Investigating the characterization of Magnetically Impelled Arc Butt welding

Nandakumar N [1], Nandhini P [2],

[1.] *Assistant Professor (Sr. Gr), Department of Mechanical Engineering, Government College of Technology, Coimbatore, Tamilnadu*
[2.] *PG Scholar, Department of Manufacturing Engineering, Government College of Technology, Coimbatore, Tamilnadu, India.*

***Abstract* — Magnetically impelled arc butt (MIAB) welding process uses a rotating electromagnetic arc as its heat source and preheats the welding region which is known as an efficient method for pipe butt welding. The arc generated in the gap of the pipe butt joints is rotated along the circumferential weld line by the electromagnetic force resulting from the interaction of the arc current and the magnetic field in the gap. The paper presents the MIAB welding of thin walled tubes accomplished with a longitudinal electro magnetization system, designed for possibilities of the magnetic flux concentration on the tube wall. The main stages of the process are presented, starting with arc initiation, to creation of molten metal, upsetting and ending with the weld achievement. Experiments are performed in MIAB welding of Low carbon Steel tubes based on half factorial design. Based on the design of experiments investigation were done for analysing the upset current and reducing arc stabilization time.**

***Keywords* - Magnetically impelled, arc rotation, butt welding, Electromagnetic, arc current, half factorial design.**

I. Introduction

Magnetically Impelled Arc Butt (MIAB) welding is a fusion welding technique which generates constant heating at the joint through rapid rotation of an arc. The progress of current carrying conductor in magnetic field is a well established fact in electrical system. The direction of rotation of arc is defined by the principle Fleming's left hand rule. This rotation results from forces imposed on the arc by an external magnetic field and the interactions between an arc both an applied and induced magnetic field. MIAB welding is a solid state welding process for tubes and pipes in which heat is generated prior to forging by an electric arc moving along the peripheral edges of the weldment with the aid of an external magnetic field. In this method it relies on an electric arc to generate the necessary temperature to melt the faying surfaces being welded. On the basis of welding parameters, Half factorial design technique were used with different combinations of arc rotation current, upset current and arc rotation time were investigated. MIAB welding trials are performed with these parameters to investigate the mechanical and metallurgical properties to find out the best suited parameters for efficient welding.

II. REVIEW OF LITERATURE

Arungalai Vendan S, [1] et al Strength assessment using destructive testing on MIAB welded alloy steel tubes and subsequent techno-economical evaluation is studied in this paper in relation to current & time of arc heating and upset time and force. Steffen and Welz [2] investigated a variety of conditions and their effect on arc behaviour, including the use of internal and external magnets and different power sources. Steel tubes of various dimensions were utilized.

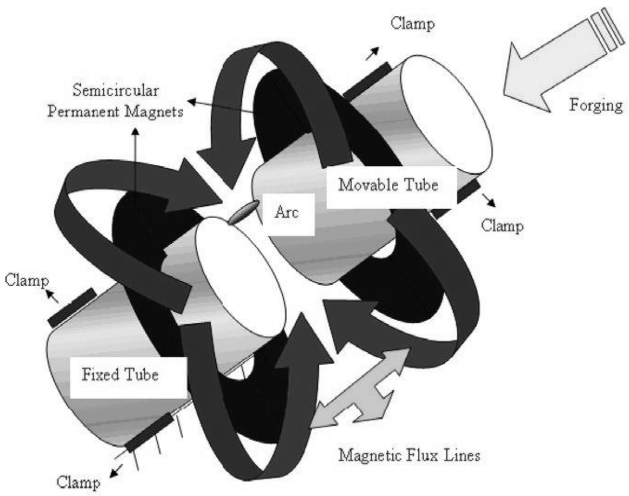

Fig. 1 MIAB welding Principle

Nentwig and Ludwig [3] also studied and contrasted the effect of an internal verses external magnetic coil on arc behaviour during MIAB welding of tubes. It was determined that the maximum radial flux density in the weld gap is always along the edge of the tube closest to the coil. When welding ferromagnetic materials, the magnetic flux density drops sharply across the wall thickness of the tube.

Nentwig and Schmidt [4] used iron filings to study and contrast the radial and axial magnetic field lines in the joint of ferrous and non-ferrous materials. These experiments showed that the location of the joint relative to the applied magnetic field can have a large impact on whether the axial or radial portion of the magnetic field dominates at the joint. They also observed irregularities in the distribution of the magnetic field in the presence of ferrous materials.

III TECHNICAL BACKGROUND

It consists of two concentric solenoids surrounding the ends of the pipes to be joined. The polarities are arranged in opposition. This essentially cancels the axial component of the magnetic field on the weld midline, producing a radial field in

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the weld gap around the full circumference. An arc is struck in the gap between the pipes by applying a suitable DC voltage to the two pipes. The arc current and the radial magnetic field are at right angles to each other producing a Lorentz force on the arc current that is right angles to both (by Fleming's left hand rule) the arc travels at high velocity around the pipe circumference.

