EXPERIMENTAL INVESTIGATION OF STRENGTH OF V & U GROOVE BUTT WELDED JOINT CARBON STEEL MATERIALS USED IN PRESSURE VESSEL BY USING GTAW & SMAW WELDING TECHNIQUES

Mr. Bhushan Bhagwat Wadekar[1], Prof. V. L. Kadlag[2]

[1] *M.E.Scholar, Department of Mechanical Engineering ,SVIT, Chincholi, Sinner, Nashik, India.*
Email- wadekar_bb@rediffmail.com
[2] *HOD, Department of Mechanical Engineering ,SVIT, Chincholi, Sinner, Nashik, India.*
Email- vijaykadlag2@gmail.com

ABSTRACT

Welding is an area in which technological development out match in its science base which is primarily driven by the phenomenal industrial demand for welded structure. Reliability, Reproducibility and Viability requirements are forcing Technologists to look at weld defects such as distortion, hot cracking, in a systematic and logical approach than on experimental basis. Distortion is an unwanted physical change from specifications in a fabricated structures is caused by non-uniform expansion and contraction of the weld metal during heating and cooling cycle of the welding process many factors viz., material properties, welding process and procedures adopted make accurate prediction of distortion difficult. Type of Groove was taken to analyze tensile, compressive, shear, bend and impact strength in butt weld joints.

The current study aim to compare mechanical properties of A516 Gr.70 and IS 2062 E250 for different groove angle and bevel heights keeping root opening, voltage and current constant. The specimens are prepared by using V groove butt weld joints by SMAW process then compare the tensile strength. High tensile jointed material between these materials is taken for comparing of strength of U & V groove geometry. For which work gas tungsten arc welding process has been selected because TIG welding is the process of joining different materials with high quality in the presence of inert gas. Alternating current power source has been selected because of better cleaning action and due to alternating current the high heat concentration on the material can be avoided. Mechanical tests such as tensile test, impact test and hardness test have been conducted to find out the mechanical properties such as tensile strength, impact strength of HAZ.

Keyword : - *Bevel height, groove angle, root opening, U groove butt weld joint, V groove weld joint, SMAW, TIG Welding.*

---

1. INTRODUCTION

Welding is a joining process of similar metals but nowadays it is also joining dissimilar metals by the application of heat. Welding can be done with or without the application of pressure. It is can be done addition of filler materials or without addition of filler materials. While welding the edges of metal pieces either melted to plastic condition and it is used for permanent joints. The joint gets stronger after cooling down. It's heats when the weld pool is used with the work-piece and produces weld in that time. In all fabrication companies welding is very essential. Welding is used in steel fabrication its uses and is expanded in other industrial sectors like construction, mechanical and car manufacturing etc.

1.1 Shielded metal arc welding.

This is a simply called as arc welding. It is one of the methods of fusion welding process for joining two metal pieces by melting their edges by an electric arc between two conductors. The electrode and the work piece are conductors. The electrode and work piece are brought together with a small air gap, the gap should maintaining nearer 3mm approximately. These processes require coated or covered electrodes for producing an arc to act as a heat source; the covering on burning provides the necessary shield to protect the molten metal from the effect of oxygen and hydrogen from the surrounding atmosphere. This process is popularly known as stick electrode welding or in almost all sectors of our lives. It in the most places, the things are doing or use to accomplish our work. One of the strongest methods of joining any metal is the fusion with the help of Arc welding. The electric current allows the electric arc to melt two metal pieces, a filter material is used which enables the pieces to mix and as it cools it solidifies into one piece.

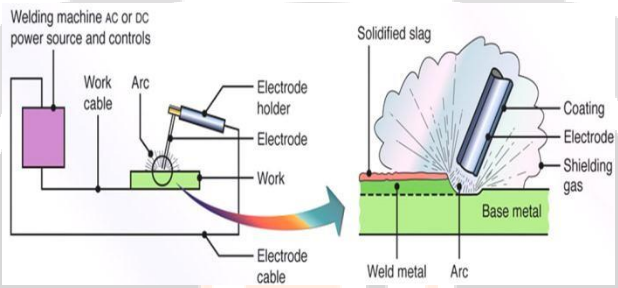

Fig-1.1 SMAW Welding

1.2 Gas Tungsten Arc Welding

GTAW is also known as TIG welding and is an abbreviation for Tungsten Inert Gas Welding**.** GTAW welding is an electric arc welding process in which the fusion energy is produced by an electric arc burning between the work piece and the tungsten electrode. If it is necessary to use filler material it is added a bare wire either manually or automatically. The arc and the weld pool are protected against the damaging effects of the atmospheric air by an inert shielding gas during the welding process the electrode. A shielding gas is lead to the welding zone from the nozzle where it replaces the atmospheric air.

