CORROSION AND MECHANICAL PROPERTIES STUDY OF CAR STEEL SHEET

AHMAD BASYIR BIN SADAN

BACHELOR OF ENGINEERING

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06500 LANGGAR,
KEDAH DARUL AMAN.

Nama Penyelia:

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Name of Supervisor	: Mr. Luqman Hakim Ahmad Shah
Date	: 06 December 2010

CORROSION AND MECHANICAL PROPERTIES STUDY OF CAR STEEL SHEET

AHMAD BASYIR BIN SADAN

Report submitted in partial fulfillment of the requirements
for the award of
Bachelor of Mechanical Engineering with Automotive Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

NOVEMBER 2010

SUPERVISOR'S DECLARATION

"I hereby declare that I have read this thesis and in my opinion this thesis sufficient in terms of scope and quality for the award the degree of Bachelor of Mechanical Engineering with Automotive Engineering"

Signature : ……………………………………………

Name of Supervisor : Madam Dayangku Noorfazidah Binti Awang Sh'ri

Date : 06 December 2010

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I declare that this thesis entitled corrosion and mechanical properties study of car steel sheet 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 of Candidate	: Ahmad Basyir Bin Sadan
ID Number	: MH07055
Date	: 06 December 2010

This work is dedicated to my beloved ones,

Sadan Bin Jusoh

Rognan Binti Tayib

Abdul Hadi Bin Sadan

Abu Hanifah Bin Sadan

Nukman Rashid bin Sadan

Mohd Najib Bin Sadan

Busyra Binti Sadan

Husna Binti Sadan

And

Allies…

Thank you for the endless support and encouragement.

You all always have a special place in my heart.

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ABSTRACT

This study is to understanding the corrosion behavior of deformed automobile parts, the effect on the mechanical properties and also to examine the microstructure changes due to corrosion. The methodology for this study started with preparing the sample which is deformed and undeformed steel for the immersion testing experiment and finished with the microstructure observation using optical microscope. Result is where all the data collected are analyzed and discussed with detailed explanation. Lastly, it covers the conclusion for the study. The study is hopefully will help automobile manufacturer in producing a better product for the automobile industry.

ABSTRAK

Kajian ini adalah bertujuan untuk memahami peri laku pengaratan sesebuah bahagian automobil, kesannya terhadap sifat-sifat mekanikal dan juga untuk menyelidik perubahan struktur mikro disebabkan oleh pengaratan. Kaedah-kaedah untuk kajian ini bermula dengan penyedian sampel iaitu sampel yang rata dan yang mempunyai bentuk untuk eksperimen rendaman dan disudahi dengan permerhatian mikro struktur menggunakan mikroskop ilusi. Data-data yang dikumpul dianalisi dan dibincang dengan huraian-hurainan yang jelas dan diletakan di bab keputusan. Yang terakhir ialah konklusi untuk kajian ini. Kajian ini diharapkan akan membantu pengilang-pengilang menghasilkan produk yang lebih baik untuk kegunaan industri automobil.

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$$CR = {}^{KW}\!/_{ATD}$$

LIST OF SYMBOLS

A	Area
A10	Elongation
CR	Corrosion Rate
D	Density
HRC	Rockwell Hardness Value
K	Constant in Corrosion Rate Equation
Qr	Shear Strength
Rr	Tensile Strength
T	Time
TS	Tensile Strength
W	Weight Loss
YS	Yield Strength

LIST OF ABBREVIATIONS

$g/cm^2.h$	gram per centimeters square hours
Kg/mm^2	kilogram per millimeter
mm	millimeter
MPa	Mega Pascal
% wt	Percent Total Weight

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Corrosion is degradation of materials' properties due to interactions with their environments, and corrosion of most metals (and many materials for that matter) is inevitable. The corrosion behavior of car body steel in service has been studied over many decades. Coating seems to be a good resolution but we should know that in car manufacturing, the deformation process during car body stamping also have a great contribution for development of corrosion on car parts. Due to that, galvannealed steel has been developed and has been used to reduce the effect of corrosion. They perform good formability and high strength at the same time but galvannnealed steel is not suitable or practical to be used at all parts due to cost and properties some part required.

It is essential to do more study in corrosion behavior and performance of the material in order to evaluate and improve the design, cost effectiveness and reliability of each material used. Study on the corrosion behavior of deformed steel for automobile parts in various environments shall be discussed further in this thesis.

1.2 PROJECT OBJECTIVE

There are three main objectives that have to be achieved in this research.

1. To study the corrosion behavior of deformed and undeformed steel of a car steel sheet body
2. To determine the corrosion effect on mechanical properties of car steel sheet body.
3. To examine the microstructure changes which occurs due to deformation and corrosion.

1.3 PROJECT SCOPES

There are three main scopes in this research.

1. To perform corrosion immersion testing.
2. To perform Rockwell Hardness testing.
3. To observe the microstructure changes using optical microscope.

1.4 PROBLEM STATEMENT

In automobile industry, deformations of a steel sheet due to the applying external forces change the shape of metal and also alter the arrangement of the atom. These changes more or less may affect the properties of by improving the strength of the part and at the same time may develop more reactive region for the corrosion to occur. Generally, the deformed parts will show more corrosion damage compared to the flat part. It is also said that it tends to corrode rapidly as reported in many journals. Usually coating the part with paint may retain the part from corrosion for a period of time. However there is still a tendency for the corrosion to develop underneath the paint due to a lot of causes such as strain, residual stress or microstructure alteration during the stamping process and others.

Therefore, it is essential to understanding the corrosion behavior of deformed automobile parts to avoid producing a low quality product due to short life cycle than specification. Proper study on this matter is highly necessary.

1.5 THESIS ORGANIZATION

This thesis consists of five chapters raging from chapter 1 to chapter 5. Chapter 1 gives an overview of the study conducted. It also includes objective, scope of the project and problem statement. Chapter 2 reviews the previous research works that was conducted by other people. All the relevant material including technical paper, journals, and books taken from those researches will be discussed in this chapter. Chapter 3 is the methodology. This chapter is about the method used and the progress of the project. It will discuss about the experiment conducted and flow in details of this research. Results of the experiment conducted and discussion of it will be discussed in chapter 4. Chapter 5 which is the last chapter concludes the entire thesis.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter consists of an overview about car steel sheet which is used in automotive industry to manufactured car part and body panels. The following includes a brief explanation about properties of sheet metal, review about it and concept of steel sheet used in automotive industry. The information and the review are taken from the journals, books, and information from websites.

2.2 STEEL SHEET

The thickness of a steel sheet raging from 0.8 mm to 1.5 mm is the most frequently used in vehicle body construction. Obtainable in sheets or rolls, this material has specific gravity of 7.8. The steel normally used is the low carbon steel with average carbon content 0.8% and it is, therefore, a good welding material. The permitted phosphorus (P) and sulphur (S) contaminations are, respectively 0.04% and 0.045%. In recent years, copper (Cu) or nickel (Ni) and chromium (Cr) are often added to improve the anti-corrosive properties of the sheet metal. All steels sheets after hot rolling go through a pickling process which removes the iron oxides or scale from the surface since this scale is a poor electric conductor which would prevent spot welding. After pickling, the sheets are cold rolled. The number of passes determines an important quality of the sheets, the smoothness of the surface. Apart from purely metallurgical considerations, for instance, the sheets used for deep pressings are made from certain parts of the ingots. The formability of a sheet depends upon its surface, and even small seams or surface irregularities cause cracking of the drawn material. Therefore, the sheets used for deep pressing are kept for as long as possible in packing paper and later transferred to the press very carefully. The basic deviations or grades of sheet steel are shown in Table 2.1 (where Rr is tensile strength, Qr is shear strength and A10 is elongation and their formability measured according to Erichsen in Table 2.2. A common workshop trial for the formability of the sheet metal is the bend test. After bending around 180 degrees the sample of the sheet should not show any cracks, tears or separation (J. Pawlowski and G. Tidbury 1969).

Table 2.1: Thin Steel Sheet

Description	Rr (kg/mm^2)	Qr (kg/mm^2)	A10 (%)
Very deep pressing	28-40	19	28-29
Deep pressing	28-42	20	27-28
Pressing	28-42	20	25-26
Shallow pressing		not given	

Source: J. Pawlowski and Guy Tidbury (1969)

Table 2.2: Sheet Steel durability according to Erichsen

Type	Thickness (mm)				
	0.80	0.90	1.00	1.25	1.50
I B (B9)	10	10.3	10.5	11.1	11.5
II G (B7)	9.5	9.9	10.1	10.7	11.2
III T (B5)	9.3	9.6	9.9	10.5	11
III P (B3)	7.8	8.2	8.6	8.6 9	9.2

Source: J. Pawlowski and Guy Tidbury (1969)

2.2.1 Steel Sheet Used in Automobile Industry

Excellent press formability and weldability during assembling, fatigue resistance, corrosion resistance as complete vehicle, crashworthiness when involved in collision and other strength as component are some of the typical required characteristic of ferrous material used for outer body. Although these characteristics are required of the steel sheets themselves, many of the characteristics also need to be evaluated for the assembled auto body as a whole. Ferrous materials are generally considered to be general-purpose materials, but the required characteristics actually depend on the positions where they are used, and ferrous materials of different thickness, strength, and formability are used with or without galvanizing. Accordingly, almost no identical materials are used at different positions (K. Sakata, S. Matsuka and K. Sato 2003).

In addition to the essential functions of transportation and comfort, high fuel efficiency and emission control from the viewpoint of global environmental protection and safety and durability as people-friendly features have nowadays become necessary. Automobile weight reduction, improvement of crashworthiness and extended life of body parts are considered as the main approaches to achieving these goals. Respond to those needs in the automotive industry, steel manufacturers have been paying great efforts in developing suitable steel products for each automotive part.

2.2.2 Hot Rolled and Cold Rolled Steel

At first steel are classified as hot rolled and cold rolled. The thickness of hot rolled steel usually greater than 1.83 mm for unexposed surface. Cold rolled steel was initially hot rolled steel at 4.0 mm and then cooled down to 2.0 mm or less.

Hot rolled steel are used in making chassis and underbody component that are about 25% of the total weight of the car. For some component, crashworthiness is required. Since relatively thick sheets are used for these components, considerable weight reductions are expected. Safety is a major concern for the chassis. High durability and reliability are required as well as good press formability to their complicated shapes. The application of hot rolled high-strength steel sheets to the chassis components, which leads to considerable weight reduction, is expected to expand rapidly in the coming years. It is, therefore, demanded to be developed as hot rolled high-strength steel sheets with good press formability and fatigue strength (M. Takahashi 2002).

Cold rolled sheet steels are available in several surface finishes that is, surface smoothness or luster. Matte finish is a dull finish, without luster. Commercial bright is a relatively bright finish having a surface texture intermediate between that of matte and luster finish. Luster finish is a smooth, bright finish. Normally these finishes are furnished to specified surface roughness values (Automotive Steel Design Manual 2002).

An increased demand of formability and uniformity on steel properties from the automotive industry has led the Society of Automotive Engineers to classify the properties, formable steels into property classifications. Below are types of properties of steel available for automotive industry. One should have a total understanding of each material listed before choosing it for particular automobile parts application.

2.3 MECHANICAL PROPERTIES

Topics such as elastic properties of materials, fracture toughness, fatigue crack propagation, plastic yielding at room temperature, at elevated temperatures, creep, viscous flow etc. all belong to the concept of “Mechanical Properties”. Furthermore, several metal families are involved, of which the main ones are those based on steel, on aluminum, on copper, on titanium and on magnesium. The number of researchers working in all these fields, and the number of industries involved is vast. In this sub chapter, focus will be mainly on metals and on plastic properties at room temperature, including strength and ductility. Even then the variety of activities, needs and potentialities is great. The present discussion is written with an eye to the future, and will therefore take the future needs of society as its starting point, rather than the present state.

2.3.1 High Strength Steels

High Strength sheet steels cover a broad spectrum of steels designed and used for higher yield and tensile strength applications than the low carbon formable steels. Many different high strength steels have been developed by the various steel producers and are available in hot rolled, cold rolled, and coated products.

2.3.2 Material Characteristics of High Strength Steels

Flat rolled steels are versatile materials. They provide strength and stiffness with favorable mass to cost ratios and they allow high-speed fabrication. In addition, they exhibit excellent corrosion resistance when coated, high-energy absorption capacity, good fatigue properties, high work hardening rates, aging capability, and excellent paint ability, all of which are required by automotive applications. These characteristics, plus the availability of high strength steels in a wide variety of sizes, strength levels, chemical compositions, surface finishes, and various organic and inorganic coatings have made sheet steel the material of choice for the automotive industry. Sheet steels have been reclassified in recent years by the Society of Automotive Engineers (SAE), both the formable low carbon grades (SAE J2329) and the higher strength grades (SAE J2340). There are differing opinions as to what determines a high strength steel and at what strength level the classification begins.

The SAE specifies low carbon formable materials where the formability is the prime consideration in making a part, whereas in high strength steels the yield and tensile strength level is the prime consideration. Higher strength steels are desirable for dent resistance, increased load carrying capability, improved crash energy management or for mass reduction through a reduction in sheet metal thickness or gauge. An increase in strength generally leads to reduced ductility or formability. Care must be taken in designing parts, tooling, and fabrication processes to obtain the greatest benefit from the higher strength sheet steels. Strength in these steels is achieved through chemical composition, or alloying, and special processing. Special processing includes mechanical rolling techniques, temperature control in hot rolling, and time/temperature control in the annealing of cold reduced steel. Table 2.3 shows types of high strength steel and grades available.

