THE APPLICATION OF ADHESIVE BONDING FOR DIFFERENT TYPES OF MATERIAL FOR CAR BODY PART

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ABSTRACT

The application of adhesive bonding as a new technology method to join car body parts shows the pace of development in automotive technology recent years. But, adhesive technology application used and advantages are not fully explored. This study deals with effectiveness of adhesive bonding as an alternative to spot weld to join car body parts and to investigate the tensile strength of the adhesive bonding based on the different material specification of varying thickness. Two types of joining method involve in this study which is adhesive bonding and spot weld. By joining two different materials with varying thickness, these two types of joining method are tested by undergoing tensile shear test for multiple specimens. Load/extension graph is plotted from data collected and result based on tensile shear strength is compared. From the study, adhesive bonding achieve higher tensile strength compared to spot weld with shear tensile strength up to 12.0847 MPa.

ABSTRAK

Aplikasi ikatan pelekat sebagai kaedah teknologi baru untuk mencantumkan bahagian badan kereta menunjukkan kadar pembangunan dalam teknologi automotif kebelakangan tahun ini. Tetapi, aplikasi teknologi pelekat yang digunakan dan kelebihannya tidak diterokai sepenuhnya. Kajian ini berkaitan dengan keberkesanan ikatan pelekat sebagai alternatif kepada *spot welding* untuk mencantumkan bahagian-bahagian badan kereta dan mengkaji kekuatan tegangan ikatan pelekat berdasarkan spesifikasi bahan yang berbeza dan ketebalan yang berbeza-beza. Dua jenis kaedah pencantuman terlibat dalam kajian ini iaitu ikatan pelekat dan *spot welding*. Dengan mencantumkan dua bahan yang berbeza dengan ketebalan yang berbeza-beza, dua jenis kaedah pencantuman ini diuji dengan menjalani ujian ricih tegangan bagi spesimen berganda. Beban / lanjutan graf diplot daripada data yang dikumpul dan keputusan berdasarkan kekuatan ricih tegangan akan dibandingkan. Dari kajian ini, ikatan pelekat mencapai kekuatan tegangan yang lebih tinggi berbanding *spot welding* dengan kekuatan tegangan ricih sehingga 12.0847 MPa.

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LIST OF SYMBOLS

Q	Heat generated
I	Current
R	Resistance of the work
T	Duration of current
σ	Stress
ε	Strain
τ	Shear stress
F	Force applied
A	Cross-sectional area of material with area parallel to the applied force vector

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

As a result of the pace of development in automotive technology in recent years, a new technology method of joining car body parts is introduced that is adhesive bonding. Nowadays, adhesive bonding is used for various applications in the modern automotive industry, ranging from flexible car body sealing to high-performance structural adhesives. Adhesive types with specific properties are available for miscellaneous processing. The requirements for adhesive bonds have increased due to the extended life of the car. Industrial health and environmental protection aspects have become more and more important in adhesive processing. Therefore, requirement for the adhesive to be used in the future is necessary. Moreover, the demands for better quality standards are increasing promote the adhesive as an alternative to join the car body parts.

In the body assembly department in automotive industry, there are several method were used such as tailor welded blank, spot weld and laser weld. For this report, adhesive will be taken as the main research and case study to be compared with spot weld.

1.2 PROBLEM STATEMENT

In the world's major car manufacturers manufacturing trends adhesive, their technology application used and advantages are not fully explored. One of the factors that influence the selection is the strength of the adhesive bonding based on the different material specification of varying thickness. Understanding the effectiveness of adhesive bonding as an alternative to spot weld to join car body parts also will lead the automotive industries to explore various methods to assemble the body parts in future.

1.3 OBJECTIVES OF THE RESEARCH

In the end of this project, there are 2 objectives that are going to be achieved

1. Study the effectiveness of adhesive bonding as an alternative to spot weld to join car body parts
2. Investigate the tensile strength of the adhesive bonding based on the different material specification of varying thickness

1.4 SCOPE

This project is to investigate the effectiveness of adhesive bonding as an alternative to spot weld to join car body parts. In order to determine the effectiveness, further investigation on the strength of the adhesive bonding based on the different material specification of varying thickness will be done. The samples are tested by using tensile shear test to determine the displacement at maximum load and maximum load before fracture of the spot weld joint and adhesive joint.

