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Comparative studies on joint design of mild steel using MAW and MIG welding

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Abstract: Welding is one of the major manufacturing techniques for joining metals. It is a challenge to produce welded joints with strength equivalent to parent metal. It is felt that by using TIG or MIG welding, the joint efficiency can be improved considerably. Hence the present work is undertaken with the following objectives by comparing conventionalMAW welding and MIG welding. To select steel plate thickness from 6mm to 10mm and do surface preparation with joint design, namely butt, V, U , and J. To subject these plates by joining using MIG and MAW welding to evaluate mechanical properties of weld joints namely tensile strength, .hardness, and impact strength. To study the quality of weldment using scanning electron microscope (SEM) by comparing the properties of weldment.

This study reveals that joint design with 'J' gives better mechanical properties than other shapes. Also MIG welding process produces better mechanical properties than MAW process.

Keywords: MAW, Mechanical Properties, MIG, Mild steel, SEM, Welding, Wire cut EDM

I. INTRODUCTION

GENERAL BACKGROUND

Traditionally mechanical components have been joined through fasteners, rivet joints and other joint techniques. In order to improve mechanical properties and weight reduction, welding process is adopted. Today, a variety of different welding processes are available for joining materials in a wide range of compositions and sizes. 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 and either by pressure or heat or both are applied to obtain a bond. The tendency of atoms to produce metallurgical bond is the fundamental basis of welding. The inter-diffusion between the materials that are joined is the underlying principle in all welding processes. Thus any welding process needs some form of heat energy,tojoin the two metals.

Welded joints are finding applications in critical components where failures are catastrophe. Hence, inspection methods and adherence to acceptable standards are increasing. 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. (11)

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. This paper deals with Comparative Studies on Joining of Structural steels using MIG Welding and MAW welding processes using various joint designs.

OBJECTIVEOF THE PRESENT WORK

From the literature survey, the information available on mechanical properties of weld joint using MIG and MAW welding are insufficient. Hence the present work is undertaken with the following objectives.

- To select various thickness of mild steel plates and prepare for joint design.
- To subject these plates with different thickness by joining using MIG and MAW welding processes.
- To evaluate mechanical properties of weld joint such as hardness, tensile test and impact test.
- To study the quality of weldment using Scanning Electron Microscope (SEM).
- To compare the properties of weldment obtained from MIG and MAW welding processes and compiles the data.

II. EXPERIMENTAL DETAILS

2.1 Parent Metal

The Mild Steel specimen selected for the investigation is Indian standard with code IS2062 and is taken as the base material for welding. It is easily available and commonly used materials for welding and fabrication in industry. The chemical compositions of the base metals obtained from the supplier are shown in Table 2.1

2.2 Welding arrangements for MIG and MAW processes.

In this work Mild steel plates with thickness 6,8 and 10mm are taken for MIG and MAW processes. These plates are cleaned from dirt, grease and other foreign materials to obtain a clean surface. Edge preparation is carried out with joint design for single V,U and J joint. In all the cases 2mm root gap is maintained. The mild steel plates are placed on welding table and clamp it to avoid the distortion during welding.MIG Welding machine of model WIM ECO400F is used as shown in Fig 2.1. The welding parameter maintained during welding are Current: (100- 120)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 diameter. (1)(2)

For MAW the current and voltage are maintained in the same range of MIG welding. Also the power source used for welding is a Rectifier type air-cooled welding machine of model Adore MAW 601 as shown in Fig 2.2 (5)(6).

2.3 Sample preparation and mechanical testings

The samples for tensile, impact tests are prepared of the strips, cut from the welded plate followed by machining them according to the ASTM standards. The samples for hardness and SEM examination are prepared according to the Indianstandards. Welding has been carried out using MIG and MAW welding. Welding plates have been sized both for straight butt joint, single V-joint, single U-joint and single J-joint.The MIG and MAW test coupons are shown in Fig 2.3.

2.3.1 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 Fig 3.4.

The typical tensile specimen shown in the Fig 2.4. 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 gauge length is the region over which measurements are made and is centered within the reduced section. The prepared samples are shown in the Fig 2.5 ,2.6,and 2.7 (3).

2.3.2 Charpy impact testing

Test samples for Charpy V-notch impact toughness evaluation are prepared according to the ASTM E23 standard shown in the Fig 2.8. Also charpy test specimen before and after test as shown in Fig 2.9 and 2.10.

2.3.3 Hardness testing

Hardness testing of welding joints is performed in accordance to ASTM A370-14 standard using Rockwell Testing Machine (HR_c) C Scale. Hardness Test is carried out to the whole width of weldment.