Table 2.3: Types of High Strength Steels and grades available are shown

Steel description	SAE Grade	Available Strengths Yield or Tensile MPa
Dent Resistant Non Bake Hardenable	A	180, 210, 250, 288 (YS)
Dent Resistant Bake Hardenable	B	180, 210, 250, 280 (YS)
High Strength Solution Strengthened	S	300, 340 (YS)
High Strength Low Alloy	X & Y	300, 340, 380, 420, 490, 550 (YS)
High Strength Recovery Annealed	R	490, 550, 700, 830 (YS)
Ultra High Strength Dual Phase	DN & DL	500, 600, 700, 800, 950, 1000 U(TS)
Ultra High Strength Low Carbon Martensite	M	600, 700, 800, 1000 U(TS)
Transformation-Induced Plasticity (TRIP)	NONE	800, 900, 1000, 1100, 1200, 1300, 1400, 1500 U(TS)

Source: High strength steel stamping design manual (2008)

2.3.3 Dent Resistant Bake Hardenable and Non-Bake Hardable Sheet Steels

There are two types of dent resistant steels, non bake-hardenable and bake hardenable. SAE has classified them as Type A and Type B, both of which are available in grades with minimum yield strengths of 180 MPa. Dent resistant steels are cold reduced low carbon (0.01-0.08%), typically deoxidized and continuous cast steel made by basic oxygen, electric furnace, or other processes that produce a material that satisfies the requirements for the specific grade. The chemical composition must be capable of achieving the desired mechanical and formability properties for the specified grade and type. For grades 180 and 210, using an interstitial free (IF) base metal having a carbon content less than 0.01%, an effective boron addition of <0.001% may be required to minimize secondary work embrittlement (SWE) and to control grain growth during welding.

2.3.3.1 Dent Resistant Type A

Steel is a non bake-hardenable dent resistant steel achieving the final strength in the part through a combination of initial yield strength and the work hardening imparted during forming. Solid solution strengthening elements such as phosphorus, manganese and/or silicon are added to increase strength. Work hardenability depends upon the amount of carbon remaining in solution, which is controlled through chemistry and thermo-mechanical processing. Small amounts of columbium, vanadium, or titanium are sometimes used, but are limited because they reduce ductility.

2.3.3.2 Dent Resistant Type B

Steel is a bake-hardenable dent resistant steel that makes up a relatively new class of sheet steel products. They offer a combination of formability in the incoming steel and high yield strength in the application that is not attained in conventional high strength steels. They can potentially be substituted for drawing quality sheet at the stamping plant without requiring major die modifications. The combination of formability and strength makes bake hardenable steels good options for drawn or stretched applications where resistance to dents and palm printing is important in applications such as hoods, doors, fenders, and deck lids. Bake hardenable steels may also assist in vehicle mass reduction through downgaging. The forming operation imparts some degree of strain hardening which increases yield strength in bake hardening Type B steels. The paint baking cycle, typically 175°C (350°F) for 20 to 30 minutes provides another increase in yield strength due to moderate "carbon strain aging". Material properties are generally stable, depending on the process. Figure 2.1 illustrates the hardening process with bake hardening steels.

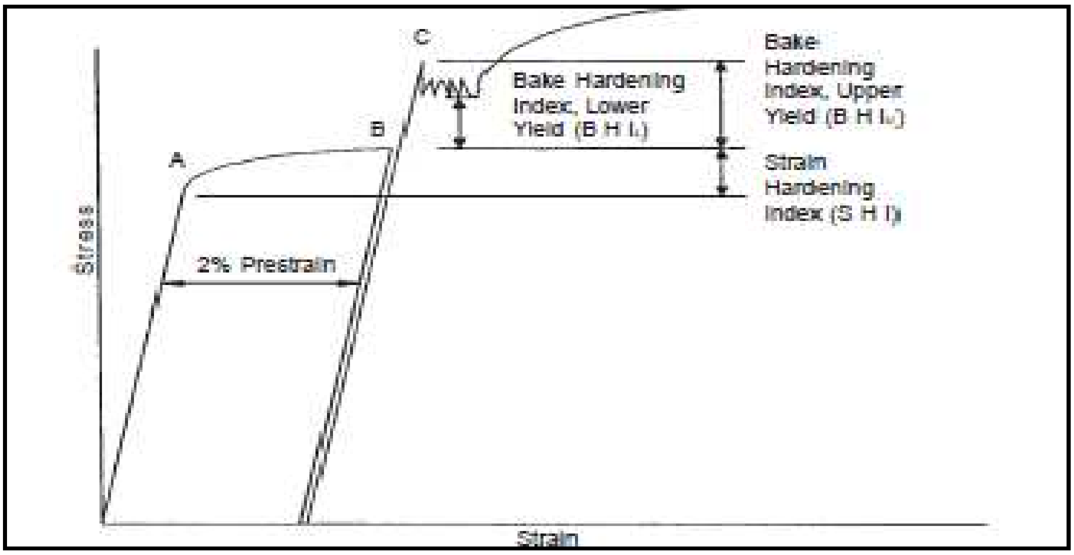


Figure 2.1: Schematic Illustration Showing Strain Hardening and Bake Hardening Index and the Increase in Yield Strength that Occurs During the Bake Cycle

Source: High strength steel stamping design manual (2008)

Table 2.4 shows the required mechanical properties for the Type A and Type B bake-hardenable and non bake-hardenable dent resistant steels as described in the SAE J2340 specification. Mechanical property requirements of dent resistant, cold reduced, uncoated and coated sheet steel grades are based on the minimum values of as-received yield strength (180, 210, 250, and 280 MPa) and the n value of the sheet steel, the minimum yield strength after strain and bake and tensile strength.

Table 2.4: Required Minimum Mechanical Properties of Type A and Type B Dent Resistant Cold Reduced Sheet Steel

SAE J2340 Grade Designation and Type	**As Received Yield Strength MPa**	**As Received Tensile Strength MPa**	**As Received n value**	**Yield Strength After 2% Strain MPa**	**Yield Strength After 2% Strain and Bake Mpa**
180A	180	310	0.20	215	
180B	180	300	0.19		245
210A	210	330	0.17	245	
210B	210	320	0.18		275
250A	250	355	0.16	285	
250B	250	345	0.16		315
280A	280	375	0.16	315	
280B	280	365	0.15		345

Source: High strength steel stamping design manual (2008)

2.3.4 Solution Strengthened, High Strength Low Alloy (HSLA) and High Strength Recovery Annealed Hot Rolled and Cold Reduced Sheet Steel

High strength, HSLA, and high strength recovery annealed categories include steel grades with yield strengths in the range of 300 to 830 MPa. Steel made for these grades is low carbon, deoxidized and continuous cast steel made by basic oxygen, electric furnace, or other process that will produce a material that satisfies the requirements for the specific grade. The chemical composition must be capable of achieving the desired mechanical and formability properties for the specified grade and type.

Several types of high strength steel based on chemistry fall in the above group. Solution strengthened high strength steels are those that contain additions of phosphorus, manganese, or silicon to conventional low carbon (0.02-0.13% carbon) steels. HSLA steels have carbide formers such as titanium, niobium (columbium), or vanadium added to conventional low carbon steels along with solid solutions strengthening from P Mn and Si. High strength recovery annealed steels have chemistries similar to the above varieties of steel, but special annealing practices prevent recrystallization in the cold-rolled steel. Classification is based on the minimum yield strength of 300 to 830 MPa. Several categories at each strength level are defined as follows:

Type S: High strength solution strengthened steels use carbon and manganese in combination with phosphorus or silicon as solution strengtheners to meet the minimum strength requirements. Carbon content is restricted to 0.13% maximum for improved formability and weldability. Phosphorus is restricted to a maximum of 0.10%. Sulfur is restricted to a maximum of 0.02%.

Type X: High Strength Low Alloy steels, typically referred to as HSLA, are alloyed with carbide and nitrite forming elements, commonly niobium (columbium), titanium, and vanadium, either singularly or in combination. These elements are used with carbon, manganese, phosphorus, and silicon to achieve the specified minimum yield strength. Carbon content is restricted to 0.13% maximum for improved formability and weldability.

Phosphorus is restricted to a maximum of 0.06%. The specified minimum for niobium (columbium), titanium, or vanadium is 0.005%, while sulfur is restricted to a maximum of 0.015%. A spread of 70 MPa is specified between the required minima of the yield and tensile strengths.

Type Y: Same as Type X, except that a 100 MPa spread is specified between the required minimum of the yield and tensile strengths.

Type R: High strength recovery annealed or stress-relief annealed steels achieve strengthening primarily through the presence of cold work. Alloying elements mentioned under Types S and X may also be added. Carbon is restricted to 0.13% maximum for improved formability and weldability. Phosphorus is restricted to a maximum of 0.10%. Sulfur is restricted to a maximum of 0.015%. These steels are best suited for bending and roll-forming applications since their mechanical properties are highly directional and ductility and formability are limited.

Table 2.5 shows the required mechanical properties for the Type SA, Type X, and Type Y of the High Strength Low alloy steels. The SAE Specification of these properties is described in SAE specification J-2340.

Table 2.5: Required Mechanical Properties of High Strength and HSLA Hot Rolled and Cold Reduced, Uncoated and Coated Sheet Steel

SAE J2340 Grade and Type	**Yield Strength MPa**		**Tensile Strength MPa**	**%Total Elongation MinimumDesignation(ASTM.L)**	
	Minimum	Maximum	Minimum	Cold Reduced	Hot Rolled
300 S	300	400	390	24	26
300 X	300	400	370	24	28

300 Y	300	400	400	21	25
340 S	340	440	440	22	24
340 X	340	440	410	22	25
340 Y	340	440	440	20	24
380 X	380	480	450	20	23
380 Y	380	480	480	18	22
420 X	420	520	490	18	22
420 Y	420	520	520	16	19
490 X	490	590	560	14	20
490 Y	490	590	590	12	19
550 X	550	680	620	12	18
550 Y	550	680	650	12	18

Source: High strength steel stamping design manual (2008)

Table 2.6 shows the required mechanical properties for the Type R, Recovery Annealed steels. The SAE Specification of these properties is described in SAE specification J-2340.

Table 2.6: Required Mechanical Properties of Type R High Strength Recovery Annealed Cold Reduced Sheet Steel

SAE J2340 Grade Designation and type	Yield Strength MPa	Tensile Strength MPa	%Total Elongation(ASTM.L)	
	Minimum	Maximum	Minimum	Minimum
490 R	490	590	500	13
550 R	550	650	560	10
700 R	700	800	710	8
830 R	830	960	860	2

Source: High strength steel stamping design manual (2008)

2.3.5 Ultra High Strength Cold Rolled Steels; Dual Phase, Transformation Induced Plasticity, and Low Carbon Martensite

The ultra high strength dual phase (DP), transformation induced plasticity (TRIP), and low carbon martensite (LCM) categories include steel grades with minimum tensile strengths in the range of 500 to 1500 MPa. These sheet steels may be ordered and supplied as uncoated or zinc coated. Coating availability differs among the various steel suppliers. Special heat treating practices that involve quenching and tempering treatments are used to generate a martensite phase in the steel microstructure. The volume fraction and carbon content of the martensite phase determines the strength level. These steels are primarily alloyed with carbon and manganese. Boron may be added in some cases. Specification of chemical limits for low carbon martensitic grades may be found in ASTM A980 “Standard Specification for Steel, Sheet, Carbon, and Ultra High Strength Cold Rolled”. The typical mechanical properties of ultra high strength sheet steels are specified in Tables 5 thru 7 on pages 11-13. Classification is based on the minimum tensile strength of the sheet steel: 500 to 1500 MPa. The formability and weldability requirements of these ultra high strength steels are determined upon agreement between purchaser and supplier.

2.3.6 Dual Phase (Type D)

The ultra high strength dual phase steel microstructure is composed of ferrite and martensite, with the volume fraction of low-carbon martensite primarily determining the strength level. Two types of dual phase steels are available; a high yield ratio (YS/TS) product designated DH and a low yield ratio product designated DL. Table 2.7 shows the required mechanical properties for the Type D, Dual Phase High Strength steels. The SAE Specification for these properties is included in SAE J-2340.

Table 2.7: Required Mechanical Properties of Ultra High Strength Dual Phase Hot Rolled and Cold Reduced Sheet Steel

SAE J2340 Grade Designation and Type	Yield Strength MPa Minimum	Tensile Strength MPa Minimum	Total Elongation in 50 mm % Minimum (ASTM.L)
500 DH	300	500	22
600 DH	500	600	16
600 DL1	350	600	16
600 DL2	280	600	20
700 DH	550	700	12
800 DH	500	800	8
950 DH	650	950	8
1000 DH	700	1000	5

Source: High strength steel stamping design manual (2008)

2.3.7 Martensite (Type M)

Martensitic high strength steel is a low carbon deoxidized steel made by basic oxygen, electric furnace, or other process that will produce a material that satisfies the requirements for the specific grade. This steel is continuously cast. The chemical composition is capable of achieving the desired mechanical and formability properties for the specified grade and type. The steel supplier must define the chemical composition range that will be furnished on a production basis. The microstructure is low carbon martensite, with the carbon content determining the strength level. These materials have limited ductility. Table 2.8 shows the required mechanical properties for the Type M, Martensitic Ultra High Strength steels. The SAE Specification for these properties is included in SAE J-2340.