1.5 PROJECT FLOWCHART

The flow of this project is presented in Figure 1.1 in order to make sure the process flow of this project run smoothly.

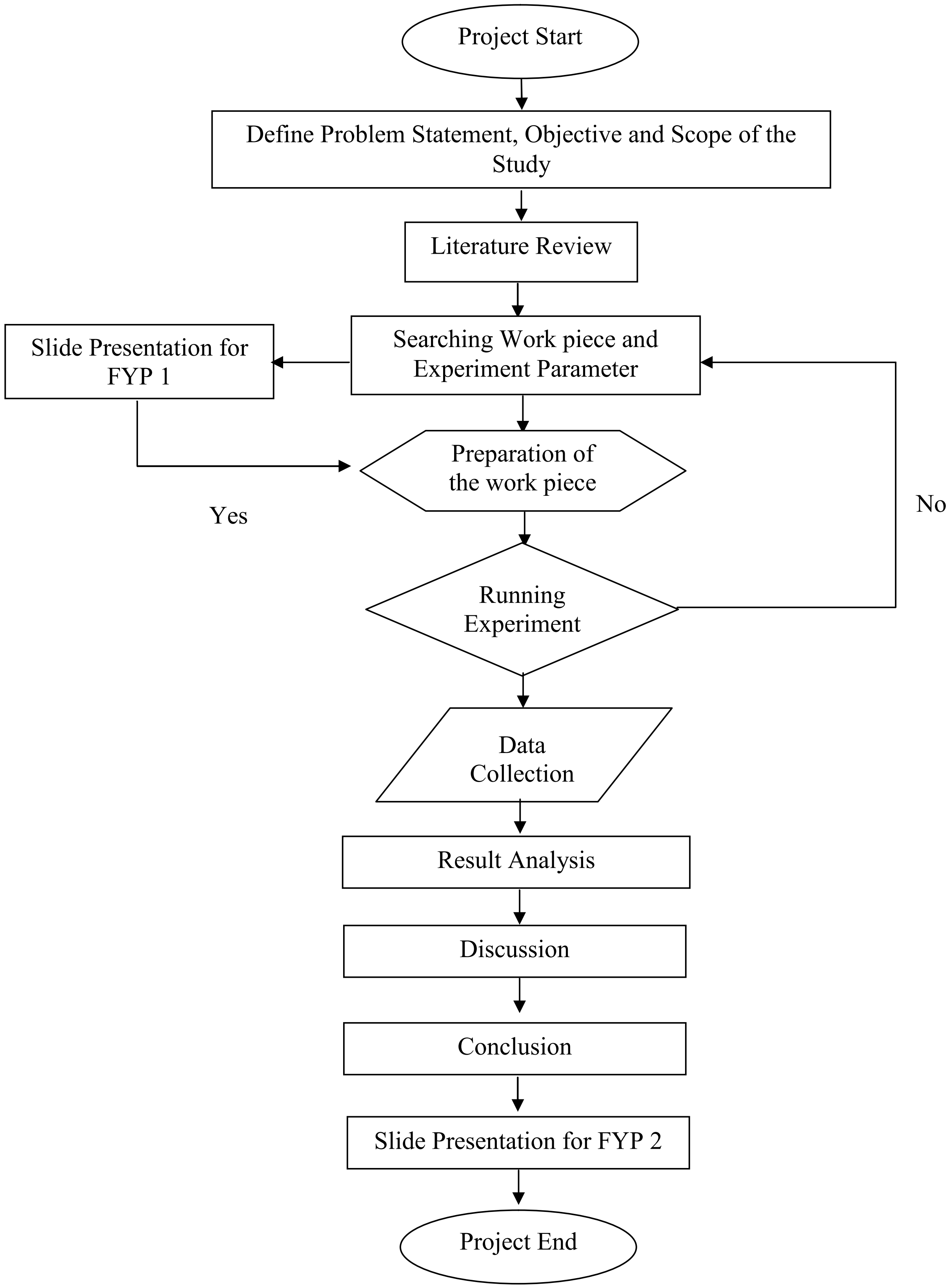


Figure 1.1: Flow Chart of the Project

1.6 OVERVIEW OF THE PROJECT

This project will investigate the strength of the adhesive bonding based on the different material specification of varying thickness and to study the effectiveness of adhesive bonding as an alternative to spot weld to join car body parts. Tensile shear strength will show the behavior of adhesive by comparing its strength with the spot weld strength.

Project background, problem statement, scope and objective are discussed in Chapter 1. The details and researches reviews in adhesive bonding and spot welding will be briefly discussed in Chapter 2. Chapter 3 is for the methodology flow in this project. Chapter 4 will discuss about results and discussion. And the last chapter which is Chapter 5 will explain about conclusion and recommendation of this project.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter presents related article, journal and other references regarding application of adhesive bonding in joining different material for car body parts. The subtopic also will explain more about principle, theoretical and example for further investigation. Thus, all the topics can be referred and used as guidance to make sure the project objective is achieved,

2.2 BACKGROUND OF RESISTANCE SPOT WELDING

There is vary kind of joining method used in automotive industry such as laser welding, shield arc welding, clinch joining and resistance welding. Resistance spot welding will be main subject in this study. Resistance spot weld is a thermo-electric process to join metal parts by generating heats at the interface of the metals by passing electrical current through them under controlled time