2.3.4 Dye penetrant test

A red colored dye penetrant is applied to the surface.After10 minute, the surface is wiped dry with clean cloths. Developer is applied on the surface as shown in Fig 2.11 and the crack if any is highlighted as red lines on the white background .

2.3.5 Wire cut EDM

Wire cut EDM is used for cutting specimen suitable for SEM analysis.

2.3.6 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. In Fig 2.12theSpecimen for SEM analysis are shown.

III. RESULTS AND DISCUSSION

The M.S plates with varied thickness and different joint designs are subjected to various tests to evaluate the properties and the details are given below.

3.1 Tensile test

Tensile strength of different thickness in different joints for MAW are observed and values are given in Figure 3.1.

Similarly, the results of ultimate tensile strength of different thickness with different joints for MIG welding are shown in Figure 3.2.

Tensile strength of welded test samples are varied from 22.5 KN to 69.5 KN depending upon the welding conditions shown above. 10mm thick MAW welded jointgives with highest ultimate strength and 6mm thick MAW welded specimen has shown the lowest ultimate strength. Also increase in plate thickness increases tensile strength. However in tensile test analysis MAW gives higher strength values than MIG welding.

It is noted that compared with straight butt, single V,and single U joint, single J joint gives higher strength than other joints. This is due to high volume of metal deposition which results in higher depth of molten metal penetration in fusion zone. In straight butt joint, without surface preparation ,only the root joints on both sides are joined having unweld portion in the Centre. Hence the strength of weldment is poor.

3.2 Charpy impact strength test

The energy absorbed by breaking the test samples using charpy impact tester is measured in joules. The results are shown in Fig 3.3 and 3.4 both the processes. Here single J joint shows better results in both MAW and MIG welding.

Among joint design MIG produces better impact strength than MAW.

3.3 Hardness test

Rockwell hardness number for the specimens is checked with diamond cone. The average values are taken and shown in the Fig3.5, 3.6, 3.7, 3.8, 3.9 and 3.10.

The hardness profile of 6mm, 8,and 10mm thickness ,to obtain harder joint, MAW welding is better than MIG welding. Considering single U joint, MIG welding found better than MAW welding in all thicknesses of specimen. Whereas single J joint, MAW is better than MIG welding. Considering for hardness on fusion zone, MAW welding is again found to be higher than MIG welding. Single U joint showed better results than other joints in fusion zone. Also hardness is found to increase while increase in plate thickness.

In all joints the maximum hardness values are observed in the area of heat affected zone (HAZ) near fusion zone(FZ).The variation in hardness across the weld is attributed to factor such as residual stresses and thickness after welding.

3.4 Dye penetrant test results

Dye penetrant test has been performed to check the quality of the weldments on tensile test samples. The results of the tests are presented in Table 3.1. Hence it is concluded that welding process is properly carried out in all thickness plates without flaws.

3.5 Scanning electron microscope analysis results.

Microstructural changes have been analyzed using Scanning Electron Microscope (SEM). The microstructure of welded metals are observed after completion of surface preparation. . The magnifications fixed for viewing SEM samples vary from x30,x500,x1000.

Fig 3.11 represents microstructure of 6mm thickness mild steel plate single U joint welded using MAW welding. It is observed that the weldment section subjected to MAW single U joint reveals that the structure becomes smooth and refined with fine grains. This finding is also supported by tensile strength test ,which reveals that single U joint gives higher strength than single V joint and straight butt joints.

Fig 3.12 showed that the weldment region of 8 mm thick single U MAW welded joint. Here it is very clear that the structure become smooth and there is no defects identified on the surface.

Similarly the microstructure of 10mm single U MAW welded joint shown in the respected Figs 3.13. It is observed that the weldment section subjected to manual MAW single U joint reveals that the structure becomes smooth and refined with fine grains. This findings is also reflected in tensile values.This fine grains produces higher strength and is observed in the tensile strength behavior of the joint.

General Observation

However from the overall investigation of properties ,it is found that MIG welding gives better values than MAW welding in most of the joint design.

