SUPERVISOR’S DECLARATION

I have read this thesis and in my opinion this thesis coincides with the scope and the quality to be awarded Bachelors Degree in Mechanical Engineering (Automotive).

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Date : 27th June 2012

THE INVESTIGATION OF THE INFLUENCE OF FILLER WELDING MATERIALS ON THE MICROSTRUCTURE AND HARDNESS OF GTA WELDING IN DUAL PHASE STEEL

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This report was submitted in accordance with the partial requirements for honor of Bachelor of Mechanical Engineering (Automotive)

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DECLARATION

"I hereby declare that the work in this report is my own except for summaries and quotations which have been duly acknowledged."

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ABSTRACT

Dual phase steel is new class of high strength low alloy steel where it is still in development process. Therefore, there is no dual phase steel filler material that has been produced as of yet. The main objective of this research is to study the influence of filler welding material on the microstructure and hardness of GTAW welding in dual phase steel. This study will be conducted using mild steel plate with a certain preset dimension and the type of joint involved is butt joint. The plates then undergo intercritical annealing process at 740°C in 40 minutes followed by rapid cooling to transform ferrite and pearlite phase in mild steel to ferrite and martensite phase to obtain the dual phase steel. The plates then undergoes welding process using five different filler material which are mild steel, stainless steel, aluminium, brass and copper as per the specific welding parameter. The measurement of strength of weldment and dual phase steel itself is determined using hardness test and the microstructure is then viewed under an optical microscope. The higher the Brinell Hardness Number obtained means the higher the strength of the weld. The result obtained indicate which filler material is suitable and gives best solution for welding dual phase steel in GTAW welding and will be suggested for further research and development as dual phase steel is become widely used in automotive and aerospace industries.

ABSTRAK

Keluli dua fasa adalah kelas baru aloi keluli yang berkekuatan tinggi yang masih dalam proses pembangunan. Oleh itu, tiada pengisi bahan keluli dua fasa yang telah dihasilkan sebelum ini. Objektif utama kajian ini adalah untuk mengkaji pengaruh jenis pengisi bahan kimpalan mikrostruktur dan kekerasan kimpalan arka tungsten gas (GTAW) dalam keluli dua fasa. Kajian ini akan dijalankan menggunakan plat keluli lembut dengan dimensi tertentu dan jenis sambungan yang terlibat adalah sambungan hulu. Plat kemudiannya menjalani proses pemanasan kritial pada 740 ^{0} C selama 40 minit diikuti dengan penyejukan pesat melalui pemendapan dalam air untuk mengubah fasa ferit dan pearlit dalam keluli lembut kepada fasa ferit dan martensit untuk mendapatkan keluli dua fasa. Plat kemudiannya menjalani proses kimpalan menggunakan lima bahan pengisi yang berbeza iaitu keluli lembut, keluli tahan karat, aluminium, tembaga dan kuprum berdasarkan parameter kimpalan tertentu. Pengukuran kekuatan hasil kimpal dan keluli fasa dua itu adalah ditentukan dengan menggunakan ujian kekerasan dan mikrostruktur kemudiannya dikaji di bawah mikroskop optik. Semakin tinggi nombor kekerasan Brinell yang diperolehi, semakin tinggi kekuatan kimpalan. Keputusan yang diperolehi menunjukkan bahan pengisi yang sesuai dan memberikan penyelesaian yang terbaik untuk pengimpalan keluli dua fasa dan akan dicadangkan untuk penyelidikan dan pembangunan keluli dua fasa supaya keluli ini dapat digunakan secara meluas dalam industri automotif dan aero-angkasa.