The electrode holder in which the non-consumable tungsten electrode is fixed. The inert gas from the cylinder passes through the welding head around the electrode when the arc is produced between the electrode and work. Inert gas surrounds the arc and protects the weld from atmospheric effect, so those welds are made without defects. For welding steels, aluminum, cast iron, magnesium, stainless steel, this process is mostly used.

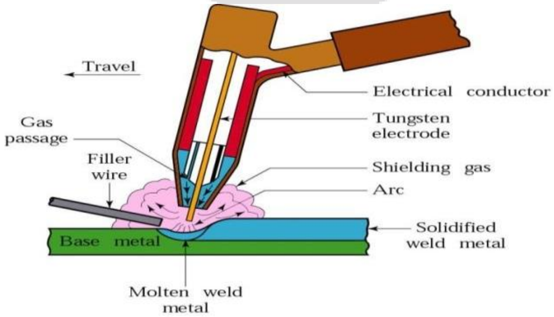

Fig-1.2 TIG Welding Process

1.3 Carbon steel MATERIALS

A-516-70 is the most widely used pressure vessel steel. It maintains its strength to temperatures of 345º C and can be used to -50ºC if normalized and impact tested. It is commercially available in thicknesses from 6mm to 40mm in the "as rolled" condition. For thicknesses in excess of 40mm, the plate must be normalized to prevent potential cracking in forming or in service. A516-70 plates are commercially stocked in warehouses today in widths of 2.5meter and 3meter and lengths of 12meter. Of course it can be ordered to any width and length and thickness, but it is rare to find stock plates that are longer than 12meter or wider than 3meter.

There are other Indian standard carbon steels that are used in pressure vessel IS 2022 and IS 2062, but they are for specialized small market applications and we shall not take one of them for strength comparative with international standard carbon steel i.e. SA 516 grade 70.

2. LITERATURE REVIEW

G.B.Jang, H.K.Kim and S.S.Kang et.al. "The Effects of Root Opening on Mechanical Properties, Deformation and Residual Stress of Weldments" In steel bridge manufacturing, dimensional differences caused by weld deformation often occur because multipass welding is used to join thick plates. It frequently develops that root openings are out of tolerance at butt joints. For example, to be within tolerance, root openings must be controlled to below 6 mm for butt-joint welds in plates under 20 mm thick, but a root opening of 30 mm can develop in the field. In that case, a part 24 mm out of tolerance is generally built up.

However, there has been no accumulated data and standards developed regarding these built-up welded parts. In the present case, a study was performed to accumulate data on the behavior of built-up parts and to verify the effects of root opening on the mechanical properties of the welded parts. For that purpose, tensile, bend, impact and hardness tests were carried out on weld specimens having 0-2, 6-10 and 30-40 mm root openings. Additionally, the finite element common code (MARC) was used to study the effects of 0-2, 6-10 and 30-40 mm root openings on residual stress and weld deformation in multipass welding.

G. Magudeeswaran et.al "Optimize the Process Parameters of Activated Tungsten Inert Gas welding." The activated TIG (ATIG) welding process mainly focuses on increasing the depth of penetration and the reduction in the width of weld bead has not been paid much attention. The shape of a weld in terms of its width-to-depth ratio known as aspect ratio has a marked influence on its solidification cracking tendency.

Bhawandeep Singh et.al Observed the Performance of activated TIG process in mild steel welds. Gas tungsten arc welding is fundamental in those industries where it is important to control the weld bead shape and its metallurgical characteristics. However, compared to the other arc welding process, the shallow penetration of the TIG welding restricts its ability to weld thick structures in a single pass thus its productivity is relativity low.

M. Murugananth , S.S.Babu, and S.A.David et. al "Optimization of Shielded Metal Arc Weld Metal Composition for Charpy Toughness" This coupled model was used to optimize the carbon, nickel, and manganese concentrations in a weld to achieve a maximum toughness of 120 J at -60°C. The coupled model used linear and nonlinear techniques to explore the possible combinations of carbon, manganese, and nickel concentrations for a given set of welding process parameters. An optimum weld metal composition was achieved only with nonlinear methods. The number of iterations and the exploration of input parameter space varied depending upon the type of nonlinear technique.

