EFFECT OF WELDING TECHNIQUES (GTAW & SMAW) ON THE MICROSTRUCTURE & MECHANICAL PROPERTIES OF MILD STEEL SA 516 Gr. 70

By

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ABSTRACT

Two different Welding techniques (SMAW, GTAW) were applied to mild steel of ASTM grade SA 516 Gr. 70 which is frequently used in boiler and pressure vessel etc. Welding was carried out according to commercial practice under controlled welding conditions. For each welding techniques three portions i.e. base metal, HAZ and weld zone were examined microscopically on optical microscope.

Mechanical properties were determined by using Universal Tensile Testing machine, while the hardness was evaluated with the Vicker's Hardness Testing Machine. Bend test was performed to check the soundness of weld using Universal Bend Test Machine. The purpose of metallography and destructive testing was to determine the effect of different welding techniques (GTAW & SMAW) on the microstructure & mechanical properties of boiler & pressure vessel steel grade SA 516 Gr. 70.

In the present work it was found that for getting the benefits of GTAW, root pass can be made with these techniques, while the hot & face pass can be prepared by SMAW to achieve the best combination of strength & economy.

INTRODUCTION

Welding is a process of joining two or more pieces of the similar or dissimilar materials to achieve complete coalescence. This is the only method of developing monolithic structures and it is often accomplished by the use of heat and pressure. Although in its present form it has been used since about the beginning of 20^{th} century but it is fast replacing other joining processes like riveting and bolting. At times it may be used an alternative to casting.

Thermo-chemical sources, the electric arc or some form of radiant energy can be used to melt the weld metal. In each case the equipment must be capable of focusing the high-energy heat source on to the weld area.

Presently welding is used extensively for fabrication of vastly different components including critical structures like boilers and pressure vessels, ships, off-shore structures, bridges, storage tanks, pipelines, missile and rocket parts, nuclear reactors, fertilizer and chemical plans, earth moving equipment and automobile bodies etc. Welding is also used in heavy plate fabrication industries pipe and tube fabrication.

Two different Welding techniques (SMAW, GTAW) were applied to ASTM SA 516 Gr. 70 low alloy carbon steel. Welding was carried out according to commercial practice under controlled welding conditions. For each welding three portions separately base metal, HAZ and weld zone were examined microscopically on optical microscope while mechanical properties of each zone alongwith the hardness and bend test were performed.

SHIELDED METAL ARC WELDING (SMAW)

Shielded Metal Arc Welding (SMAW) or Stick welding is a process which melts and joins metals by heating them with an arc between a coated metal electrode and the work-piece. The electrode outer coating, called flux, assists in creating the arc and provides the shielding gas and slag covering to protect the weld from contamination. The electrode core provides most of

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the weld filler metal. The Stick welding power source provides constant current (CC) and may be either alternating current (AC) or direct current (DC), depending on the electrode being used. The best welding characteristics are usually obtained using DC power sources.

The amperage needed to weld depends on electrode diameter, the size and thickness of the pieces to be welded, and the position of the welding. Generally, a smaller electrode and lower amperage is needed to weld a small piece than a large piece of the same thickness. Thin metals require less current than thick metals, and a small electrode requires less amperage than a large one. It is preferable to weld on work in the flat or horizontal position. However, when forced to weld in vertical or overhead positions it is helpful to reduce the amperage from that used when welding horizontally. Best welding results are achieved by maintaining a short arc, moving the electrode at a uniform speed, and feeding the electrode downward at a constant speed as it melts.

GAS TUNGSTEN ARC WELDING (GTAW)

GTAW, an arc welding process that uses an arc between a tungsten electrode (no consumable) and the weld pool. The process is used with shielding gas and without the application of pressure. Gas tungsten arc welding (GTAW) may be used with or without the addition of filler metal. GTAW has become indispensable as a tool for many industries because of the high-quality welds produced and low equipment costs.

The most significant feature of GTAW is that the electrode used are not intended to be consumed during the welding operation. It is made of pure or alloyed tungsten which has the ability to withstand very high temperatures, even those of the welding arc. Therefore, when current is flowing, there is an arc created between the tungsten electrode and the work.

When filler metal is required, it must be added externally, usually manually, or with the use of some mechanical wire feed system. All of the arc and metal shielding is achieved through the use of an inert gas which flows out of the nozzle surrounding the tungsten electrode. The deposited weld bead has no slag requiring removal because no flux is used.