Table 2.8: Required Mechanical Properties of Low Carbon Martensite Hot Rolled and Cold Reduced Sheet Steel

SAE J2340 Grade Designation and Type	Yield Strength MPa Minimum	Tensile Strength MPa Minimum	Total Elongation in 50 mm % Minimum (ASTM.L)
800 M	600	800	2
900 M	750	900	2
1000 M	750	1000	2
1100 M	900	1100	2
1200 M	950	1200	2
1300 M	1050	1300	2
1400 M	1150	1400	2
1500 M	1200	1500	2

Source: High strength steel stamping design manual (2008)

2.3.8 Transformation Induced Plasticity Steels (TRIP) (Typically 600-1000 MPa Tensile)

Trip steels have improved ductility by virtue of special alloying and thermal treatment, or annealing after rolling. The microstructure of TRIP steels contains residual austenite in a ferritic-bainitic matrix that transforms into martensite during forming. Availability of these steels is currently very limited.

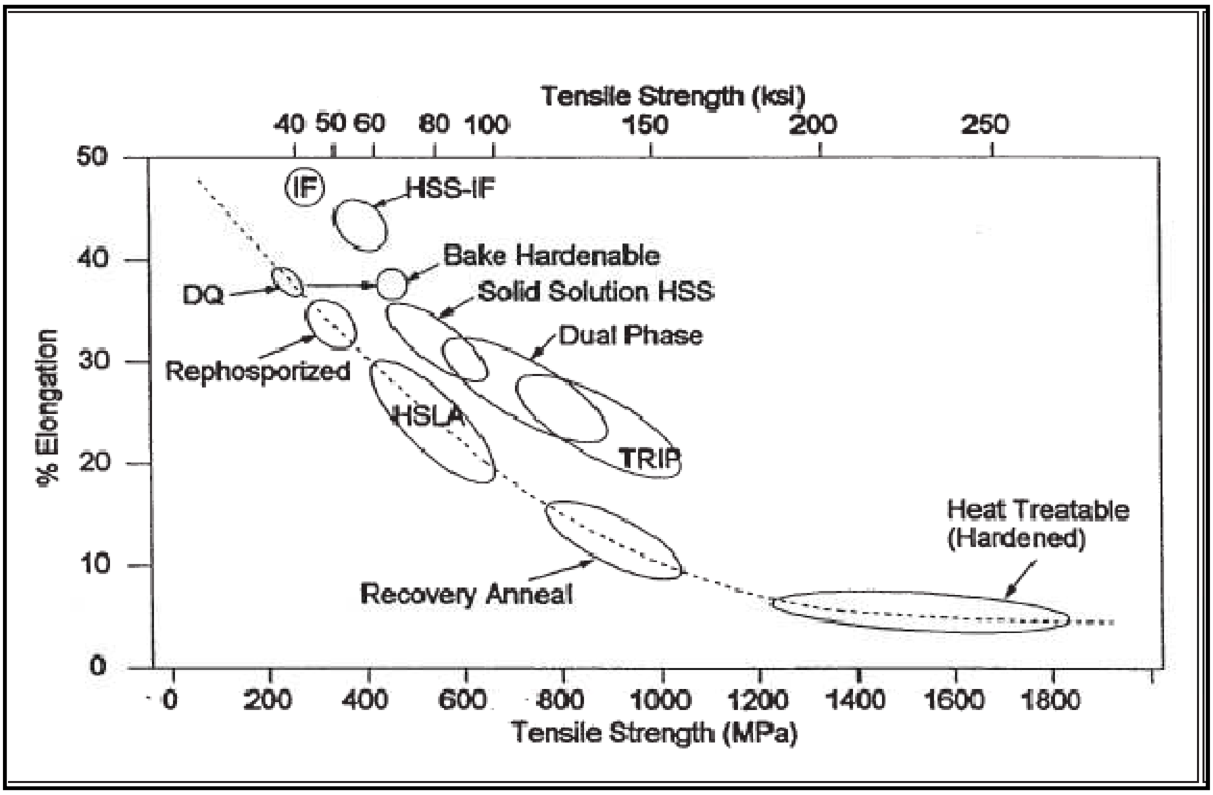


Figure 2.2: A Comparison of Tensile Strength and % Elongation for Various Grades of Automotive Sheet Steels

Source: High strength steel stamping design manual (2008)

Table 2.9 shows the typical mechanical property values and available width and thickness of numerous dent resistant, high strength, and ultra high strength grades of sheet steel used in the automotive industry

Table 2.9: Compilation of Typical Mechanical Property Values and Limited Steel Sheet Thickness and Width Availability

Material	SAE	Grade		Yield strength	Tensile	Elon	r value n		Hard	Width range	Thickness
	Class	SAE	OLD	Mpa/Ksi	Mpa/Ksi	%	r	n	Rb	mm	mm
CR	SAE J2340	180A	Dent Resist	200/29	350/50	40	1.7	0.22	63	610-1829	0.64-2.79
CR	SAE J2340	210A	Dent Resist	210/30	375/54	39	1.6	0.21	65	610-1829	0.64-2.79
CR	SAE J2340	250A	Dent Resist	270/39	400/58	36	1.5	0.20	68	610-1829	0.64-2.79
CR	SAE J2340	280A	Dent Resist	300/43	430/62	36	1.4	0.18	70	610-1829	0.64-2.79
CR	SAE J2340	180B	Brake Hard	200/29	320/46	39	1.7	0.20	52	610-1829	0.64-2.79
CR	SAE J2340	210B	Brake Hard	221/32	352/51	41	1.6	0.20	54	610-1829	0.64-2.79
CR	SAE J2340	250B	Brake Hard	255/37	379/55	39	1.4	0.17	58	610-1829	0.64-2.79
CR	SAE J2340	280B	Brake Hard	324/47	421/61	37	1.1	0.16	67	610-1829	0.64-2.79
HR	SAE J2340	300S	HSS	331/48	407/59	35	N/A	0.17	72	610-1829	0.64-3.75
CR	SAE J2340	300S	HSS	303/44	379/55	37	1.0	0.17	63	610-1829	0.64-2.79
HR	SAE J2340	340S	HSS	407/59	483/70	31	N/A	0.17	75	610-1829	0.64-3.75
CR	SAE J2340	340S	HSS	379/55	455/66	30	1.3	0.16	76	610-1575	0.64-2.79
HR	SAE J2340	300X	HSLA	350/51	407/59	35	N/A	0.17	72	610-1829	0.64-3.75
CR	SAE J2340	300X	HSLA	350/51	469/68	28	1.1	0.16	70	610-1829	0.38-3.30
CR	SAE J2340	300Y	HSLA							610-1829	0.38-3.30
HR	SAE J2340	340X	HSLA	407/59	483/70	31	N/A	0.17	75	610-1829	0.64-3.75
CR	SAE J2340	340X	HSLA							610-1524	0.76-3.18
CR	SAE J2340	340Y	HSLA							610-1524	0.76-3.18
CR	SAE J2340	380X	HSLA							610-1524	0.76-3.18
CR	SAE J2340	380Y	HSLA							610-1524	0.76-3.18
HR	SAE J2340	420X	HSLA	476/69	531/77	27	N/A	0.15	87	610-1524	0.76-3.18
CR	SAE J2340	420X	HSLA							610-1524	0.76-3.18
CR	SAE J2340	420Y	HSLA							610-1524	0.76-3.18
HR	SAE J2340	490X	HSLA	531/77	600/87	26	N/A	0.13	90	610-1524	0.76-3.18
CR	SAE J2340	490X	HSLA							610-1524	0.76-3.18
CR	SAE J2340	490Y	HSLA							610-1524	0.76-3.18
HR	SAE J2340	550X	HSLA	558/85	676/98	22	N/A	0.12	96	610-1524	0.76-3.18
CR	SAE J2340	550X	HSLA							610-1524	0.76-3.18
HR/CR	SAE J2340	550Y	HSLA							610-1524	0.76-3.18
CR	SAE J2340	490R	Rec Anneal	490/71	500/72	13	N/A	N/A	N/A	610-1524	0.76-3.18
CR	SAE J2340	550R	Rec Anneal	550/80	560/81	10				610-1524	0.76-3.18
CR	SAE J2340	700R	Rec Anneal	700/101	800/115	8				610-1524	0.76-3.18

CR	SAE J2340	830R	Rec Anneal	830/120	960/139	2			610-1524	0.76-3.18
HR/CR	SAE J2340	500DH	Dual Phase	340/49	550/80	28	N/A N/A	N/A	610-1524	0.76-3.18
HR/CR	SAE J2340	600DH	Dual Phase	550/80	710/103	20	N/A N/A	N/A	610-1524	0.76-3.18
HR/CR	SAE J2340	600DL1	Dual Phase	390/57	650/94	22	N/A N/A	N/A	610-1524	0.76-3.18
HR/CR	SAE J2340	600DL2	Dual Phase	340/49	660/96	27	N/A N/A	N/A	610-1524	0.76-3.18
HR/CR	SAE J2340	700DH	Dual Phase	600/87	760/110	16	N/A N/A	N/A	610-1524	0.76-3.18
HR/CR	SAE J2340	800DL	Dual Phase	580/84	860/125	14	N/A N/A	N/A	610-1524	0.76-3.18
HR/CR	SAE J2340	950DL	Dual Phase	680/98	1050/152	12	N/A N/A	N/A	610-1524	0.76-3.18
HR/CR	SAE J2340	1000DL	Dual Phase	810/117	1070/155	9	N/A N/A	N/A	610-1524	0.76-3.18
HR/CR	SAE J2340	800M	Martensite	N/A	N/A	N/A	N/A N/A	N/A	610-1575	0.51-1.52
HR/CR	SAE J2340	900M	Martensite	900/130	1025/149	5	N/A N/A	N/A	610-1575	0.51-1.52
HR/CR	SAE J2340	1000M	Martensite	N/A	N/A	N/A	N/A N/A	N/A	610-1575	0.51-1.52
HR/CR	SAE J2340	1100M	Martensite	1030/149	1180/171	4	N/A N/A	N/A	610-1575	0.51-1.52
HR/CR	SAE J2340	1200M	Martensite	1140/165	1340/184	6	N/A N/A	N/A	610-1575	0.51-1.52
HR/CR	SAE J2340	1300M	Martensite	1200/174	1400/203	5	N/A N/A	N/A	610-1575	0.51-1.52
HR/CR	SAE J2340	1400M	Martensite	1260/183	1480/214	5	N/A N/A	N/A	610-1575	0.51-1.52
HR/CR	SAE J2340	1500M	Martensite	1350/196	1580/229	5	N/A N/A	N/A	610-1575	0.51-1.52

Source: High strength steel stamping design manual (2008)

2.4 CORROSION

Corrosion is usually defined as the deterioration of a metal or its properties caused by a reaction with its environment. Most metals occur naturally in the form of oxides and are usually chemically stable. When exposed to oxygen and other oxidizing agents, the refined metal will try to revert to its natural oxide state. In the case of iron, the oxides will be in the form of ferrous or ferric oxide, commonly known as rust.

Metallic corrosion generally involves the loss of metal at a particular location on an exposed surface. Corrosion occurs in various forms ranging from a generalized attack over the entire surface to a severe concentrated attack. In most cases, it is impossible or economically impractical to completely arrest the corrosion process; however, it is usually possible to control the process to acceptable levels.

2.4.1 Corrosion Behavior of Steel Sheet

Every car user a facing a major problem of corrosion which affect almost all part of the car body. Corrosion of a motor car body is the result of the flow of electricity from one region of the metal (of the car) which is not well oxygenated (which acts as negative electrode) to another region which is plentifully supplied with oxygen (which is the positive electrode) and in the presence of water or an electrolyte (E. Hamzah and M. Kanniah, 2005). Bad design consideration is the major cause of corrosion of car body. Usually car body designer address sales potential by designing attractive shapes and accountants monitor costs to meet price competition. Therefore, lack of consideration on corrosion prevention occurs. This factor increases the potential of corrosion to occur (E. Hamzah and M. Kanniah, 2005).

Car body normally suffers from crevice and general corrosion. Crevice corrosion usually occurs when constricted gaps are filled with water. When sheet metal component are welded together or onto members, brackets, etc., narrow gaps are almost invariably formed between the sheets. General corrosion mainly occurs in vehicles in large areas of uncoated steel, often wheel arches, where gravel thrown up by the wheels has worn away the protective surface coating of paint and underbody compound. General corrosion also occurs in underbody members and pillars that are penetrated by dampness (M. Hugh, 1988).

Thus coating plays a major role on the protection of car body from corrosion. Various types of coating are used by car manufacturers to produce better car bodies to fulfill the customers need. However, cost factor limits this protection.

2.4.2 Corrosion of Deformed Steel

Deformation of metal causes the stress cells. They can exist in single a single piece of metal where the portion of the microstructure possesses more store strain energy then the rest of the metal. Metal atoms are at their lowest strain energy state when situated in a regular crystal array. Deviations from this lowest-strain state can occur due to the followings:

1. Grain boundaries: metal atoms situated along grain boundaries are not located in a regular crystal array (i.e. a grain). Their increased strain energy translates into an electrode potential that is anodic to the metal in the grains proper. Thus, corrosion can selectively occur along grain boundaries.