The net axial magnetic field and the Lorentz force propel the arc to the centre of the pipe. The arc moves at high speed around the circular path, and develops a force pushing the arc outwards. As a result the arc speeds up, at a certain speed and the centrifugal force cause the arc flips from the inside of the pipe to outside. At that moment the joining surfaces reach the suitable welding temperature, an upsetting force is applied to perform joining. The electromagnetic force density can be expressed as the following vector equation:

$$f = J \times B$$

Where, f is the electromagnetic force density and J is the electric current density

IV PROCESS DESCRIPTION

When current flows in the tube, an external magnetic field is applied across the flow, so that the tube experiences a force perpendicular both to the arc field and to the direction of the current flow. Magnetically impelled arc is carried out in four stages.

Arc Initiation
Arc Rotation
Arc Stabilization
Upsetting

A. *Arc Initiation*

Tubes are coaxially fixed with their abutting surfaces in contact. A DC arc welding source is connected to the tubes and opposite magnetic fields is applied in the tubes abutting area by means of the solenoids. The arc initiation occurs on the tubes inner diameter.

B. *Arc Rotation*

Arc starts rotating due to the interaction between the welding current Iw and the magnetic field B existing in the gap. The electric arc begins accelerating slowly and moves from the tubes inner diameter to the outer diameter.

C. *Arc Stabilization.*

Electric arc forms a continuous ring, in a uniform relative high frequency vibrant, due to the high rotating velocity. A thin uniform layer of molten metal on the tubes abutting surfaces forms, that ends when molten metal bridges appear between the tubes ends.

D. *Upsetting*

The formation of bridges is the right moment for upsetting. By upsetting, the molten metal mostly flashes, whilst the plasticized material from the tubes contact area flows, producing a transversal burr of barrel shape and the weld seam.

V EXPERIMENTAL WORK

The experimental procedure involved to investigate the characterization of the magnetically impelled arc welding process is as follows,

- Base Metal - Chemical Analysis
- Base Metal Characterisation (Microstructure & Hardness)
- Macro examination of welded tube sections by Stereo microscope with camera
- Micro examination of welded tube sections by Optical microscopy
- Hardness survey of welded tube sections by Vickers Micro hardness tester
- DOE – Plot by Minitab (software)

Table. 1 Welding parameters

SS No	I 2 (amp)	I 3 (amp)	T1 (sec)	T2 sec)	T3 (sec)	Hardness (VHN at 100g load)	UTS (mpa)
1	310	1000	1	6	12	194	443
2	280	600	1	6	8	196	432
3	280	1000	1	4	12	196	445
4	310	1000	1	4	8	203	471
5	280	600	1	6	12	181	459
6	310	600	1	4	8	170	373
7	310	1000	1	6	8	218	463
8	310	600	1	6	12	182	452
9	280	600	1	4	12	249	460
10	280	1000	1	4	12	194	445
11	280	1000	1	6	8	212	459
12	310	600	1	6	8	211	433
13	280	600	1	4	8	205	447
14	280	600	1	4	12	162	216
15	310	600	1	4	12	145	403
16	280	1000	1	4	8	205	455

A. *Welding parameters*

The analysis was done by DOE-half factorial design, in which different combinations of welding current and time are obtained. Welding trials were performed with these parameters to investigate the mechanical and metallurgical properties. Based on the DOE Arc Rotation Current (I_2), Upset Current (I_3) & Arc Rotation Current (T_3) can be varied for welding of the tubes. Parameters that are varied in the machine are denoted as follows.

I_2 = Arc rotation current
I_3 = Upset current
T_3 = Arc rotation time

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The Parameters that are kept constant throughout the process are Arc Initiation Time (T_1), Arc Stabilization Time (T_2), Upset Time (T_4) & Starting Current (I_1)

Starting Current I_1 = 310 amps
Arc Initiation Time T_1 = 1 second
Arc Stabilization Time T_2 = 3 seconds
Upset Time T_4 = 0.3 seconds

Gap distance between the two tubes before arc initiation is around 2mm to 3mm.

The T11 tube that is used for MIAB welding is of the following dimensions. The edges of the tubes are well prepared before welding for smooth joining of tubes during upsetting.

Tube length = 200 mm
Tube Outer Diameter = 44 mm
Tube Inner Diameter = 32 mm
Tube Thickness = 4.5 mm

Welding parameters based on the half factorial design were taken for analysis as shown in table.1 The MIAB practice utilizes a constant current power supply to provide the arcing current. As a result, the arc voltage is greatly dependent on setting of the arc gap between the two components being welded. Since voltage plays an important role in the MIAB welding process, it was determined to statistically analyze the effect of the gap. The gap setting refers the gap that was set to generate arc where the parts were fixture in the equipment. This gap becomes the arc gap upon initiation of the arc.