TABLE OF CONTENT

CHAPTER	SUBJECT	PAGE
	TITLE	i
	DECLARATION	ii
	ABSTRACT	v
	TABLE OF CONTENT	vii
	LIST OF TABLE	xi
	LIST OF FIGURES	xii
CHAPTER 1	**INTRODUCTION**	1
	1.1 Introduction	1
	1.2 Problem Statement	2
	1.3 Objective	3
	1.4 Scope	4
CHAPTER 2	**LITERATURE REVIEW**	5
	2.1 Introduction	5
	2.2 Steel	5
	2.2.1 Mild steel	6

2.2.1.1 Limitations of plain carbon steel ` 7
2.2.2 Dual phase steel 7
2.3 Welding Process 9
2.3.1 GTA welding 11
2.3.2 Filler material 13
2.4 Mechanical Testing 14
2.4.1 Hardness Test 14
2.5 Microstructure Analysis 16
2.5.1 Optical Microscopy 17

CHAPTER 3 METHODOLOGY 18

3.1 Introduction 18
3.2 Methodology 18
3.3 Sample Specification 20
3.3.1 Sample Dimension 20
3.3.2 Type of material 21
3.3.3 Material Composition 21
3.4 Sample Preparation 22
3.4.1 Cutting 22
3.4.2 Squaring 23
3.4.3 Beveling 24
3.4.4 Heat Treatment 24
3.4.5 Welding Process 24
3.4.6 Grinding 25
3.4.7 Mounting 25
3.4.8 Polishing 26
3.5 Microstructure Analysis 28
3.6 Mechanical testing 28

3.6.1 Hardness Test 29
3.6.1.1 Rockwell Hardness Test 30

CHAPTER 4 RESULTS AND DISCUSSION 32

4.1 Introduction 32

4.2 Experimental Results

4.2.1 Hardness testing 32
4.2.1.1 Filler Material Type SS7018 33
4.2.1.2 Filler Material Type SS6013 34
4.2.1.3 Filler Material Type SS308L 35
4.2.2 Microstructure Analysis 36
4.2.2.1 Filler Material Type SS7018 36
4.2.2.1.1 Dual Phase Steel 36
4.2.2.1.2 Welding Zone 37
4.2.2.1.3 Heat Affected Zone 37
4.2.2.2 Filler Material Type SS6013 38
4.2.2.2.1 Dual Phase Steel 38
4.2.2.2.2 Welding Zone 39
4.2.2.2.3 Heat Affected Zone 39
4.2.2.3 Filler Material Type SS308L 40
4.2.2.3.1 Dual Phase Steel 40
4.2.2.3.2 Welding Zone 41
4.2.2.3.3 Heat Affected Zone 41

4.3 Discussion 42

CHAPTER 5 CONCLUSION AND RECOMMENDATION 44

5.1 Conclusion 45

5.2 Recommendation 46

REFERENCES 47

APPENDIX 50

LIST OF TABLES

NO.	TITLE	PAGE
3.1	Chemical composition of base metal 0.19 wt %C	21
3.2	Properties of 1018 Mild Steel	21
3.3	Welding Filler Materials and parameters	24
4.1	Table of hardness results for Filler SS 7018	33
4.2	Table of hardness results for Filler SS 6013	34
4.3	Table of hardness results for Filler SS 308L	35

LIST OF FIGURES

NO.	TITLE	PAGE
2.1	Iron-iron Carbide Phase Diagram	8
2.2	Master Chart for welding and allied processes	11
2.3	Optical Microscope	17
3.1	Sample dimension	20
3.2	Sample after cutting	22
3.3	Milling Machine used for Squaring	23
3.4	Mounting Machine	26
3.5	Sandpaper Hand Grinder	27
3.6	Rotating Grinder	27
3.7	Optical Microscope	28
3.8	Hardness Testing Machine	30
4.1	Front view of the welding region and the points of indentation for hardness test	33
4.2	Graph of Hardness against distance for Filler 7018	33
4.3	Graph of Hardness against distance for Filler 6013	34
4.4	Graph of Hardness against distance for Filler 308L	35
4.5	Magnification at 50x	36
4.6	Magnification at 100x	36
4.7	Magnification at 200x	36
4.8	Magnification at 500x	36
4.9	Magnification at 50x	37