IV. FIGURES AND TABLES

Table2.1: composition of mild steel for welding

ELEMENT	Wt.%
CARBON	0.23
MANGANESE	1.50 max
SILICON	0.40

ELEMENT	Wt.%
SULPHUR	0.045
PHOSPHORUS	0.045
IRON	REMAINDER

Fig 2.1: MIG welding machine
Fig 2.2 MAW machine

Fig 2.3 MIG and MAW test coupons

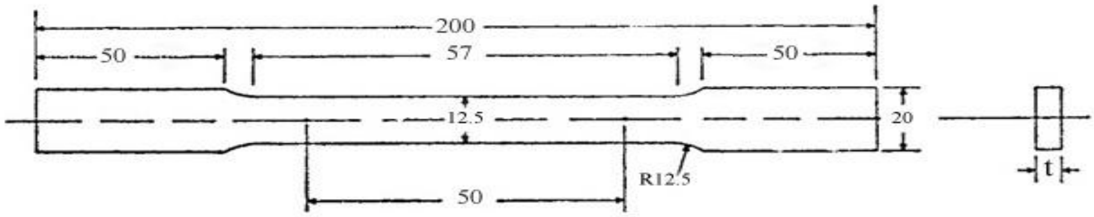

Fig 2.4: standard tensile test specimen (ASTM E8-09)

Fig 2.5: 6mm thick tensile specimen

Fig 2.6: 8mm thick tensile specimen

Fig 2.7 10mm thick tensile specimen

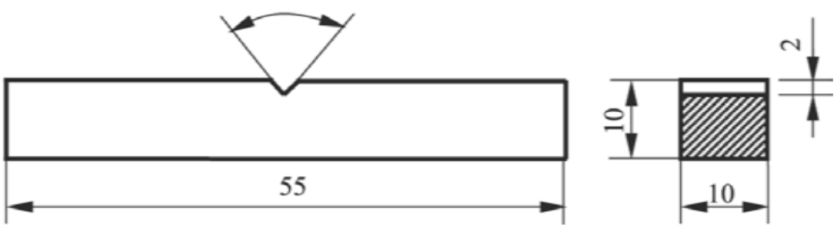

Fig 2.8 : standard charpy impact test specimen (ASTM E-23)


Fig 2.9: Specimen before testing.


Fig 2.10: specimen after testing.

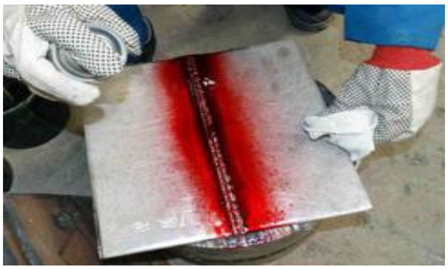
Fig 2.11: Dye penetrant inspection


Fig 2.12 Specimen for SEM analysis

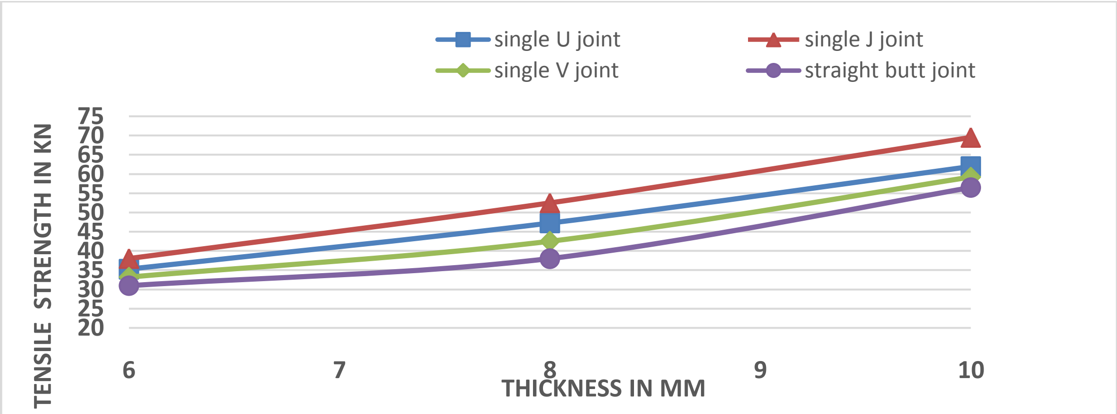

Fig 3.1: Variations of tensile strength of different thickness in different joints for MAW welding

