International Journal of Advanced Multidisciplinary Research
ISSN: 2393-8870
www.ijarm.com
DOI: 10.22192/ijamr Volume 4, Issue 6 -2017

Research Article

DOI: http://dx.doi.org/10.22192/ijamr.2017.04.06.008

Effect of different welding electrodes on welding of chrome moly steel to carbon steel material

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Keywords

Metal parts,
Arc Welding,
Grade 91 material,
Carbon steel,
Electrodes,
Mechanical test,
Metallurgical test

Abstract

The recent trend in power sector utilising alloy steels with high strength and elevated working temperature to enhance the capacity of the power plant. In view of that the boiler manufacturers concentrate on chrome molybdenum steel (gr 91).The material requires controlled process and weld procedures to maintain its mechanical and metallurgical properties. In boiler components many parts with different material specification are used. So, the welding of dissimilar materials are inevitable. This project is to study and analyse the behaviour of chrome molybdenum steel when welded with different material specification by different electrodes using submerged arc welding process (SAW).The weld specimen subjected to different mechanical and metallurgical test.

1. Introduction

1.1welding:

Welding is a permanent joining process used to join different materials like metals, alloys or plastics, together at their contacting surfaces by application of heat and or pressure.

During welding, the work-pieces to be joined are melted at the interface and after solidification a permanent joint can be achieved. Sometimes a filler material is added to form a weld pool of molten material which after solidification gives a strong bond between the materials. Weld ability of a material depends on different factors like the metallurgical changes that occur during welding, changes in hardness in weld zone due to rapid solidification, extent of oxidation due to reaction of materials with atmospheric oxygen and tendency of crack formation in the joint position.

1.2 Different type of welding processes

Based on the heat source used welding processes can be categorized as follows:

Arc Welding

In arc welding process an electric power supply is used to produce an arc between electrode and the work-piece material to joint, so that work-piece metals melt at the interface and welding could be done. Power supply for arc welding process could be AC or DC type. The electrode used for arc welding could be consumable or non-consumable. For non-consumable electrode an external filler material could be used.

Gas Welding

In gas welding process a focused high temperature flame produced by combustion of gas or gas mixture is used to melt the work pieces to be joined. An external filler material is used for proper welding. Most common type gas welding process is Oxyacetylene gaswelding where acetylene and oxygen react and producing some heat.

Resistance Welding

In resistance welding heat is generated due to passing of high amount current (1000–100,000 A) through the resistance caused by the contact between two metal surfaces. Most common types resistance welding is Spot-welding, where a pointed electrode is used. Continuous type spot resistance welding can be used for seam-welding where a wheel-shaped electrode is used.

High Energy Beam Welding

In this type of welding a focused energy beam with high intensity such as Laser beam or electron beam is used to melt the work pieces and join them together. These types of welding mainly used for precision welding or welding of advanced material or sometimes welding of dissimilar materials, which is not possible by conventional welding process.

Solid-State Welding

Solid-state welding processes do not involve melting of the work piece materials to be joined. Common types of solid-state welding are ultrasonic welding, explosion welding, electromagnetic pulse welding, friction welding, friction-stir-welding etc.

Submerged arc welding :

Submerged arc welding(SAW) involves the formation of an arc between a continuously fed electrode and the workpiece. A blanket of powdered flux which generates a protective gas shield and a slag protects the weld zone. The arc is submerged beneath the flux blanket and is not normally visible during welding. The electrode may be a solid or cored wire or strip made from sheet. The chemical nature and size distribution of the flux assists arc stability and determines mechanical properties of the weld metal and shape of the bead. SAW is usually operated as a mechanised process. Welding current (usually 300A to 1000A),arc voltage and travel speed all affect bead shape, depth of penetration and chemical composition of the deposited weld metal since the operator cannot see the weld pool the weld quality depends on parameter, position setting of filler wire. SAW is normally operated with single wire using either AC or DC. SAW is ideally suited to the longitudinal and circumferential butt welds required for the manufacture of pipe and pressure vessels. Welding is normally carried out in flat position because of high fluidity of the weld pool and molten slag and need to maintain a flux layer.

Advantages:

- ❖ The process has high deposition rate
- ❖ Mechanized process
- ❖ Suitable for indoor and outdoor applications
- ❖ No chance weld spatter

Disadvantage:

- ❖ Operation limited to some specific material
- ❖ Operation limited to straight seam in pipe and pressure vessel
- ❖ Flux handling tough
- ❖ Health issue because of flux
- ❖ Slag removal needed after weld

Applications:

- ❖ Joining of pressure vessels
- ❖ Railroad construction ship building
- ❖ Repairing machine parts
- ❖ Many structural shapes

Scope of the project:

Aim:

The main aim of the project is to study the effect of different welding electrodes on welding of chrome molybdenum steel(SA387Grade 91) to carbon steel(IS2062E240) in submerged arc welding process(SAW).

Objective of the project:

The objective of the project is to study the effect of different welding electrodes on welding of chrome molybdenum steel(SA387GR 91) to carbon steel (IS2062E240) using SAW (Submerged Arc Welding) process with the help of conducting and evaluating mechanical andmetallurgical tests by adopting standard codes

2.Description of test material:

2.1 Grade91 material:

It is high strength material with good creep and corrosion resistance properties.it has tempered martensitic structure with 9% chromium and 1%molybtenum and controlled addition of niobium (nb) vanadium(V) and tungsten(W).