4.10	Magnification at 100x	37
4.11	Magnification at 200x	37
4.12	Magnification at 500x	37
4.13	Magnification at 50x	37
4.14	Magnification at 100x	37
4.15	Magnification at 50x	38
4.16	Magnification at 100x	38
4.17	Magnification at 200x	38
4.18	Magnification at 500x	38
4.19	Magnification at 50x	39
4.20	Magnification at 100x	39
4.21	Magnification at 200x	39
4.22	Magnification at 500x	39
4.23	Magnification at 50x	39
4.24	Magnification at 100x	39
4.25	Magnification at 50x	40
4.26	Magnification at 100x	40
4.27	Magnification at 200x	40
4.28	Magnification at 500x	40
4.29	Magnification at 50x	41
4.30	Magnification at 100x	41
4.31	Magnification at 200x	41
4.32	Magnification at 500x	41
4.33	Magnification at 50x	41
4.34	Magnification at 100x	41
4.35	Graph of comparison between filler rods SS6013, SS 7018 and SS 308L	42
4.36	HAZ of SS 7018	43
4.37	HAZ of SS 6013	43
4.38	HAZ of SS 308L	43

CHAPTER 1

INTRODUCTION

1.1 Background of Study

This chapter describes the background study of how the filler welding materials influence the microstructure and hardness of TIG welding in dual phase steel. Tungsten inert gas (TIG) or more commonly known as Gas Tungsten Arc Welding (GTAW) according to ASME standards was originally known as Heliarc welding. It was invented by Russell Meredith who was an engineer working for Northrup Aircraft during World War II. The first paper on the process appeared in the *Welding Journal* in 1941. Meredith was awarded three patents on the process, the first of which was Patent No. 413,711, issued on February 24, 1942. The objective had been to develop a process to weld magnesium without the use of flux. On June 15, 1942, Meredith was presented with the prestigious Award of Merit by Frank Knox, Secretary of the Navy [1].

TIG uses an arc between a tungsten electrode and the work to fuse the joints. The electrode is not metal and any filler metal needed to build up the weld profile is added separately. Both the molten metal in the weld pool, the tip of the filler wire and the hot electrode are protected from atmospheric contamination by a shield of inert gas. Usually the gas is argon, but helium by itself or mixed with argon may be used for special applications. Argon – Hydrogen mixtures can be used for stainless steel [2].

In this study, dual phase steel is used as the base metal. Dual phase steel is one of the more common advanced steels and is widely used in industries. This material is mainly used to create complicated and strong metal parts. The composition of the dual phase steel is mainly branched into two phases that is ferrite and martensite. Dual phase steel can be categorized by the advantages of each phase and how it complements each other. Starting with ferrite, ferrite has a chromium content of 16-20% with a corrosion resistance better than martensitic steel but inferior to austenitic steel. Ferrite steel is highly ductile but are subjected to brittle failure at low temperatures. They have moderate strength and limited weldability and are hardenable but heat treatment. Due to the low carbon content, it is very suitable for forming without cracking. Besides that, ferrite steel are magnetic and have low coefficients of thermal expansions. Martensite has a chromium content which is 12-18% and a nickel content which is 1-3%. These types of steel are the least corrosion resistant of all. They are unsuitable for welding or cold forming. They have moderate machineability and are used where high resistance to tempering at high temperature is important. Nevertheless, they can be heat treated to improve their properties and can be produced with a wide range of properties [3].

In perspective to the automotive sector, dual phase steel seem to be the solution to the increase in demands for fuel consumptions as well as the need to comply with the international environmental regulations [4]. After years of losing ground in automotive applications to Aluminium, steel is winning interest back with lighter and higher-strength steel grades. Evaluation of newer materials with improved combinations of strength, ductility and toughness has led to the development of a series of microstructurestrengthened steels, in which dual phase (DP) steels represent a distinguished class. DP steels are one of the important new advanced high strength (AHSS) product developed for the automobile industry. They offer, besides higher strength, possibilities to reduce weight and increase passenger safety . DP microstructure consists typically of a dispersion of a hard phase islands in a ductile matrix of ferrite. The second phase is usually martensite, but other low-temperature constituents, such as bainite, can be present. The amount of martensite present in ferrite-martensite steel will depend on the intercritical annealing temperature in the ferrite plus austenite region. Further increasing the volume fraction of martensite increases the strength of the dual phase material. Unfortunately, increasing the martensite content might reduce ductility and toughness [5].