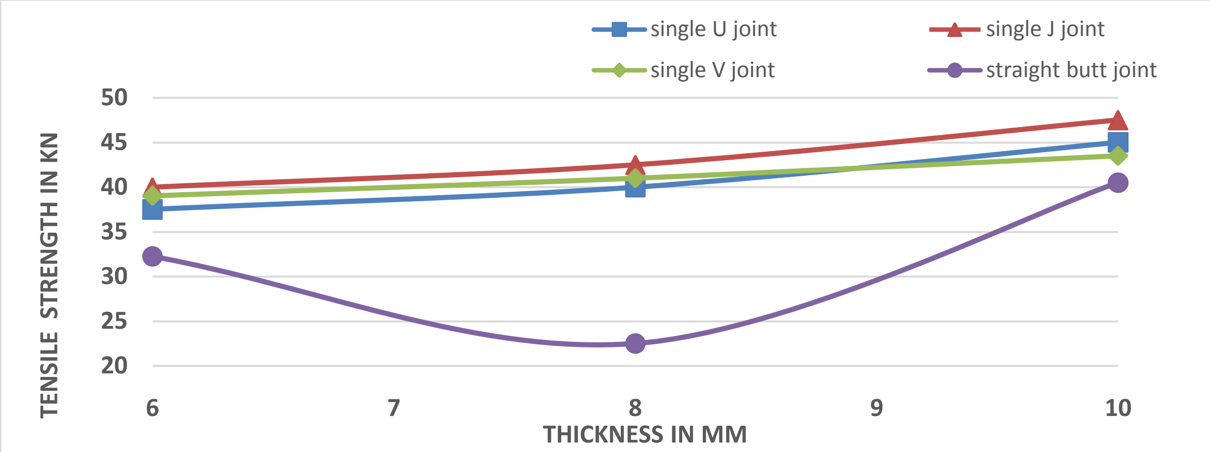

Fig 3.2: Variations of tensile strength of different thickness in different joints for MIG welding.

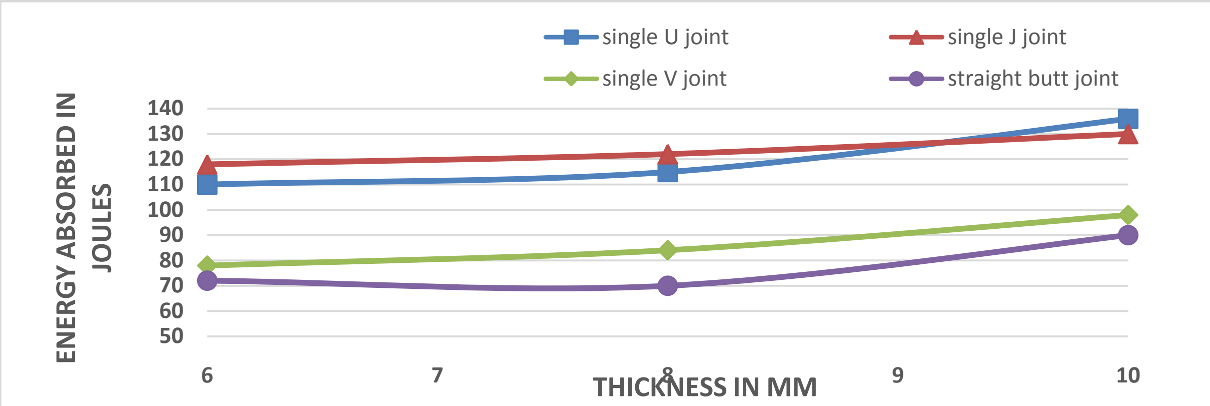

Fig3.3:variations of impact load of different thickness in different joints for MAW welding

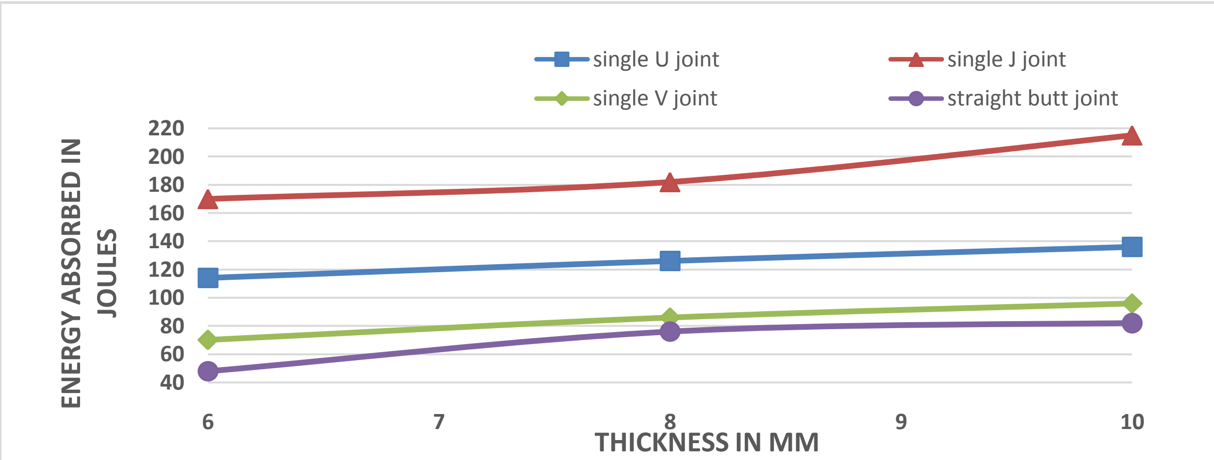

Fig 3.4:variations of impact load of different thickness in different joints for MIG welding.

