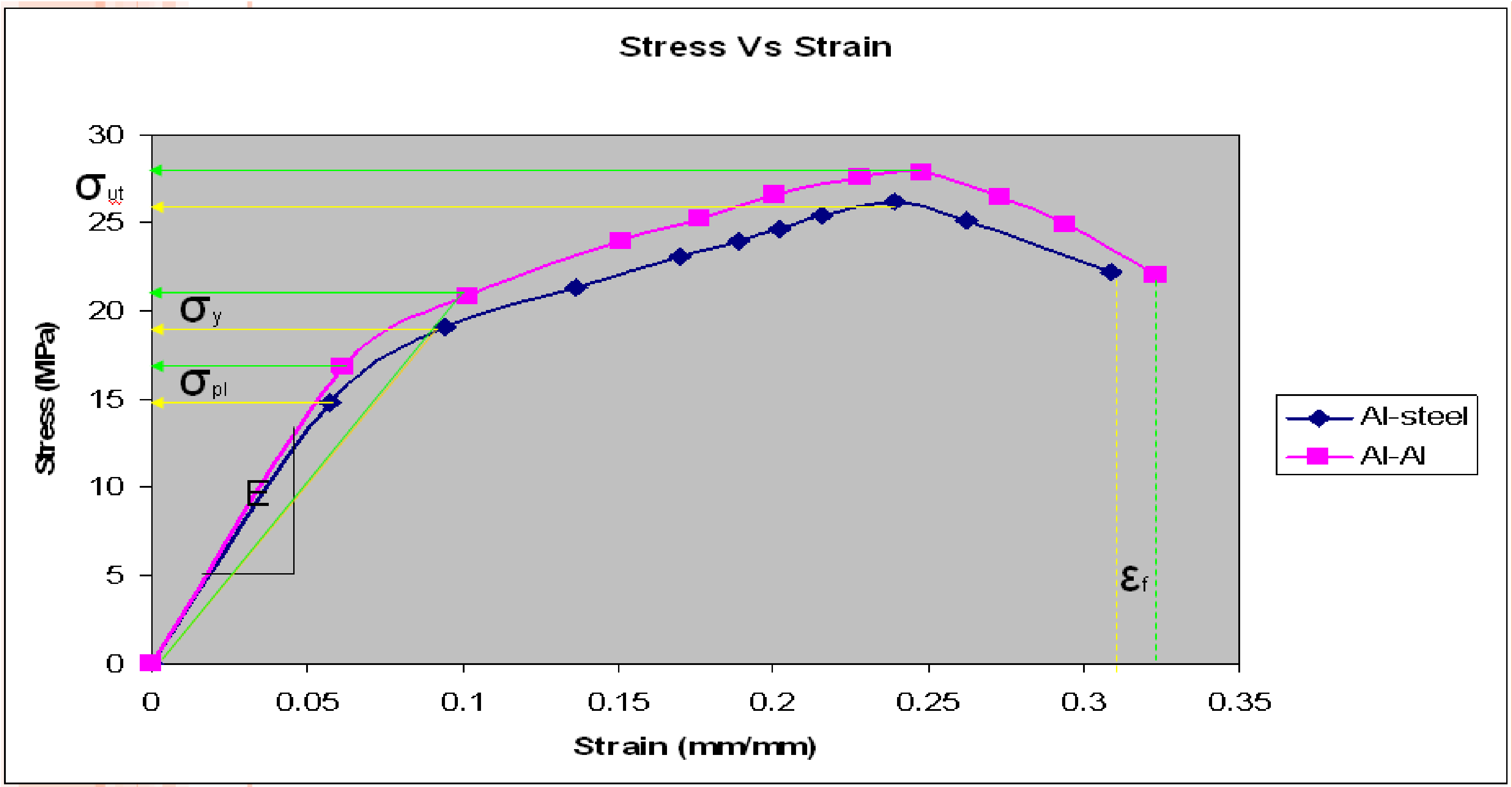


Figure 4.6: Graph 2: Stress-strain Diagram

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 INTRODUCTION

Chapter 5 is the last chapter in this thesis writing. In this chapter, the whole conclusion of this project that has been carried out in last two semesters will be discussed.

