The study of microstructural and mechanical properties of butt-welded plates using MIG welding- A literature review

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Abstract - *MIG welding parameters are the most important factors affecting weld joint quality, productivity and cost. Weld size, shape, and penetration depend on a number of parameters. Much research has been done on the effects of variables on processes. Weld joint quality is directly affected by weld input parameters.*

Key Words: MIG welding, heat input, weld quality.

INTRODUCTION

Metal Inert Gas welding is defined as arc welding using a continuously fed consumable electrode and the shielding gas. The arc is created between the bare consumable electrode and the work piece. The shielding of molten weld pool is done by supplying the shielding gas (usually inert gas such as Helium, Argon and mixture of both or sometimes combined with oxygen). It produces high quality welds and yields higher productivity.

Power Source for MIG welding

Depending upon the electrode diameter, material and electrode extension is required. Either constant voltage or constant current type of the welding power source can be used in MIG welding.

For smaller diameter electrodes (< 2.4mm) where electrical resistive heating controls the melting rate predominantly, constant voltage power source (DCEP) is used to take advantage of the self-regulating arc. In case of large diameter electrode constant current power source is used with variable speed electrode feed drive system to maintain the arc length.

Shielding gases used for MIG welding

1.Argon 2.Helium 3.Carbon Dioxide

Shielding gas affects the width of weld bead and depth of penetration owing to difference in heat generation during welding.

Effect of Process Parameters

1.Arc Voltage – directly affects the width of weld bead. An increase in arc voltage in general increases the width of theweld.

2. Welding Current – is primarily used to regulate the overall size of weld bead and penetration. Too low welding current results pilling of weld metal on the faying surface in the form of bead instead of penetrating into the work piece.

3. Welding speed – increase in welding speed reduces the penetration.

Types of Metal Transfer in MIG welding

1.Typical set transfer 2.Short circuit transfer3.Globular transfer 4.Spray transfer

METHODOLOGY

In this review paper, various articles related to MIG welding has been collected and comparative analysis has been carried out on how welding parameters are affecting microstructure and mechanical properties in MIG welding process.

LITERATURE REVIEW

H.T Zhang (2007) & JC Feng (2007) studied the microstructure and properties of aluminum-zinc coated steel lap joints fabricated by a modified metal inert gas CMT weld brazing process. It was found that the type and thickness of the hard intermetallic layer formed at the steel-weld metal interface during the welding process varies with the heat input. Tensile test results show that the welding process can provide solid aluminum zinc coated steel joints.

Shaohua Yan el at (2014) studied hybrid fiber laser metal inert gas (MIG) welding which is an advanced joining technique increasingly used in modern industries. In this article, hybrid fiber laser MIG welding was applied to join 5 mm thick AA6005-T5 alloy used for high-speed rail car bodies. The mechanical properties of hybrid welded joints were investigated. Results showed that the hybrid welded joint had better mechanical properties than the MIG joint. However, there is still a loss of strength in hybrid welded joints compared to the base metal. The cause of decrease in strength was investigated in terms of microstructure and evaporation of reinforcing elements.

D. Gery el at (2005) presents a model of a moving heat source based on Goldak's double ellipsoidal heat flux distribution. A C++ program was developed to implement the heat input to the thermal finite element simulation of plate butt welds. The transient temperature distribution and temperature fluctuation of the weld plate during welding were predicted, and the molten zone and heat-affected zone were obtained. The effects of heat source distribution, energy input and welding speed on temperature change were further investigated.

M. Ericsson el at (2003) tells us about the purpose of his study was to determine whether the fatigue strength of friction stir welding (FS) is affected by welding speed and to compare the fatigue results with those of conventional arc welding processes (MIG pulse and TIG). Al-Mg-Si alloy 6082 was FS welded under T6 and T4 temperature conditions and pulsed MIGand TIG welded at T6. Post-weld aging treatment was applied to the T4 welding material. Results show that welding speed does not significantly affect the mechanical and fatigue properties of FS welds in the test range representing low and high commercial welding speeds. However, significantly lower welding speeds improved fatigue performance, presumably due to the increased amount of heat delivered to the weld per unit length. MIG impulse and TIG welding showed lower static and dynamic strength than FS welding. This is consistent with previous comparative studies in the literature on fusion fatigue strength (MIG) and FS welding. TIG welding had better fatigue performance than MIG pulse welding. The softening of the alloy around the weld line is modelled. A good description of the hardness profile across the weld as a function of welding speed was obtained using a model with no adjustable parameters. The softening before the friction stir welding tool was also estimated. Complete softening is expected at low welding speeds and partial softening is expected at high welding speeds.