Based on a study done by Aendraa Azhar Abdul Aziz, it is concluded that different filler materials used will affect the tensile stress and the tensile elongation of the material. By studying the hardness and microstructure of the welded joints of the dual phase steel, the influence of filler welding material can be investigated [6].

1.2 Problem Statement

GTA welding is suitable for both manual and mechanized welding. However, the hardness of the weld is questionable based on the filler material used. Different filler material causes various defects in the weldment. This is due to the mechanical properties of the filler metal itself. By using dissimilar filler metals, we can determine the influence of filler metals on the weldment and contemplate the best filler that should be used for GTA welding by studying the mechanical properties (hardness) and microstructure of the welded joints [7].

1.3 Objective

The investigation of the influence of filler welding materials on the microstructure and hardness of GTA welding in dual phase steel.

1. To study the microstructure characterization and hardness of GTA welding with dissimilar filler welding material.
2. To identify the influence of various filler materials and its defects in a weldment.
3. To compare the effects of dissimilar filler materials on the microstructure and hardness of a weld joint.

1.4 Scope

Following statements are the scopes of project:

1. The study involves butt joints as the welding type and dual phase steel as the base metal.
2. To investigate the influence of filler welding materials on the hardness of the weld.
3. Vickers Hardness Test is used to determine the hardness of the welded joints based on the dissimilar filler material used.
4. A microscopic view of the weld surface is analyzed using an optical microscope.

Chapter 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, the review of pass journals is done. When doing a literature review, you systematically examine all sources and describe and justify what you have done. This enables someone else to reproduce your methods and to determine objectively whether to accept the results of the review. For this research, Ferrite-Austenite Dual-Phase steel is used. This type of DP steel relates to a high strength, low-alloy, having an improved combination of formability and high product steel. This is the reason this steel is chosen for research [8].

2.2 STEEL

Steels are a large family of metals. Majority of them are alloys in which iron is mixed with carbon and other elements to produce the various types of alloys. Steels are described as mild, medium- or high-carbon steels according to the percentage of carbon they contain, although this is never greater than about 1.5%. Iron on the other hand can be pure. Cast iron is iron that contains the maximum amount of carbon that can be held which is 4% [9]. Since the influence of carbon on mechanical properties of iron is much larger than other alloying elements. The atomic diameter of carbon is less than the interstices between iron atoms and the carbon goes into solid solution of iron. As carbon dissolves in the interstices, it distorts the original crystal lattice of iron. This mechanical distortion of crystal lattice interferes with the external applied strain to the crystal lattice, by mechanically blocking the dislocation of the crystal lattices. In other words, they provide mechanical strength. Obviously adding more and more carbon to iron (up to solubility of iron) results in more and more distortion of the crystal lattices and hence provides increased mechanical strength. However, solubility of more carbon influences negatively with another important property of iron called the 'ductility' (ability of iron to undergo large plastic deformation). The a-iron or ferrite is very soft and it flows plastically. Hence we see that when more carbon is added, enhanced mechanical strength is obtained, but ductility is reduced. Increase in carbon content is not the only way, and certainly not the desirable way to get increased strength of steels. More amount of carbon causes problems during the welding process [10].