and controlled pressure. It is commonly utilized in the automotive industry where it is used to weld the sheet metal of varying thickness to form a car. This joining technique is applied due to its major advantages which are high speed and its adaptability for automation in high volume and high rate production. Despite these advantages, resistance spot welding suffers from a major problem of inconsistent quality from weld to weld. The quality itself define how joining method need to be improve when automation, weld quality, demand over welding and drive up production cost is take into consideration. Thus, ensuring weld and joining quality has been and remains a major challenge and goal (Mohamad, 2008). Resistance spot welding (RSW) is widely used in sheet metal assemblies. Thousands of spot for passenger vehicle had performed resistance spot welding; therefore, each welded has its importance both on quality and production manufacturing (Cho et al., 2006). This process is extensively used to join low carbon steel component for the bodies and chassis of automobile, trucks, buses and many other product.

2.3 PRINCIPLE OF RESISTANCE SPOT WELDING

To ensure the spot welding process in this study work at best performance, its fundamental need to be studied first. Basically, resistance welding is completed when current is flowed through electrode tip to join the separate pieces of metal. The weld is made when the resistance of the base metal to electrical current flow causes localized heating in the join

The uniqueness of spot weld is because the weld nugget is formed internally in relation to the surface of the base metal. The comparison of resistance spot weld nugget and gas tungsten arc (TIG) spot weld is shown in Figure 2.1

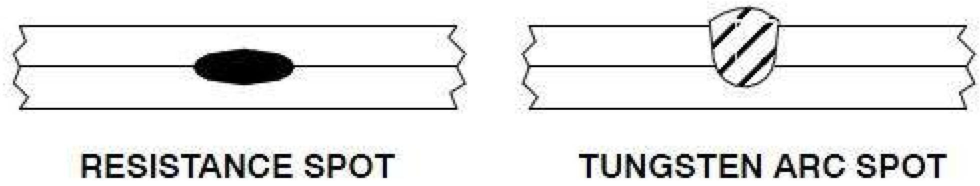


Figure 2.1: Comparison of Resistance and TIG Spot Weld

Source: Miller (2012)