5.2 CONCLUSION

Rivets are considered to be a permanent fastener beside clinch, spot welding and adhesive joint. Rivets have been used in many large scale applications including automotive industry, ship-building, boilers, pressure vessels, bridges and building. After the overall the view of the experimental result and discussion of rivets joining similar and dissimilar sheet materials, it can be concluded the rivets joining under dissimilar sheet material can be applying in industry due to the weight reduction and the strength of structure and also because of the low cost.

This is proven by the tensile test that done to the rivets joining similar and dissimilar specimens, which the tensile strength for both specimens was small difference value is only about 0.22%. It is very small value between both specimens for the tensile strength. This value shown that the rivet joining under dissimilar sheet material is available to apply in industry specializes in automotive industry due to weight reduction and the strength of structure. More over, this is another way to solve the spot welding problem due to dissimilar combination of sheet materials.

5.3 RECOMMENDATION FOR FUTURE WORK

This recommendation was made because; from the result of tensile strength of rivets joining it only give the stress-strain diagram due to tension force that applied to the joining. Therefore, for further analysis for improving the strength of rivets joining, it should focus on other parameters such as cycle of life (N) of rivets joining similar and dissimilar sheet material using fatigue test using MTS Servo-Hydraulic testing machine. This is because due to the rivet application in industry more bare to fatigue.

Beside that, the strength of rivets joining can be improve when using self-piercing, where this type of rivet is more effective, simplicity, and versatility, relatively low cost and not need use large energy during installation of rivets. More over, this rivets joining can be joining in many design of specimen such as lap-shear, U-shape and cross-section as other parameters.