2.2 Carbon steel:

It is high strength steel used for pressure vessel plate where the working temperature is moderate and lower. The carbon content in this steel is 0.31

2.3 Material specification:

Table 2.3(1) Material selection for test specimen:

Description	Length (MM)	Width (MM)	Thickness (MM)	Material Specification
PLATE	200	150	25	SA 387 GR 91
PLATE	200	150	25	IS2062E240

Table 2.3(2) Chemical composition of the material.

Material	Composition %									
	C	Mn	P	S	Si	Cr	Ni	V	Al	Mo
SA 387GR91	0.08-0.12	0.3-0.6	0.020	0.010	0.2-0.5	8-9.50	0.4	0.25	0.4	0.85-1.05
IS2062E240	0.23	1.50	0.045	0.045	0.40	-	-	-	-	-

Table 2.3(3) Mechanical properties of the material

Material	Temperature limit (°C)	Tensile strength (MPa)	Yield strength (MPa)
SA 387 GR 91	540◦c -610◦c	585-760	415
IS2062E240	427◦c-538◦c	410	240

3.Selection of welding electrode:

Selection of welding electrode is based on the requirement of ASME boiler and pressure vessel code section-II, Part C.

Welding electrode:

An electrode is a piece of wire or a rod of a metal or alloy, with or without coatings. An arc is set up between theelectrode and work piece.

Table3.1 Chemical composition of the electrodes.

Material	Composition %										
	C	Mn	P	S	Si	Cr	Ni	V	Cu	Al	Mo
EBG	0.05-0.15	1.20-1.70	0.025	0.025	0.20	-	-	-	0.35	-	0.45-0.65
EB3	0.05-0.15	0.40-0.80	0.25	0.25	0.05-0.30	2.25-3.00	-	-	0.35	-	0.90-1.10
EB9	0.07-0.13	1.25	0.010	0.010	0.50	8.50-10.50	1.00	0.15-0.25	0.10	0.10	0.85-1.15

Literature survey:

Siddharth Pant., et al, [1] A good quality P91 weld joint can be obtained only when proper chemical composition of weld metal is obtained. For SMAW electrode selected for P91 steel is E-9015-B9-H4. It contains 0.08-0.13% C, 1.25 % Mn, 0.3% Si, 0.1 % S and P each, 1% Ni, 8-10.5% Cr, and 0.85-1.2% Mo. Additional elements are V, Cu, Al, Nb, and N in small amount. The welding polarity selected is DCEP. The main thing of this electrode is that it contains very low hydrogen less than 4 ml per 100 gms of weld metal. Backing of electrode is strongly recommended. Though P91 material is having hardening problem during welding, it is very highly susceptible for hydrogen induced crack (HIC).

Dr. Leijun Li, [2] P91 material is widely used in fabrication of process equipment for nuclear and steam power plant. P91 material is having very good creep resistance and corrosion resistance at elevated temperature. This material is having low thermal coefficient of expansion. The steel ASTM A335 Gr. P91 is a high-Cr martensitic heat-resistant steel and is applied particularly to large diameter thick-walled pipes in thermal power plants.

ZakariaBoumerzoug., et al [3] The study of the effect of shielded metal arc welding on industrial low carbon steel (0.19 wt. % C). The microstructures in dif-ferent zones are determined from the base metal to the weld metal. The microstructure of the center of weld zone is completely different from the heat-affected zone.

Merchant Samir Y., [4] PWHT at 750°C is best suited for maintaining uniform hardness of base metal, HAZ and weld metal. It neither increases hardness of weld metal nor softness of base metal.

Talabi, S.I., et al [5] A significant decrease in UTS value was recorded as the current increased. The decrease in strength may be associated with the presence of void and other defects occurring as a result of increasing current. Excessive grain growth could also lead to the decrease in the tensile properties.

Asibeluo I.S., et al [6] The factors are responsible for the transfer mode of SMA welding. The major ones are the current, voltage, electrode diameter, melting temperature of the core material, coating thickness and temperature of the electrode. [7] reported about higher penetration due to increase in Sio2 content of the flux. It was reported that sodium and potassium salt and other elements which improved arc stability and reduced cathode spot wandering generally increased penetration.

Eroglu M ., et al [7] investigated the effect of coarse initial grain size with varying heat input on microstructure and mechanical properties of weld metal and heat affected zone. It was concluded that the coarse initial grain size had a great influence on the microstructure, hardness and toughness of HAZ of low carbon steel. The investigators recommended a higher heat input to obtain maximum toughness of the HAZ in the welding of grain-coarsened low carbon steel, taking into consideration the plate thickness.

Literature discussion:

From the literature survey we came to know the properties of both grade 91 steel and carbon steel. then its weldablity when welded with dissimilar materials. The selection of welding procedures and welding electrodes. The mechanical properties of both the materials when subjected to heat and its metallurgical changes in weldment and heat affected zone, and the test procedure of the weldment to understand and analysethe changes of the weldment.