Resistance spot welds may be made with the work piece in any position. The resistance spot weld nugget is formed when the interface of the weld join is heated due to the resistance of the join surfaces to electrical current flow. In all cases, of course, the current must flow or the weld cannot be made. The pressure of the electrode tips on the workpiece holds the part in close and intimate contact during the making of the weld. However, that resistance spot welding machines are not designed as force clamps to pull the work pieces together for welding. A modification of Ohm’s Law may be made when watts and heat are considered synonymous. When current is passed through a conductor the electrical resistance of the conductor to current flow will cause heat to be generated. The basic formula for heat generation may be stated:

$$Q = I^2 Rt \quad \text{---} \quad (1)$$

Where Q = heat generated, joules; I = current, amperes; R = resistance of the work, ohms; t = duration of current, seconds.

The secondary portion of a RSW circuit, including the parts to be welded, is actually a series of resistances. The total additive value of this electrical resistance affects the current output of the resistance spot welding machine and the heat generation of the circuit. The key fact is, although current value is the same in all parts of the electrical circuit, the resistance values may vary considerably at different points in the circuit. The heat generated is directly proportional to the resistance at any point in the circuit (Miller, 2012)

2.4 RESISTANCE SPOT WELDING FOR UNEQUAL SHEET THICKNESS

This study involves resistance spot welding for dissimilar thickness. In resistance spot welding, one of the important factors that may affect the strength of the joining is undergo resistance spot welded on unequal sheet thickness. Previous research shows that the fatigue strength of resistance spot-welded dissimilar sheet thickness without considering the residual stress based on net section stress was 149% higher than that based on nominal stress, the percentage become smaller by considering the residual stress, even vice versa in lower stress range. (Triyono et al., 2011)

2.5 RESISTANCE SPOT WELDING FOR DISSIMILAR MATERIALS

When then welding involves of joining 2 or more materials, it is called dissimilar metal welding. Since this study involves spot welding of dissimilar materials, the requirement of different properties of material needed in the same weldment, dissimilar metal welding techniques is proposed. But, there is a challenge in welding dissimilar material that is because of the difference in physical and chemical properties of the base metal, such as poor wettability and different thermal. This process starts when the weld metal is heated to its melting point and then melted it to form a molten nugget (Zuhailawati et al., 2010). The heat imbalance in the dissimilar joints caused the asymmetrical shape of weld nuggets thus it will affect the strength of the welding itself.

2.6 BACKGROUND OF ADHESIVE BONDING IN LOW VOLUME AUTOMOTIVE MANUFACTURING

Nowadays, car body design and production is not just to "convectional" joining technologies for stampings. Important role for joining individual car body parts plays bonding technology possible application of adhesives are shown in Figure 2.2. These days using adhesives do not serve only for sealing function, anti-acoustic or anti-vibration barriers but are also using like structural joining types which into great extent influence strength and stiffness of car-body and thus its safeness and whole comfort. Car body design is normally use the thinnest (namely steel) sheets which are subsequently joined mainly by welding. However nowadays there is increasing tendency to use just bonded joins car body parts. Properly design of bonded joins can reduce problems with welding as well as to improve the quality (Kolnerová et al., 2010).