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APPENDIX 1

Rivet process

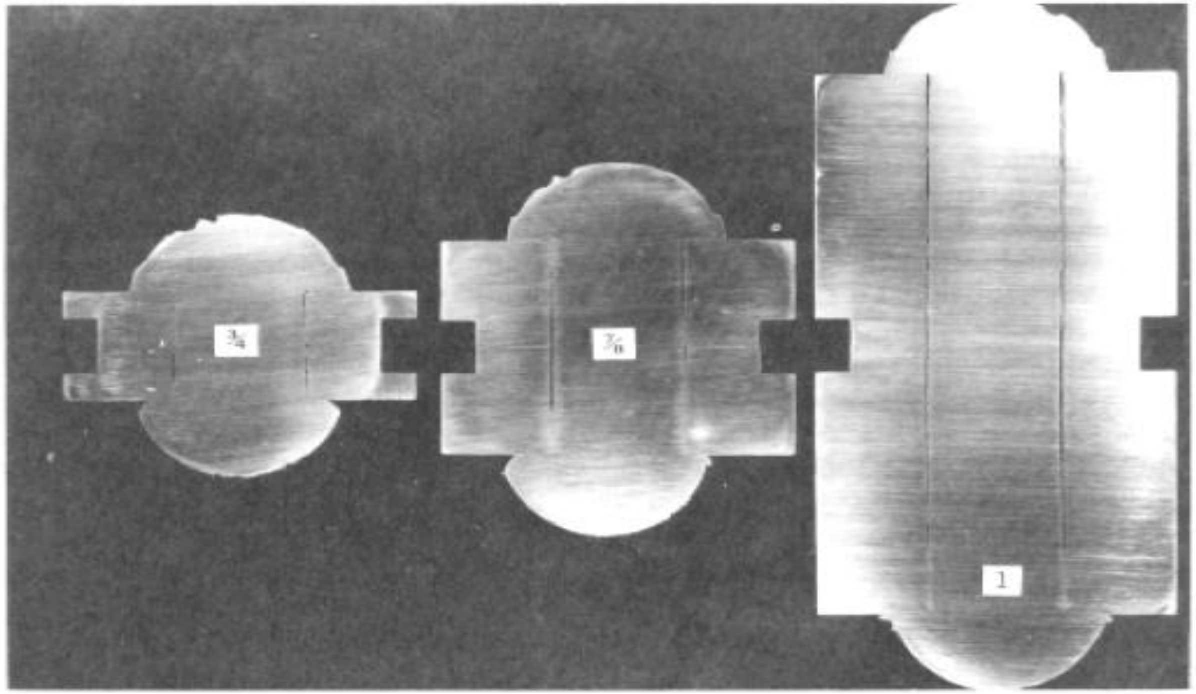
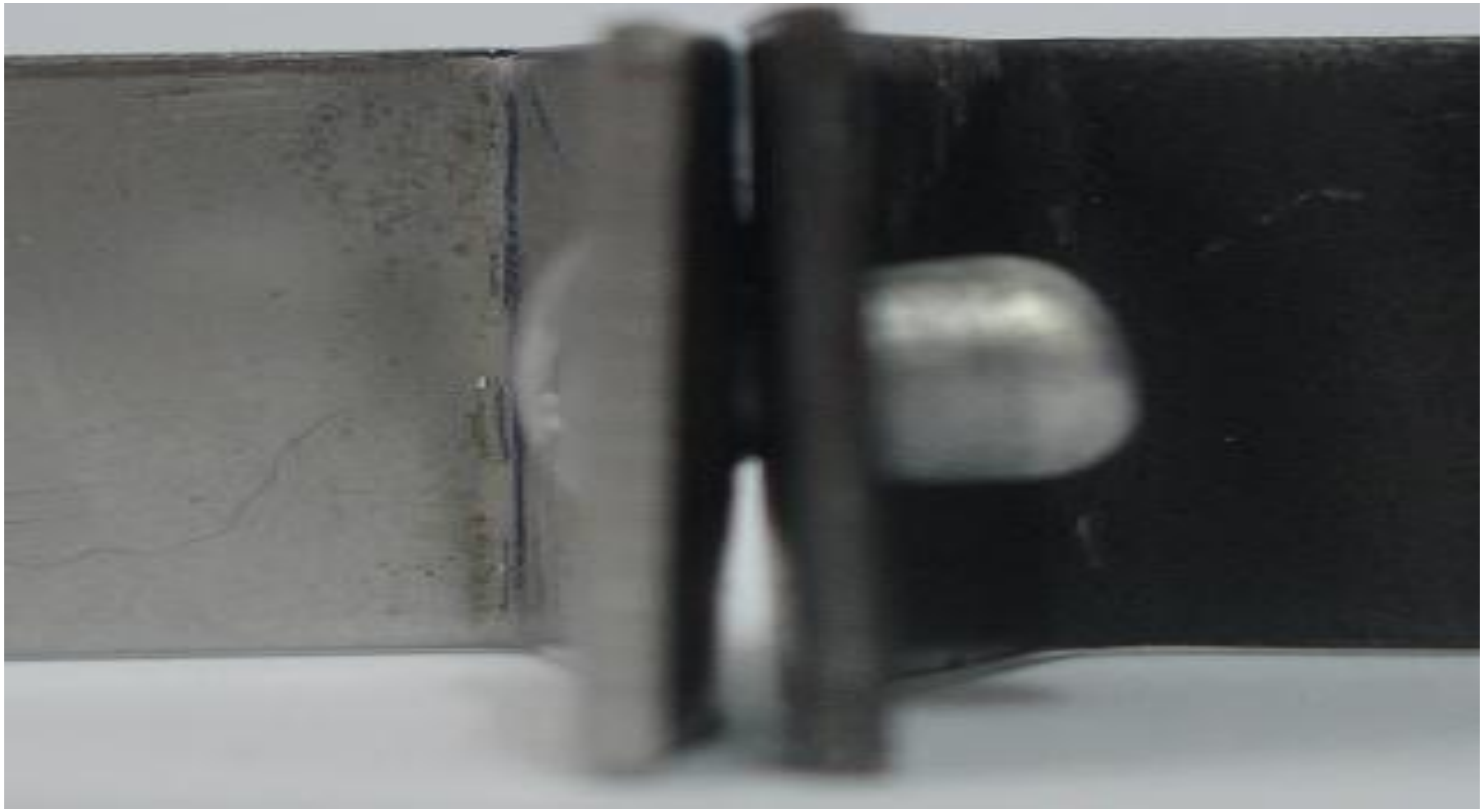


Fig 3.1. Sawed Sections of driven rivets. (Courtesy of University of Illinois.)