MATERIALS AND METHODS

Two different welding techniques (SMAW, GTAW) were employed on SA 516 Gr. 70 low alloy carbon steel. Welding was carried out according to the commercial practice (described in ASME section IX) under controlled conditions.

Material is purchased with its inspection certificate (MTC) which includes the plate size, plate weight and its composition is according to the composition mentioned in ASTM (volume 1).

REQUIRED AMOUNT OF MATERIALS

Number of samples required for different testing from each welded plate as:

1) For physical testing, width of the specimen should be ¾” (1”)* (Microscopy, Macroscopy). No. of specimen required from each plate = 4
2) For Hardness testing, width of the specimen should be 1” (1.25”)* (Vicker’s). No. of specimen required from each plate = 8
3) For tensile testing, width of the specimen should be 1 ¼” (1 ½”)*.No. of specimen required from each plate = 1
4) For Bend test, width of the specimen should be 1 ½” (1 ¾”)*.No. of specimen required from each plate = 2

TESTING OF SPECIMENS

Standard specimens were prepared for each test according to ASME. Tensile specimen was prepared by using milling machine, while tensile test of the welded specimens were primed on universal testing machine and the results were recorded for their tensile strength, yield strength, and ductility (in term of % elongation). The Root Bend specimen and Face Bend specimen were prepared using Shaper Machine. In the Face Bend specimen, face of the weld was flushed and in the Root Bend specimen, root of the weld was flushed. Guided bend tests were carried out on the universal testing machine. Here two kinds of tests were performed (i.e. Face Bend Test and Root Bend Test)

Hardness testing was performed by using Vicker's hardness testing machine. Hardness measurement can provide information about the metallurgical changes caused by welding. Rapid cooling from HAZ temperatures may cause the formation of martensite of much higher hardness than the base metal. In HAZ areas where the maximum temperature is lower, however, the hardness may be lower than the base metal due to tempering effects. Welding of cold worked or age hardened materials may result in significantly lower HAZ hardness due to recovery recrystallization or over aging. Hardness values in a welded joint are usually sensitive to such condition of welding, as the process used, heat input, preheat or interpass temperature, electrode composition, and plate thickness.

Hardness testing of welds was performed on ground, polished and etched cross-section of the joint area. Indentations are made in the specific areas of interest, including the weld centre line, face or root regions of the deposit, the HAZ and the base metal.

For physical testing, specimens were prepared by Grinding, Polishing and finally Etching. The structures were observed by optical microscope.

RESULTS AND DISCUSSION

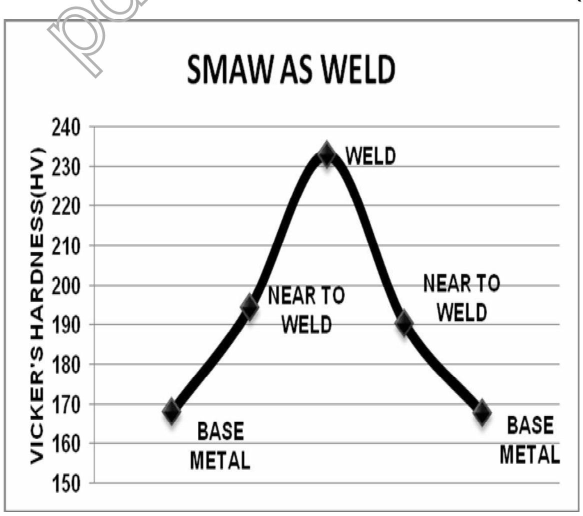
The results are obtained on the basis of the following technique:

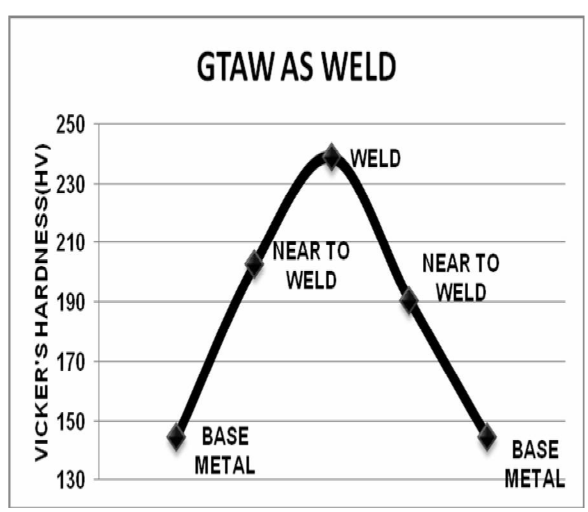
The comparison of properties of shielded metal arc welding and gas tungsten arc welding has been discussed in this work.