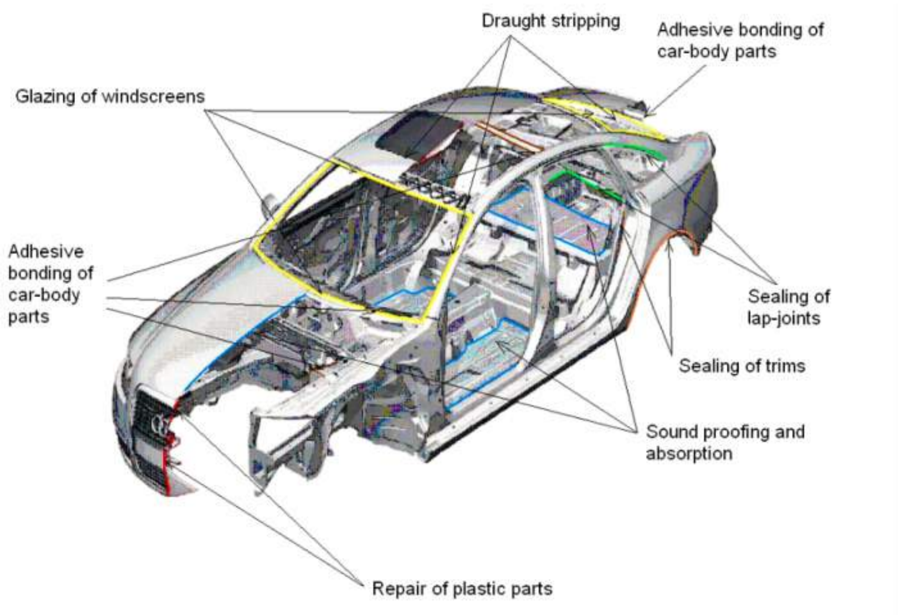
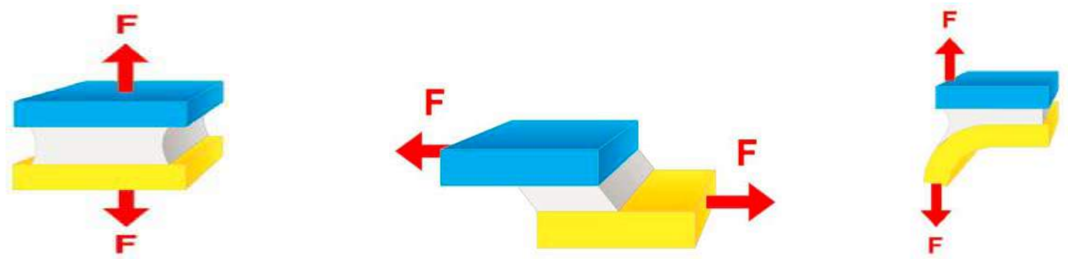


Figure 2.2: Adhesives application for car design

Source: Kolnerová et al, (2010)

From the functional loading point of view and the design point of view, adhesive is choose as an alternative in structural bonded joins in automotive industry. Bonded join is suitable for join design because of its pre condition for fine strength that is sufficient. Besides, bonded join are also know for very high shearing strength. Tensile strength is much lower and the worse properties are given under peel loading (see Figure 2.3). Principles of bonded join whether it is suitable to be use are given by firstly determine the character of used adhesive and also by requirement to reduce or eventually minimize tensile and peel loading. If there is not possibility to reduce these factors and is necessary to increase joining safety, bonding is combines with other joining technologies. In many cases bonded joins are used in combination with spot welding (e.g. door trims) (Kolnerová et al., 2010). In this study, shear bonded join loaded will be the main subject to determine the shear tensile test.



a) b) c)

Figure 2.3: Bonded join loading: a) tensile, b) shear, c) peel

Source: Kolnerová et al, (2010)

2.7 PRINCIPLE OF ADHESIVE BONDING IN JOINING

Adhesive bonding in this study can be referred to surface to surface joining of similar or dissimilar materials when using a substance which usually is of a different type, and which adheres to the surfaces of the two adherents to be joined, transferring the forces from one adherent to the other. An adhesive is a nonmetallic substance that fit of joining materials by surface bonding (adhesion), and the bond possessing sufficient internal strength (cohesion). In the traditional sense, bonding is a material joining technique that cannot be broken without destruction of the bond. Lately, development of specific bonding on demand techniques is done, for example as an assembly tool without further function, or for recycling based on a separation of materials, a method that today is becoming increasingly important (Brockmann et al., 2009).

