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Research Article

COMPARATIVE STUDIES ON JOINING OF STRUCTURAL STEELS USING MIG AND ARC WELDING PROCESSES

Sudhin Chandran[1] and Nagarajan N.M[2]

[1]Manufacturing Engineering, KMCT College of Engineering, Calicut, Kerala
[2]Head of the Department Mechanical Engineering, KMCT College of Engineering, Calicut, Kerala

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ABSTRACT

Welding technique is one of the widely used permanent fastener techniques, where in different types of welding are used for different applications. Welding creates property changes in the welded location. So it is important to investigate the mechanical properties after welding to create better joint design using welding techniques. In this work the effect of welding process using Metal Inert Gas Welding (MIG) and Manual Arc Welding (MAW) process on mild steel is studied. Welding process is carried out on 4 mm, 5 mm, 6mm thick plates of mild Steel using MIG and MAW welding processes. Properties such as tensile strength, toughness, hardness and micro structure of the each welding process of weld joints are evaluated and compared with the properties of MIG and MAW processes. The investigation reveals that MIGW joints are having higher mechanical properties than MAW joints while joining mild steel plates and V joint design is better than square butt joint.

INTRODUCTION

Traditionally mechanical components have been joined through fasteners, rivet joints etc. In order to reduce time for manufacturing and improvement in mechanical properties, welding process is usually adopted (1). Today, a variety of welding processes are available. However MAW welding is extensively used for fabrication process to join metals. Welding is an important joining process because of high joint efficiency, simple set up, flexibility and low fabrication costs. A welded joint is obtained when two clean surfaces are brought into contact with each other either by pressure, heat or both. The tendency of atoms to bond is the fundamental basis of welding. The inter-diffusion between the materials that are joined is the underlying principle in all welding processes exist. In welding the metallic materials are joined by the formation of metallic bonds and a perfect connection is formed. Any welding process needs some form of energy, often heat to connect the two metals. The relative amount of heat and pressure required to join two metals may vary considerably between two extreme cases in which either heat or pressure alone is applied. When heat alone is applied to make the joint, pressure is used merely to keep the joining members together.

Welded joints are finding applications in producing critical components where failures are catastrophe. Hence, inspection methods and adherence to acceptable standards are essential. These acceptance standards represent the minimum weld quality which is based upon test of welded specimen containing some discontinuities. Welding of steel is not always easy. There is the need to properly select welding parameters for a given task to provide a good weld quality.

Steel is an important engineering material. It has found applications in many areas such as vehicle parts, truck bed floors, automobile doors, domestic appliances etc. It is capable of presenting economically a very wide range of mechanical and other properties (1). This paper deals with Comparative Studies on Joining of Structural steels using MIG Welding and ARC welding processes. Groove design, plate thickness are the welding parameters and Tensile strength, Impact strength, Hardness, Microstructure analysis are the investigated mechanical properties.

Experimental Details

Parent Metal

The Mild Steel specimen selected for the investigation is Indian standard with code IS2062 and is taken as the parent metal for welding. It is easily available. Figure 1 shows that mild steel plate taken for welding operation. The chemical compositions of the base metals obtained from the supplier are shown in table 1.

*Corresponding author: **Sudhin Chandran**
Manufacturing Engineering, KMCT College of Engineering, Calicut, Kerala

Figure 1 Mild steel plate

Table1 composition of mild steel for welding

ELEMENT	Wt%
CARBON	0.23
MANGANESE	1.50 max
SILICON	0.4
SULPHUR	0.045
PHOSPHORUS	0.045
IRON	REMAINDER

Metal Inert Gas Welding (MIG)

In this work Mild steel plates of dimensions (200×200×4, 5,6) mm are taken for MIG welding operation. In order to perform this the finished plates are again cut transversally into four equal sheets of (50×50×4,5,6) mm usingpower hacksaw. These plates are cleaned from dirt, grease and other foreign materials to obtain a good quality weld. Edge preparation is carried out where single V edge is prepared for a bevel angle of 60 and square butt joint plates are prepared by smoothing their faces. In all the cases the root gap of 2 mm is maintained are shown in figure 5 and figure 6. The mild steel plates are placed on welding table and in order to avoid the distortion the right size of stiffeners are provided at critical locations where the welding process is carried out (2). The welding machine of model WIM ECO400F is used as shown in figure 2. During welding machines set at a range of, Current: (100-110) A and Voltage: (19 - 22) V. The welding wire rod (MIG/CO2 welding wire AWS ER70S-6 precision layer wound) used is of mild steel having 1.20 mm

Figure 2 MIG welding machine

Manual Arc Welding (MAW)