2.2.1 Mild Steel

Carbon steel is by far the most widely used kind of steel. The properties of carbon steel depend primarily on the amount of carbon it contains. Most carbon steel has a carbon content of less than 1%. Carbon steel is made into a wide range of products, including structural beams, car bodies, kitchen appliances, and cans. In fact, there are 3 types of plain carbon steel and they are low carbon steel, medium carbon steel, high carbon steel, and as their names suggests all these types of plain carbon steel differs in the amount of carbon they contain. Indeed, it is good to precise that plain carbon steel is a type of steel having a maximum carbon content of 1.5% along with small percentages of silica, sulphur, phosphorus and manganese. Generally, with an increase in the carbon content from 0.01 to 1.5% in the alloy, its strength and hardness increases but still such an increase beyond 1.5% causes appreciable reduction in the ductility and malleability of the steel. These are the types of mild steel;

i. Low carbon steel or mild steel, containing carbon up to 0.25%. It responds to heat treatment as improvement in the ductility is concerned but has no effect in respect of its strength properties.
ii. Medium carbon steels, having carbon content ranging from 0.25 to 0.70% improves in the machinability by heat treatment. It must also be noted that this steel is especially adaptable for machining or forging and where surface hardness is desirable.

2.2.1.1 Limitations of plain carbon steel.

Like everything, the plain carbon steels do have some appreciable properties but also consists of some limitations. These are:

i. There cannot be strengthening beyond about 100000 psi without significant loss in toughness (impact resistance) and ductility.
ii. Large sections cannot be made with a martensite structure throughout, and thus are not deep hardenable.
iii. Rapid quench rates are necessary for full hardening in medium-carbon leads to shape distortion and cracking of heat-treated steels.
iv. Plain-carbon steels have poor impact resistance at low temperatures.
v. Plain-carbon steels have poor corrosion resistance for engineering problems.
vi. Plain-carbon steel oxidises readily at elevated temperatures [11]

2.2.2 Dual Phase Steel

In depth, this invention is a microalloy-free, low carbon, manganese steel categorized as a ferrite matrix microstructure comprising dispersed particles that are initially austenite but are transformed to martensite due to the forming process. By definition, Dual-Phase steel is high strength, low-alloy steel that is characterized by a matrix microstrucutre composed of a continuous ferrite having a second phase distributed within. In conventional dual phase steel, the second phase is martensite although austenite or bainite may also be present, in which case the steel may include more than the two iron metallurgical phases that the name implies. Dual phased steel is used, for example, in cold-formed sheet steel articles. The composite microstructure produces an advantageous combination of mechanical properties that allow the steel to be readily formed, but to develop a high-formed strength. The iron-carbon equilibrium diagram is a plot of transformation of iron with respect to carbon content and temperature. This diagram is also called iron-iron carbon-phase diagram and is shown in **Figure 2.1** below.

