

Effect of Thermo Mechanical Analysis of GMAW by Using SA 387(Grade 12) Pressure Vessel Material

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ABSTRACT: In this competitive world, the customers perceive the most reliable high quality with low cost product. Gas metal arc welding famously abbreviated MIG is one of the most important metals joining process in manufacturing industries. The selection of improper MIG welding process parameter increases the power consumption, material consumption, man power and cost of the product decreasing the weld quality. This project work was part of the program for the development of SA 387 steels has to be increase mechanical properties and minimization of metallurgical defects to increasing weldment quality. The quality of weld in MIG mainly influenced by independent variables such as welding current, speed of electrode and electrode stick out. The planned experiments were conducted in the MIG welding machine.. Image J software were used to find out the depth of penetration depending upon the temperature variation. Experimentally found the input parameter value AMPS 160 VOLT-22 ROOT GAP 1.5 was the best value and it did not create any major changes and failures in the testing process and it was comparatively moderate toughness value than other value and it also induces high tensile strength. According to the Taguchi design the optimized parameter value for 10 mm plate of SA387 steel is AMPS 180 VOLT-22ROOT GAP- 1.5.

KEYWORDS: Depth of penetration, Hardness, optimization, orthogonal array, S/N ratio.

1. INTRODUCTION

Metal inert gas/metal active gas (MIG/MAG) welding is an arc welding process, the melting takes place by Joule effect and a continuous electric arc, where the additional metal is supplied by a roll of wire. The weld is made by falling successive drops on the weld puddle. Argon gas (MIG welding) or active gas, CO₂ (MAG welding) are used as plasma for providing protective atmosphere for the weld metal, so that contamination between oxygen and nitrogen is avoided. Electric energy is supplied from the welding generator for melting between wire and work piece to weld. According to two different control modes the arc mode, where voltage supplied from the generator is controlled to reach a point chosen by the welder the short-circuit mode, where current flows at pre-defined law, in gas metal arc

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welding the molten metal drop detachment from an electrode have complex interactions between different physical phenomena. Some of the researchers have studied the electromagnetic effects and some studied the thermal effects and the fluid dynamics. It is an arc welding process where heat is generated for arc between the workpiece and a consumable electrode. A bare solid wire called electrode is continuously fed to the weld zone, it becomes filler metal as it is consumed. Gas metal-arc welding overcomes the restrictions of using electrode of limited length and overcomes the inability to weld in various positions, which is a limitation of submerged-arc welding. In gas metal arc welding, the variations of power supplies, shielding gases and electrodes have significant effects, resulting in different process variations. All important metals used in different commercial applications such as aluminum, copper, stainless steel and carbon steel can be joined by this MIG welding process by choosing appropriate electrode, shielding gas and different welding conditions. It has been very important to know the performance of a welding process over a wide range of input process parameters. MIG welding is such a welding process which is extensively used in the industries for its high precision and accuracy capability. But performance of the welding depends largely upon the parameters like voltage, current and also on type of work-piece materials, electrode material combinations. A large amount of research works have been noticed to find out the most suitable combination of input process parameters for a desired output. In our present study workpiece of mild steel material of grade High Carbon High Chromium steel has been used tolerances.

II. PROBLEM IDENTIFICATION

In many cases the welder needs only to know the techniques of actual welding and does not need to be concerned about the type or grade of steel being welded. This is because a large amount of steel used in fabricating a metal structure is low Carbon or plain carbon steel (also called mild steel). When welding these steels with any of the common arc welding processes like Stick Mig or Tig there are generally few precautions necessary to prevent changing the properties of the steel.

Steels that have higher amounts of Carbon or other alloys added may require special procedures such as preheating and slow cooling, to prevent cracking or changing the strength characteristics of the steel. The welder may be involved in following a specific welding procedure to ensure weld metal and base metal has the desired strength characteristics.