V.S.R Murti el at (1993) tells how a special grade of High Strength Low Alloy (HSLA) steel developed for armor applications is now welded by SMAW. Here its weldability was studied by Auto-MIG welding with 309L electrode wire. This results in faster welding and deposition speeds and deeper penetration. HSLA steel is difficult to weld because it has a high carbon equivalent and as a result is prone to cracking at low and high temperatures. The cooling rate is higher compared to SMAW where the slag cover produces a lower cooling rate of the weld bead. Similarly, with Auto-MIG welding, high welding speeds can introduce air into the weld, leading to contamination. However, in multi-pass welding mode, the bead is tempered and the residual stresses are reduced. Welding speed can also be appropriately selected to control the heat input, an important parameter that affects the microstructure and mechanical properties of the melt zone. Heat input is defined by the formula: IV/1000S (kJ/mm). Therefore,it is possible to change the heat input rate by changing the voltage and current settings, but this is not desirable. Highervoltages can change the bead shape and melting extent, affecting the resulting microstructure, destabilizing the arc and causing spatter. Variations in current are unacceptable due to the small recommended range of current settings for a given wire. Therefore, in this study, the heat input rate varies with different welding speeds. These were selected in 6 steps between 250 and 600 mm/min, resulting in a corresponding heat input range of 1.9 to 0.8 kJ/mm.

Shih Jing-Shiang el at (2011) tells that this study uses a combination of principal component analysis (PCA) and the Taguchi method to optimize several quality characteristics of metal inert gas (MIG) arc welding of aluminum foam panels. The quality characteristics examined are the microhardness and bending strength of the welded part. The eight control factors selected are filler metal type, MIG current, welding speed, MIG gas flow, workpiece gap, MIG arc angle, groove angle, and electrode extension length. Test results show that the optimum combination of parameters for the MIG welding process is A2 (filler metal: type number 5356), B3 (MIG current: 100 A), C1 (welding speed: 80 mm/min). , D (MIG gas flow rate: 13 l/min), E2 (work gap: 1.7 mm), F3 (MIG arc angle: 50°), G3 (groove angle: 20°), and H1 (electrode extension length: 15 mm) .In addition, from the results of analysis of variance (ANOVA), it was found that B (MIG current), C (welding speed), and E (work gap) are themost important control factors in process design, and strict control is required. Test results also show that optimal process design can actually improve multiple quality attributes of MIG-welded aluminum foam panels.

Junyu Xue el at(2018) studies hybrid laser metal inert gas (MIG) welding-brazing which was employed to achieve butt dissimilar metal joining of 6061-T6 aluminum alloy and 304 stainless steels. The effects of laser power and welding speed on wettability, intermetallic compound (IMC) layer microstructure, and bond strength with and withoutreinforcement were investigated. The results show that the diffusion width of molten metal on both sides of the steel increases with welding heat input, and the maximum diffusion width on both sides of the steel is 5.7 and 4.8 mm, respectively, for a welding speed of 5 mm/s and 1000 W laser power. With increasing heat input, the overall thickness of the IMC layer increased and its morphology changed. The ultimate tensile strength of the joint without reinforcement was improved to 180 MPa at a welding speed of 5 mm/s and a laser power of 1000 W. The tensile strength of joints with reinforcement was up to 200 MPa (70% of the tensile strength of 6061-T6). Fracture occurred in the heat affected zone of 6061-T6 aluminum alloy.

H. Tong el at (2003) says that pulsed AC metal inert gas welding is the preferred method for joining aluminum alloy sheets due to its large gap tolerance, low heat input and avoidance of burn through. However, at welding speeds above 2 m min-1, low heat input is no longer an advantage as poor penetration becomes a problem. This problem can be solved by irradiating the laser light near the arc, and penetration can be controlled by adjusting the laser output.

This means that thin aluminum alloy sheets can be joined at a high speed of 4 m min-1 with sufficient gap tolerance. Furthermore, investigation of the effect of laser beam diameter on the resulting welds of sheet metal indicates that a defocused laser beam with a diameter of several millimeters can further improve the ability to fill the joint gap and tolerance to torch alignment deviations. is showing. As a result, high power diode lasers with relatively thick beam waists are well suited for this application.