G. Atkins, D.Thiessen , N.Nissley, and Y.Adonyi et. al. "Welding Process Effects in weldability Testing of Steels" This work was part of a nationwide program for the development of new high-performance steels with 70 ksi (485 MPa) minimum yield strength, improved toughness, and lower manufacturing costs through the elimination of preheat for welding. The purpose of the present work was to evaluate the fusion zone hydrogen-induced cracking susceptibility of single-pass weld deposits made using four different welding processes at equivalent diffusible hydrogen levels.

T. Kasuya and N.Yurioka et.al "Carbon Equivalent and Multiplying Factor for Hardenability of Steel" The carbon equivalent and the multiplying factor are indexes for hardenability of steels. The carbon equivalent is used generally in welding and is related to the critical cooling time for the full martensite structure in the HAZ. The multiplying factor is used in heat treatment of hardenable steels and is related to the critical diameter for the full martensite. A heat conduction in a round bar has clarified that the ideal critical diameter should be expressed in a product form of alloy elements as long as the carbon equivalent is expressed in a linear combination of elements.

A. Q. Bracaense and S. Liu et al. "Chemical Composition Variations in Shielded Metal Arc Welds" The use of shielded metal arc (SMA) welding can result in chemical composition variations along the weld length. Manganese and silicon, commonly found in low-carbon steel welds, change in composition with weld position. This research was performed to better characterize the composition variations observed in structural steel welds and to understand the controlling factors that determine the extent of these composition changes.

3. OBJECTIVES

Determine the overall joint strength of a single U or V welded joint at optimum geometrical configuration i.e. root gap, root face and bevel angle with two different carbon steel materials used in pressure vessel and two different welding techniques

It can also be defined as determination of high strength groove joint geometry by experimental method on the basis of tensile strength, hardness, Micro test and Macro test toughness of HAZ as use in the ASME Section IX.

Objective of proposed project is to find out,

1 Suitable Material
2 Suitable welding Technique
3 Suitable groove geometry between U & V
4 Increasing Welding Strength
5 Minimize cost of welding

4. METHOLOGY

To produce quality weld joints, it is necessary to keep an eye on what is being done in three different stages of the welding

1. Before welding such as cleaning, edge preparation, baking of electrode etc. to ensure sound and defect free weld joints.
2. The selection of input parameters (pressure of oxygen and fuel gas, welding current, arc voltage, welding speed, shielding gases and electrode selection) affecting the heat input and so melting, solidification and cooling rates besides protection of the weld pool from atmospheric contamination are various aspects such as manipulation of heat source.
3. After welding steps, if any, such as removal of the slag, peening and post welding treatment Selection of optimal method and parameters of each of above steps and their execution in different stages of production of a weld joint determine the quality of the weld joint. Inspection is carried out to assess the progress of the work or how meticulously parameters are being implemented.
4. Testing helps to assess the suitability of the weld joint for a particular application and take decision on whether to go ahead at any stage of welding with further processing or accept/reject the same.

Testing methods of the weld joint are broadly classified as destructive testing and non-destructive testing. A destructive testing method is physical damage the test piece for some extent. The extent destructive tested specimens sometime can be up to complete fracture like in tensile, fatigue testing, etc. Thus making it is useable for the intended purpose.

Weld joints are generally subjected to destructive tests such as hardness, toughness, bend and tensile test for developing the welding procedure specification and assessing the suitability of weld joint for a particular application.

Visual inspection gives the quality of external features for a weld joint like weld bead profile, weld width and reinforcement, bead angle and external defects such as craters, cracks, distortion etc. only.

5. EXPERIMENTAL INVESTIGATION OF STRENGTH OF V & U GROOVE BUTT WELDED JOINTS

5.1 Experimental Methodology

However the steel can able to weld in different welding processes which results into having different strength. So welding effect of TIG and SMAW welding process on steel is changes its property. Again welding effect of TIG and SMAW welding process on different steel is different.

The mechanical property of the SMAW piece and GTAW welding piece for IS 2062 Gr.250 Material and SA516 Gr 70 material is to be analyzed and each weldment has to shows the strength value that closer to parent metal property.

To determine the micro hardness values of the weldment of SMAW piece and TIG arc welding piece so as to say the better hardness value by compared to Base metal hardness. To analyze micro structure of shielded metal arc welding and tungsten inert gas welding pieces on weldment and base metal so as to shows the micro structural effect of welding.

Chemical composition for the both metal on which we need to experiment is shown below.

Composition	C	Si	Mn	S	P	CE
IS 2062 Gr.250	0.23	0.40	1.50	0.045	0.045	0.42
A 516 Gr.70	0.27	0.40	1.20	0.035	0.035	0.42

Welding material & its Composition for above material is shown below.

