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THE FRACTURE MECHANIC ON THE SPOT WELDED JOINT

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Laporan ini dikemukakan sebagai memenuhi sebahagian daripada syarat penganugerahan Ijazah Sarjana Muda Kejuruteraan Mekanikal (Struktur & Mekanikal)

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APRIL 2009

"I hereby declare that this project report entitled "the fracture mechanic on the spot welded joint" is written by me and it is my own effort except the ideas and summaries which I have clarified their sources".

Signature :…………………………………

Author :…………………………………

Date : ………………………………...

To my beloved parents,
Syamsulrizal bin Mustafa.and Kamsiah bt. Zakaria
Who inspired me with their love and kindness.

To all my friends,
For giving me support and idea.

ACKNOWLEDGEMENTS

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ABSTRACT

My Projek Sarjana Muda (PSM) is regarding a study and analyze problem those related the fracture mechanic on the spot welded joint. This project enables me to collect all the relevant information about spot welded concept and the application of spot welded. This study presents the fracture of the spot weld, sheets thickness and stresses on the the spot-weld joints to predict the maximum stress and location of the weakest spot-welds at the specimen of spot welded joint. A simple model was used to illustrate the technique of spot-weld stress analysis. Finite element model and analysis were carried out utilizing the finite element analysis commercial codes. MSC nastran patran analysis was carried out to predict the stress state along the weld direction. It can be seen from the results that the predicted life greatly influence the sheet thickness, nugget diameter and loading conditions of the model. Acquired results were shown the predicted life for the nugget and the two sheets around the circumference of the spot-weld at which angle the worst damage occurs. The spot-welding fracture analysis techniques are awfully essential for automotive structure design.

ABSTRAK

Projek Sarjana Muda (PSM) saya adalah mengenai satu kajian dan analisa masalah yang berkenaan dengan retakan mekanik pada satu sambungan kimpalan titik (spot weld). Projek ini membolehkan saya bagi mengumpul semua maklumat yang relevan tentang konsep kimpalan titik dan aplikasi kimpalan titik. Kajian ini membentangkan tentang retakan kimpalan titik, ketebalan kepingan logam dan tekanan pada kawasan kimpalan titik untuk meramalkan tekanan maksimum dan lokasi yang paling lemah pada kawasan.kimpalan titik di spesimen sambungan kimpalan titik. Satu model ringkas telah dibentuk untuk menjelaskan teknik analisis tegasan kimpalan titik. Model elemen terhad dan analisis (fenite element method) dijalankan dengan menggunakan kod-kod analisis unsur . Analisis MSC NASTRAN PATRAN telah dijalankan untuk mengetahui tekanan yang terdapat pada kimpalan. Ianya boleh dilihat melalui keputusan yang telah jelas diketahui yang mempengaruhi ketebalan kepingan, garis pusat ketulan dan situasi daya pada model. Keputusan yg diperolehi telah menunjukkan kehidupan yang diramal untuk ketulan dan dua kepingan sekitar lilitan kimpalan titik dimana kerosakan paling teruk berlaku. Teknik analisis retakan kimpalan titik adalah penting untuk reka bentuk struktur automotif.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Welding is a fabrication process that joins materials, usually metals or thermoplastics, by causing coalescence. This is often done by melting the work pieces and adding a filler material to form a pool of molten material (the *weld puddle*) that cools to become a strong joint, with pressure sometimes used in conjunction with heat, or by itself, to produce the weld.

There are many different energy sources can be used for welding, including a gas flame, an electric arc, a laser, an electron beam, friction, and ultrasound. While often an industrial process, welding can be done in many different environments, including open air, underwater and in outer space. Regardless of location, however, welding remains dangerous, and precautions must be taken to avoid burns, electric shock, eye damage, poisonous fumes, and overexposure to ultraviolet light.

Spot welds are very commonly used in the automotive industry in the fabrication of all manner of components and structures, and the durability of such structures is very often controlled by the strength of the spot welds. This project will investigate and analysis the effect of geometrical variables on the fatigue resistance and fracture mechanic of the spot welded joint. The automotive part that will be analysis is Front

Door of Proton car. The Finite Element Method (FEM) will carried out to analysis the structure and all stresses on the part of spot welded joint. The model will be designed according to the real dimension using the Solidwork. The complete model from solidwork will be exported to nastran patran software to analysis and calculate the stress on the spot welded.

1.2 OBJECTIVE

This project carried out the study and analyze problem those related to the fracture mechanic on the spot welded joint. The other objectives that contain in this project are:

1. To understand the using of spot welded joint in Automotive.
2. To testing the spot weld using ASTM E8M-04 (Tensile Test)
3. To simulate the part using MSC Nasran/Patran software.