2. High localized stress: Regions within a metal subject to a high local stress will contain metal atoms at a higher strain energy state. As a result, high-stress regions will be anodic to low-stress regions and can corrode selectively. For example, bolts under load are subject to more corrosion than similar bolts that are unloaded.

3. Cold worked: Regions within a metal subjected to cold-work contain a higher concentration of dislocations, and as a result will be anodic to non-cold-worked regions. Thus, cold-worked sections of a metal will corrode faster. For example,

nails that are bent will often corrode at the bend or at their head where they were worked by the hammer (J. Pawlowski,1961)

In many published literature, it is reported that deformed galvanneal sheets exhibit rough surface, the extent of which depends upon the degree of deformation. Sacco *et.tals*, who carried out polarization resistance studies of uniaxially deformed galvanneal steel, showed an increase in the corrosion rate with an increase in the degree of deformation. This effect was related to an increase in the actual surface area of the coating and the activation of the cathodic reaction because of galvanic coupling between the coating and the exposed steel substrate. An almost linear relation has been found to exist between the effective strain applied to the specimen and damage caused to the coating. The degree of delamination/flaking of the coating are plotted in.

Figure 2.3. These plots show the dependence of severity of flaking/ delamination on the nature of strain paths.

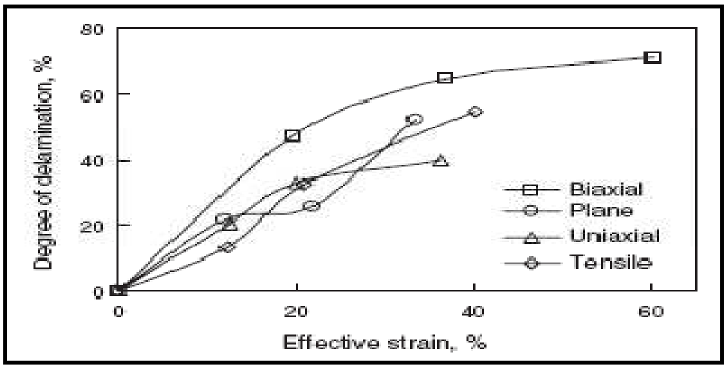


Figure 2.3: Degree of delamination vs effective strain for differently deformed sample

Source: Ezah Hamzah and Maiiyeaalagan Kanniah (2005)

CHAPTER 3

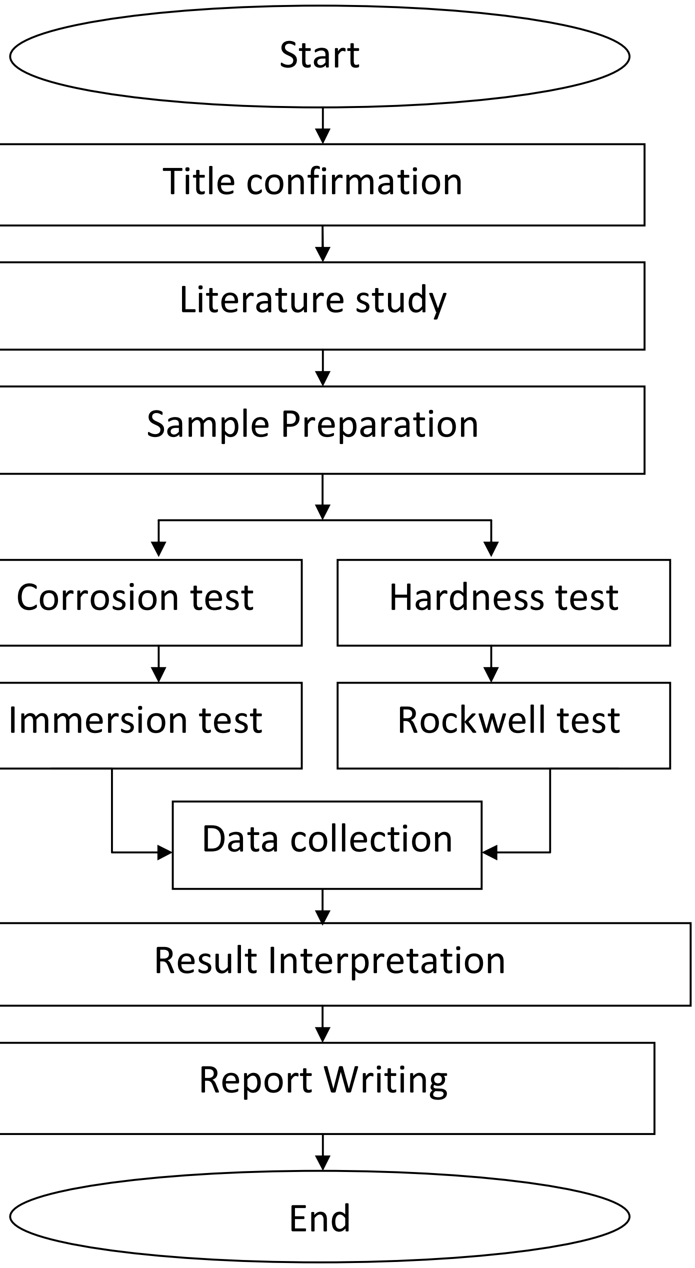
METHODOLOGY

3.1 INTRODUCTION

This chapter will describe further on the study of this project which is immersion test and Rockwell Hardness test. This chapter also will briefly describe about the hardness test and immersion test and all machine or apparatus that are involved. The objective of methodology is to ensure the flow of the project is according to schedule.

In this chapter, all the details and related discussions on the process involved will be explained. There is a flow chart that shows the process timeline. The chart will explain every step that is followed to ensure the objective of the project will be successfully achieved.

3.2 FLOW CHART OF THE RESEARCH

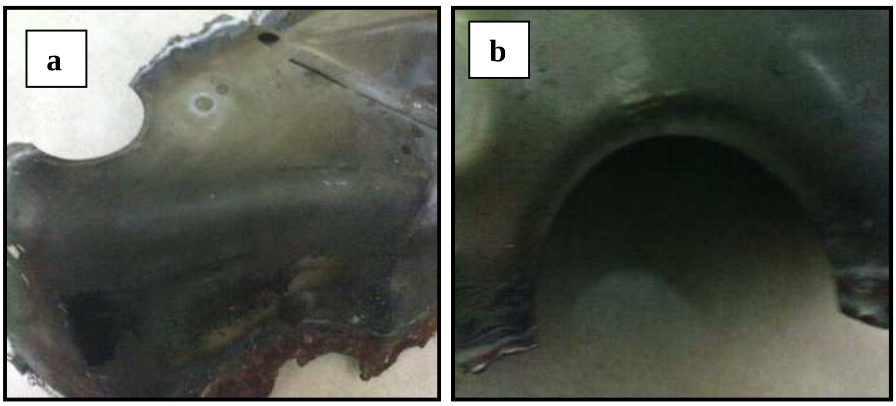


3.3 PREPARING THE MATERIAL

Type of the material used in this study is high strength low alloy steel. The material is used to produce inner part of a car in this case panel spring house. Figure 3.1 below shows the picture of the material.

Figure 3.1: Specimen before been cut.

The material was in shape that required it to be cut into pieces. In order to do that a certain tools has been used to cut it. Figured 3.2 shows the desired shape to be used in this study.



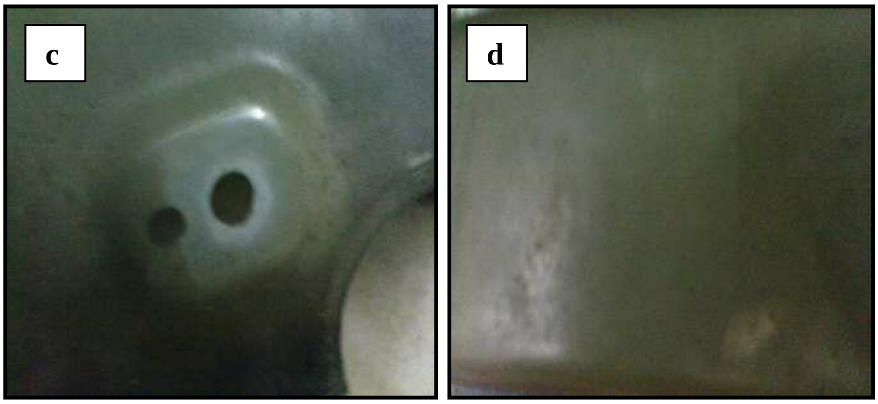
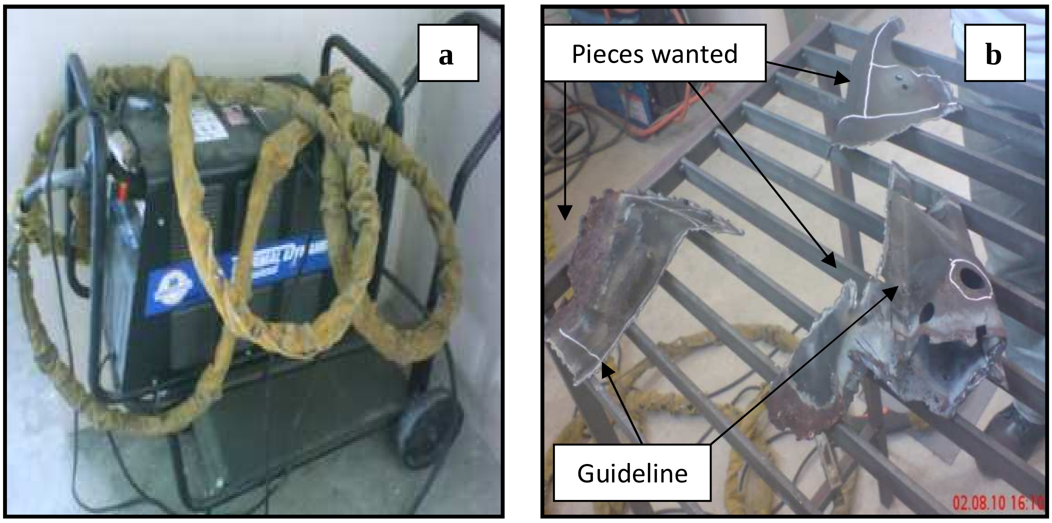


Figure 3.2: Sample shape wanted: bend (a), stamp (b) round (c), flat (d)

3.3.1 Cutting Process

The plasma cutter (model: Cutmaster 101) was used to cut the material into small piece. The material was mark by marker as a guide line for the cutting process. The small pieces was then became the sample to be use in the experiment later on. Figure 3.3 shows the plasma cutter used in the cutting process and the pieces wanted.



(a) (b)

Figure 3.3: Plasma Cutter (a), pieces wanted (b)

3.3.2 Grinding process

The grinding machine (model: D-70745 Leinfelden) was used to remove any sharp edge at the sample that was cut previously using the plasma cutter. Figure 3.4 shows the grinding machine used in this process.

Figure 3.4: Grinding machine

3.3.3 Coating removing process

The sample coating was removed using sand paper in order to prepare it for laboratory experiment. Figure 3.5 shows the material after coating removing process.

Figure 3.5: Samples after coating removing process

3.4. PREPARING SAMPLE FOR LABORATORY EXPERIMENT

For laboratory corrosion tests that simulate exposure to service environments, a commercial surface, closely resembling the one that would be used in service, will yield the most meaningful results.

Procedure

The sample was cleaned from any kind of dirt. Then the sample was rinsed thoroughly using tap water and dried using hot air. Next, the sample was stored in the desiccators. Finally, the sample was weighted and the data was recorded.

Figure 3.6 shows the sample used in immersion testing experiment.

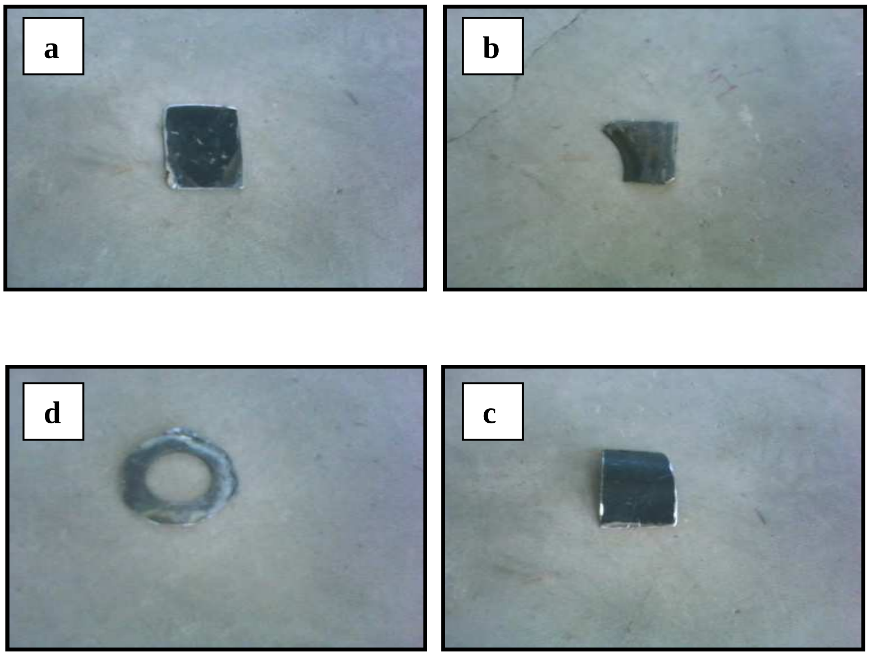


Figure 3.6 Samples: flat (a), stamp (b), round (c), bend (d)

3.4.1 Corrosion Experiment (Immersion Testing)

Immersion testing is the most frequently conducted test for evaluating the corrosion of metals in aqueous solutions. Totally immerse a test specimen in a corrosive solution for a period of time and then remove the specimen for examination. Figure 3.7 shows the experimental setup for the immersion testing.