Composition	C	Si	Mn	S	P
E 7018	0.15	0.75	1.60	0.035	0.035
ER 70 S-2	0.07	0.70	1.40	0.035	0.035

5.2 Welding parameters

Because of inspection two processes of different welding processes have same parameter and electrode and base metal. The process parameters for two different welding process are same.

Phase	3phase, 50 cycles/sec
Current	50 A to 400 A
Open circuit voltage	80 volts
Efficiency	0.85%
Power factor	0.4

Energy consumption	4kWh/kg of Metal deposit
Welding speed	1 min/200mm

The SMAW and TIG welding same chemical composition electrodes grade E 7018 and ES 70 SP2 for carbon steel used. The welding parameters of each process should same including the electrodes for testing of the welded material with same procedure have to select same material.

5.3 Destructive Test

5.3.1.Tensile test

The yield and ultimate strength and ductility i.e. %age elongation, %age reduction in area can be obtained either in ambient condition or in special environment like low temperature, high temperature, corrosion etc. depending upon the requirement of the application using tensile test which is usually conducted at constant strain rate (ranging from 0.0001 to 10000 mm/min)

5.3.2 Bend test

Bend test is the most common and important method used destructive tests to determine the ductility and soundness for the presence porosity, inclusion, penetration and other macro-size internal weld discontinuities of the weld joint produced using under one set of welding conditions. Bending of the weld joint can be done from face or root side depending upon the purpose i.e. face side or root side of the weld is to be assessed. The root side bending test shows the lack of penetration and fusion if any at the root.

5.3.3 Hardness test

Hardness of any material is defined as resistance to indentation and is commonly used as a measure of resistance to abrasion or scratching. For the formation of a scratch or causing abrasion, a relative movement is required between two bodies and out of two one body must penetrate/indent into other body. The penetration of Indentation is a pointed object harder into other object softer under the external load. Resistance to the penetration of pointed object (indenter) into the softer one depends on the hardness of the sample on which load is applied through the indenter.

5.3.4 Impact Testing

The prepared specimen was placed on the Anvil with V-notch gauge. The Pendulum was set to predetermined level 298 J and released to strike and fracture the positioned specimen. The value of Energy Impacted was taken and recorded.

5.3.5 Metallographic Testing

Metallographic samples were produced from welds in accordance to ASTM E 23. Grinding, Polishing, etching with 2% Nital and Metallographic examination of butt and groove welds were performed using optical microscope Olympus PMG3 with magnification X500.

6. STAGE WISE EXPERIMENTAL PROCEDURE

6.1 Stage 1

There are four carbon steel plates we have taken .i.e. two of IS 2062 Gr.E250 and two of A516 Gr 70 having the length and width 125mmX160mm and 8mm thick plate. Two plates of same material will be butt welded by SMAW welding method with V Groove which is having 60^0 angle & 2mm root gap.

All welding and sample preparation is done as per ASME section.XI and tested for tensile test. Superior of IS2062 Gr.E250 & SA516 Gr.70 is investigated. High strength welded material is found to be SA516 Gr.70 during testing.

This superior of above carbon steel which is SA 516 Gr.70 material is taken for investigation high strength joint for two groove weld i. e U & V groove in stage 2.

6.2 Result for Stage 1

Table: Result for Mechanical Properties of IS 2062 Gr.E250

Sample		1A	1B	1C
Thickness	mm	8.01	8.04	8.01
Width	mm	19.00	19.00	19.00
Ultimate Load	KN	75.12	74.96	76.62
Ultimate Strength	MPa	493.59	490.70	503.45
Fracture	At	Base metal	Base metal	Base metal
Result	found	Satisfactory	Satisfactory	Satisfactory

Table: Result for Mechanical Properties of SA516 Gr.70

Sample		2A	2B	2C
Thickness	mm	8.46	8.37	8.46
Width	mm	19.00	19.00	19.00
Ultimate Load	KN	88.56	88.64	86.84
Ultimate Strength	MPa	550.95	557.38	540.25
Fracture	At	Base metal	Base metal	Base metal
Result	found	Satisfactory	Satisfactory	Satisfactory

6.3 Stage 2

In stage 2, we will make again four plates of SA 516 Gr.70 material having the length and width 125mmX450mm and 14mm thick plate to make two test sample according to ASME section IX. Two plates are joined by two different welding method (i.e root run and first layer by GTAW then remain welding by SMAW) with V Groove which is having 60^0 angle & 2mm root gap. And another two plates joined by again SMAW & GTAW with U Groove which is having 50^0 angle & 2mm root gap. GTAW is abbreviation for TIG welding.