Faruk Varol el at (2013) studied, a 1.5 mm thick TRIP 800 (transformation induced plasticity) steel plate was connected to a copper-based (CuAl8) wire by a gas metal arc brazing technique. Specimens were made with two types of connections: butt joints and lap joints. Both types ofsoldering were performed at eight different arc voltages and welding currents of 45, 50, 55, 60, 65, 70, 75 and 80 A. Cu 6100(CuAl8) wire, which is mainly made of copper, wasused as filler metal. After the soldering operation was completed, the tensile properties of the joints were measured and the micro- and macrostructure of the joints were investigated to study the joinability of TRIP 800 steelby gas metal arc brazing.

Eshan Gharibshahiyan el at (2011) tells that the heat-affected zone (HAZ) can change the microstructure and residual stresses, thus significantly affecting the properties of welded joints. In this work, the effects of welding parameters and heat input on HAZ and grain growth were investigated. The role of grain size on hardness and toughness of low-carbon steelshas also been studied. It has been observed that at high heat inputs coarse grains appear in the HAZ and the hardness values in this zone are low. For example, increasing the voltage from 20 V to 30 V reduced the grain size number from 12.4 to 9.8 and the hardness from 160 to 148 HBN. A high heat input and a slow cooling rate cause the austenite grains to become smaller, resulting in the formation of fine-grained polygonal ferrite at ambient temperature.

RESULTS AND DISCUSSIONS

1. Different metal joining of Aluminum to galvanized steel sheet without cracking is possible by means of a modified metal inert gas (CMT) welding–brazing process in a lap joint.

2. The width of the HAZ in hybrid laser-MIG welded joints is narrower than that of the MIG welded joint. Although the tensile strength of the welded joints can be enhanced by using hybrid laser-MIG welding, there is still loss of strength in the hybrid laser-MIG welded joints. Energy input rate has an obvious effect on temperature values in areas closed to HAZ in the welded plate. There is an approximate linear relationship between the change of temperature and energy input. The increase of the welding speed causes temperature decrease mainly in FZ but has a less effect to the areas outside of FZ and HAZ.

3. Fatigue and Mechanical properties of the Friction Stir welds are comparatively independent of speed of welding in the range of low to high commercial welding speed in this alloy. Additional decrease in speed showed improvement in properties.

4. HSLA steel exhibits satisfactory weldability with a 309L wire electrode on an Auto-MIG welder. At all of the welding speeds employed (which also govern the heat input rate), there was no incidence of under-bead or fusion-zone cracking. The microstructure of the fusion zone was invariably austenite with 5 to 10% ferrite. The hardness in the HAZ and weld zone reduces with heat input.

5. Increased power of laser and decreased speed of welding created a higher welding heat input. As the heat input of welding increased, the rear and front spreading widths of the molten metals on the surface of steel were increased ignoring the interaction of other parameters.

6. The AC pulsed MIG process can supply effectively the desired deposit metal for gap bridging and avoid excessive heat input. Furthermore, the feature of low heat input in acpulsed MIG welding provides the flexibility to add laser power to the vicinity of the arc so that penetration depth isreadily controlled.

7. HSLA steel exhibits satisfactory weldability with a 309L wire electrode on an Auto-MIG welder. At all of the welding speeds employed (which also govern the heat input rate), there was no incidence of under-bead or fusion-zone cracking. The microstructure of the fusion zone was invariably austenite with 5 to 10% ferrite. The hardness in the HAZ and weld zone reduces with heat input.