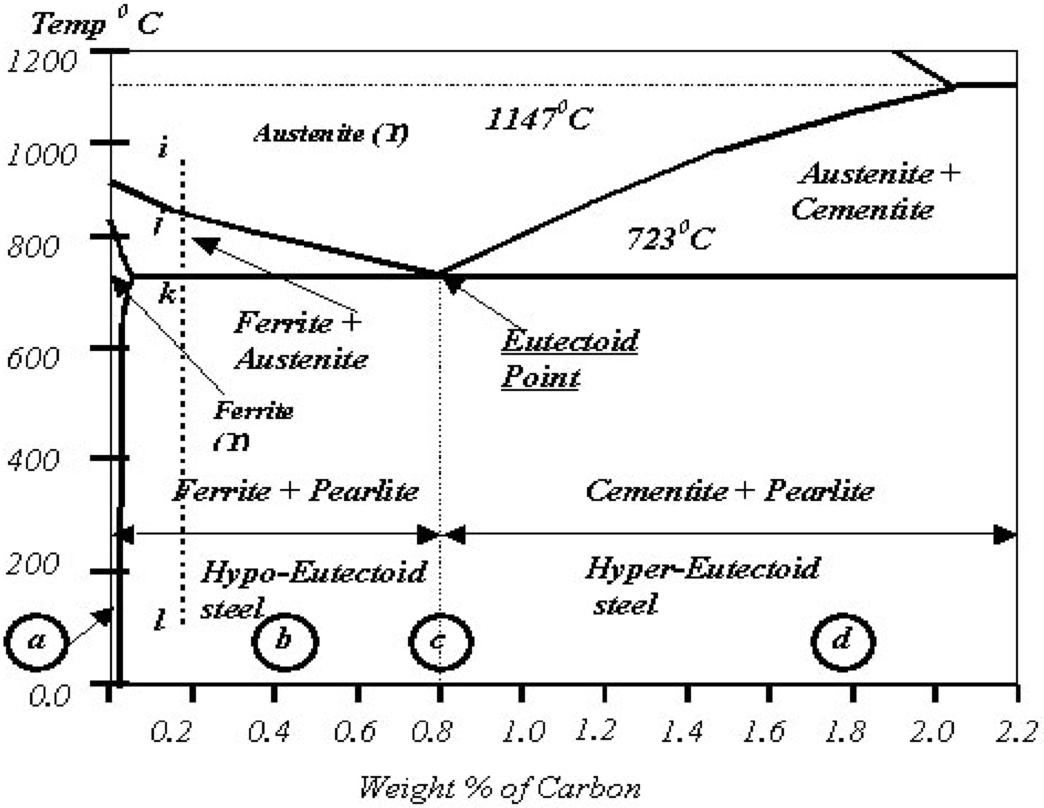

Figure 2.1 Iron-iron carbon phase diagram

(Source: Metallurgy of steel, Design of steel structures. Journal by Prof. S.R. Satish Kumar and Prof. A.R Santha Kumar)

Ferrite (α): Virtually pure iron with body centered cubic crystal structure (bcc). It is stable at all temperatures upto 9100C. The carbon solubility in ferrite depends upon the temperature; the maximum being 0.02% at 723^{o}C.

Cementite: Iron carbide (Fe3C), a compound iron and carbon containing 6.67% carbon by weight.

Pearlite: A fine mixture of ferrite and cementite arranged in lamellar form. It is stable at all temperatures below 723^{o}C.

Austenite (γ): Austenite is a face centred cubic structure (fcc). It is stable at temperatures above 723^{o}C depending upon carbon content. It can dissolve upto 2% carbon.

The maximum solubility of carbon in the form of Fe3C in iron is 6.67%. Addition of carbon to iron beyond this percentage would result in formation of free carbon or graphite in iron. At 6.67% of carbon, iron transforms completely into cementite or Fe3C (Iron Carbide). Generally carbon content in structural steels is in the range of 0.12- 0.25%. Upto 2% carbon, we get a structure of ferrite + pearlite or pearlite + cementite depending upon whether carbon content is less than 0.8% or beyond 0.8%. Beyond 2% carbon in iron, brittle cast iron is formed [12].

2.3 WELDING

Welding is widely used by metalworkers in the fabrication, maintenance, and repair of parts and structures. While there are many methods for joining metals, welding is one of the most convenient and rapid methods available. The term welding refers to the process of joining metals by heating them to their melting temperature and causing the molten metal to flow together. These range from simple steel brackets to nuclear reactors. Welding, like any skilled trade, is broad in scope and you cannot become a welder simply by reading a book. You need practice and experience as well as patience; however, much can be gained through study. For instance, by learning the correct method or procedure for accomplishing a job from a book, you may eliminate many mistakes that otherwise would occur through trial. The primary differences between the various welding processes are the methods by which heat is generated to melt the metal. The most common types of welding are oxyfuel gas welding(OFW), arc welding(AW), and resistance welding(RW). Welding current is the most influential variable in arc welding process which controls the electrode burn off rate, the depth of fusion and geometry of the weldments. Welding voltage is the electrical potential difference between the tip of the welding wire and the surface of the molten weld pool. It determines the shape of the fusion zone and weld reinforcement. High welding voltage produces wider, flatter and less deeply penetrating welds than low welding voltages. Depth of penetration is maximum at optimum arc voltage. Welding speed is defined as the rate of travel of the electrode along the seam or the rate of the travel of the work under the electrode along the seam. Some general statements can be made regarding speed of travel. Increasing the speed of travel and maintaining constant arc voltage and current will reduce the width of bead and also increase penetration until an optimum speed is reached at which penetration will be maximum. Increasing the speed beyond this optimum will result in decreasing penetration. In the arc welding process increase in welding speed causes:

i. Decrease in the heat input per unit length of the weld.
ii. Decrease in the electrode burn off rate.
iii. Decrease in the weld reinforcement.

