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COMPARISON OF MECHANICAL AND METALLURGICAL PROPERTIES OF CONVENTIONAL GMAW WITH SPIN ARC GMAW PROCESS FOR CARBON STEEL SA 515

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Abstract – *In this research was to evaluate the possibilities of improving the weld joint quality and productivity by spin arc GMAW with oscillating arc narrow gap square butt joint with root opening for SA 515 Gr 70 carbon steel. Under this research work of weld joints the mechanical and metallurgical properties were evaluated, and also the conventional GMAW process, the comparison namely, microstructure, micro-hardness tensile strength, bends and, impact toughness. The test results indicated that mechanical properties of weld joints spin arc GMA welding were good and also reduces the amount of welding defects detected by non-destructive testing. The properties obtained in the weld joint were found to meet stipulated ASME code requirements. To comparison with conventional GMAW process the oscillating arc narrow gap GMA welding is a promising process for welding SA 515 Gr 70 thick steels due to the better mechanical and metallurgical properties, low energy input and narrow groove welding.*

Key Words: **Conventional GMAW, Spin arc GMAW, Narrow gap square butt joint**

1. INTRODUCTION

There are two processes used in this research, conventional GMAW and spin arc GMAW process. The conventional GMAW is the process of arc welding and its continuously filler wire fed through the base metal, then shielding gases from externally mixed with argon and CO_2 gases. It is named as binary gas blends to protect the electrode wire. They also success in DC pulsed GMAW process. The filler wire is ER70S-6 and filler wire chemical composition nearby same for base metal, both process same filler wires but different current and constant voltage.

The spin arc process is the process of GMAW only the torch will be differed from the conventional GMAW. If the filler wire is a rotary motion at a controlled speed, and different spin diameter is available. The Speed of the spin rotation is 2000 RPM to 4000 RPM and different types of weld joints possible in this process. It is constant voltage spin arc GMAW power sources. The torch design is robotic and mechanized. The weaving action will be automatic and good penetration.

The base material is SA 515 Gr 70 for boiler pressure vessel plates and it is used in higher temperature service. Welding geometry of the base material in both processes for plate 300x150x25 mm. The conventional GMAW process is the narrow V-groove included angle is 20° and spin arc GMAW process is the narrow groove square butt joint.

BASE METAL CHEMICAL COMPOSITINON

Table-1: Base metal chemical composition

GRADE	C %	Si%	Mn%	P%	S%
SA515 Gr 70	0.132	0.277	1.193	0.020	0.010

FILLER WIRE CHEMICAL COMPOSITION

Table-2: Chemical composition of ER 70S-6 1.2mm Ø

Name	C %	Mn %	Si %	P %	S %
ER 70S-6	0.06	1.40	0.80	0.025	0.035

2. EXPERIMENTAL WORK

PROCESS PARAMETER FOR GMAW

Table-3: Process parameter for GMAW

S.NO	P.NO	CURRENT (A)	VOLTAGE (V)	SPIN DIA(mm)
1	1	305 – 308 A	34.3 - 34.5V	1mm
2	2	305 – 308A	34.3 - 34.5V	1mm
3	3	305 – 308A	34.3 - 34.5V	2mm
4	4	305 – 308A	34.3 - 34.5V	2mm
5	5	305 – 308A	34.3 - 34.5V	2mm

PROCESS PARAMETER FOR SPIN ARC GMAW

FILLER WIRE: ER70S-6 (Ø 1.2 mm)

GAS FLOW RATE: Ar 80%, CO_2 20%

WIRE FEED RATE SETTING: 9.8 m/min

VOLTAGE SETTING: 31.3 V

SPIN SETTING: 2 STROKES

SPIN R.P.M: 4000

S.O.D: 20mm

MATERIAL: CARBON STEEL

PLATE DIMENSION: 300 ×150 × 25 T in mm

JOINT: SQUARE BUTT JOINT

ANGLE: 10°

Table-4: process parameter for spin arc GMAW

S. NO	P. NO	A	V	WIRE/F m/min	GAS FLOW Ltr/min	
					Ar	CO_2
1	1	243	31.3	9.8	22	08
2	2	252	31.2	9.8	22	08
3	3	257	31.3	9.8	22	08
4	4	265	31.3	9.8	22	08
5	5	262	31.2	9.8	22	08
6	6	29	31.2	9.8	22	08
7	7	156	25.7	4	22	08
8	8	152	25.6	4	22	08
9	9	153	26.0	4	22	08