Bonded join is rarely competes with other joining method used in industry. Case in point, considering bonding a steel bridge or a gantry is not suitable, but for the lightweight construction of car bodies using steel, aluminum, glass and plastics, adhesive joining offers extremely interesting applications. It is more appropriate for adhesive bonding to join large-sized surfaces of different materials, such as in the construction of sandwich assemblies. The advantages and disadvantages of adhesive bonding compared to other joining techniques are summarized in Table 2.1

Table 2.1: Characteristic features of adhesive join

Advantages	Disadvantages
• The adherents are not affected by heat • Uniform stress distribution • Possibility to join large surfaces • Possibility to join different materials • Possibility to join very thin adherents • Gas-proof and liquid-tight • No crevice corrosion • No contact corrosion • No precise fits of the adherent surfaces are necessary • Good damping properties • High dynamic strength	• Limited stability to heat • Long-term use may alter the properties of the bond-line • Cleaning and surface preparation of the adherents is necessary in many cases • Specific production requirements to be met • Specific clamping devices are often required to fix the join • Nondestructive quality testing is only possible to a certain extent

Source: Brockmann et al, (2009)

2.8 SHEAR STRENGTH TEST

One of the method use to express the results data in this study is by plotting stress/strain curve to obtain the tensile shear strength. The shear tensile test is practical to a bar or some other specimen. From Hooke's observations, that at small stresses and hence small strains can have a linear relationship. In fact, if the load is increased, other systematic behaviors can found once it beyond the elastic limit. If a test was carried out on a round bar up to the point when the bar eventually snapped, a stress / strain curve can be found as in Figure 2.4

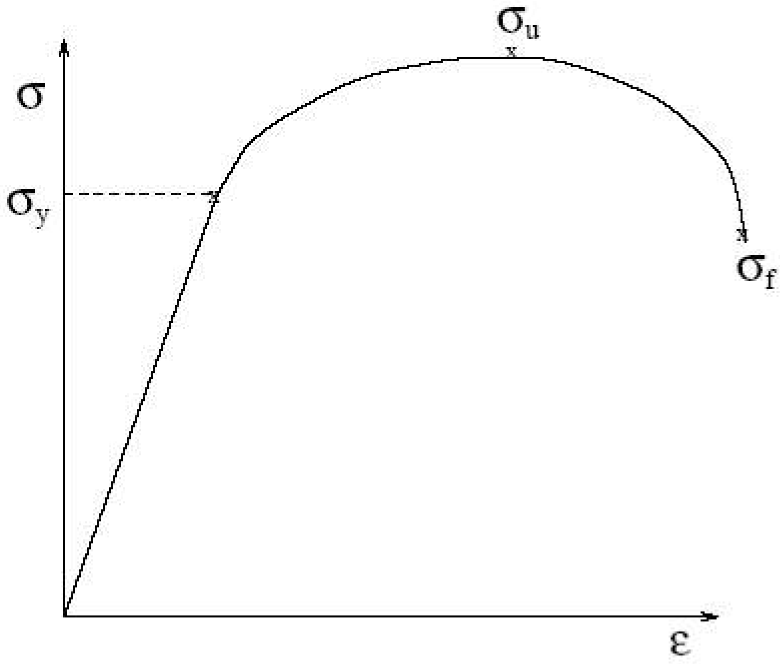


Figure 2.4: Full stress / strain curve

Source: Ibrahim (2008)

The behaviors can be summarized in terms of three regions on the curve in Figure 2.4. Region I from the origin to the point at *σy* when the behaviors in the linear. Region II is from the point at *σy* to the point at *σu* which is the maximum stress on the curve. Region III is from *σu* to *σf* is the point of failure or fracture (Ibrahim, 2008).

2.9 TENSILE MODE FAILURE FOR RESISTANCE SPOT WELDING

In shear tensile fracture samples, the crack develop around the edge of the nugget and the final failure occurs through the weld. To predict the failure of resistance spot welding in this study, three different fracture modes were observed by analyzing the fractured shear tensile testing samples, as shown Figure 2.5: (a) through weld with circumferential crack (Figure 2.5a), (b) plug pull-out with tearing (Figure 2.5b), and (c) plug pull-out with back plug, this last one presenting three variants, see Figure 2.5c. These fracture modes were observed both in sound and poor connections with the exception of the plug pull-out with back plug variants: plug on upper sheet and plug on lower sheet, Figure 2.5c. These two variants were associated to sound and poor joints respectively (Rosendo et al., 2011)