1.3 SCOPE

The scopes of this study are:

1. To understand the spot welded characteristic and behavior.
2. Testing the spot weld using the ASTM E8M-04 (Tensile Test)
3. To simulate the automotive part using nastran patran and comparison with Testing value need to be done.

1.4 PROBLEM STATEMENT

The Spot Welds are widely use in automotive industries. The problem of estimating the spot weld quality is an important component in quality control. The modern automobile, for example, includes several thousand spot welds that have to be reliable. Current methods of spot-weld inspection include destructive shear lap testing, conventional ultrasonic testing, and testing with analysis software. During the procedure of shear lap testing the weld in order to perform this test, material is sheared and welded together in a lap weld. The specimen is then pulled in a suitable tension testing machine and data is recorded. This is a time and labor consuming and labor intensive procedure, and the tested part is destroyed, which is not acceptable for inline testing. So, this study will deal with some analysis to find the possible reason of the problem.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The literature review consists of various aspects regarding the effect of geometrical variables the fracture analysis using the finite element method on the spot welded joint.

2.2 PRINCIPLE OF THE SPOT WELDED

Spot welding is a widely employed technique to join sheet metals for body and cap structure in the automotive industry. The strength of the spot welds in the unibody vehicle structure determines the integrity of the structural performance during the vehicle operations.

Most spot welds generally carry only shear forces but spot welds can also experience a significant amount of peel force or the force normal to the spot weld in certain loading conditions. The combination of the stress states and geometric shapes of the spot welds lead to stress concentration that can result in fatigue crack initiation around the spot weld. The presence of fatigue cracks can degrade structural performance and increase noise and vibration of the vehicle structure. Therefore, understanding of the fatigue strength for the spot welds is very important in automotive component design.

The static strengths of spot welds have also been investigated. Ewing *et al*.[1] investigated the strength of spot welds in terms of the specimen geometry, welding parameter, welding schedule, base metal strength, testing speed and testing configuration. Zhang and Taylor [2] reported the thickness effect of spot welded structure on fatigue life. Pan and Sheppard [3] calculated stress intensity factors for crack propagation through the thickness of plate by numerically utilizing finite element analysis. Lee *et al*.[4] adopted a fracture mechanics approach using the stress intensity factor to model their experimental results on the strength of spot welds in U-tension specimens under combined tension and shear loading conditions. Wung[5] and Wung *et al*.[6] obtained and analyzed test results from lap-shear, inplane rotation, coach-peel, normal separation and inplane shear tests and proposed a failure criterion based on the experimental data of spot welds in various specimens.

Some researchers [7-9] have studied on the effects of base metal properties on the fatigue life of spot welds. They have also studied on the effects of loading conditions with different specimen types such as tensile shear, coach peel and cross tension specimens. These studied showed in general that fatigue life of spot welds depended on the loading conditions and base metal properties.

On the other hand, numerous researchers [1,10-14] proposed analytical and/or empirical models to predict the fatigue strength of spot welds in the early vehicle design stage. Most of these models were developed based on the relationship between a fatigue damage parameter and number of cycles to failure of spot welds. The objective of this study is to investigate the effect of the sheet thickness and diameter of the spot weld nugget on the fatigue.

2.3 STRUCTURAL STRESS PARAMETER

Welded joints experience highly localized heating and cooling from welding processes. As a result, the material properties around the welding joints can be significant variations after welding. The local geometry of the welded joints may have variations due to the amount of heat inputs and welding skills. These variations present significant difficulties for reliable fatigue prediction of welded joints.

Dong[15-16] proposed a structural stress parameter for welded joins based on local stresses at weld toe. A typical through-thickness stress distribution at a fatigue critical location and the corresponding structural stress definition for through-thickness fatigue crack at the edge of a spot weld are shown in Fig. 2.1 and 2.2. Stress distribution at the edge of the spot weld nugget is assumed as shown in Fig. 2.1. In Fig. 2.2, t represents the thickness of the sheet steel, σ_x and τ are the normal and transverse shear stress under axial force P respectively. The corresponding structural stress distribution is shown in Fig. 2.2. The structural stress (σ) is expressed in

Eq.2.1:

$$\sigma = \sigma_m + \sigma_b \tag{2.1}$$

where, σ_m is the membrane stress component and σ_b is the bending stress component due to the axial force P in the x direction. The transverse shear stress can be calculated based on local structural shear stress distribution, however, the effect of transverse shear stress neglected since the spot weld does not experience significant transverse shear loads in general[15].