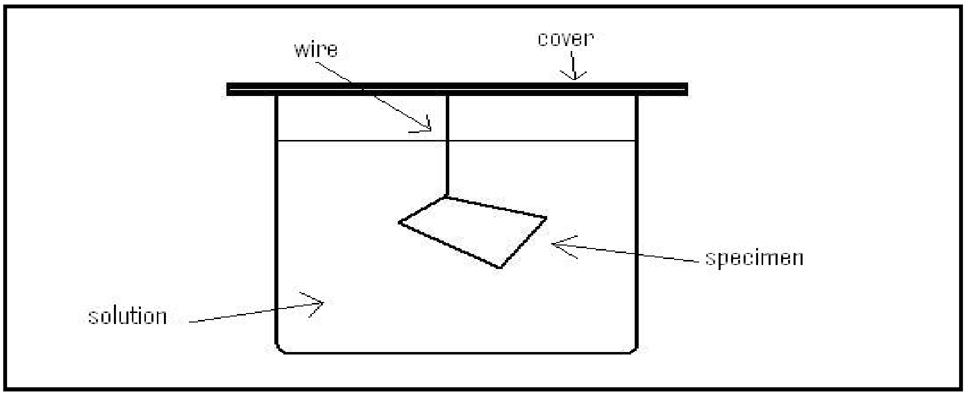


Figure 3.7: Experimental setup

3.4.2 Immersion Testing

Apparatus: beaker, supporting holder and string
Chemical reagent: acid sulfuric 5% concentration.
Temperature: 37°C

Procedure

First of all, the apparatus was set up according to the figure 3.7. Next, the beaker is filled with acid sulfuric 5% concentration until ¾ full (about 1L). On the third step, the sample is tied with wire. The sample is hang in the beaker (make sure sample does not touch the bottom of the beaker). Next, the sample is leaved in the beaker for two days.

After two days, the sample is lifted and dried using hot air. Lastly, the sample is weighed and the measurement is recorded.

Figure 3.8 shows the overall preparing process for immersion test. Figure 3.8 (a) shows the process of cleaning the beaker. Figure 3.8 (b) shows the beaker is filled with acid solution. Figure 3.8 (c) shows the beaker is ready for immersion testing experiment. Figure (d) shows the experimental setup for immersion testing experiment.

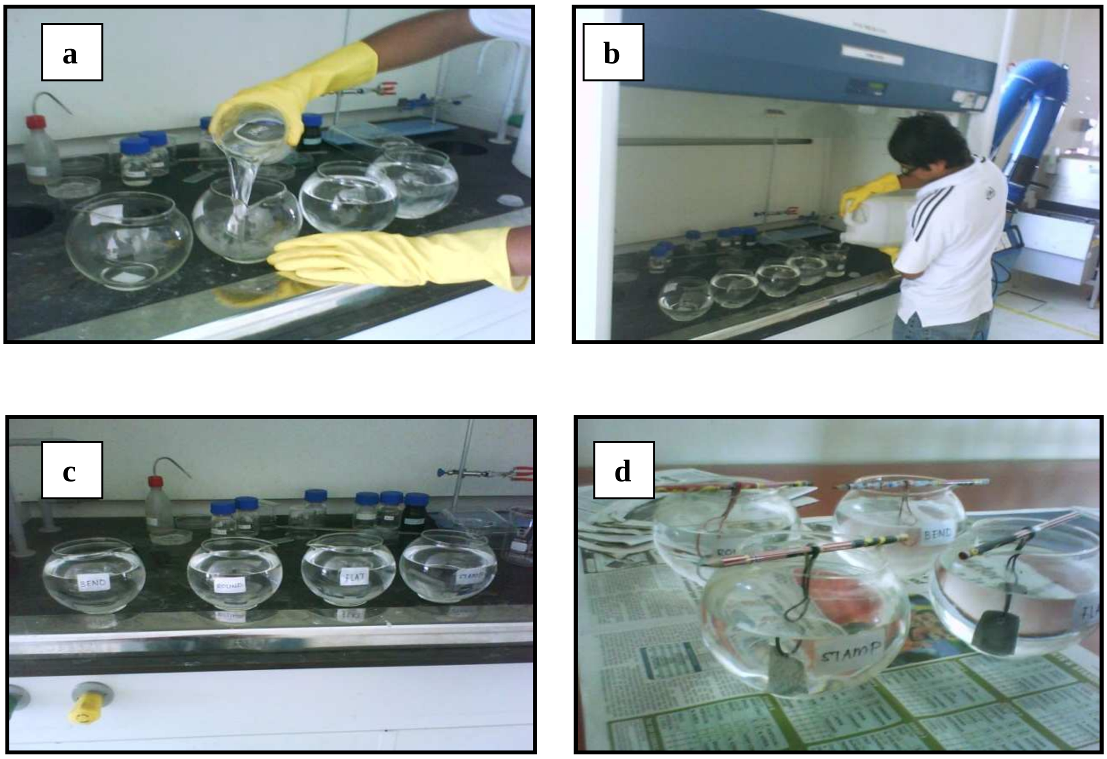


Figure 3.8: Preparing process for immersion test

For the microstructure changes

Apparatus: Meiji Techno metallurgical microscope

Model: IM7200

Procedure

First of all, the sample is placed on the plate. Next, desired lens was chose and it was used to focus the image until clear. The image was capture after it was clearly seen. Lastly the data was recorded.

Figure 3.9 shows process of capturing the image from surface morphology of the sample using the Meiji Techno metallurgical microscope.

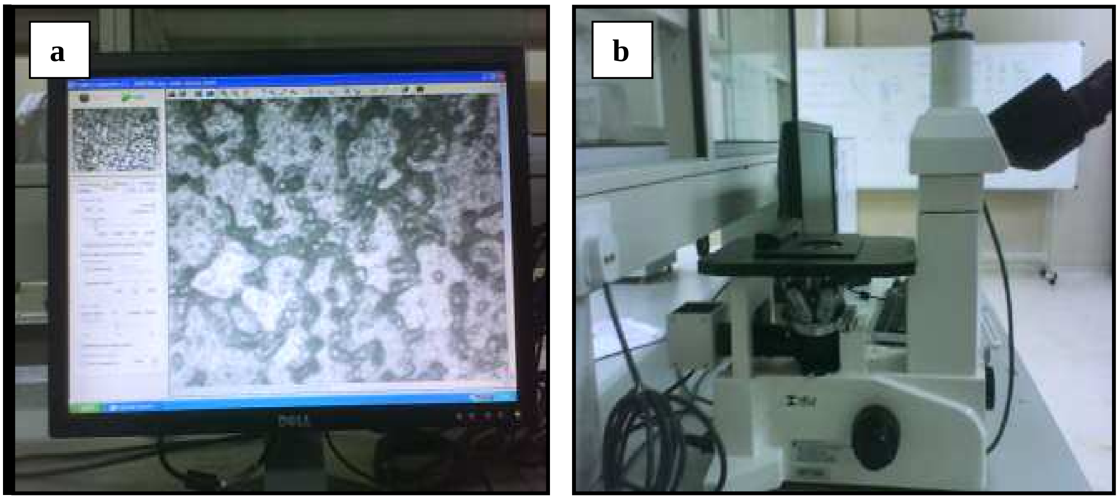


Figure 3.9: Image capture (a), Meiji Techno metallurgical microscope (b)

3.5 ROCKWELL HARDNESS

Rockwell hardness testing is a general method for measuring the bulk hardness of metallic and polymer materials. Although hardness testing does not give a direct measurement of any performance properties, hardness of a material correlates directly with its strength, wear resistance, and other properties. Hardness testing is widely used for material evaluation because of its simplicity and low cost relative to direct measurement of many properties. Specifically, conversion charts from Rockwell hardness to tensile strength are available for some structural alloys, including steel and aluminum.

3.5.1 Principal of Rockwell Hardness Test

The Rockwell hardness test method consists of indenting the test material with a diamond cone or hardened steel ball indenter. Figure 3.10 shows the Rockwell principle of measuring. The indenter is forced into the test material under a preliminary minor load F_0 (Fig 3.10A) usually 10 kgf. When equilibrium has been reached, an indicating device, which follows the movements of the indenter and so responds to changes in depth of penetration of the indenter, is set to a datum position. While the preliminary minor load is still applied an additional major load is applied with resulting increase in penetration (Fig 3.10B). When equilibrium has again been reach, the additional major load is removed but the preliminary minor load is still maintained. Removal of the additional major load allows a partial recovery, so reducing the depth of penetration (Fig 3.10C).

The permanent increase in depth of penetration, resulting from the application and removal of the additional major load is used to calculate the Rockwell hardness number.

HR = $E - e$

F_0 = Preliminary minor load in kgf

F_1 = Additional major load in kgf

F = Total load in kgf

e = Permanent increase in depth of penetration due to major load F_1 measured in units of 0.002 mm

E = A constant depending on form of indenter: 100 units for diamond indenter, 130 units for steel ball indenter

HR = Rockwell hardness number

D = Diameter of steel ball

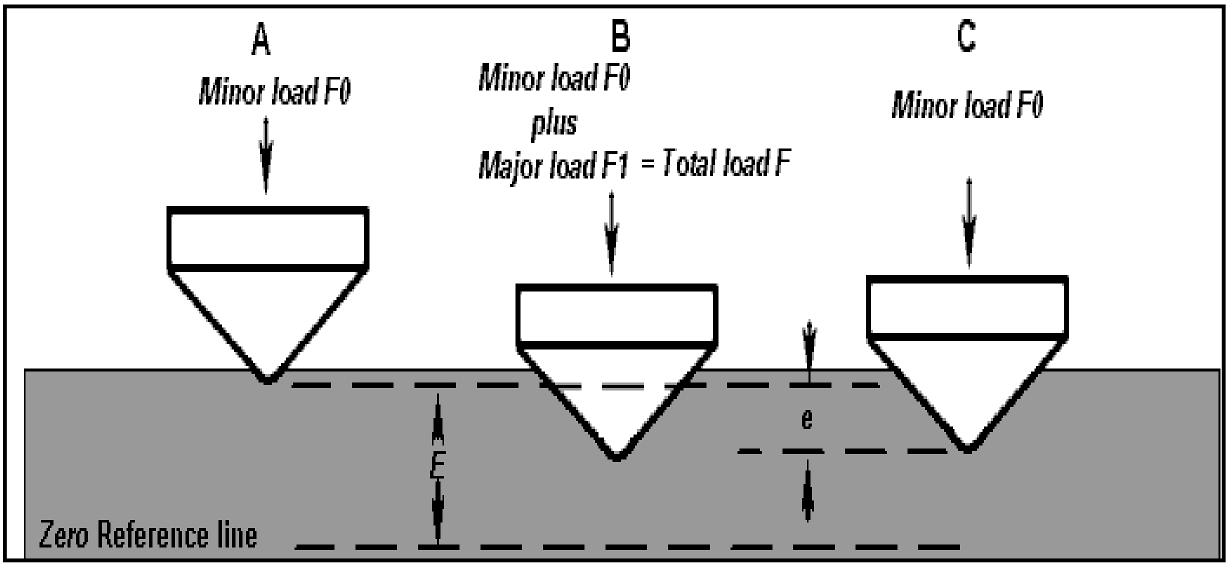


Figure3.10: Rockwell Principle

Table 3.1 shows the scale, indenter user, minor and major applied, total load applied and the constant value E

Table 3.1 Specimen Scale

Scale	Indenter	Minor Load F_0 kgf	Major Load F_1 kgf	Total Load F kgf	Value of E
A	Diamond cone	10	50	60	100
B	1/16" steel bal	10	90	100	130
C	Diamond cone	10	140	150	100
D	Diamond cone	10	90	100	100
E	1/8" steel ball	10	90	100	130
F	1/16" steel ball	10	50	60	130
G	1/16" steel ball	10	140	150	130
H	1/8" steel ball	10	50	60	130

K	1/8" steel ball	10	140	150	130
L	1/4" steel ball	10	50	60	130
M	1/4" steel ball	10	90	100	130
P	1/4" steel ball	10	140	150	130
R	1/2" steel ball	10	50	60	130
S	1/2" steel ball	10	90	100	130
V	1/2" steel ball	10	140	150	130

3.5.2 Typical Application of Rockwell Hardness Scales

HRA -Cemented carbides, thin steel and shallow case hardened steel

HRB -Copper alloys, soft steels, aluminum alloys, malleable irons, etc.

HRC -Steel, hard cast irons, case hardened steel and other materials harder than 100 HRB

HRD -Thin steel and medium case hardened steel and pearlitic malleable iron

HRE -Cast iron, aluminum and magnesium alloys, bearing metals

HRF -Annealed copper alloys, thin soft sheet metals

HRG -Phosphor bronze, beryllium copper, malleable irons HRH. Aluminum, zinc, lead

HRK -Steel, copper alloy, brass of medium thickness

HRM -Soft bearing metals, plastics and other very soft material

3.5.3 Matsuzawa Rockwell Hardness Tester

The apparatus for this experiment is Matsuzawa Rockwell Hardness tester (Model: RMT-3). Figure 3.11 shows the tester that been used in this experiment. Table 3.2 shows some features of the Matsuzawa Rockwell Hardness tester.