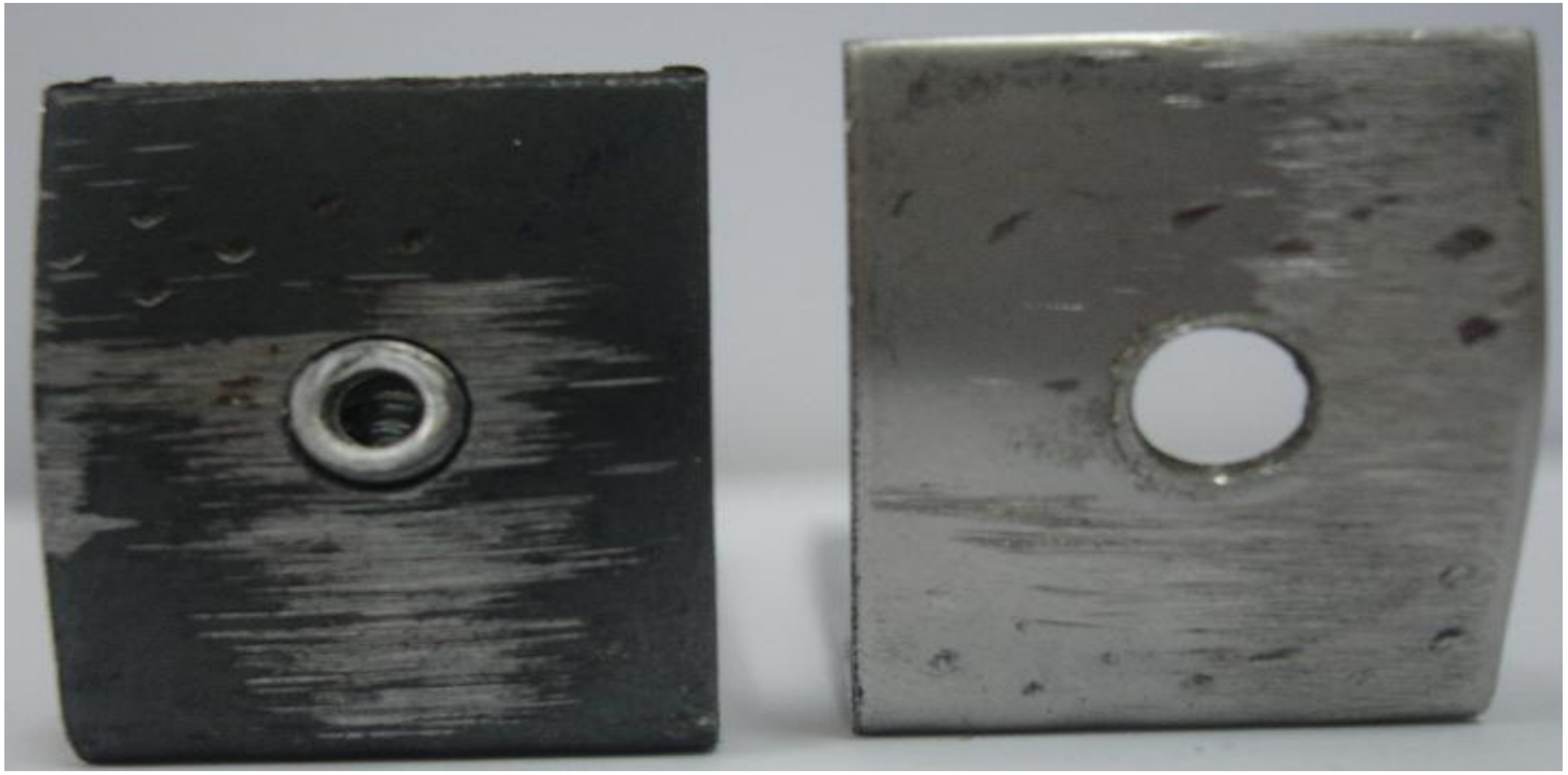
APPENDIX 2

Rivets joining dissimilar sheet materials



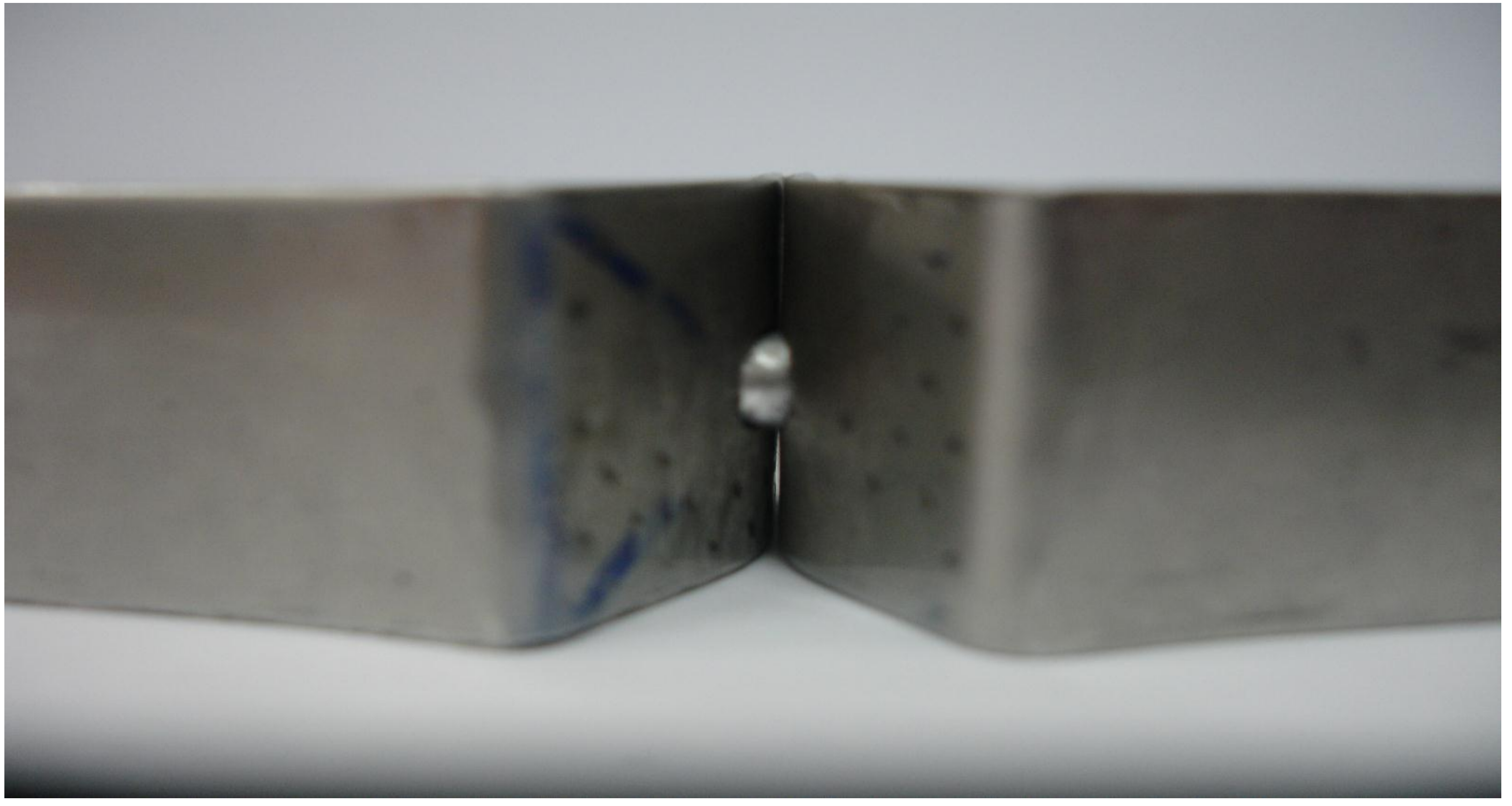
APPENDIX 3

Rivets joining dissimilar sheet material



APPENDIX 4

Displacement of rivets joining during tensile test



APPENDIX 5

The failure location; rivet head

APPENDIX 6

The application of rivets joining in automotive industry