All welding and sample preparation is done as per ASME section IX.

We have carried out Dye Penetration test for each joint as Nondestructive test before destructive test.

6.4 Result for Stage 2

In tensile test as per ASME section IX, for “V” groove welded sample the average Ultimate Tensile Strength is found 551.76 MPa which is little beat higher than that of “U” goove welded joint and also Test sample is break on parent material for “V” groove welded joint but it is break on weld for “U” groove welded test sample.

In Hardness test as per ASTM E384, It is measured on HV10 scale results comparison as follows

Sample	"V" Groove	"U" Groove
On weld	199.67	210.33
On HAZ(R)	184	190.33
On HAZ(L)	187	195.67
Parent Material (R)	175.67	171.33
Parent Material (L)	167	167.33

For Macro test and bend test as per ASME section IX , the results for both groove weld joints found satisfactory and having no difference in results.

In Microstructure test as per ASTM E112, for both groove welded joint following are observations

1. Microstructure at parent material shows ferrite & pearlite aggregate. Structure appears to be of normalized material
2. Microstructure at HAZ reveals coarse grains.
3. Microstructure at weld reveals ferrite carbide aggregate in fine boundary ferrite.
4. Microstructure for both grooves joint shows satisfactory penetration, fusion and absence of significant inclusion or other defects.

In Impact test as per ASTM E23 done at (-)25^{0}C, the result are as follows

Sample	"V" Groove	"U" Groove
Average Energy absorbed when notch location at Weld (J)	40.4	111.7
Average Energy absorbed when notch location at HAZ (J)	185	166.6

7. CONCLUSIONS

In stage 1, the basic conclusion found by the comparative study international standard carbon steel i.e. SA 516 Gr.70 with Indian standard carbon steel material i.e. IS 2062 Gr. E250 on basis of tensile strength. The above welded plates are tested for tensile test as per ASME IX. High strength welded material is found to be SA516 Gr.70 during tensile testing.

The objectives are partly completed that suitable material for high pressure vessels is SA516 Gr.70 which costlier than that of IS2062 Gr.E250.The fabrication cost of pressure vessel with SA516 Gr.70 is also higher.

In stage 2, It is primarily sheen that the welding consumables are required in U groove welded joint is higher hence the fabrication cost is higher than that of V groove welded joint.

The hardness of U groove joint weld is increase than that of V groove joint weld.

There is not much difference in the physical and microstructure properties for both groove welded joints.

In impact testing, the impact energy at weld for U groove welded joint is found higher than that of V groove welded joint.

It is also seen that heat input to welded joint in U groove is higher than that of V groove which may affect test results.

8. ACKNOWLEDGEMENT

We would like to give sincere thanks to all the members who are directly or indirectly part of this work.

9. REFERENCES

[1] G.B.Jang, H.K.Kim and S.S.Kang et.al. "The Effects of Root Opening on Mechanical Properties, Deformation and Residual Stress of Weldments"

[2] G. Magudeeswaran et.al "Optimize the Process Parameters of Activated Tungsten Inert Gas welding."

[3] Bhawandeep Singh et.al "Performance of activated TIG process in mild steel welds."

[4] M. Murugananth , S.S.Babu, and S.A.David et. al "Optimization of Shielded Metal Arc Weld Metal Composition for Charpy Toughness"

[5] G. Atkins, D.Thiessen , N.Nissley, and Y.Adonyi et. al. "Welding Process Effects in weldability Testing of Steels"

[6] T. Kasuya and N.Yurioka et.al "Carbon Equivalent and Multiplying Factor for Hardenability of Steel"

[7] A. Q. Bracaense and S. Liu et al. "Chemical Composition Variations in Shielded Metal Arc Welds"

BIOGRAPHIES

Author-1 	**Bhushan Bhagwat Wadekar** received the B.E. degree in Mechanical engineering from Maharashtra,India, in year 2002. He is currently pursuing the M.E. degree in Mechanical Design engineering from Savitribai Phule Pune University, at SVIT College, Nashik , Maharashtra, India.
Author -2 	**Prof.V.L.Kadlag,** is Head of department in Mechanical Department at SVIT College ,Nashik, Maharashtra.He received the M.E. degree in Mechanical production engineering from RIT College, Sakharale, Maharashtra, India,. He is completed the B.E. degree in Industrial engineering from Savitribai Phule Pune University, Maharashtra, India. He had vast experience in Educational and Industrial fields.