TENSILE TEST

The tensile test weldment geometry designed as per standard AWS B 4.0. than the work piece after designing show in fig

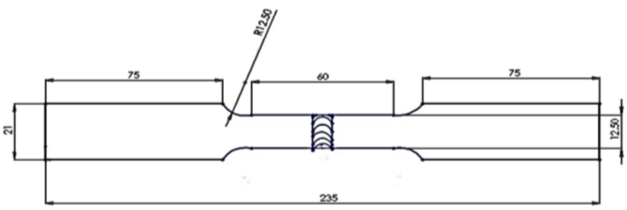


Fig-1: Tensile test

BEND TEST

The bend test weldment geometry designed as per standard AWS B 4.0. than the work piece after designing show in fig

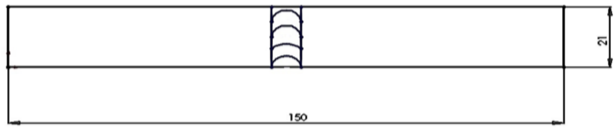


Fig-2: Bend test

IMPACT TEST

The impact test weldment geometry designed as per standard AWS B 4.0. than the work piece after designing show in fig

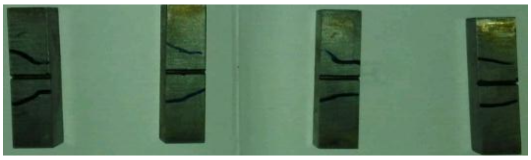


Fig-3: Impact test

MICRO-HARDNESS SURVEY

The micro-hardness survey done as per standard ASTM E-384 by a Vickers hardness testing machine. The pyramid diamond indenter used in this testing machine and face angle is 136°.If the weldment was prepared up to mirror finish and etched with Villella's reagent to identify the weld, Heat Affected Zone (HAZ) and the base metal. During testing, load of 1000 gf is applied to sample with dwell time of 10 seconds. After putting indentation, both the diagonals of pyramid indenter are measured with a microscope at magnification of 400X.

3. RESULT AND DISCUSSION

MICROSTRUCTURE FOR GMAW

The martensite microstructure is present at the base metal and most of the precipitates formed at the grain boundaries. The base metal microstructural images are shown in Fig. the etchant 3% nital and etching time 10 sec. The weld microstructures across all the weld parameters has prior ferrite grain boundaries within which elongated lath acicular ferrite microstructure was observed as the weld area gets narrow the microstructure gets coarse grains than the HAZ. All the welds have HAZ with fine martensite grain structures than the weld zone. The reason might be due to the slow cooling rate associated with the gas metal arc welding.

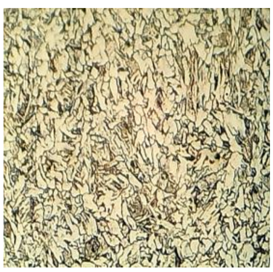


Fig-4: Base metal 200X

Fig-5: HAZ 200X

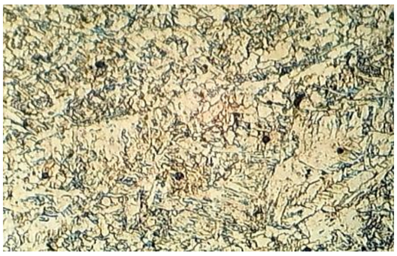


Fig-6: Weldment 200X

MICROSTRUCTURE FOR SPIN ARC GMAW

The martensite microstructure is present at the base metal and most of the precipitates formed at the grain boundaries. The base metal microstructural images are shown in Fig. the etchant 3% nital and etching time 10 sec. The weld microstructures across all the weld parameters has prior ferrite grain boundaries within which elongated lath acicular ferrite microstructure was observed as the weld area gets narrow the microstructure gets coarse grains than the HAZ. All the welds have HAZ with fine martensite grain structures than the weld zone. The reason might be due to the slow cooling rate associated with the gas metal arc welding.