If the welding speed decreases beyond a certain point, the penetration also will decrease due to the pressure of the large amount of weld pool beneath the electrode, which will cushion the arc penetrating force. The **Figure 2.2** below shows the master chart for welding and allied processes. [13].

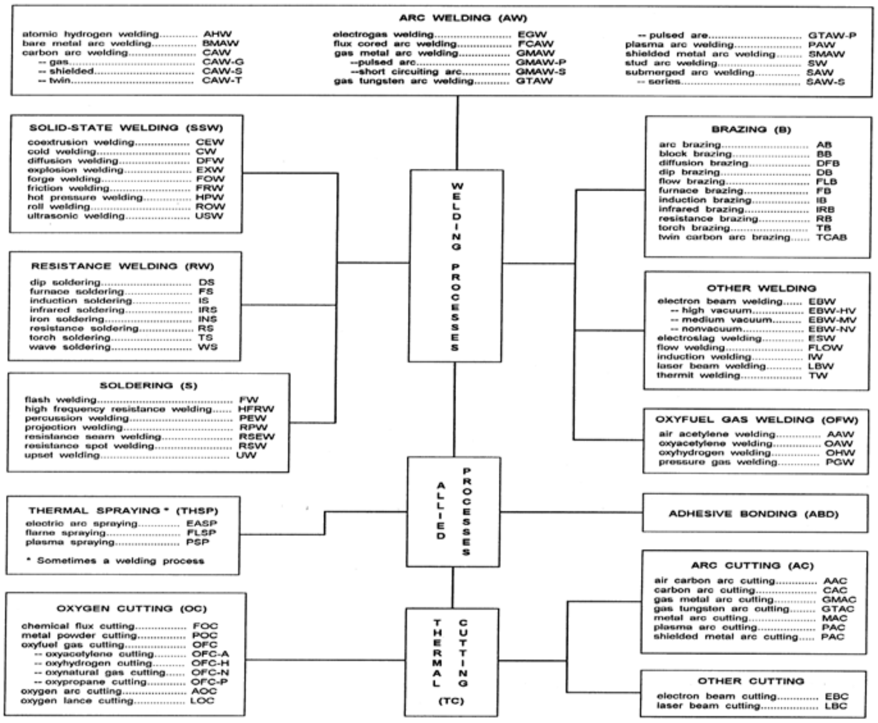

Figure 2.2 Master Chart for welding and allied processes

(Source: http://www.guthriejags.net/ag/welding/Introduction%20to%20Welding.pdf)

2.3.1 Gas Tungsten Arc Welding (GTAW)

Gas Tungsten Arc Welding (GTAW), also known as tungsten inert gas (TIG) welding is a process that produces an electric arc maintained between a nonconsumable tungsten electrode and the part to be welded. The heat-affected zone, the molten metal and the tungsten electrode are all shielded from atmospheric contamination by a blanket of inert gas fed through the GTAW torch. Inert gas (usually Argon) is inactive or deficient in active chemical properties. The shielding gas serves to blanket the weld and exclude the active properties in the surrounding air. Inert gases such as Argon and Helium do not chemically react or combine with other gases. They pose no odour and are transparent, permitting the welder maximum visibility of the arc. In some instances Hydrogen gas may be added to enhance travel speeds. The GTAW process can produce temperatures of up to 35,000° F (19,426° C). The torch contributes heat only to the