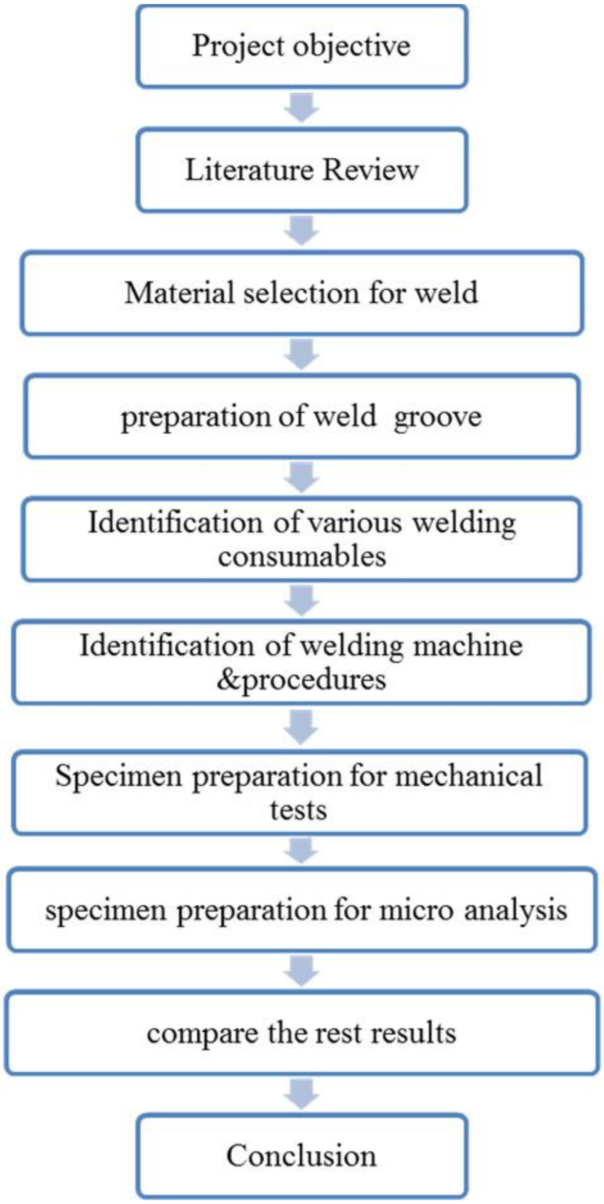
Literature conclusion:

The conclusions which can be made from the review paper are study of the mechanical properties of the weld is very important because themain purpose of the welding is to strongly join thetwo metals together as the application of the welded structure may be at dynamic or static loading conditions. It is important to check the tensile strength of the weld and the factors affecting the integrity of the weld. The major problem occurs with dissimilar metal welds is susceptible to formation of inter-metallic compounds at the interface which affect the properties and efficiency of the weld. In order to improve the strength of the dissimilar metals weld intermediate layers at the interface with suitable qualified consumables, Proper Preheat and necessary to reduce the residual stresses imparted during welding with suitable heat treatments.

7. Design of experiments:

7.1Flow diagram of experiment:

Theproposed methodology for analyzing the effect of different consumables on chrome molybtenum steel to carbon steel using shielded metal arc welding.



8.1 Experimental set up:

Experimental set up consist of welding the chrome moly plate (SA387 GR 91) with carbon steel plate (IS2062E240) by using submerged are welding(SAW) with three different welding consumablese.g EBG,EB3,EB9.

Case1: The plates are fit up with 2 mm root gap for full penetration weld. then it is preheated to 200◦c After reach the preheat temperature The Welding done by EBG(carbon wire)) in multiple pass bymaintaining the interpass temperature of 280˚c till the sufficient fillet is achieved by Submerged Arc Welding (SAW).After finish the weld the weld specimen subjected to post heat of 220◦c for 2 hrs.

Case2: The plates are fit up with 2 mm root gap for full penetration weld. then it is preheated to 200◦c After reach the preheat temperature The Welding done by EB3(GR 22wire) in multiple passbymaintaining the interpass temperature of 280˚c till the sufficient fillet is achieved by Submerged ArcWelding (SAW).After finish the weld the weld specimen subjected to post heat of 220◦c for 2 hrs.

Case3: The plates are fit up with 2 mm root gap for full penetration weld. then it is preheated to 200◦c After reach the preheat temperature The Welding done by EB9(GR 91wire) in multiple passbymaintaining the interpass temperature of 280˚c till the sufficient fillet is achieved by Submerged ArcWelding (SAW).After finish the weld the weld specimen subjected to post heat of 220◦c for 2 hrs.

The welded plates are cut to suitable profiles required for the different mechanical and metallurgical tests. The tensile and bending tests is used to measure the strength, ductility, elongation of the weld specimen. Macro analysis of the weld is used to analyze to inspect the root fusion, metallurgy of weld,penetration of the weld etc. Soundness of weld is endured by macro analysis and optimum welding method is identified. Welding procedure and parameter for this joint developed for implementation .3D stress analysis is done using ANSYS software to ensure the new weld configuration does not generate peak stress.

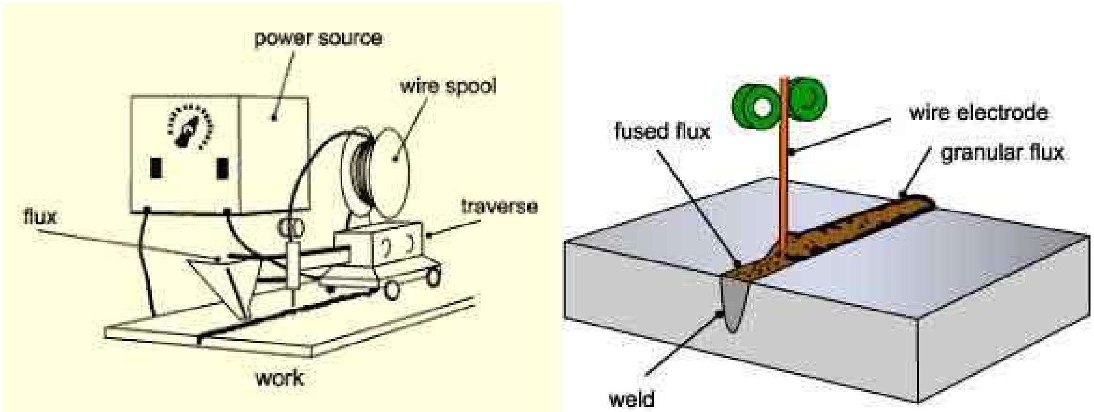
8.2 Weld parameters for the process:

S. N O	EXPERIME NT	WIRE DIAMETE R	WELD CURRE NT	WELD VOLTA GE	WELD SPEED	DEPOSIT RATE	WELD FLUX
1	CASE1: (EBG)	4.8mm	550A	28V	420mm/min	0.2KJ/mm	TAPADIA 80
2	CASE2: (EB3)	4.0mm	500A	28V	420mm/min	0.2KJ/mm	TAPADIA 80
3	CASE3: (EB9)	3.2mm	475A	28V	390mm/min	0.2KJ/mm	MARATHAN24 3

8.3 Heat treatment details:

S NO	HEAT TREATMENT PROCESS	MAX TEMP	RATE OH HEATING	SOAKING TIME	COOLING
1	STRESS RELIVING	760 ˚C	150˚C/hr	120 min	FURNACE COOLING

8.4 Graphical view of experimental setup



9. Mechanical tests:

9.1 Tension Tests:

Scope:

The tension testing of welded joints does not specify required properties or acceptance criteria. When this standard is used as a portion of specification for a welded structure or assembly or for qualification, the following information shall be furnished:

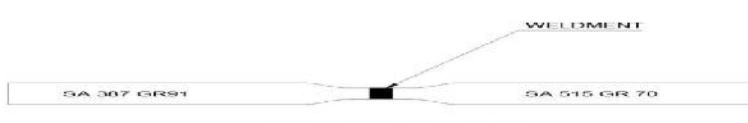
(1) The specific type(s) and number of specimens required,
(2) Base metal specification/identification,
(3) Filler material specification/identification,
(4) The anticipated property values and whether they are maximum or minimum requirements,
(5) Location and orientation of the specimens,
(6) Report form when required, and
(7) Post weld thermal or mechanical processing treatments

ASME Documents:

ASME B46.1, Surface Texture, Surface Roughness, Waviness and Lay
ASTM E 4, Standard Practices for Force Verification of Testing Machines
ASTM E 8, Standard Methods for Tension Testing of Metallic Materials
ASTM B 557, Standard Test Methods for Tension Testing Wrought and Cast Aluminium and Magnesium Alloy Products

Rectangular Tension Test Specimen:

The tension specimens for welded butt joints other than pipe or tubing shall be either transverse weld tension specimens or longitudinal weld tension specimens that comply with Figure 4.2 or 4.3. When thickness of the test weldmend is beyond the capacity of the available test equipment, the weld shall be divided through its thickness into as many specimens as required to cover the full weld thickness and still maintain the specimen size within the test equipment capacity. Unless otherwise specified, the results of the partial thickness specimens shall be averaged to determine the properties of the full thickness joint. Only ultimate tensile strength is normally determined in specimens takentransverse to the centre line of the weld.



Tensile test specimen

Universal testing machine

Table 9.2Tensile test result

IDFN	SPECIMEN SIZE IN MM	U.T.S in MPa	POSITION OF FRACTURE
1	23.66×21.90	446	Base Metal
2	23.84×21.92	454	Base Metal
3	23.54×21.95	454	Base Metal

9.3 Bend test:

Scope:

This clause covers the bend testing of fillet welds, groove welds in butt joints and the bend testing of surfacing welds. The standard gives the requirements for bend test specimen preparation, test parameters, and testing procedures, but does not specify acceptance criteria.The base materials may be homogenous, clad or otherwise surfaced, except for hard facing.

This standard is applicable to the following, where specified:

(1) Qualification of materials, welding personnel, and welding procedures;

(2) Information, specifications of acceptance, manufacturing quality control; and

(3) Research and development.When this standard is used, the following information shall be specified:(1) The specific location and orientation of the specimens;

(4) The specific types of tests, for example, face bend, side bend, or root bend and number of specimens required;

(5) Bend radius and specimen thickness (T), or percent(%) elongation. When not otherwise specified, the elongation is generally determined by the base metal or filler metal requirement, whichever is lower; specify acceptance criteria.The base materials may be homogenous, clad or otherwise surfaced, except for hard facing.

ASME Documents:

ASME B46.1, Surface Texture, Surface Roughness,Waviness and Lay
ASTM Documents:
ASTM A 370, Standard Test Methods and Definitions for Mechanical testing of Steel Products
ASTM E 190, Standard Test Method for Guided Bend test

9.4Specimen:

Bend test specimens shall be prepared by cutting the weld and the base metal to form a specimen rectangular in cross section. For transverse bends, the surfaces cut transverse to the weld shall be designated as the sides of the specimen. For longitudinal specimens, the longitudinal surfaces that were cut to form the specimen shall be designated as the sides of the specimen and may or may not contain any weld metal. Of the two remaining fulllength surfaces, the surface with the greatest weld face width shall be designated as the face while the remaining full length surface shall be designated as the root. Transverse specimens may have the side, face, or root of the weld as the tension surface. Longitudinal specimens may have the face or the root of the weld as the tension.