Figure 3.11 Matsuzawa Rockwell Hardness tester

Table 3.2 Features of Matsuzawa Rockwell Hardness tester

(http://www.mitsg.com/English/Products/Matsuzawa/RockwellHardnessTester.htm)

Liquid crystal display touch-panel	Loaded with a LCD display with backlight. The hardness tester secures very clear and high visibility
Auto start	After setting the reference load, the test load is applied automatically. (Manual start is also possible)
Easy setting	Reference load can easily set with a bar graph display on the bright screen and electronic sound. Moreover, an error-preventing device is also mounted.
Plastic measuring	Specific measuring method for plastic in compliance with ASTM and JIS

system	is activated by one-touch easy operation. Time for reading the value after unloading the test load can be set freely
Various Data processing functions	It makes acceptance and rejection judgment, conversion to other scales, and tabulation and computing for data memory (256 data), maximum value, minimum value, variation, average, standard deviation etc.
Traditional dial change-over system	Dial changeover systems make change the test load easily by turning the dial. Accordingly the design is dust-proof including the weights for test load.
Applicable to CE and safety	Safety design applicable to EU low voltage command, EMC command and machine command. In addition to high-rigidity body, overturn-preventive metal fittings are attached as standard to prevent overturning by earthquakes etc

3.5.4 Rockwell Hardness Test Procedure

Apparatus: Matsuzawa Rockwell Hardness tester

Procedure for the hardness test

The machine was set up according to the sample scale. The sample was put onto the anvil. Next, the elevating handled is rotated in order to bring the sample close to the indenture. The elevating is rotated until the screen show the sample is in maximum condition (do not overload the rotation). The machine was set to test the sample. Finally, the measurement was recorded.

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

This chapter will discuss about the result from experiment that has been conducted. The corrosion rate was determined from the immersion testing experiment. The samples were observed before and after the immersion test had been done. The hardness test had been conducted using Matsuzawa Rockwell tester. Data obtain from the test and experiments were analyzed.

4.2 MATERIAL

There were 4 types of sample consist of deformed and undeformed sections as shown in figure 3.6. The samples have undergone spectrometer analysis using Spektranalyse Foundry –Master (model: Wellesweg 31) to determine its chemical composition. Table 4.0 below shows the data taken from the spectrometer analysis.

Table 4.1: Chemical composition of material used in study

Chemical Composition	C	Si	Mn	P	Cr	Ni	Al	Nb	Ti	V	W
Spectrometer (% wt)	0.0203	0.087	0.247	0.0142	0.0538	0.0713	0.0609	0.0773	0.0442	0.0067	0.117

From the table 4.0, it can be identified that the sample type is high strength low alloy steel (http://www.materialsengineer.com/E-steels.htm). Low carbon content allows the material to have high percentage of elongation which is suitable for highly formable part. Manganese, Mn is effective for strengthening sheet steels through both solid solution hardening and transformation hardening, but it degrades spot weldability and galvanizability. Silicon, Si and phosphorus, P can economically strengthen sheet steels, but both degrade galvanizability. Thus, their contents were suppressed to the possible extent. Titanium, Ti and vanadium, V is either elementally or in combination alloyed with other composition. On the other hand tungsten, W was adopted as strengthening element to increase the strength of the specimens. As a result this material is suitable for parts which required excellent mechanical properties, crashworthiness and anti-corrosion such as cross member and side member.

4.3 MICROSTRUCTURE ANALYSIS

Figure 4.1 (a) bend sample, have martensite and bainite phase. The needle like shape is bainite that consist ferrite and cementite phase. Martensite phase is also can be found in figure 4.1 (b) flat sample, 4.1 (c) round sample and 4.1 stamp sample (d).

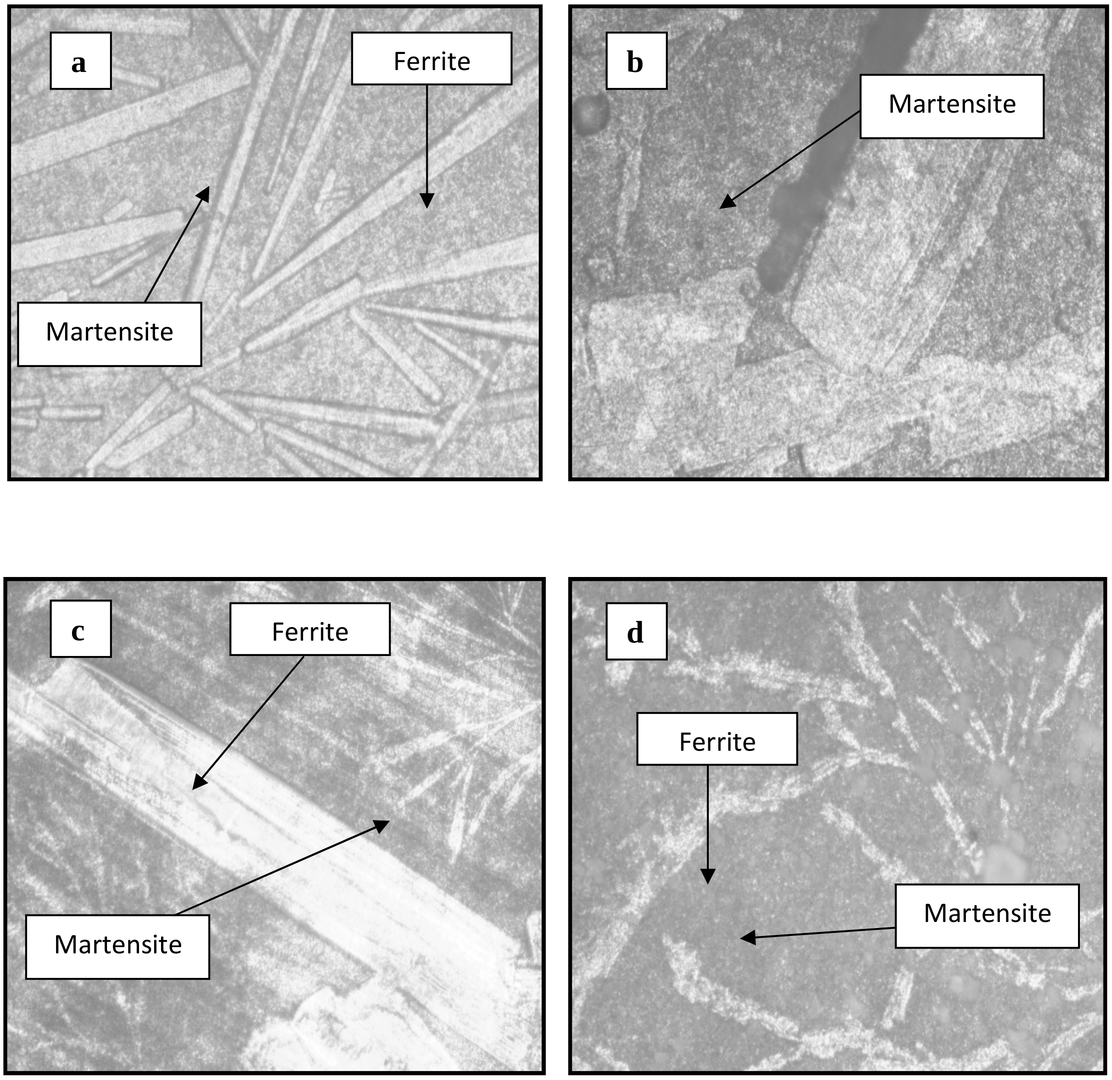


Figure 4.1: Optical micrograph (Mag: 50x) before immersion test: bend sample (a), flat sample (b), round sample (c), stamp sample (d)

The microstructure analysis of the sample reveals that there is martensite phase. Martensite is form when austenitized iron-carbon alloys are rapidly cooled (quenched) to a relatively low temperature (in the vicinity of the ambient). Martensite is a nonequilibrium single-phase structure that results from a diffusionless transformation of austenite. It may be thought as a transformation product that is competitive with pearlite. Martensite is the hardest and strongest compare to other phase such as ferrite or austenite. Its hardness is dependent on the carbon content, up to about 0.6 wt%.

Another phase that can be detected here is bainite. The microstructure of bainite consists of ferrite and cementite phases and thus diffusional process are involved in this formation. Because bainitic steels have a finer structure, they are generally stronger and harder than pearlitic ones yet they exhibit a desirable combination of strength and ductility. However they are not harder or denser than martensite. The results of microstructure observation from the immersion experiment upon 5% H_2SO_4 are shown in Figure 4.1 (a, b, c and d).

4.4 ANALYSIS OF HARDNSESS TEST

Table 4.2 shows hardness reading from the samples. Flat sample has average HRC value of 56.6. Bend sample has the average HRC value of 72.6. Meanwhile stamp and round sample has the average HRC value 35.1 and 27.6

Table 4.2 Hardness Reading

Specimen	Hardness Reading (HRC)				
	1	2	3	4	Ave
Flat	56.0	58.1	56.0	56.0	56.6
Bend	68.5	71.6	74.2	76.2	72.6
Stamp	34.4	36.9	33.7	35.3	35.1
Round	27.5	28.3	26.9	27.7	27.6

Table 4.2 shows that bend sample has the highest hardness value compared to flat sample follow by stamp sample and round sample. Auto body sheet metal has the property of withstanding much bending or distortion without tearing or breaking. Where the folds occur, the plastic deformation has been so great that the metallurgy structure has been forced out of alignment. When this happens the metal has been cold worked (it could happen during the forming of the body panels by draw dies, or in automobile collision). Whenever this cold working occurs, the metal has become “work hardened”. The metal has been physically changed for a soft pliable condition to that of being hardened and strengthened. It is well known that any strain or distortion within the lattice increases its resistance to plastic deformation and so increases its hardness and strength. Hence, the metal became strong in term of hardness. It is well to note that the areas that were not affected during the bending are still in the perfect alignment. These areas are still plastic, having the same properties as the bent areas had before they were distorted. Figure 4.2 shows the dislocation occurring at bent area while microstructure at the area that are not affected by the bending operation are remained unchanged. Source: (M. Fauzi, 2008)

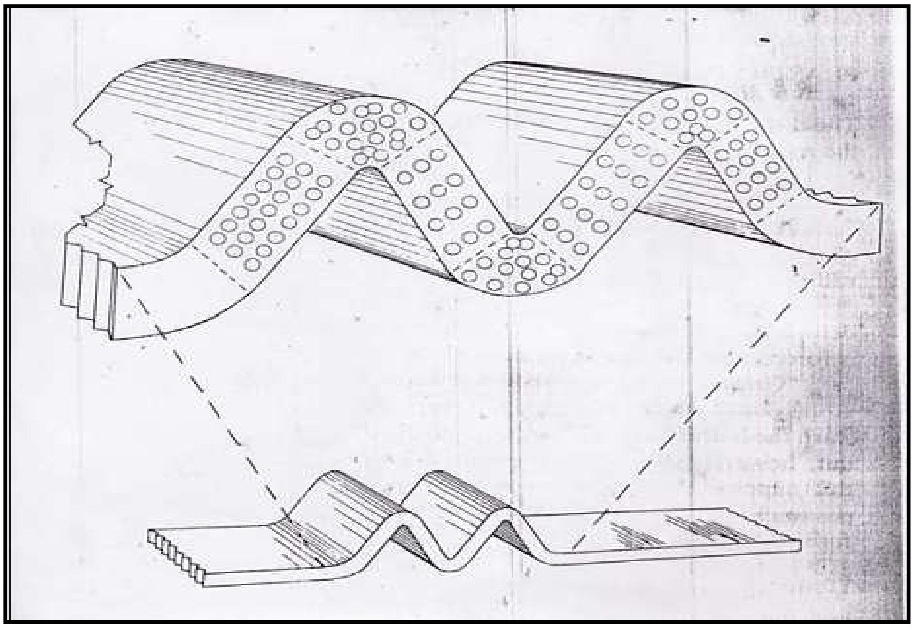


Figure 4.2: Dislocation of bent area

Source: (M. Fauzi, 2008)

4.5 ANALYSIS OF CORROSION IMMERSION TESTING

The results of the immersion test for all 4 samples upon exposure of 5% H_2SO_4 are shows in table 4.1 below. Corrosion rate were determined using corrosion rate formula which is

$$CR = {KW}/{ATD} \qquad \text{(Eq. 1)}$$

Where:

K = 1.00×10^4 x D

T = Time of exposure in hours

A = Area in cm^2

W = Weight loss in grams

D = 7.85 g/cm^3 (low alloy steel)

Table 4.3 shows bend sample has corrosion rate value of 9.00 $g/cm^2.h$ meanwhile flat stamp and round sample has corrosion rate value are 7.70, 5.50 and 7.48 $g/cm^2.h$ respectively.