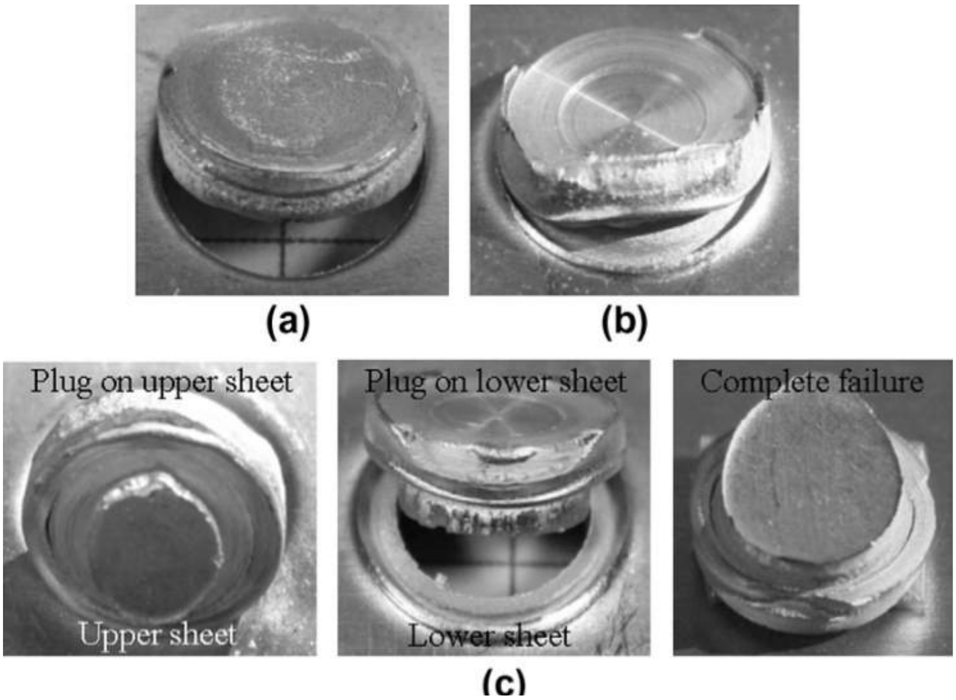


Figure 2.5: Fracture modes in shear tensile test: (a) through weld with circumferential crack, (b) plug pull-out with tearing, and (c) variants of plug pull-out with back plug.

Source: Rosendo et al. (2011)

However, in some cases, failure also can happen at the border of the spot weld. This type of failure was expected by the material properties which cause the spot welding remains its join. Figure 2.6 shows tear from the edge of nuggets which can be happen either at one side or both sides.

(a) (b)

Figure 2.6: Failure that is expected from material properties: (a) tear at the edge of one side, (b) tear at the edge of both side

Source: Aravinthan and Nachimani, (2011)

2.10 TENSILE MODE FAILURE FOR ADHESIVE BONDING

In order to gain fully understanding of the properties and the join, the mode of failure must be characterized. Three typical characterizations for the failure mode of an adhesive join had been identified which are:

a. Cohesive Failure: A cohesive failure is characterized by failure of the adhesive itself (see Figure 2.7).

b. Adhesive Failure: An adhesive failure is characterized by a failure of the join at the adhesive/adherents interface. This is typically caused by inadequate surface preparation, chemically and/or mechanically. Specimens that fail adhesively tend to have excessive peel stresses that lead to failure and often do not yield a strength value for the adhesive join, but rather indicate unsuitable surface qualities of the adherents (see figure 2.7).

c. Substrate Failure: A substrate failure occurs when the adherents fails instead of the adhesive. In metals, this occurs when the adherents yields. In composites, the laminate typically fails by way of inter laminar failure, i.e., the matrix in between plies fails. A substrate failure indicates that the adhesive is stronger than the adherents in the join being tested. This is a desirable situation in practical design, but not when determination of adhesive behavior is being studied (Tomblin, 2001)