VI RESULTS AND CONCLUSION

The investigation on MIAB welded low carbon tubes were modelled and analysed. On the basis of, Design of Experiment - Half factorial design, different combinations of arc rotation current, upset current and arc rotation time are obtained.

Half factorial design - 3^3

• If arc rotation current (I_2) increases excess melting takes place and non uniform weld is observed

• Upset current (I_3) remove impurities at faying surfaces to be welded, and if applied at last few milliseconds just before forging to get a superior weld.

• Arc rotation time (T3) plays significant role in this MIAB welding process for better fusion temperature.

A. *Hardness testing*

Micro hardness testing of the sample is done by Vickers Micro hardness tester. The instrument uses square based diamond indenter with an included angle of 136 degree between opposite faces.

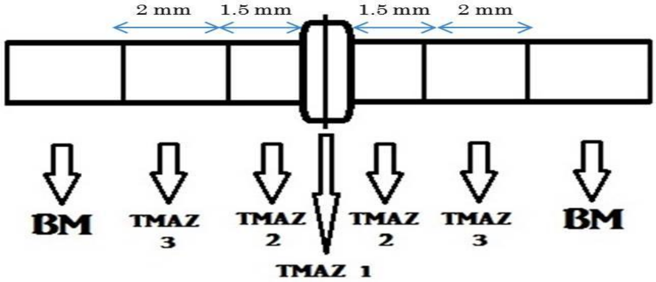

Fig. 2 Hardness testing range

The load applied is 100grams for a time period of 10 seconds. Hardness is taken along the weld interface region (both longitudinal and horizontal) at the distance of 0.5mm as shown in figure 2. The hardness of the weld for different regions is plotted in fig 3 with their main effects.

BM-TMAZ 3-TMAZ 2-TMAZ 1-TMAZ 2-TMAZ 3-BM

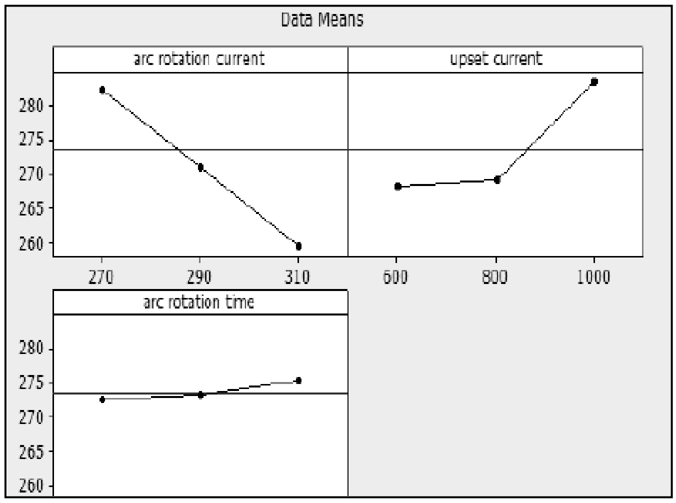

Fig. 3 Main effects for hardness

B. *Structural analysis*

The metallographic sample preparation was carried out using standard techniques. The specimen for macroscopic examination was taken on the transverse length of the weld joints by cutting and made flat by grinding operation.