Table 4.3: Corrosion Rate (CR)

Sample	Area (cm^2)	Weight Loss (g)	CR ($g/cm^2.h$)
Bend	10.5	3.595	9.00
Flat	3.8	1.108	7.70
Stamp	3.6	0.752	5.50
Round	7.5	2.115	7.48

Table 4.3 shows that bend sample specimen has the largest corrosion rate value followed by round sample, flat sample and stamp sample specimens. The result indicates that deformed sample has higher corrosion rate compared to undeformed. This is primarily because metal atoms situated along grain boundaries are not located in a regular crystal array (i.e. a grain). Their increased strain energy translates into an electrode potential that is anodic to the metal in the grains proper. Thus, corrosion can selectively occur along grain boundaries. Regions within a metal subject to a high local stress will contain metal atoms at a higher strain energy state. As a result, high-stress regions will be anodic to low-stress regions and can corrode selectively. When the sample was being immersed in H_2SO_4 solution, the grain boundary tends to react and lose itself to surrounding as corrosion product. Unlike the flat sample, the grain boundary is in relax condition. Hence, the corrosion rate is a little lower compare to bend sample.

Figure 4.3 shows the graph of corrosion rate started from lowest corrosion rate value to highest corrosion rate value.

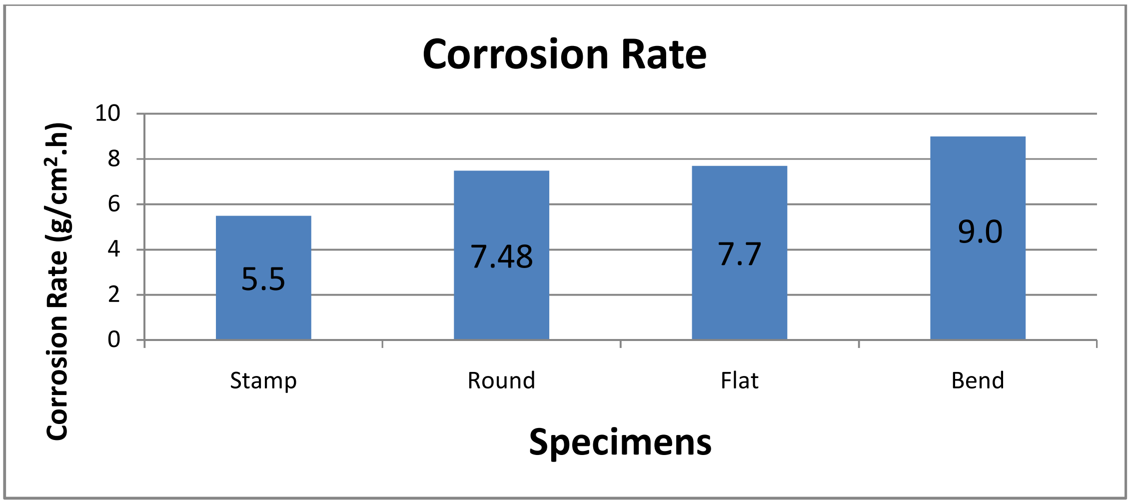


Figure 4.3: Graph of Corrosion Rate for each sample

Figure 4.4 shows the sample after being immerse in H_2SO_4 solution for 2 days. All samples are fully corroded.

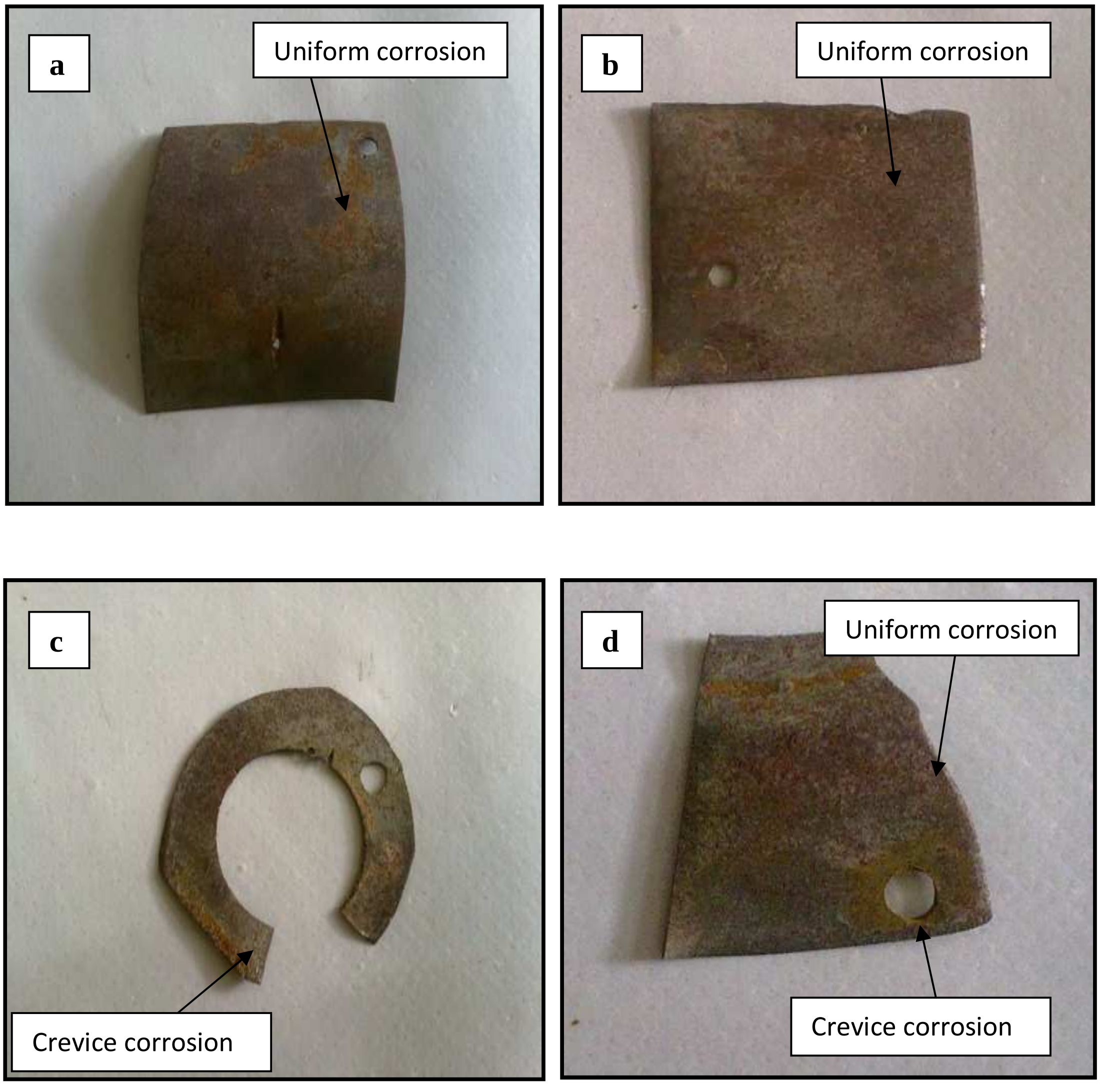


Figure 4.4: After immersion test: bend sample (a), flat sample (b), round sample (c), stamp sample (d)

In this experiment, no optical micrograph can be seen because the sample surface is fully corroded. When place under the optical microscope, no image can be seen because the sample surface cannot reflect back the light that was point to it. According to a study related to this case, all micrographs that show the pearlite matrix was dissolved. It was also observed that corrosion attacks were concentrated along grain boundary penetrated from the surface for flat sample. Elongated grains were observed on deformed sample due to severe corrosion attack. Generally, the corrosion mechanism was a uniform corrosion. There was also crevice corrosion which were located at the O-ring of the sample: example figure 4.4 (c) and 4.4 (d).

4.6 RELATION BETWEEN CORROSION AND HARDNESS

Figure 4.5 shows bend sample (deformed) has the largest hardness value compared to flat sample (undeformed).

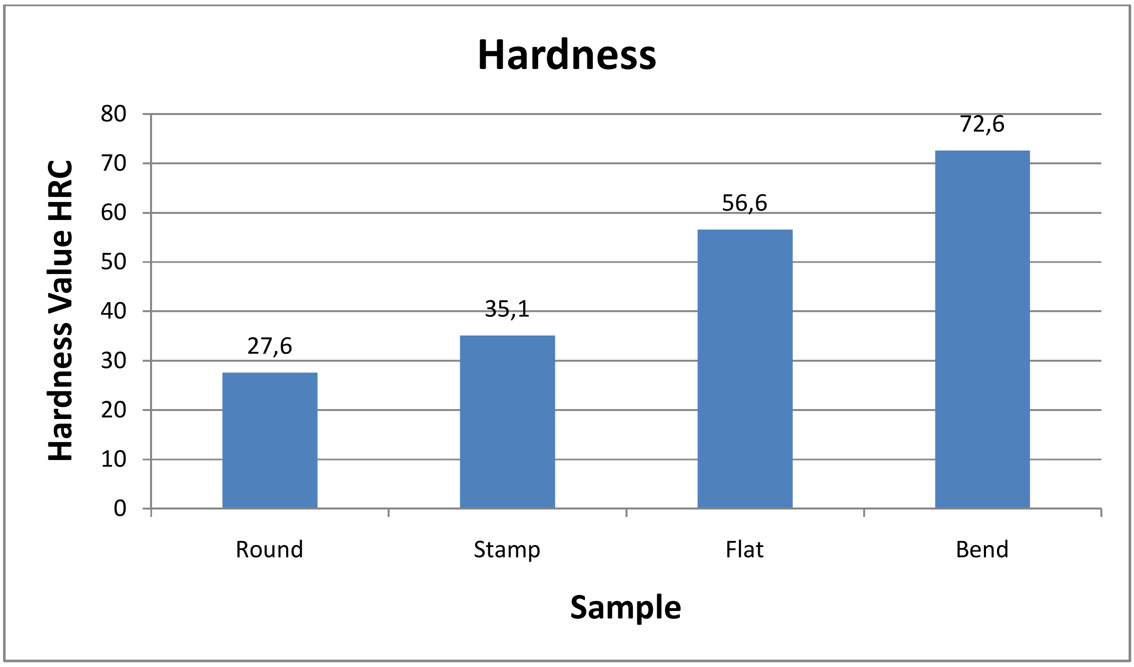


Figure 4.5: Graph of Hardness Value

As discussed in 4.4, auto body sheet metal has the property of withstanding much bending or distortion without tearing or breaking. It has been established that a very desirable feature in auto body metals is the ability to become hardened when worked or bent in any desired area.

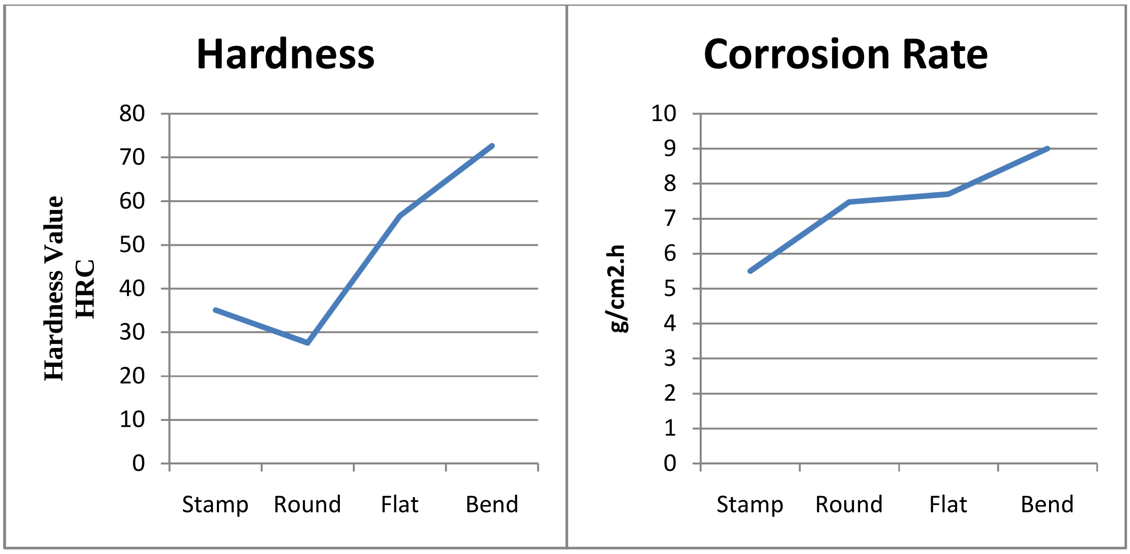


Figure 4.6: Relationship of Hardness and Corrosion Rate

Figure 4.6 shows that as the hardness of the sample increase the corrosion rate will also increase. In the previous discussion, bend sample specimen has the highest hardness value. This is because there is presence of martensite phase on the specimen alongside the bainite phase. As been studied, martensite is the hardest and strongest phase. So bend sample will shows the highest hardness value compared to the 3 others samples. Although flat, round and stamp sample have martensite phase on them, it is not as much as the bend sample's one. On the corrosion rate site, the highest corrosion rate also goes to bend sample. As discussed in section 4.5, the grain boundary of the bend sample is in stress condition. It tends to lose itself to the surrounding when it reacts with H_2SO_4.

CHAPTER 5

CONCLUSION

5.1 INTRODUCTION

This chapter will discuss the conclusion of the research and the finding based on the literature review and from the experiment conducted. The objectives of the research will also be evaluated in this chapter. The recommendations in improving the research for the future will also be discussed.

5.2 OBJECTIVES ACHIEVED

Results obtained from the experimental works had successfully fulfilled the objective of this project. The study establishes the following:

The first objective of the study which is to study the corrosion behavior of deformed steel of a car steel sheet body has been achieved since the result from the experiment showed that all specimens was undergoing uniform corrosion.