III. TESTING MATERIAL

SA387 GR 12 CLASS 2 Engineered for use in elevated temperature service, ASME SA387 Grade 12 is a chrome molybdenum carbon alloy steel for use in weldable pressure vessels and industrial boilers. The material benefits from added chromium which provides excellent corrosion and oxidation resistance making it ideal for sour service applications in the oil and gas industry

3.7.1 CHEMICAL COMPOSITION

ELEMENT	COMPOSITION,wt%
Carbon	0.15
Silicon	0.15
Manganese	0.3 to 0.6
Chromium	1.9 to 2.6
Molybdenum	0.87 to 1.13
Iron	Balance

3.1APPLICATION

Chrome Molybdenum steel plate is popular in the oil and gas industry for on and offshore production facilities because of the alloy's key properties. It is also used extensively in the energy industry as a key component in power plants. It can be found in

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- Boilers and pressure vessels,
- Heat exchangers
- Flanges, fittings and valves
- Ducting and pipe supports

IV. FINITE ELEMENT ANALYSIS

ANSYS, Inc, founded in 1970 as Swanson Analysis Systems, Inc, develops and globally markets engineering simulation software and technologies widely used by Engineers and designers across a broad spectrum of industries including aerospace, automotive, manufacturing, electronics and biomedical. It also focuses on the development of open and flexible solution that enable users to analyze decisions directly on the desktop, providing a common platform for fact, efficient and cost-conscious produce development, from decision concept to final stage testing and validation.

4.1 COMPARISION OF THERMAL FLUX AND THERMAL GRADIENT

The below table shown in thermal flux and Thermal gradient at various Heat in put

HEAT IN PUT KJ/mm		THERMAL FLUX $\frac{Q}{A}$	THERMAL GRADIENT K/m
MAX	1.232	24603	439.345
MIN		.026441	0.472×10^3
MAX	1.344	25857	461.732
MIN		.027788	0.496×10^3
MAX	1.456	27110.7	484.119
MIN		0.29135	0.520×10^3
MAX	1.689	27737.5	495.312
MIN		0.29814	0.532×10^3
MAX	1.843	28634.3	506.506
MIN		0.30483	0.544×10^3
MAX	1.996	29618	528.893
MIN		0.3183	0.568×10^3
MAX	2.112	311825.01	556.877
MIN		0.335104	0.598×10^3
MAX	2.304	32752.2	584.86
MIN		0.33514	0.598×10^3
MAX	2.496	34139.3	612.844
MIN		0.036882	0.659×10^3

4.2 ANSYS CONCLUSION

In this project work finally concluded that the changes in value of heat inputs will lead to affect the thermal distribution on the welded structures. From the above experimentation, due to higher heat input, the thermal flux is also increased (i.e.) Maximum thermal stress is acting on that point that was indicated as SMX.

Maximum thermal gradient is also acted upon due to high heat input. Temperature distribution is eventually occurred over the surface of the welded specimen. Metal joining due to high temperature metal slag which is used to produce high thermal gradient as well as thermal flux (i.e.) Maximum thermal stress.

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V. ROCKWELL HARDNESS TEST

1. Rockwell Hardness systems use a direct readout machine determining the hardness number based upon the depth of penetration of either a diamond point or a steel ball. Deep penetration indicated a material having a low Rockwell Hardness number.
2. However, a low penetration indicates a material having a high Rockwell Hardness number. The Rockwell Hardness number is based upon the difference in the depth to which a penetrator is driven by a definite light or “minor” load and a definite heavy or “Major” load.
3. The ball penetrators are chucks that are made to hold 1/16” or 1/8” diameter hardened steel balls. Also available are ¼” and ½” ball penetrators for the testing of softer materials.
4. There are two types of anvils that are used on the Rockwell hardness testers. The flat faceplate models are used for flat specimens. The “V” type anvils hold round specimens firmly.
5. Test blocks or calibration blocks are flat steel or brass blocks, which have been tested and marked with the scale and Rockwell number. They should be used to check the accuracy and calibration of the tester frequently.