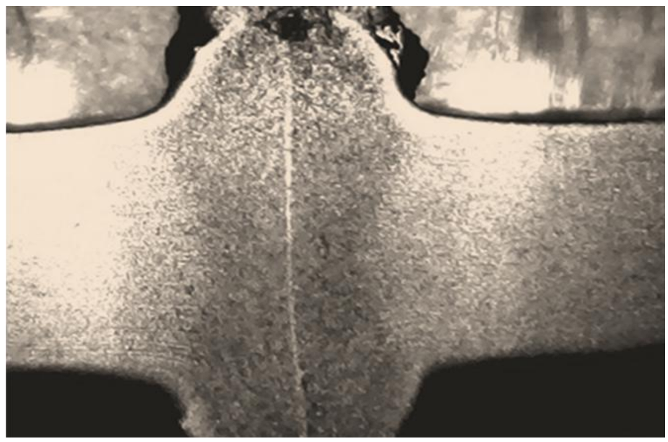

Fig. 4 Microstructural analysis

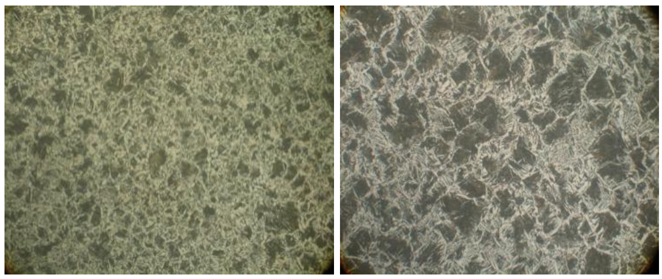

Fig. 5 TMAZ 2 TMAZ 1

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Among all the samples welded based on the structured DOE, Sample No.9 has hardness values consistent in the range of 249 VHN in the weld line as show in table 1. The hardness plunge between TMAZ 2 & TMAZ 1(Weld line) is negligible in this weld sample. This sample is subjected to Tension test and yields 460 MPa and also proves the sound weld strength and has higher strength than the Base Metal.

From the welded sample data's in table 1, low arc rotation current (280 amps) and low Upset Current (600 amps) for an arc rotation time of 12 second produces weld of superior quality. Longer arc rotation time is used for proper melting of the tube boundaries and upsetting at lower current values results in complete fusion of the metal to form the sound weld.

The Microstructure analysis for the Sample number nine shows superior integrity of the weld and hardness value of 249 VHN. The weld region consistency can be confirmed by examining the hardness along the weld line in figure 3 and it also shows consistent hardness values nearer to the weld region. The micro-structural analysis using optical microscope confirms that the microstructure formed is absolutely bainite in the weld line.

VII REFERENCES.

1. Kachinskiy, Krivenko, Ignatenko, "Magnetically Impelled Arc Butt Welding of Hollow and Solid Parts", Welding in the World, Vol. 46, no. 7/8, 2002, 49-56
2. Hiller, Schmidt, Breiksch, "Use of the Magnetarc Welding Process in the Production of Truck Cab Suspension Systems", ThyssenKrupp Techforum, December 2003, 40-43
3. Loebner, "Magnetarc Welding Theory and Practice", Second International Conference on Pipe Welding, London - 20-22 November 1979, Volume 1 - Paper 18, 29-37
4. Venkateswaran PR, Buvanshekaran G, Ganesh Kumar K. Investigations into arc rotation current behaviour for SA210 Gr. A tubes in MIAB welding process. WRI J;33:5e8
5. Welz, Nentwig, Schwarzkopf, "Experiments in Selective Control of Arc Movement when Welding with a Magnetically Impelled Arc", Welding and Cutting 5, 1989, E82-E84
6. Ganowski, "The Magnetarc Welding Process", Welding and Metal Fabrication, June 1974, 206-213
7. Steffen, Welz, "Pressure Welding of Tubes with a Magnetically Displaced Arc", Schweißen und Schneiden Translation, 4/1982, E70-E72
8. Kim JW, Choi DH. A study on the numerical analysis of magnetic flux density by asolenoid for magnetically impelled arc butt welding. Proc Inst Mech Eng B-J Eng Manuf 2003;217:1401e7.
9. Arungalai Vendan S, Manoharan S, Buvanashekaran G, Nagamani C. Development of a MIAB welding module and experimental analysis of rotational behavior of arc simulation of electromagnetic force distribution during MIAB welding of steel pipes using finite element analysis. Int J Adv Manuf Technol 2009;43:1144e2115.
10. Kuchuk-Yatsenko, et. al., "Control of the Arc Moving in a Narrow Gap Under the Effect of a Magnetic Field in Press Welding of Pipes", Welding International, 1988, no. 11, 965-968
11. Iordachescu D, Iordachesc M, Georgescu B, Miranda RM, RuizHervias J, Ocana JL. Technological windows for MIAB welding of tubes featuring original longitudinal magnetization system with peripheral solenoids. J Mater Process Technol 2010;210:951e60.
12. Taneko, Arakida, Takagi, "Analysis of Arc Rotation Velocity in Magnetically Impelled Arc Butt Welding", Welding International, 1987, Vol. 3, 247-253
13. Mori, Yasuda, "Magnetically Impelled Arc Butt Welding of Aluminum Pipes",Transactions of the Japan Welding Society, Vol. 21, No. 1, April 1990, 3-10
14. Johnson, Carter, Dinsdale, Threadgill, Wright, "Magnetically Impelled Arc Butt Welding of Mild Steel Tubing", Welding Journal, November 1979, 17-27
15. Kim J.W., Choi D.H., A study on the numerical analysis of magnetic flux density by a solenoid for magnetically impelled arc butt welding, Proceedings of the Institution of Mechanical Engineers, Part B, Journal of Engineering Manufacture, 217, 10, 2003, p. 1401- 1407
16. Kachinskiy V., Krivenko V., Ignatenko V., Magnetically Impelled Arc Butt Welding of Hollow and Solid Parts, Welding in the World, 46, 7/8, 2002, p. 49-56.

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