In this investigation Mild steel plates with dimensions (200×200×4, 5, and 6) mm are taken for MAW welding technique. In order to perform welding operation the finished sheets are again cut transversally into four equal sheets of (50×50×4, 5, and 6) mm by power hacksaw. These sheets are cleaned of dirt, grease and other foreign materials to obtain a good quality weld. Edge preparation is carried out where single V edge is prepared for a bevel angle of 60 and square butt joint plates are prepared by smoothing their faces. In all the cases the root gap of 2 mm is maintained. The mild steel sheets are placed on welding table and in order to avoid the undesired distortion to the minimal the right size of stiffeners are provided at critical locations where the welding process is carried out (7). The power source used for welding is a Rectifier type air-cooled welding machine of model Adore Arc 601 as shown in figure 3.

During welding, the unit is set at Current: (100- 110) A and Voltage: (80-100) V. The welding rod used is of mild steel having length: 350mm and diameter: 3.15mm for filling the groove.

Figure 3 MAW machine

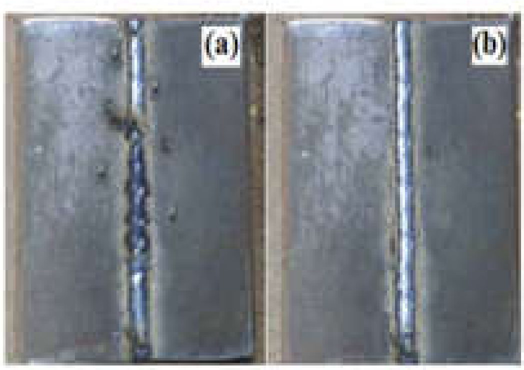

Figure 4 mild steel plates after welding (a) MAW (b) MIG welding

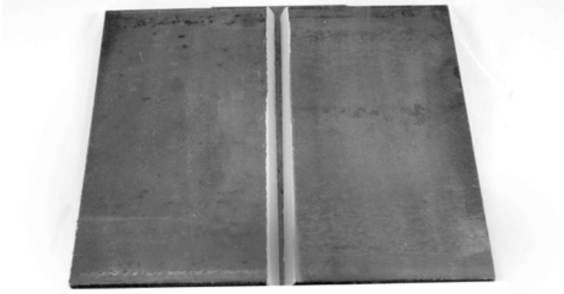

Figure 5 V- groove joint (root gap - 2 mm, angle - 45)

Figure 6 square butt joint (root gap - 2 mm)

Sample Preparation and Mechanical Testings

The samples for tensile, impact tests are prepared of the strips, cut from the welded plate followed by machining according to the ASTM standards. The samples for hardness and SEM examination are prepared according to the indian standards (4).

Welding has been carried out using MIG and ARC welding. Welding plates have been sized both for butt joint and V-joint.

Tensile Test

Tensile test specimens are prepared as per ASTM E8-09 standard. Tensile testing is carried out using Universal Testing Machine of 400 KN capacity and the geometry of the test specimen is as shown in figure 7.

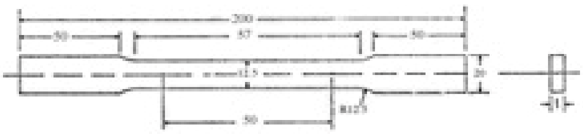

Figure 7 Standard tensile test specimen (ASTM E8--09)

The typical tensile specimen shown in fig 8. The cross-sectional area of the gauge section is reduced relative to that of the remainder of the specimen. So that deformation and failure will be localized in this region. The gouge length is the region over which measurements are made and is centered with in the reduced section.

The pre pared samples are shown below,

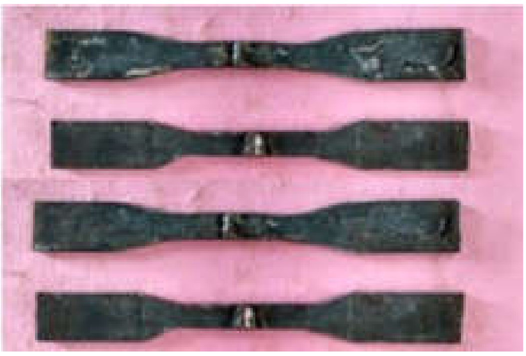

Figure 8 4mm thick plate tensile test specimens

Charpy Impact Testing

Test samples for charpy V-notch impact toughness evaluation are prepared according to the ASTM E23 standard as shown in figure 11.