Using the “B” Scale;

- a. Major load: 100 Kg, Minor load: 10 Kg

5.1 ROCKWELL HARDNESS VALUE(HRB VALUE)

SAMPLES	S1	S2	S3	S4	S5	S6	S7	S8	S9
HRB VALUE	91	89	90	92	91	95	95	92	94

5.1.1 IMPACT TEST

Izod impact strength testing is an ASTM standard method of determining impact strength. A notched sample is generally used to determine impact strength. Impact is a very important phenomenon in governing the life of a structure. In the case of aircraft, impact can take place by the bird hitting the plane while it is cruising, during take - off and landing there is impact by the debris present on the runway. An arm held at a specific height (constant potential energy) is released. The arm hits the sample and breaks it. From the energy absorbed by the sample, its impact strength is determined. The North American standard for Izod Impact testing is ASTM D256. The results are expressed in energy lost per unit of thickness (such as ft-lb/in or J/cm) at the notch. Alternatively, the results may be reported as energy lost per unit cross-sectional area at the notch (J/m² or ft-lb/in²). In Europe, ISO 180 methods are used and results are based only on the cross-sectional area at the notch (J/m²).

5.1.2 IMPACT STRENGTH

In our Project Impact Strength determined through impact testing machine by charpy method.
Specification of the machine and Size of the specimen

Materials	TEST PLATE	Average in Joules
SA 387	S1	36
	S2	47
	S3	18
	S4	54
	S5	138
	S6	28
	S7	70
	S8	32
	S9	22

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Energy Range = 0 – 300 J
Least Count (1 Division) = 1J
Specimen size = 10 X 10 X 55 mm
Notch = U NOTCH
Notch Depth = 5mm
Table5. Impact strength Result

VI. DEPTH OF PENETRATION

Inadequate weld bead dimensions such as shallow depth of penetration may contribute to failure of a welded structure since penetration determines the stress carrying capacity of a welded joint .To avoid such occurrences the input or welding process variables which influence the weld bead penetration must therefore be properly selected and optimized to obtain an acceptable weld bead penetration and hence a high quality joint . To predict the effect of welding process variables on weld bead geometry and hence quality researchers have employed different techniques

LENGTH OF BEAD WIDTH, DEPTH OF PENETRATION OF WELDED PLATES

SAMPLES	Area	Mean	Min	Max	Angle	Length	
T1	BW	0.366	111.753	59.355	163.022	-1.478	15.053
	DOP	0.168	83.246	16	122.568	90.807	6.894
T2	BW	0.229	131.64	96.804	150.199	0.591	9.418
	DOP	0.132	51.546	1.333	87.333	90	5.437
T3	BW	0.227	107.278	22.444	201.667	-178.807	9.322
	DOP	0.18	43.232	1.583	162.425	90.754	7.379
T4	BW	0.286	50.14	19.333	151.837	-0.947	11.749
	DOP	0.186	44.905	12	87.667	90	7.67
T5	BW	0.305	109.715	31.333	132.031	-1.332	12.527
	DOP	0.153	54.327	17	96.333	90	6.31
T6	BW	0.314	113.587	36.13	150.519	-0.431	12.912
	DOP	0.165	40.846	15.333	86	90	6.796
T7	BW	0.236	76.567	18	103.347	-0.573	9.709
	DOP	0.165	44.974	10	129	90	6.796
T8	BW	0.272	104.131	10.783	161.391	-0.996	11.166
	DOP	0.156	46.603	7.576	142	90.868	6.408
T9	BW	0.316	112.762	31.761	165.609	-0.428	13.009
	DOP	0.17	46.029	5	93.333	90	6.99

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VII. DESIGN OF EXPERIMENT

Process parameters and their levels

Table 4.1 Process parameters and their levels

Levels	Process parameters		
	AMPS	VOLT	ROOT GAP
1	140	22	1
2	160	24	1.5
3	180	26	2