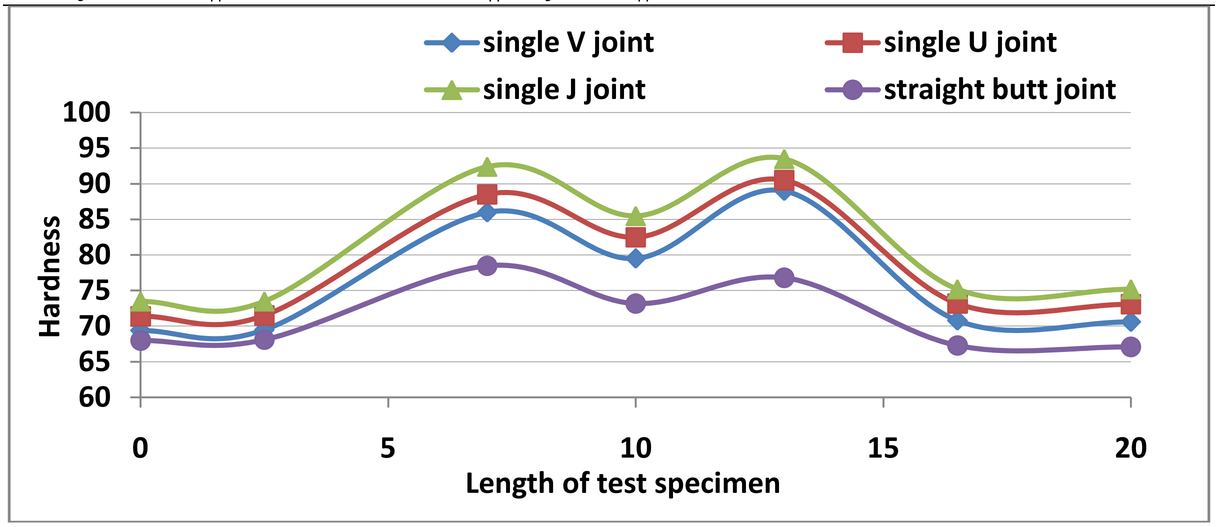

Fig 3.5: variation of hardness profile 6 mm thickness in different joints for MAW welding

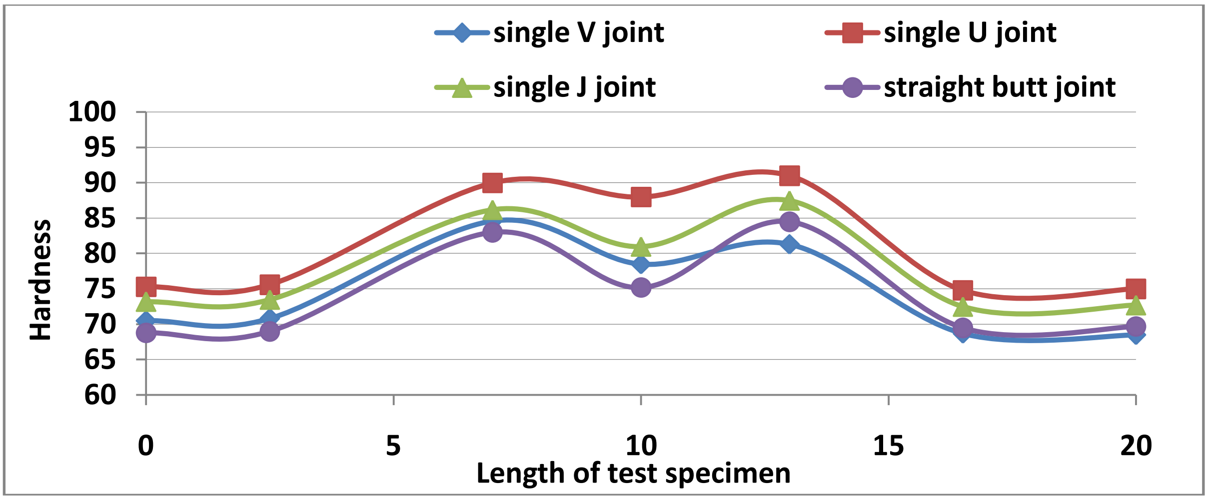

Fig 3.6: variation of hardness profile 6 mm thickness in different joints for MIG welding