Figure 9 5mm thick plate tensile test specimens

Figure 10 6mm thick plate tensile test specimens

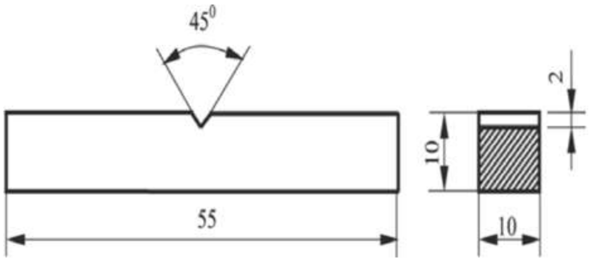

Figure 11 standard charpy impact test specimen (ASTM E-23)

Figure 12 specimens after charpy impact testing

Hardness Testing

Hardness testing of welding joints is performed in accordance to ASTM A370-14 standard using Rockwell Testing Machine (RHc), C Scale as shown in figure 13. The sample specimen is placed with the surface on the anvil, and slowly turning the hand wheel until the specimen is raised to touch the indenter. The numbers are read directly from the dial indicator and converted to the Rockwell number. Hardness Test is carried out to the whole width of weldment (9).

Figure 13 Hardness tester

Dye Penetrant Test

A red colored dye penetrant is applied to the surface and the dye enters crack interfaces through capillary action. After a specific amount of time, the surface is wiped dry with clean, dry cloths. The dye will seep back out of the cracks through reverse capillary action. Developer is applied to the surface and the cracks are highlighted as red lines on the white background (8).

Figure 14 Dye penetrant inspection

Scanning Electron Microscope (SEM)

The welded samples made as described previously are subjected to microstructure study under optical microscope. The specimens of area 0.5 cm^2 surfaces are initially dry grinded and then wet grinded on abrasive belts. Then the surfaces are polished first roughly and then finely with emery belts. The final fine polishing is done by using a wet rotating wheel covered with a special cloth that is charged with fine polishing abrasives so that a mirror like fine polishing is achieved (6,12). The setup is shown in figure 15.

Figure 15 scanning electron microscope

MIG welded specimen has shown highest ultimate tensile strength and 4 mm thick with square groove MAW specimen has shown least UTS. It is analyzed that the ultimate strength is proportional to the thickness of the specimen and also it is clear that V-groove weld is better than square. The

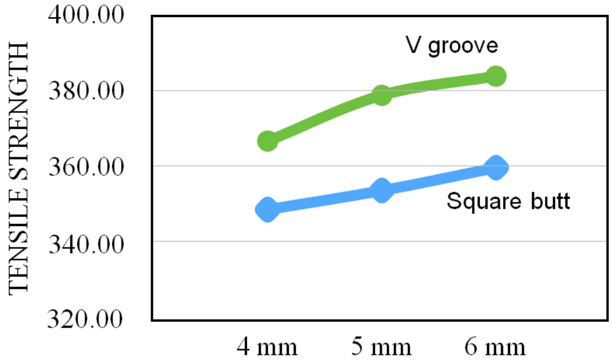

Figure 16 Effect of tensile strength on thickness of welded plates subjected to MAW

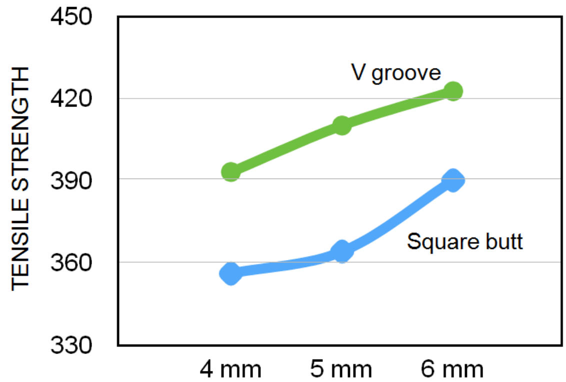

Figure 17 Effect of tensile strength on thickness of welded plates subjected to MIG

RESULTS AND DISCUSSION

Tensile Test

Tensile testing is carried out using universal testing machine of 400 KN capacity as per ASTM code E8-09. Tensile strength of MIG and MAW welds of mild steel for each observation three test coupons are cut and the average strength values are noted. Similarly butt joint of three specimens are made and the average values are tabulated.

Tensile strengths of welded test samples varies from 349 to 422 MPa depending upon the welding conditions. 6 mm thick with V-groove

The tensile strength using V Groove surface preparation is found more than simple butt joint without surface preparation. This is due to high depth of penetration of molten metal in the joint. In both these process it is found that increase in plate thickness increases the tensile strength as more amount of depth of penetration is possible for higher thickness plates.

In butt joint, without surface preparation only the root joints on both sides are welded having unweld portion in the centre. Hence the strength of weldment is poor.