The structural stress is defined at a location of interest such as plane A-A in Fig. 2.3 and the second reference plane can be defined along plane B-B. Both local normal and shear stress along plane B-B can be obtained from the finite element analysis. The distance in local x-direction between plane A-A and B-B is defined as δ. The structural membrane stress and bending stress must satisfy Eq. 2.2 and 2.3 for equilibrium conditions between plane A-A and B-B. Equation 2.2 shows the force balances in x-direction, evaluated along the plane B-B. On the other hand, Eq. 2.3 shows moment balances with respect to plane A-A at y = 0. When δ between planes A-A and B-B becomes smaller then transverse stress τ in Eq. 2.3 is negligible. Therefore, Eq. 2.2 and 2.3 can be evaluated at Plane A-A in Fig. 2.3

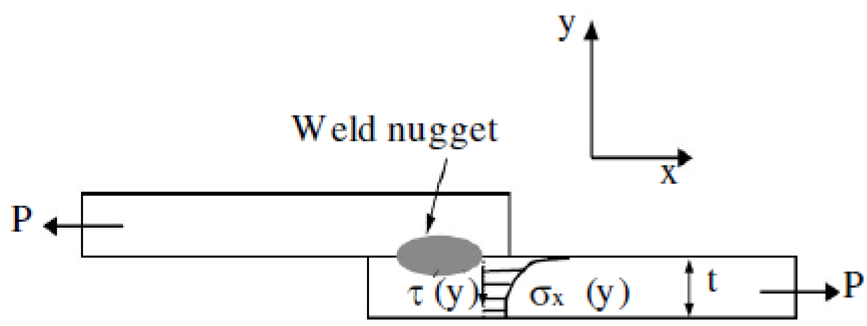

Figure. 2.1: Local normal and shear stress in thickness direction at the edge of a spot weld

(Source : Dong. P. (2001))

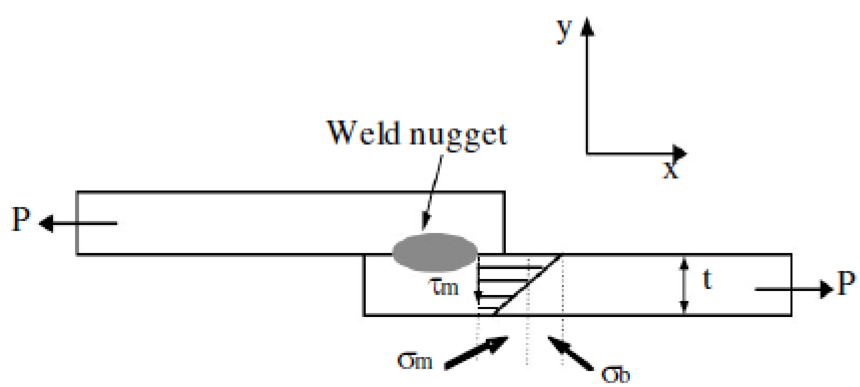

Figure 2.2 : Structural stress definition at the edge of spot weld nugget

(Source :Dong. P. (2001))

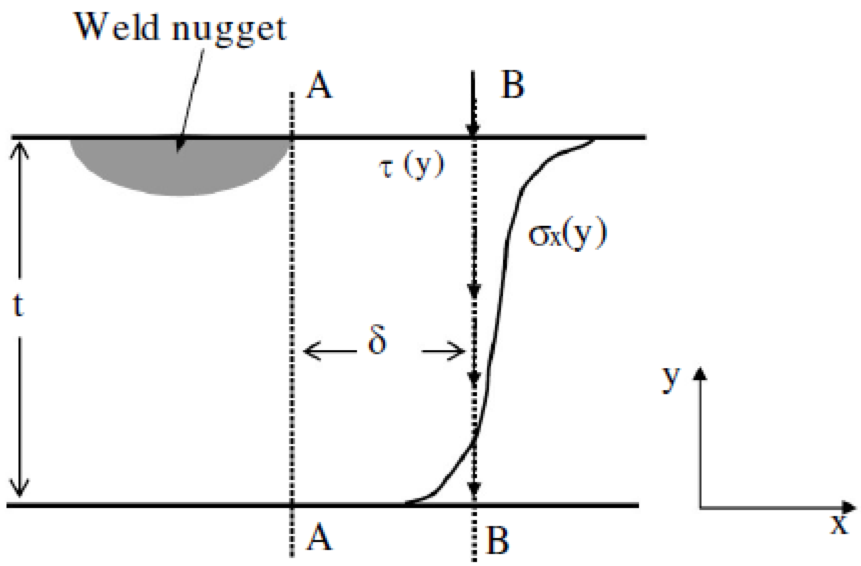

Figure 2.3: Structural stress calculation procedure for fatigue crack in thickness direction at the edge of the weld nugget

(Source : Dong. P. (2001))

$$\sigma_m = \frac{1}{t}\int_0^t \sigma_x(y)dy \tag{2.2}$$

$$\sigma_m\left(\frac{t^2}{2}\right) + \sigma_b\left(\frac{t^2}{2}\right) = \int_0^t y\sigma_x(y)dy + \delta\int_0^t \tau(y)dy \tag{2.3}$$

2.4 ANALYZE USING FINITE ELEMENT METHOD (FEM)

Traditionally, a very detailed finite element model of a spot welded joint is required to calculate the stress states near the joint[17-19]. This model produces reasonable results but it requires a good amount of effort for modeling and computational time.