The second objective is to determine the corrosion effect on mechanical properties of car steel sheet body. It is achieved from the experiment result. The result follow the theory which is deformed parts has higher corrosion rate compared to undeformed part.

The last objective is to examine the microstructural changes due to formation of corrosion. Unfortunately this objective is not achieved. All the specimens were fully corroded. Hence, it became impossible to observe the microstructure changes under the optical microscope.

5.3 RECOMMENDATION

1. Usage of different types of solution as recommended by ASTM G31 should be conducted.
2. To further understand the corrosion behavior of the automotive system, different parts of automobile parts made of different alloys should be tested.

5.4 Overall Conclusion

This study has achieved the objective in understanding corrosion behavior of deformed automobile parts. As the automobile industry develops, the need for a better product that has excellent mechanical properties, crashworthiness and can withstand corrosion is extremely essential. By this study hopefully it will help automobile manufacturer in producing a better product for the automobile industry.

REFERENCES

ASTM International Designation: G 1 – 03- *Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens*

ASTM International Designation: G 31 – 72 (Reapproved 1999) - *Standard Practice for 4. Laboratory Immersion Corrosion Testing of Metals*

Automotive steel design manual. August 2002. *American iron and steel institute & auto/steel partnership*. Revision **6.1**

Ezah Hamzah and Maiiyeaalagan Kanniah, Jun 2005. Corrosion behavior of low carbon steel sheet for a car body, *Jurnal Mekanikal*. NO. **19**: 57-70

High strength steel stamping design manual (A/SP-0080-2 0100 1M PROG)

Hugh, M. 1988. *Corrosion prediction and prevention in motor vehicles*. Ellis Horwood Limited.

J. Pawlowski and Guy Tidbury. 1969. *Vehicle body engineering.* Business book limited pg. 22-23

JFE steel corporation. March 2006. *Relationship between press formability and mechanical properties of thin steel sheets*

Jones D.A. 1995. *Principles and prevention of corrosion*. 2nd ed. Prentice Hall, Upper Saddle River, NJ

Kei Sakata, Saiji Matsuka and Kazuhiro Sato. March 2003. Highly formable sheet steels for automobile through advanced microstructure control technology. *Kawasaki Steel Technical Report*. No. **48**

Kazunori Osawa, Yoshitusgu Suzuki and Shungo Tanaka. March 2003. TS590-980 MPa Grade low-carbon equivalent type galvannealed sheet steels with Superior Spot-Weldability, *Kawasaki Steel Technical Report*. No. **48**

Manabu Takahashi, Teruki Hayashida, Hirokazu Taniguchi, Osamu Kawano and Riki Okamoto. 2003. *High strength hot-rolled steel sheets for automobiles*

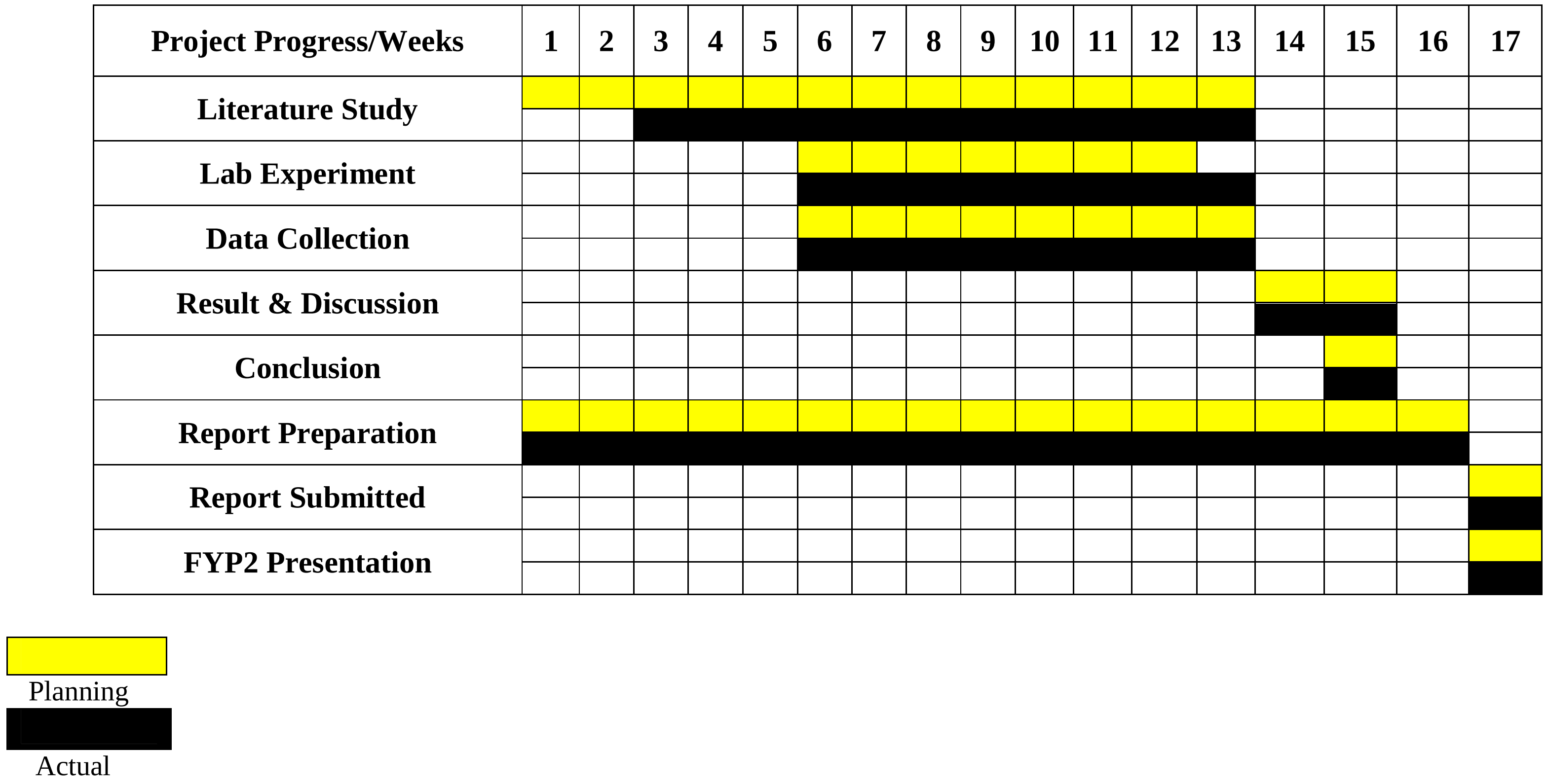
Mars G. Fontana. 1986. *Corrosion Engineering*. Third Edition

Mohd Fauzi Bin Nazlan. 2008. Effect of metal deformation on the microstructure and properties of car bodies

V.S.Raja, C.K.Panday, V.S. Saji, S.T.Vagge and K, Narasimhan. 2006. *An Electrochemical study on deformed galvanneal steel sheets*

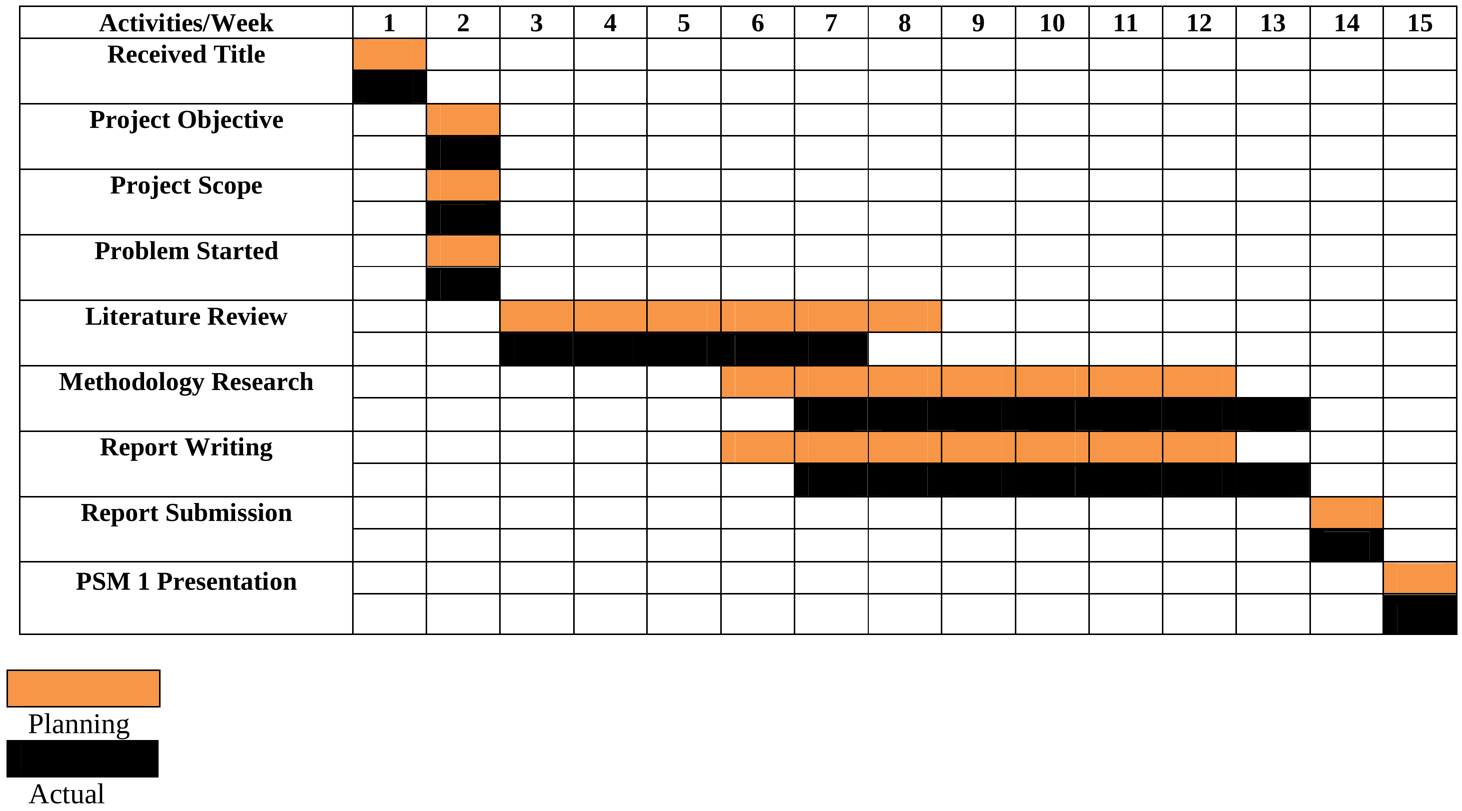
APPENDIX A

GANTT CHART FYP II



APPENDIX B

GANTT CHART FYP I



APPENDIX C

Sample of Corrosion Rate Calculation

For bend sample.

$$CR = {}^{KW}\!/_{ATD}$$

Where:

K = $1.00x10^4$ x D

T = Time of exposure in hours

A = Area in cm^2

W = Weight loss in grams

D = 7.85 g/cm^3 (low alloy steel)

$$CR = {}^{KW}\!/_{ATD}$$

$$CR = {}^{[(1.00x10)(\ 7.85)][3.595]}\!\Big/_{[10.5][48][7.85]}$$

$$= 9.0\ g/cm^2.h$$

APPENDIX D

Spectrometer Analysis Result

WORLDWIDE ANALYTICAL SYSTEMS AG
WAS Sample Testing of different Qualities

Worldwide Analytical Systems AG

Chemical Results

Probe Nr. / sample ID :1

Grundwerkstoff / material :Cu300

Kunde / customer :chandran laa

Abmessung / dimension :copper ingot

Kom.-Nr. / commision :10%

Zusatzwerkstoff / filler metals :no

Labor Nr. / lab-no. :foundry UMP

Wärmebehandlung / heat treatment :no

PTQ-Nr. / PTQ-no. :

Schmelze-Nr. / heat-no. :no

Spektralanalyse Foundry-MASTER   Werkstoff / grade :

	Fe	C	Si	Mn	P	S	Cr	Mo
1	99,6	0,0149	< 0,0100	0,123	< 0,0100	< 0,0100	0,0232	< 0,0100
2	99,3	0,0123	0,116	0,187	< 0,0100	< 0,0100	0,0464	< 0,0100
3	98,3	0,0338	0,145	0,432	0,0332	0,0177	0,0917	0,0128
Ave	99,1	0,0203	0,0870	0,247	0,0142	< 0,0100	0,0538	< 0,0100

	Ni	Al	Co	Cu	Nb	Ti	V	W
1	0,0376	0,0216	< 0,0100	< 0,0050	0,0398	0,0209	< 0,0050	< 0,0250
2	0,0518	0,0608	< 0,0100	< 0,0050	0,0679	0,0342	< 0,0050	< 0,0250
3	0,124	0,100	< 0,0100	0,0053	0,124	0,0775	0,0197	0,332
Ave	0,0713	0,0609	< 0,0100	< 0,0050	0,0773	0,0442	0,0067	0,117

	Pb
1	< 0,0500
2	< 0,0500
3	0,0519
Ave	< 0,0500

Ort / town

Datum / date
22/09/2010

Prüfer / tester

Sachverständiger / engineer

Worldwide Analytical Systems AG
Wellesweg 31