Charpy Impact Strength Test

The energy absorbed by breaking the test samples using charpy impact tester are measured in joules. The results obtained is shown in figure 18.

It is evident that, the 6 mm V-groove MIG welded specimen which absorbed more energy with a value of 75 J compared to other specimens. This is the measure of toughness of the materials

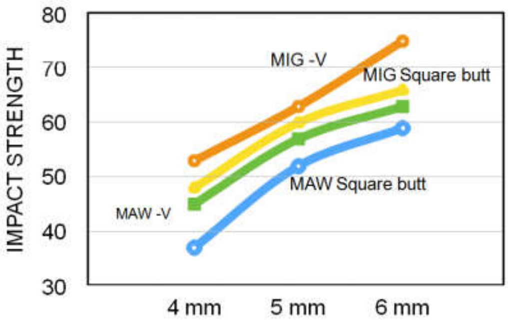

Figure 18 Impact Strength in terms of Grooves and Thickness

Hardness Test

Rockwell hardness number for the specimens is checked with diamond cone. The average values are taken and shown in the figures. External load - 100 kg
Internal load - 10 kg

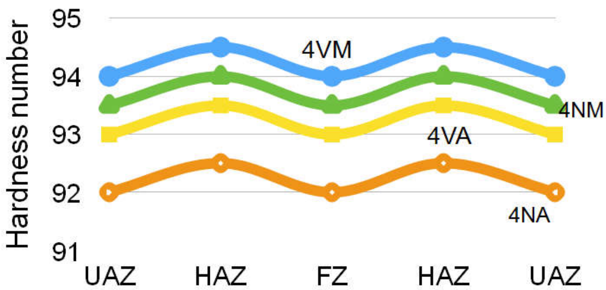

Figure 19 Hardness profile of 4mm thick specimens

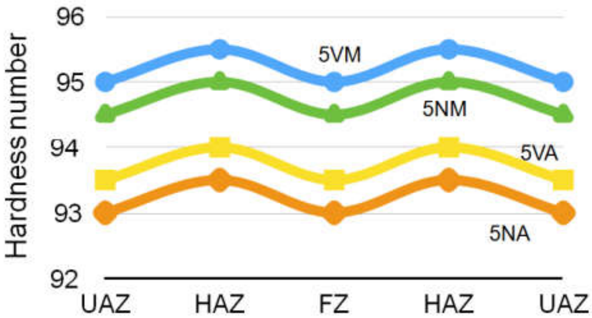

Figure 20 Hardness profile of 5 mm thick specimens

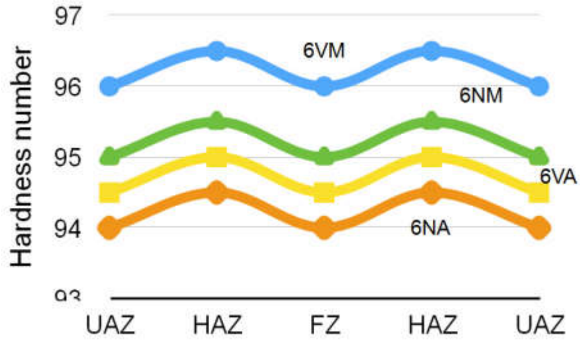

Figure 21 Hardness profile of 6 mm thick specimens

Figures 19,20,21 reveals that the hardness profile of 6 mm V-groove MIG is superior to all other weld joints. In all joints the maximum hardness values are measured in the area of heat affected zone (HAZ).The variation in hardness across the weld can be attributed to several factors, mainly to residual stresses just after welding. However, other factors like grain size, phase composition and metallic inclusion can also contribute to this hardening.

Dye Penetrant Test Results

Dye penetrant test has been performed to check the quality of the weldments before tensile test sample preparation. The results of the tests are presented in table 7.

Table 7 Results of the DPI test

specimen	thickness	status	test date
MIG-V	4,5,6	OK	13-3-16
MIG- square butt	4,5,6	OK	13-3-16
MAW-V	4,5,6	OK	13-3-16
MAW- square butt	4,5,6	OK	13-3-16

Metallographic Test Results

Microstructural changes have been analysed using Scanning Electron Microscope (SEM).

The microstructure of welded metals are observed after completion of surface preparation namely grinding, polishing and etching. The magnifications fixed for viewing SEM samples vary from X1000 to X5000. However for uniformity magnification X1000 is fixed for samples with square butt and V butt joints welded both using Manual Arc Welding (MAW) and MIG welding respectively.