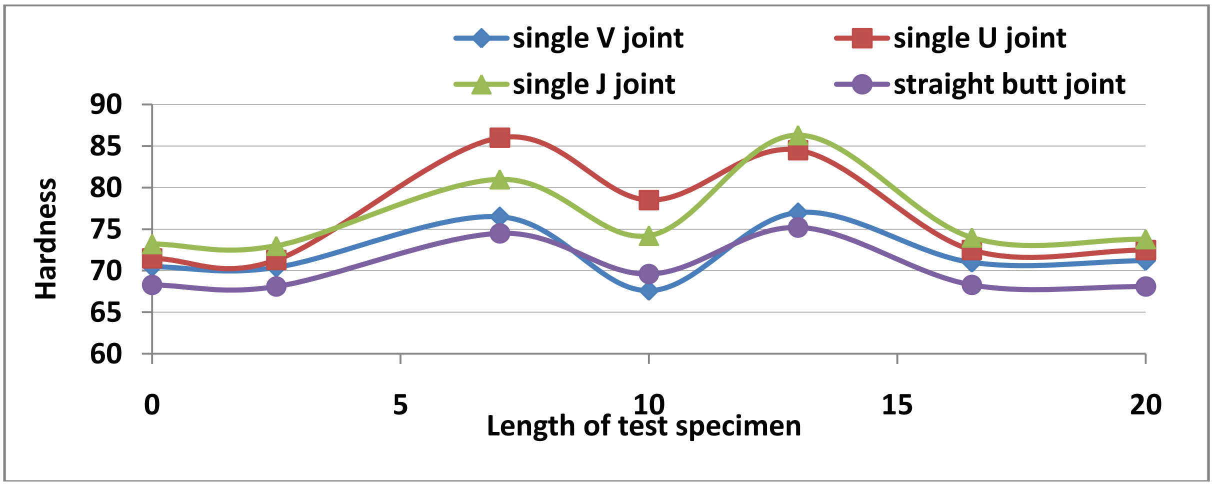

Fig 3.7: variation of hardness profile 8 mm thickness in different joints for MAW welding.

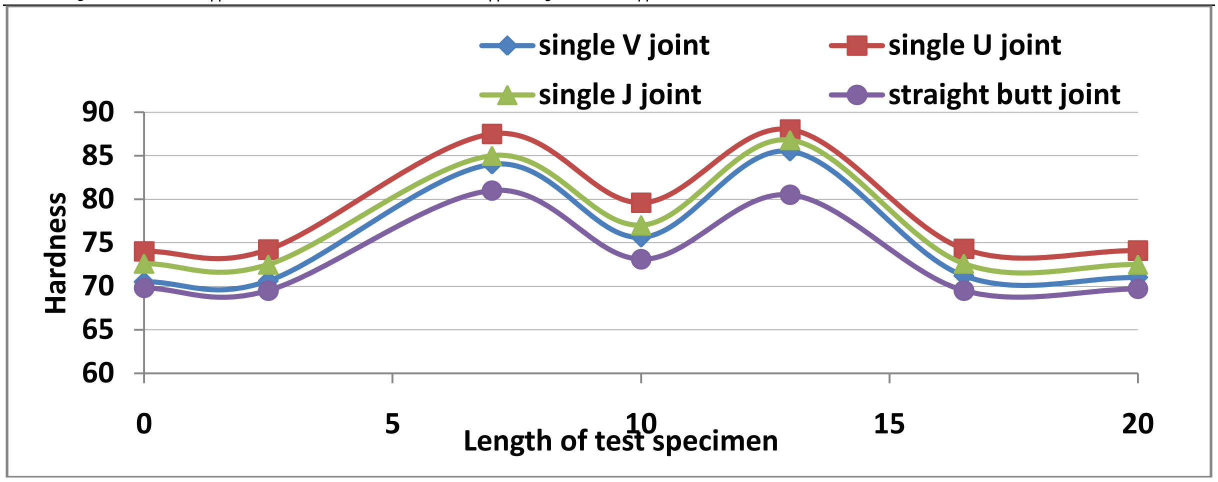

Fig 3.8: variation of hardness profile 8 mm thickness in different joints for MIG welding.