9.5 Table Bend test result:

IDENTIFICATION	SIDE BEND	REMARKS
11	No open discontinuity	passed
12	No open discontinuity	passed
21	No open discontinuity	passed
31	No open discontinuity	passed
32	No open discontinuity	passed

Bending machine

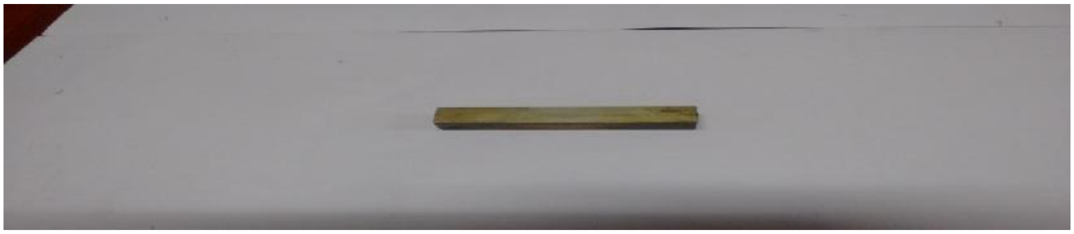
Bend test specimen

9.6 Impact test:

Impact test is carried out to measure and identify the behaviour of each material when subjected to sudden load.

9.7 Table Impact test result:

IDFN	IMPACT ENERGY IN JOULES	IDFN	IMPACT ENERGY IN JOULES
11	119	23	87
12	113	24	82
13	103	31	16
14	114	32	18
21	78	33	23
22	89	34	16



Impact test specimen

10.1Microhardness measurements:

Micro indention hardness measurement is performed acrossthe specimens to obtain the hardness profiles in the Basemetal, heat affected zone and buffer layers at a load of 200g in the interval 2000 micron distance by usingmicro indention hardness tester(Vickers Hardness Tester). .

10.2 Table Vickers hardness in vertical:

SAMPLE	NO OF INTENT	BASE MATL	HAZ	WELD METAL	HAZ	BASEMETAL
		IS2062				SA387GR91
EBG	1	153	166	197	200	211
EBG	2	157	165	212	222	192
EBG	3	183		190		280
EBG	4	162		187		234
EB3	1	175	210	192	218	213
EB3	2	175	202	199	210	243
EB3	3	190		200		217
EB3	4	196		213		222
EB9	1	175	313	239	305	300
EB9	2	186	267	273	296	257
EB9	3	158		270		233
EB9	4	178		308		233

10.3 Macro& microstructure:

Micro test is conducted by optical microscope at differentfocal length to find out the microstructure present in theweld metal, HAZ, weld interface, Root interface and basemetal.Metallography procedure is used to study the microstructureof base metals, weld metals and heat affected zone andmicrostructure changesThe recording observed under metallurgical microscope canbe the effective way to analysis the effectsOf cladding layers base plate and SA387 GR91&IS2062.Microstructure reveals the better bonding of SA387 GR 91 isobserved with lesser dilution as compared to IS2062.