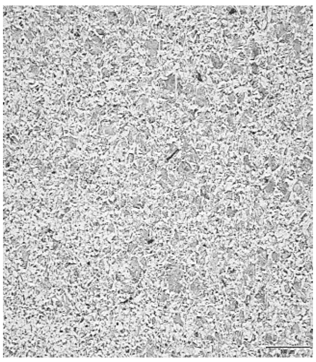


Fig-7: HAZ 200X

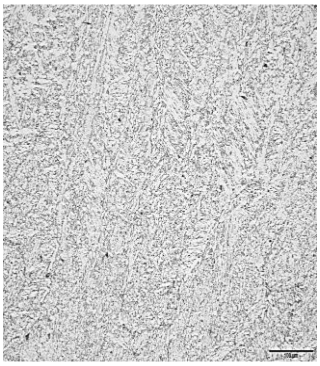


Fig-8: Weldment 200X

MACROSTRUCTURE

The macrostructure is shown in fig. the good fusion at the weldment and also there is no cracks and porosity present at the weldment. If fine grains at the HAZ and weldment will be coarse grains. the reason for that fine grain HAZ, very high cooling rates associates with the gas metal arc welding.

Fig-9: Macrostructure

MICRO-HARDNESS SURVEY FOR GMAW

The microhardness values across different regions are shown in Table 5 and the comparison graph is shown in Figure. Microhardness values were in the range of 182-187 HV in welds, 210-229 HV in HAZ and 170-173 HV in base metal. From the hardness survey, it is clear that weld and HAZ are stronger in all welds than the Base metal. It is also clear that there is no significant softening in the HAZ-BM boundary. This could be due to the rapid cooling rate characterized with the gas metal arc welding process couples with W restricting the growth of precipitates.

Table-5: Micro-hardness survey result

MICRO-HARDNESS	BASE METAL HV	WELD METAL HV	HAZ 1 HV	HAZ 2 HV
TOP	172	182	210	219
MIDDLE	173	187	228	229
BOTTOM	170	184	223	226

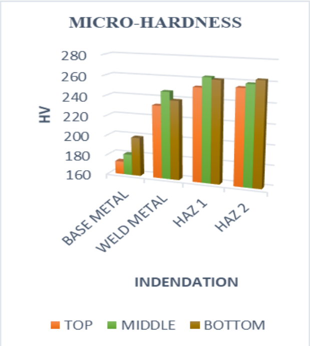
MICRO-HARDNESS SURVEY FOR SPIN ARC GMAW

The microhardness values across different regions are shown in Table 6 and the comparison graph is shown in Figure. Microhardness values were in the range of 233-247 HV in welds, 253-263 HV in HAZ and 173-199 HV in base metal. From the hardness survey, it is clear that weld and HAZ are stronger in all welds than the Base metal. It is also clear that there is no significant softening in the HAZ-BM boundary. This could be due to the rapid cooling rate characterized with the gas metal arc welding process couples with W restricting the growth of precipitates.

Table-6: Micro-hardness survey result

MICRO-HARDNESS	BASE METAL HV	WELD METAL HV	HAZ 1 HV	HAZ 2 HV
TOP	**173**	**233**	**253**	**255**
MIDDLE	**181**	**247**	**263**	**259**
BOTTOM	**239**	**261**	**263**	**264**

GRAPHICAL REPRESENTATION



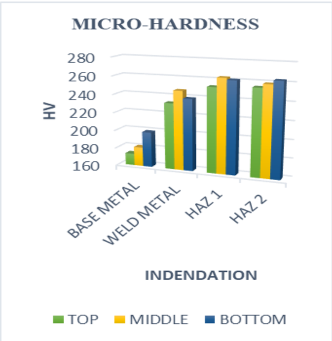


Chart-1: Graphical representation

TENSILE TEST FOR GMAW

In the tensile test conducted at room temperature (28°C), the tensile properties of the weld were higher compared to the base metal and the failures observed were comfortably far away from the weld and HAZ which indicate the quality of weld. Even though elongation is not considered in Transverse tensile it could be helpful in explaining the loss of ductility in the welds. In the current work, from elongation point of view the values obtained from welded samples were less compared to the base material and proves that there has been some loss in ductility compared to the base material. The loss in ductility could be because of the high hardness in the weld metal compared to the base material.

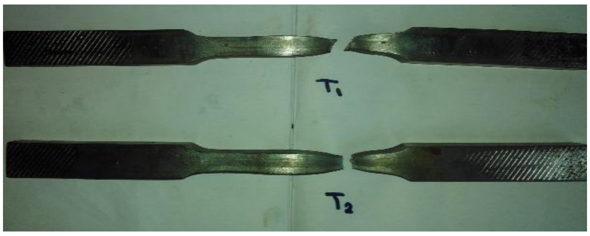


Fig-10: Tensile test

Table-7: Tensile test result

ID.NO	GRADE	U.T.S IN Mpa	POSITION OF FRACTURE
T1	SA 515 GR 70	558	BASE METAL
T2	SA 515 GR 70	565	BASE METAL

The high tensile strength could be simply explained as the significance of narrow and low width weld metal zone which reduces the effect of high hardness in the middle. The minimal required value of tensile strength could be found in EN10216-2 – for SA 515 the values must be in the range from 508 to 540 MPa and it could be observed from the current study that the tensile properties obtained are comfortably lays within the specified range.