HARDNESS TESTING

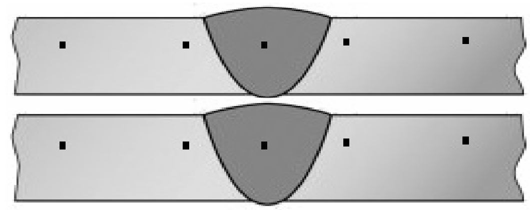
In these tests, Vicker's hardness test were performed on the various zones such as base metal, heat affected zone and weld zone. Hardness profiles of welding specimens were made to show the variation of hardness with the distances from the weld zone. Hardness profile of each welding specimen is shown below

HARDNESS Vs ZONE (base metal, near to weld, weld)



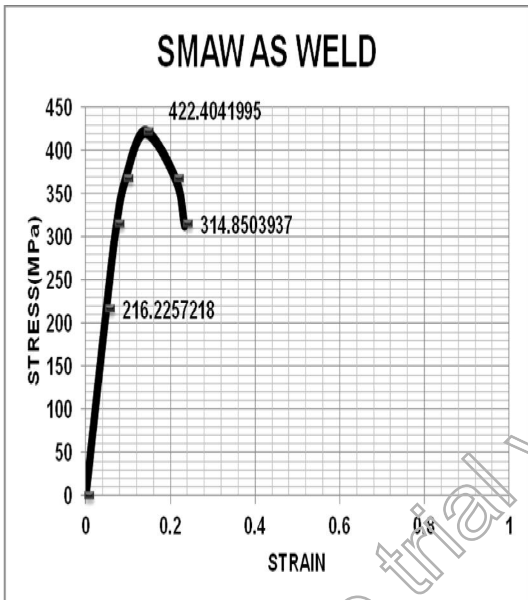


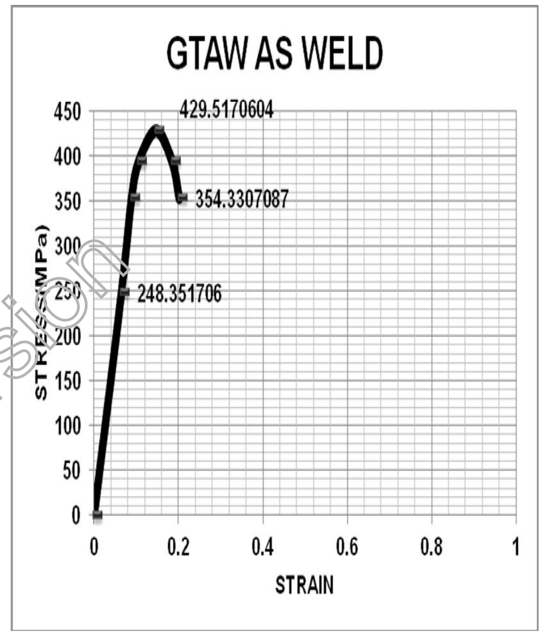
The Vicker's hardness profile of as welded specimen is shown in above figure. This shows that hardness of all the specimens are minimum at the base metal, which reaches maximum at the weld zone and then decreases gradually to the HAZ and then to the base metal.



TENSILE TESTING
In these tests, specimens stretched under tension and the load elongation diagrams were found and then converted into stress strain curves. Mechanical properties were then found from stress strain curves such as tensile strength, yield strength, percentage elongation or ductility etc.

The experimentally determined stress strain curves of base metal, heat affected zone and weldments of each welding techniques are shown below ;



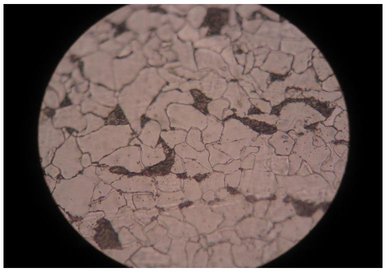


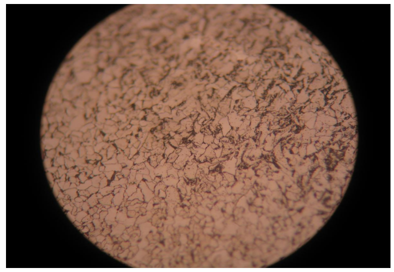
BEND TESTING
These tests were performed according to the standard procedure as Face Bend and Root bend for SMAW and GTAW.