7.1 ANORTHOGONAL ARRAY L9 FORMATION

TRIAL NO.	DESIGNATION	AMPS	VOLT	ROOT GAP
1	A ₁ B ₁ C ₁	140	22	1.0
2	A ₁ B ₂ C ₂	140	24	1.5
3	A ₁ B ₃ C ₃	140	26	2.0
4	A ₂ B ₁ C ₂	160	22	1.5
5	A ₂ B ₂ C ₃	160	24	2.0
6	A ₂ B ₃ C ₁	160	26	1.0
7	A ₃ B ₁ C ₃	180	22	2.0
8	A ₃ B ₂ C ₁	180	24	1.0
9	A ₃ B ₃ C ₂	180	26	1.5

7.2 EXPERIMENTAL DATA

IMPACT STRENGTH (ANALYSIS OF RESULT)

IMPACT STRENGTH AND S/N RATIOS VALUES FOR THE EXPERIMENTS

TRIAL NO.	DESIGNATION	AMPS	VOLT	ROOT GAP	IS	SNRA1
1	A ₁ B ₁ C ₁	140	22	1.0	36	31.1261
2	A ₁ B ₂ C ₂	140	24	1.5	47	33.4420
3	A ₁ B ₃ C ₃	140	26	2.0	18	25.1055
4	A ₂ B ₁ C ₂	160	22	1.5	22	26.8485
5	A ₂ B ₂ C ₃	160	24	2.0	138	42.7976

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6	A ₂ B ₃ C ₁	160	26	1.0	54	34.6479
7	A ₃ B ₁ C ₃	180	22	2.0	70	36.9020
8	A ₃ B ₂ C ₁	180	24	1.0	32	30.1030
9	A ₃ B ₃ C ₂	180	26	1.5	22	26.8485

Taguchi Analysis: IS versus AMPS, VOLT, RG

Level	AMPS	VOLT	ROOT GAP
1	29.89	31.63	31.96
2	34.76	35.45	29.95
3	31.28	28.87	34.93
Delta	4.87	6.58	5.89
Rank	3	1	2

Response Table for Signal to Noise Ratios
Larger is better

Factor	TYPE	LEVELS	VALUES
AMPS	FIXED	3	140,160,180
VOLT	FIXED	3	22,24,26
RGAP	FIXED	3	1.0,1.5,2.0

General Linear Model: IMPACT versus AMPS, VOLT, RGAP

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7.3 ANALYSIS OF VARIANCE FOR IMPACT, USING ADJUSTED SS FOR TESTS

SOURCE	DF	SEQ SS	ADJ SS	ADJ SS	F	P	% of contribution
AMPS	2	2378	2378	1189	0.83	0.547	21
VOLT	2	2690	2690	1345	0.94	0.516	23
RGAP	2	3334	3334	1667	1.16	0.462	29
ERROR	2	2867	2867	2867	1.433		27
TOTAL	8	11264					100

S = 37.8609 R-Sq = 74.56% R-Sq(adj) = 0.00%

VIII. RESULT & CONCLUSION

GMAW welding can be used successfully to join SA387. The processed joints exhibited better mechanical and metallurgical characteristics. The joints exhibited 90-95% of parent material's Hardness value. The specimen failures were associated depending upon the improper changes of heat value. According to experimental investigation found out the input parameter value AMPS 160 VOLT-22 ROOT GAP is 1.5 is the best value and it does not create any major changes and failures in the testing process. The toughness value of the GMAW welded SA387 steel was comparatively moderate value (AMPS 160 VOLT-22 ROOT GAP- 1.5) than other value. It also induces high tensile strength. According to the Taguchi design and optimized parameter is value for the 10 mm plate of sa387 steel is AMPS 180 VOLT-22 ROOT GAP- 1.5.

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