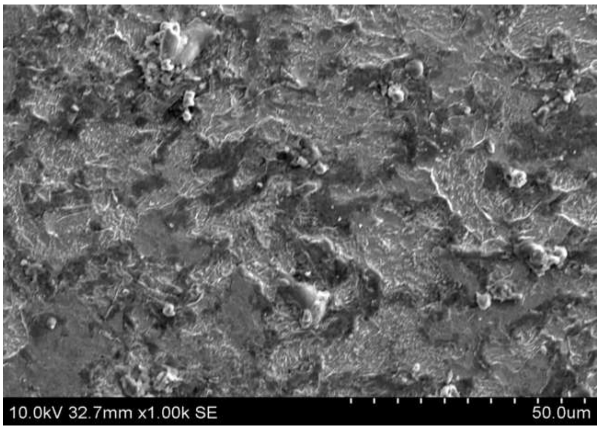

Figure 22 microstructure of MAW-Square butt joint weld

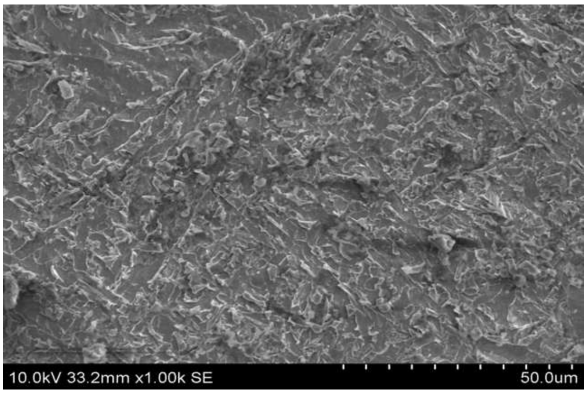

Figure 23 microstructure of MAW-V joint weld

Figure 22 represents microstructure of m.s plate square butt welded joint using manual arc welding. It is observed that the weldment structure is having coarse grains with dendritic structure. However the weldment section subjected to manual arc V joint reveals that the structure becomes smooth and refined with fine crystals. This also support tensile strength effect that manual V joint gives higher strength than square butt joint and is seen in figure 23.

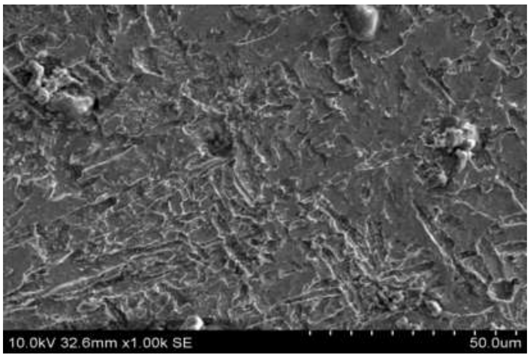

Figure 24 microstructure of MIG-SQUARE BUTT joint weld

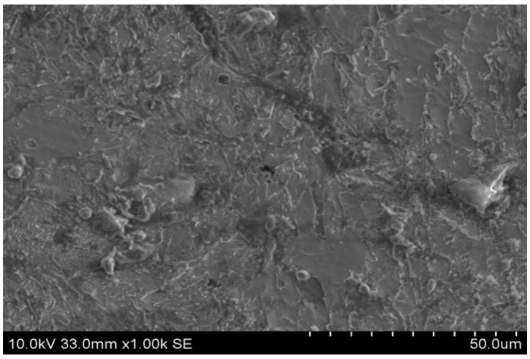

Fig 25 microstructure of MIG-V joint weld

The SEM pictures of test pieces subjected to MIG welding of square butt and V butt joints are shown in figures 24 & 25 respectively. Here also plate like structures visible for square butt whereas fine equiaxed grains are seen in MIG-V joints. In strength analysis also it is clear that MIG-V produces higher tensile strength, hardness, impact strength than MIG square type.

Here it is proved that MIG welding for joining M.S plates gives better mechanical properties than weldment produced by manual arc welding. The same trend is noticed while changing the plate thickness.

CONCLUSIONS

During the project, mild steel plates are joined using MIG and Manual arc welding. The mechanical properties such as tensile strength, hardness, impact strength of welded joints are investigated. From the work, following are the conclusions.

1. Adequate edge preparation of the weldment enhances the strength of the weld joint.
2. The tensile strength of Vgroove joint is found more than simple butt joint.
3. In both these process it is found that increase in plate thickness increases the tensile strength as more amount of depth of penetration is possible for higher thickness plates.
4. In charpy impact, the metal inert gas welded (MIG) specimen absorbed more energy while comparing with square butt specimens.
5. The strength of weldment of MIG welded joints are better than MAW joint.

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