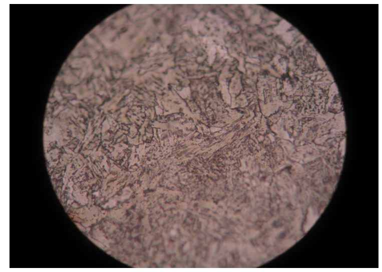
METALLOGRAPHY
When the structural members are joined by fusion welding the material of the plates has to be heated to its melting point and then cooled again rapidly under conditions of restraint imposed by the geometry of the joint. As a result of this very severe thermal cycle the original micro structure and the properties of the metal in a region close to the weld are changed and this volume of metal or zone is usually referred to as the heat affected zone.

The HAZ can be conveniently divided into number of sub zones. Each sub zone refers to a different type of microstructure and each structural type is likely to possess different mechanical properties. The structure type and its sub zone width are partially determined by the thermal cycle, i.e. due to the moment of arc and thermal properties of the base metal.

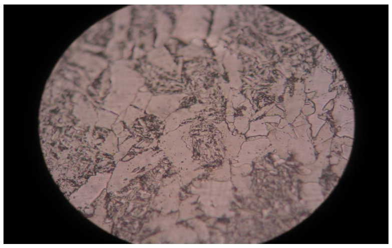
The grain size is of paramount importance in metals, being a key factor in determining the strength of a material. It also has enormous importance with respect to determining an alloy susceptibility to cold cracking and reheat cracking in welds. The weld thermal cycle is such that in majority of metals in some grain growth occurs in HAZ zone and this not only affects the strength but also influence the grain size of the weld metal by epitexial solidification.

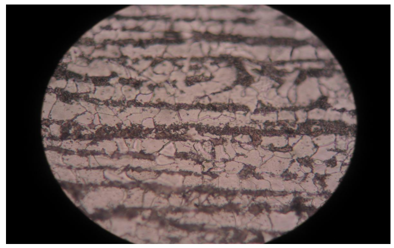


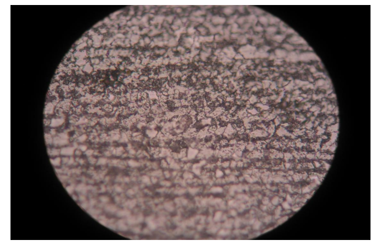




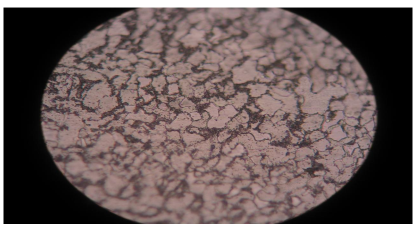
BASE METAL (1000x SMAW) FUSION ZONE (500X SMAW) HAZ (1000X SMAW)

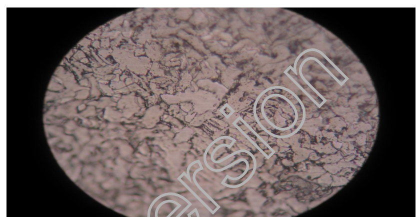






WELD METAL (1000X SMAW) BASE METAL (1000X GTAW) HAZ (1000X GTAW)





FUSION ZONE (1000X GTAW) WELD METAL (1000X GTAW)

The present study shows that due to more heat input in SMAW there is large grain growth in HAZ zone of the weld metal as compared to GTAW, so the grain size in weld and HAZ is large by SMAW. It is a well known phenomenon that strength of material largely depend upon the grain size of a material i.e. smaller is the grain size higher is the strength and vice versa. In this study it is concluded that the grain size of the weldment which is produced by GTAW is smaller than that of SMAW, so the strength of the weldment produced by GTAW is more.

MECHANICAL PROPERTIES

Welding Technique	Tensile Strength (MPa)	Yield Strength (MPa)	Basemetal Hardness (VHN)	HAZ Hardness (VHN)	Weldmetal Hardness (VHN)	Face bend	Root bend
GTAW	429.51	248.31	150	205	240	ok	Ok
SMAW	422.40	216.22	165	193	230	ok	Ok

CONCLUSIONS

In the present work, it is concluded that the proper shielding, current control and heat input, gas tungsten arc welding (GTAW) gives more strength and hardness than SMAW. The disadvantage of GTAW process is that it is relatively expensive. Therefore, due to economical reasons gas tungsten arc welding is only recommended for more critical and special fabrication conditions. Generally for getting the benefits of GTAW, root pass can be made with this technique, while the hot & face pass can be prepared by SMAW to achieve the best combination of strength & economy.

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