S no	Author	Title of the Paper	Type of the Material Used	Type of welding Process	Types of Mechanical Testing
1	H.T. Zhang, J.C. Feng(2006)	Interfacial Microstructure and Mechanical Properties of Aluminium–Zinc-Coated Steel Joints Made by A Modified Metal Inert Gas Welding–Brazing Process	Aluminium And Zinc Coated Steel	Metal Inert Gas Welding	1. Hardness 2. Tensile Test
2	Shaohua Yan, Hui Chen(2014)	Hybrid Laser-Metal Inert Gas Welding of Al-Mg-Si Alloy Joints: Microstructure and Mechanical Properties	Al-Mg-Si Alloy	Hybrid Laser-Metal Inert Gas Welding	1. Hardness 2. Tensile Test
3	D. Gery a, H. Long (2005)	Effects Of Welding Speed, Energy Input and Heat Source Distribution on Temperature Variations in Butt Joint Welding	Low Carbon Steel (0.1% Carbon)	Thermal Simulation of Plate Butt Joint Mig Welding Processes	1. Temperature Distributions Effects Of Welding Process Parameters
4	M. Ericsson, R. Sandstro(2002)	Influence Of Welding Speed on The Fatigue of Friction Stir Welds, And Comparison with Mig and Tig	Al–Mg–Si Alloy 6082	Friction Stir Welding, And Mig and Tig	1. Hardness 2. Tensile Test 3. Fatigue Strength
5	V.S.R. Murti, P.D. Srinivas(1993)	Effect Of Heat Input on The Metallurgical Properties of HSLA Steel in Multi-Pass Mig Welding	HSLA Steel	Multi-Pass Mig Welding	1. Tekken Test 2. Swinden Test 3. Metallographic And Composition Analysis 4. Hardness Tests
6	Jing-Shiang, Tzeng Yih-Fong (2010)	Principal Component Analysis for Multiple Quality Characteristics Optimization of Metal Inert Gas Welding Aluminum Foam Plate	Aluminum Foam Plate	Metal Inert Gas Welding	1.Microhardness Test
7	Xue, Yuanxing Li (2017)	Effects Of Heat Input on Wettability, Interface Microstructure and Properties of Al/Steel Butt Joint in Laser-Metal Inert-Gas Hybrid Welding-Brazing	Aluminium And Steel	Laser-Metal Inert-Gas Hybrid Welding	1. Weld Appearance and Wettability Microstructure Analysis Tensile Test Analysis Hardness Test
8	ong, T. Ueyama (2002)	High Speed Welding of Aluminium Alloy Sheets Using Laser Assisted Alternating Current Pulsed Metal Inert Gas Process	Aluminium Alloy	Laser Assisted Alternating Current Pulsed Metal Inert Gas Process	Tensile Test Analysis Hardness Test
9	Varol, Erman Ferik(2013)	Influence Of Current Intensity and Heat Input in Metal Inert Gas-Brazed Joints of Trip 800 Thin Zinc Coated Steel Plates	Zinc Coated Steel Plates	Metal Inert Gas Welding	Tensile Test Macro And Micro Hardness
10	Ehsan Gharibshahiyan , Abbas Honarbakhsh Raouf(2010)	The Effect of Microstructure on Hardness and Toughness Of Low Carbon Welded Steel Using Inert Gas Welding	arbon Welded Steel	Metal Inert Gas Welding	1. Toughness 2. Hardness 3. Impact Test 4. Microstructure

Table: 1 Comparison of Materials used, Welding types, Mechanical testing conducted.

CONCLUSIONS

(i) It was found that the nature and the thickness of the high-hardness intermetallic compound layer which formed at the interface between the steel and the weld metal during the welding process varied with the heat inputs.

(ii)The results depicts that the hybrid joint welds have better mechanical properties than that of the Metal inert Gas joints. However, there is still strength loss in the hybridwelded joints relative to the base metal.

(iii)The distributions of transient temperatures and variations of temperature of the welded plates during welding were assumed and the heat affected zone and fusion zone were obtained.

(iv)The MIG-pulse showed lower static and dynamic strength than the FS welds.

(v)High Strength Low Alloy steels are difficult to weld due to their high carbon content and consequent susceptibility to hot- and cold-cracking.

(vi)Taguchi methods coupled with Principal component analysis (PCA) are employed in the study for different quality characteristics optimization of MIG arc welding aluminum foam plates.

(vii)A dissimilar metal butt joint of 6061-T6 aluminum alloy and 304 stainless steel was achieved using laser metal inert gas (MIG) hybrid weld brazing. The effects of laser power and welding speed on wettability, intermetallic compound (IMC) layer microstructure, and bond strength with and without reinforcement were investigated.

(viii)AC pulsed metal inert gas welding is a suitable process for joining aluminium alloy sheets because of its great gap tolerance and low heat input, which assists in avoiding burn through. However, when welding speed is higher than 2 m min-1 the low heat input is no longer an advantage since lack of penetration becomes a problem.

(ix)After the soldering operation was completed, the joint tensile properties were measured and the micro-andmacrostructure of the joint were examined to confirm the weldability of TRIP 800 steel by gas metal arc brazing.

(x)The heat-affected zone HAZ can change the microstructure and residual stresses, thus significantly affecting the properties of welded joints. In this work, the effects of welding parameters and heat input on HAZ and grain growth were investigated. The role of grain size on hardness and toughness of low-carbon steels has also been studied.

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