Macroimage of sample1

Macro image of sample2

Macro image of sample 3

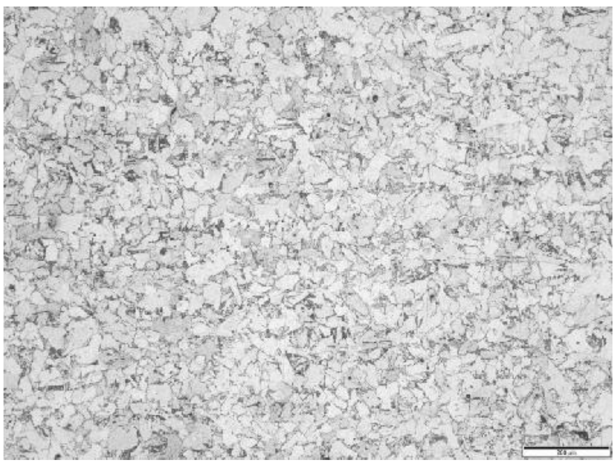


Fig 1MicrostructureofmetalIS2062-100X

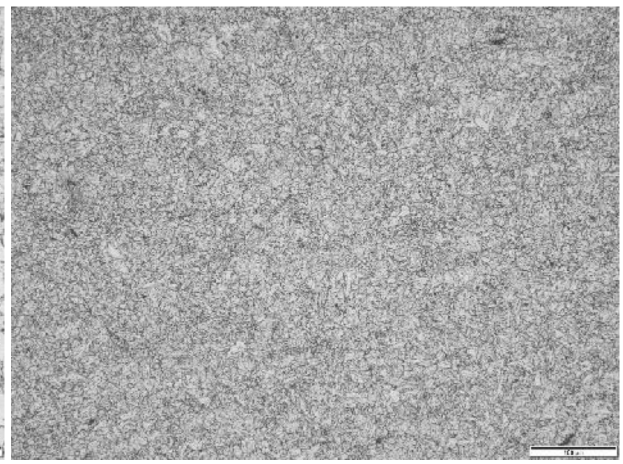


fig 2Microstructure of metal SA387 GR 91-200X

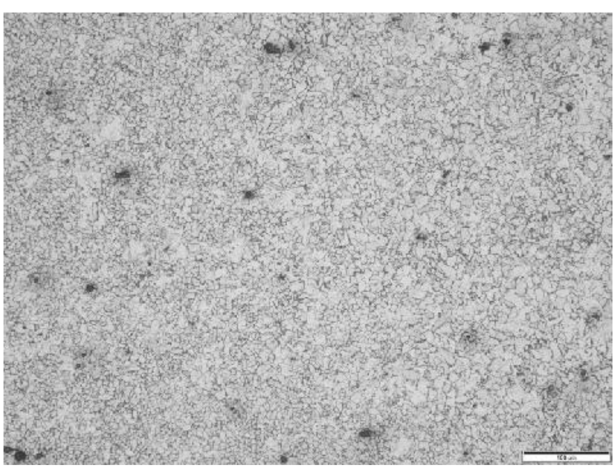


Fig3 Microstructure of HAZ IS2062-200X

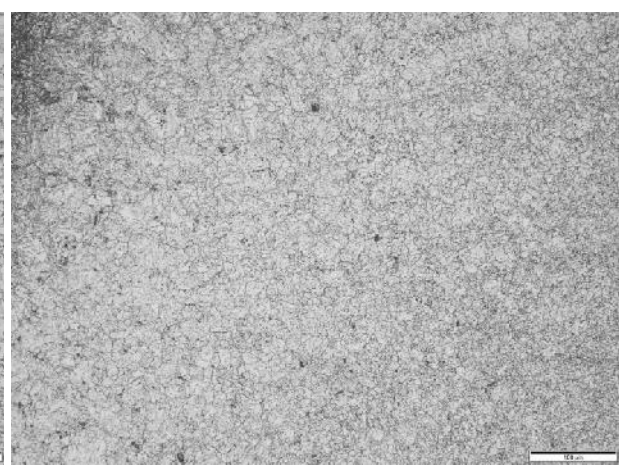


fig4 Microstructure of HAZ SA387 GR 91-200X

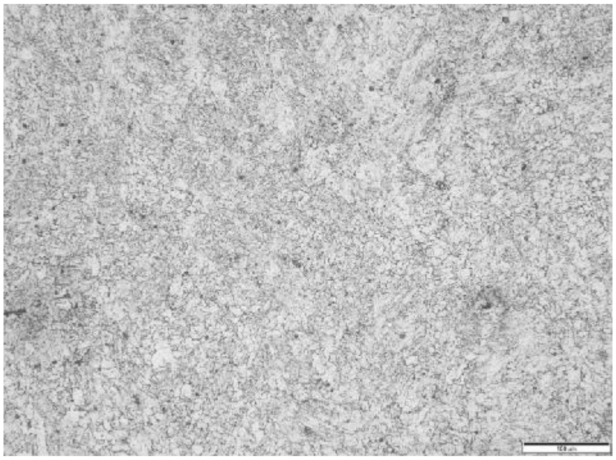


Fig5 Microstructure of weldment (EBG)-200X

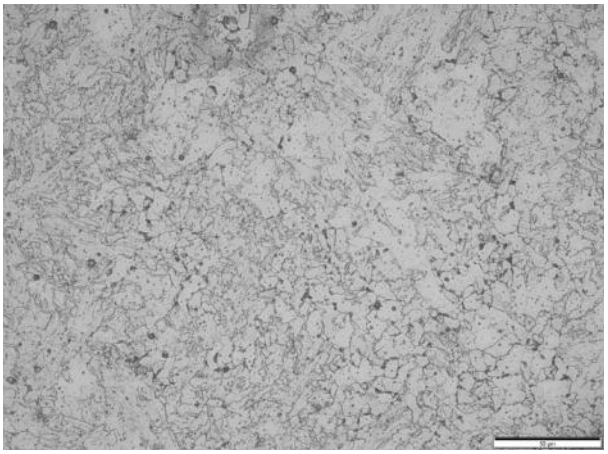


fig6 Microstructure of weldment(EBG)-500X

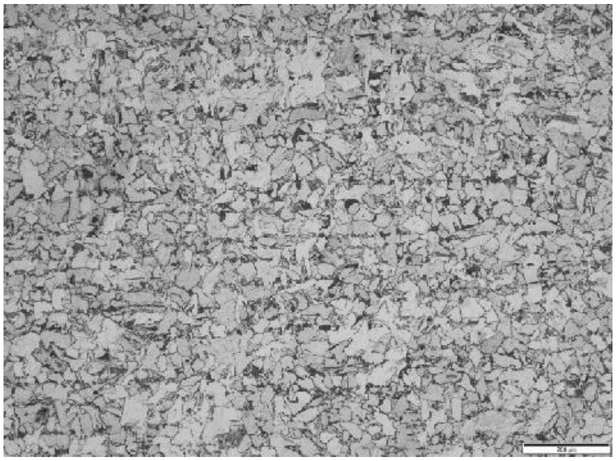


Fig7Microstructure of metal IS2062-100X

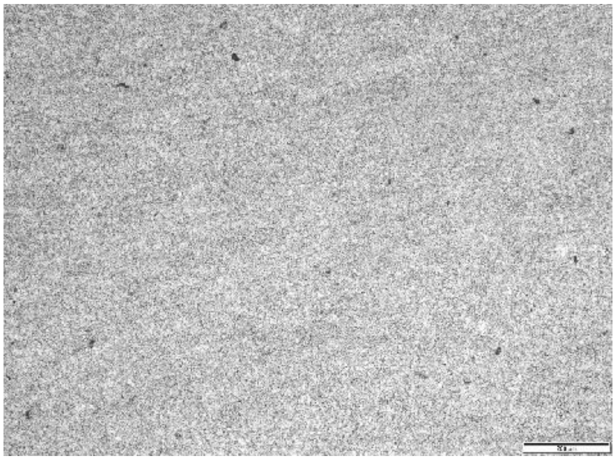


fig8 Microstructure of metal SA387 GR91-100X

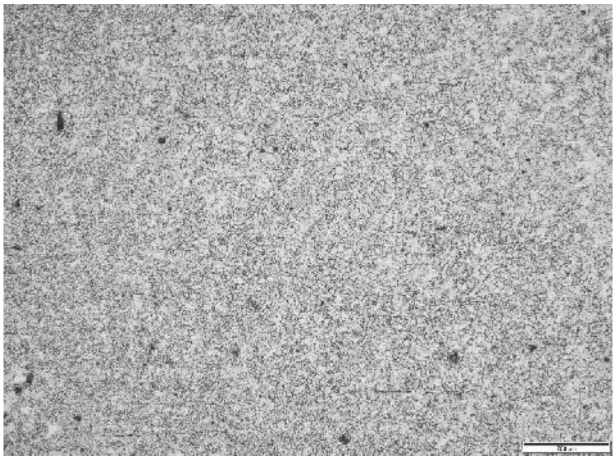


Fig9 MicrostructureofHAZIS2062-100X

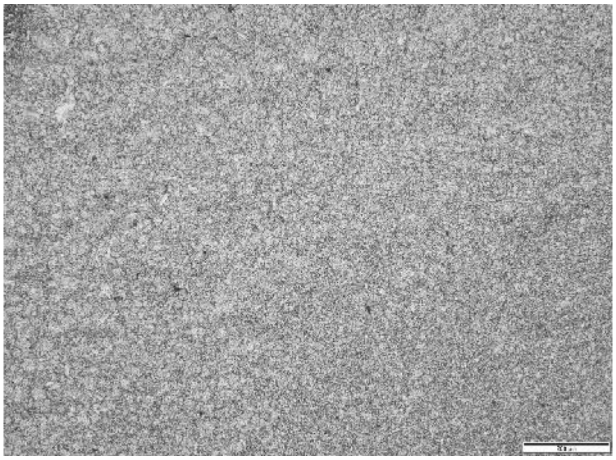


fig10Microstructureof HAZSA387GR91-100X

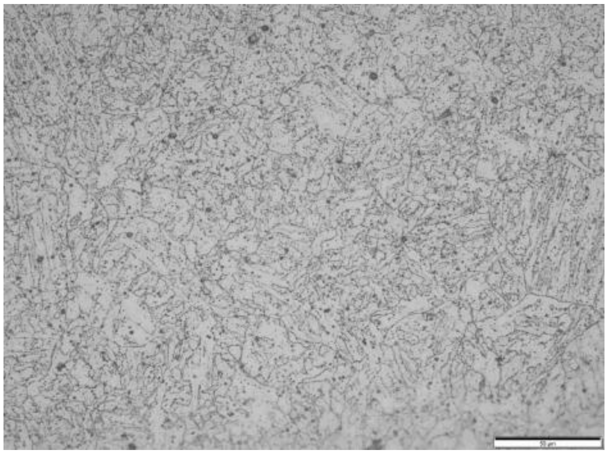


Fig11 Microstructure of weldment (EB3)-100X

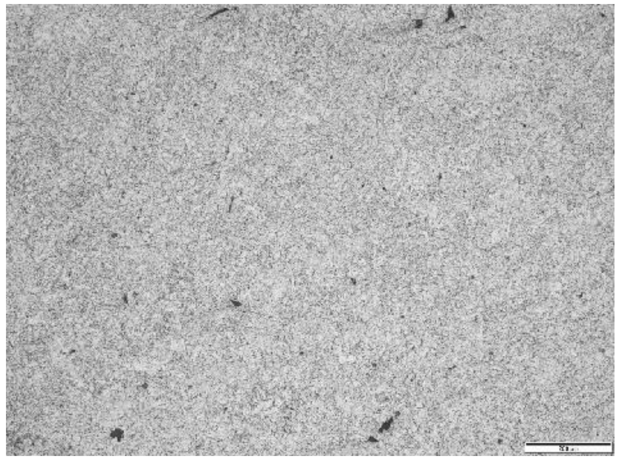


fig12 Microstructure of weldment(EB3)-200X

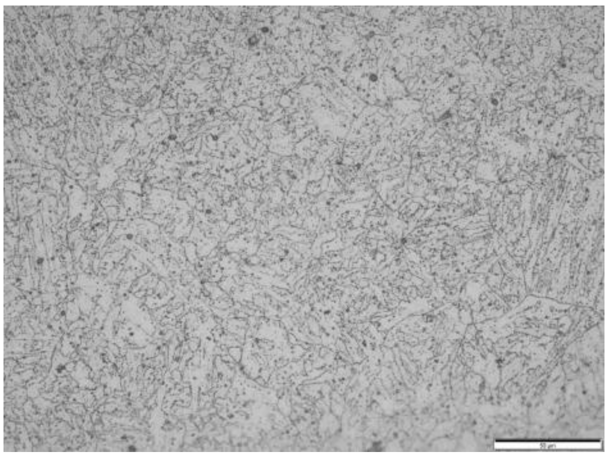


Fig13 Microstructure of metalIS2062-100X

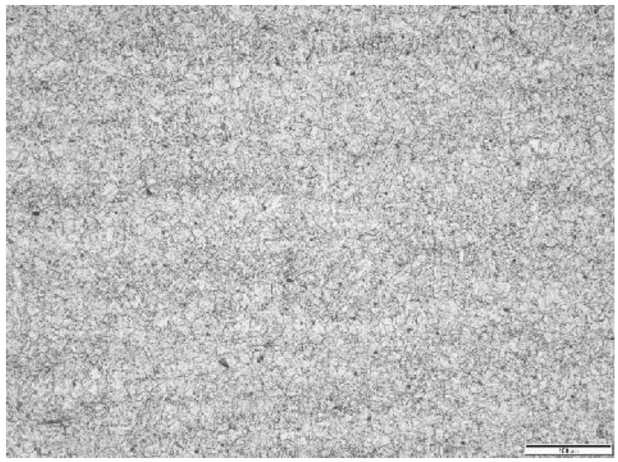


fig14 Microstructure of metal SA387GR91-200X