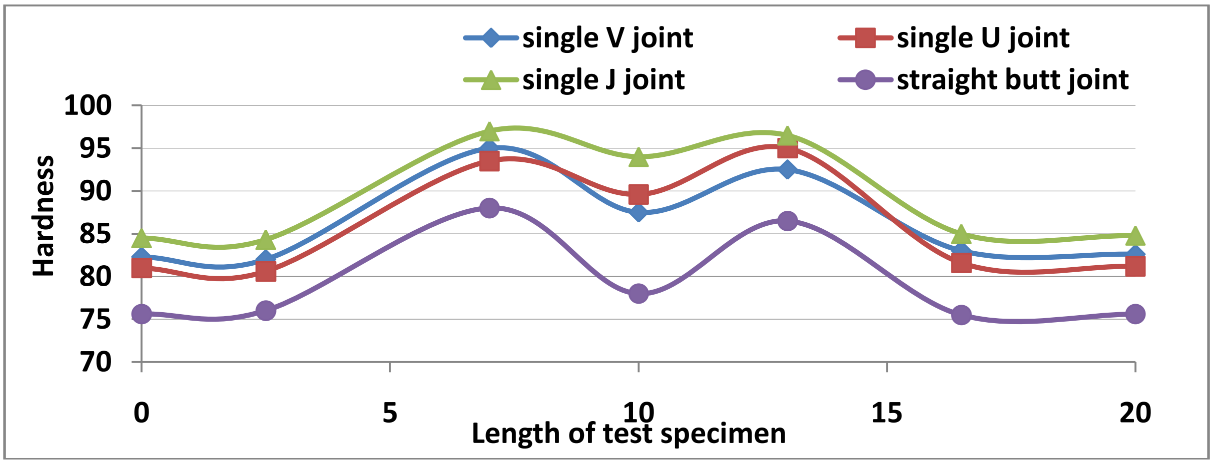

Fig 3.9: variation of hardness profile 10 mm thickness in different joints for MAW welding.

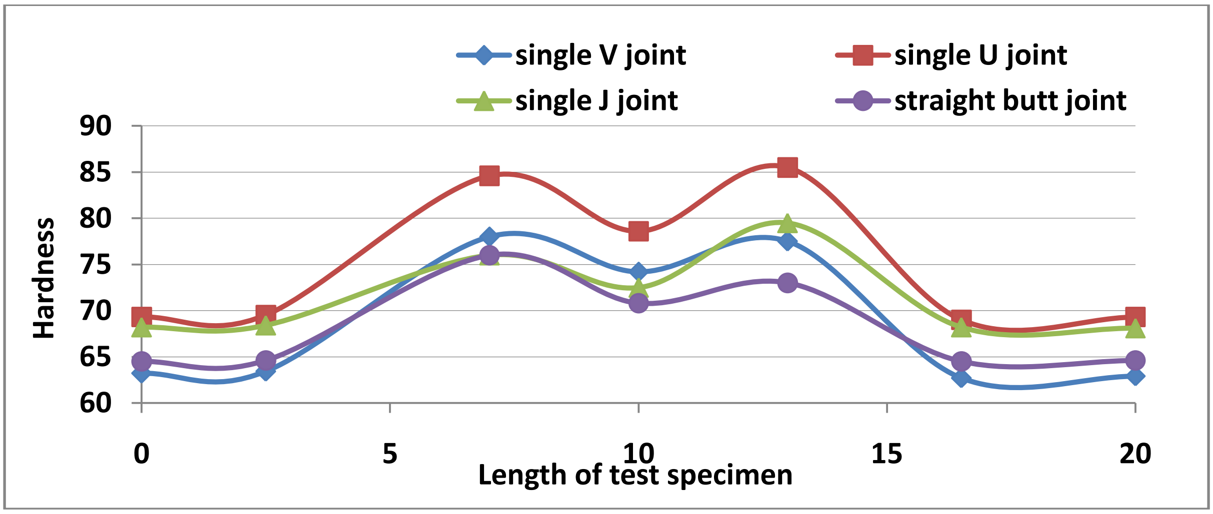

Fig 3.10: variation of hardness profile 10 mm thickness in different joints for MIG welding.

Table 3.1: Results of the DPI test

SPECIMEN	THICKNESS	STATUS
MAW Single U joint	6,8,10	OK
MAW Single J joint	6,8,10	OK
MAW Single V joint	6,8,10	OK
MAW Straight butt joint	6,8,10	OK
MIG Single U joint	6,8,10	OK
MIG Single J joint	6,8,10	OK
MIG Single V joint	6,8,10	OK
MIG Straight butt joint	6,8,10	OK

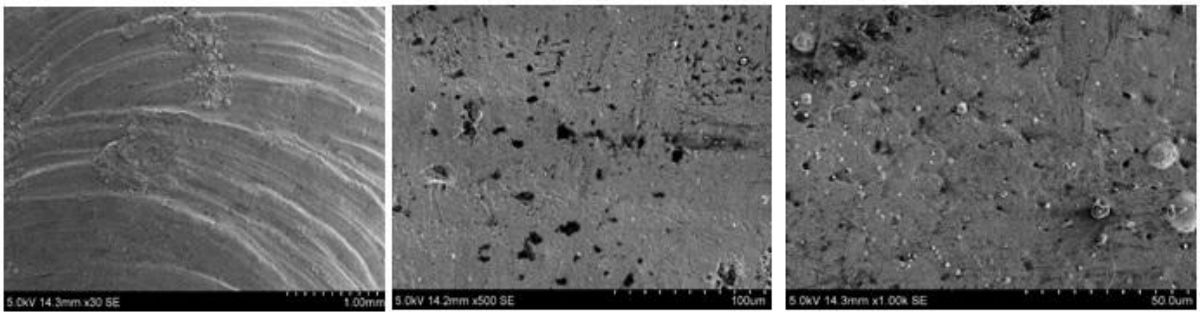

Fig 3.11: microstructure of 6 mm thick single U MAW welded joint of X30,X500,X1Kmagnification