TENSILE TEST FOR SPIN ARC GMAW

The high tensile strength could be simply explained as the significance of narrow and low width weld metal zone which reduces the effect of high hardness in the middle. The minimal required value of tensile strength could be found in EN10216-2 – for SA 515 the values must be in the range from 558 to 565 MPa and it could be observed from the current study that the tensile properties obtained are comfortably lays within the specified range.

Table-8: Tensile test result

ID.NO	GRADE	U.T.S IN Mpa	POSITION OF FRACTURE
T1	**SA 515 GR 70**	**540**	**BASE METAL**
T2	**SA 515 GR 70**	**508**	**BASE METAL**

BEND TEST FOR GMAW

The samples prepared from the weld specimen were subjected to 180° four side bend testing. The samples were bent to a radius of 4T, where T is the thickness of the sample. The four side bend test results are shown in Figure 4.15. The welds were found to have excellent 180° bend ductility in four side bend on the weld and also no crack was visible on side of the weld after bending.

Fig-11: Bend test

Table-9: Bend test result

ID.NO	SIDE BEND	REMARKS
B1	NO OPEN DISCONTINUITY	PASSED
B2	NO OPEN DISCONTINUITY	PASSED
B3	NO OPEN DISCONTINUITY	PASSED
B4	NO OPEN DISCONTINUITY	PASSED

BEND TEST FOR SPIN ARC GMAW

Table-10: Bend test result

ID.NO	SIDE BEND	REMARKS
B1	NO OPEN DISCONTINUITY	PASSED
B2	NO OPEN DISCONTINUITY	PASSED
B3	NO OPEN DISCONTINUITY	PASSED
B4	NO OPEN DISCONTINUITY	PASSED

IMPACT TEST

Charpy V-Notch impact tests were carried out according to AWS B4.0 standard specimen and the results are shown in the Table 11 & 12. The weld samples were found to have marginally lower toughness values compared to the base metal values.

IMPACT TEST FOR GMAW

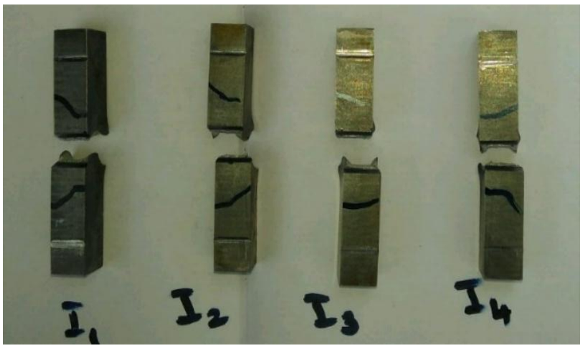


Fig-12: Impact test

Table-11: Impact test result

IDENTIFICATION	IMPACT ENERGY IN JOULES
I_1	125
I_2	114
I_3	117
I_4	150

IMPACT TEST FOR SPIN ARC GMAW

Table-11: Impact test result

IDENTIFICATION	IMPACT ENERGY IN JOULES
I_1	150
I_2	147
I_3	149
I_4	153

CONCLUSION

In the present work, GMA welding of SA 515 carbon steel performed and studies are conducted in order to evaluate the mechanical and metallurgical properties such as tensile strength, bend, hardness and toughness properties of in weld. Initial X-Ray radiography testing and macro analysis proved that GMAW SA 515 carbon steel can be successfully performed without the formation of any kind of internal and external defect with full depth of penetration for the thickness used and with narrow groove welds. After radiographic testing then the mechanical testing carried out, the test results indicated that mechanical properties of weld joints spin arc GMA welding were good. The impact toughness properties obtained with spin arc GMA weld are very good, even though marginally less compared with that of the base material. The reason to good properties obtained is believed to be due to the presence of smaller prior martensite grains. Thus, from an overall point of view based on the results obtained from the study and comparative literatures, spin arc GMA welding is improving the weld joint quality and productivity.

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