Therefore, the very detailed finite element modeling of spot welds is not feasible for 3000- 5000 spot welds in a typical automotive body structure[12]. Instead of the detailed modeling of the spot welds, a simple beam element represents a spot weld for fatigue calculation of the spot welds in a vehicle structure[12,14,20].

For the mesh insensitive structural stress calculation, the specimen for a spot welded joint is modeled with shell/plate, beam and rigid elements. The circular weld mark in each plate is modeled by triangular shell elements and rigid beams forming a spoke pattern as shown in Fig. 2.4. The rigid beam elements are connected from the center node to the peripheral nodal points of the circular weld marks in the both plates. Then the center nodes of the circular weld marks in both plates are connected with a beam element.

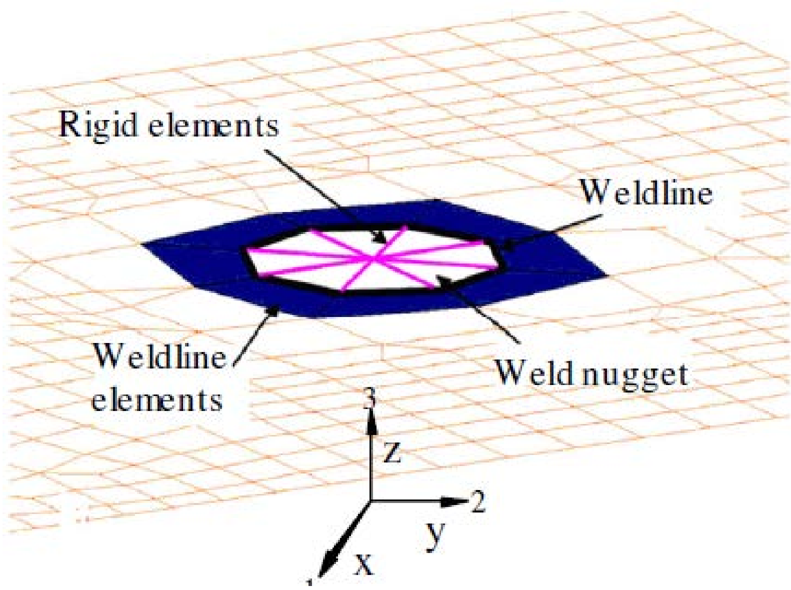

Fig.2.4: FEM around spot weld nugget

(Source : Rupp. A., K Srorzel and Z. Grubisic (1995))

Fig. 2.4 shows a finite element mesh around a circular weld mark. The geometry of the circular weld mark is required in the finite element model since the structural stress is calculated along the periphery of the weld. The normal direction of the shell elements (weldline elements) along the outside of the weldline is important for the calculation of the structural stress. Here, the weldline is defined as the periphery of the weld mark as shown in Fig. 2.4. A beam element represents the weld nugget to connect the top and bottom sheet steels. The length of the beam element is determined to be equal to one half of the total thickness for two sheets.

The nodal forces and moments in a global coordinate system at each mesh corner along the weld line (nugget periphery) with respect to the shaded elements in Fig. 2.4 are directly obtained from a linear elastic finite element analysis.

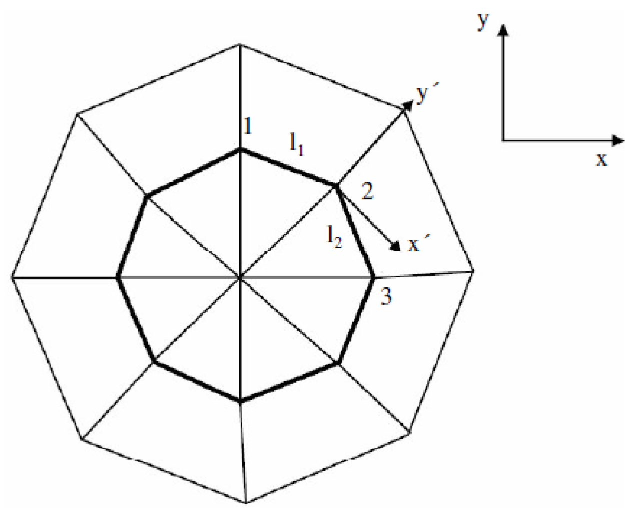

Fig. 2.5: Local coordinate system at a grid point

(Source : Rupp. A., K Srorzel and Z. Grubisic. (1995))