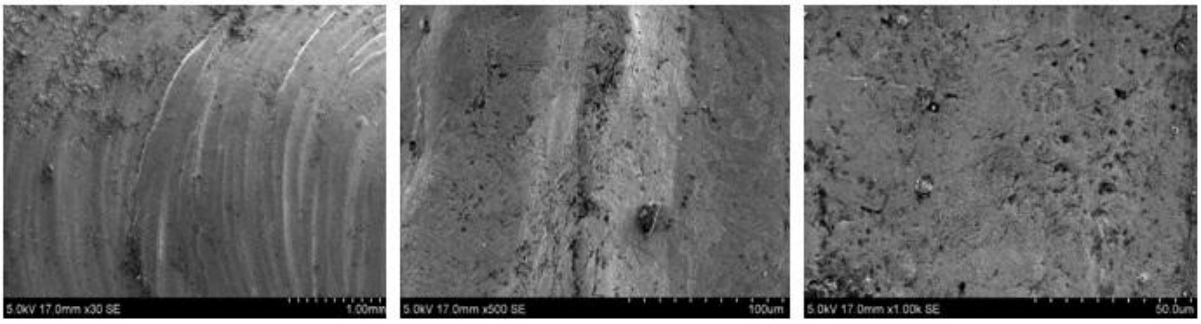

Fig 3.12: microstructure of 8 mm thick single U MAW welded joint of X30,X500,X1K magnification

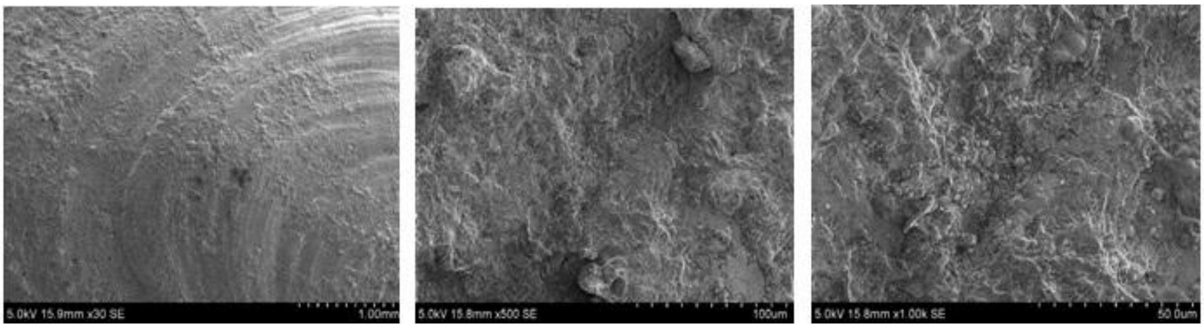

Fig 3.13:microstructure of 10 mm thick single U MAW welded joint of X30,X500,X1K magnification

V. CONCLUSION

Mild steel test plates with various joint designs are welded using MAW and MIG welding processes. The results of these processes are compared and the following are the conclusions.

1. Adequatejoint preparation of the weldment enhances the strength of the weld joint.
2. In tensile strength, it is noted that compared with straight butt, single V, and single U joints, single J joint

gives better strength than other joints. This is due to high volume metal deposition in fusion zone.

3. In both these process it is found that increase in plate thickness increases the tensile strength as more amount of depth of penetration of molten metal is possible for higher thickness plates.
4. In charpy impact, MIG produces better properties than MAW,in J joint.
5. In Hardness profile of various thickness, MAW welded joints show higher hardness than MIG welded joints.
6. In all joints the maximum hardness values are measured in the area of heat affected zone (HAZ) very close to fusion zone(FZ).The variation in hardness across the weld is attributed to factor such as residual stresses and thickness after welding.
7. In dye penetrant test, the results reveal that not much flaws are observed and hence the welding has been properly carried for both the processes.
8. 8.SEM studies carried out for MAW welding reveal that the weld joint produces fine grains associated high mechanical properties.
9. Overall comparison from various tests carried out it is noted that MIG welding gives better properties than MAW .

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