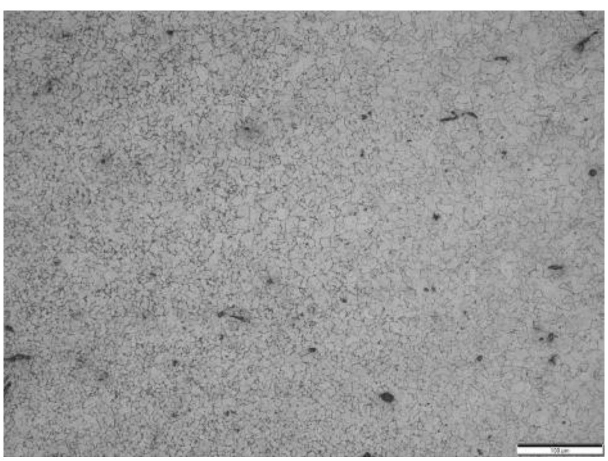


Fig15 Microstructure of HAZ IS2062 -100X

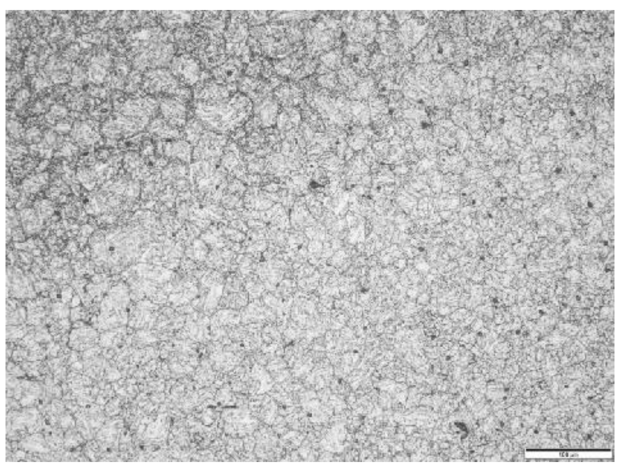


fig16 Microstructure of HAZ SA387GR91-200X

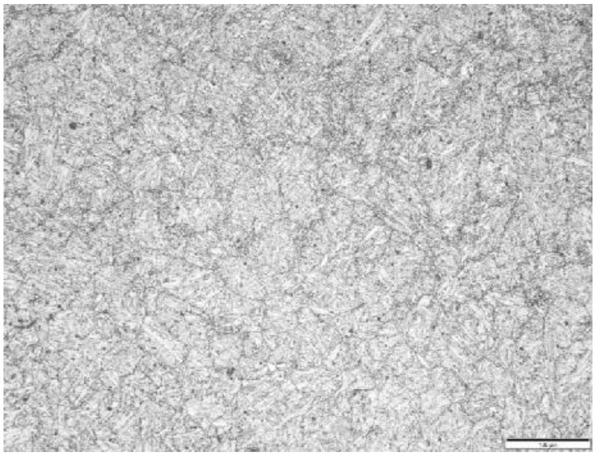


Fig17 Microstructure of weldment (EB9)-200X

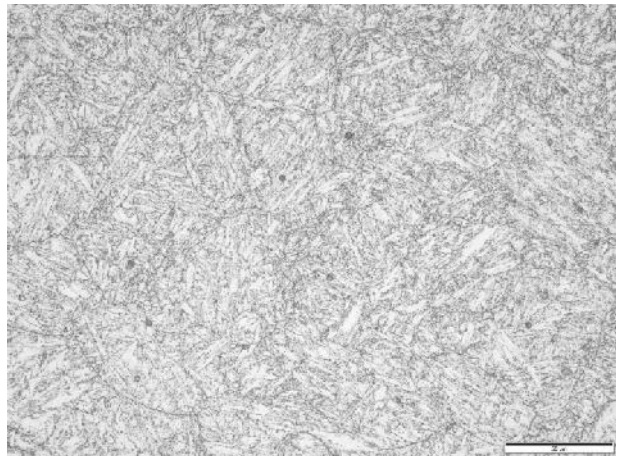


Fig18 Microstructure of weldment(EB9)-500X

Conclusion:

The conclusions which can be made from the review papers are study of the mechanical properties of the weld is very important because the main purpose of the welding is to strongly join the two metals together as the application of the welded structure may be at dynamic or static loading conditions. It is important to check the mechanical properties and metallurgical changes occurred duo to welding of dissimilar materials and the various factors affecting the weldment dueto specific property of each material. The experiment performed based on standard codes and procedures. The various test report reveals that the property of the two test materials(SA387GR91 and IS2062E240) doesn't change too much while welding together.From the tensile test the probability of weld failure occurs at low grade material at given load, from impact test we can understand the failure occurs at high chrome materials and micro and macro analysis indicates soundness of the weld and metallurgical changes of the material. This thesis of report concludes that the welding of these two dissimilar material using different electrodes can provide a quality weld in terms of mechanical and metallurgical aspects. but, the selection of welding electrode and process should be selected based on its working condition and type of load might encounter the weld joint.

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integrity of the weld. The major problem occurs with dissimilar metal welds is susceptible to formation of inter-metallic compounds at the interface which affect the properties and efficiency of the weld. In order to improve the strength of the dissimilar metals weld intermediate layers at the interface with suitable qualified consumables, Proper Preheat and necessary to reduce the residual stresses imparted during welding with suitable heat treatments.

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DOI:10.22192/ijamr.2017.04.06.008	

How to cite this article:
Ramesh kumar .A , Senthil kumar .T. (2017). Effect of different welding electrodes on welding of chrome moly steel to carbon steel material. Int. J. Adv. Multidiscip. Res. 4(6): 64-79.
DOI: http://dx.doi.org/10.22192/ijamr.2017.04.06.008