Nano World Journal

https://doi.org/10.17756/nwj.2023-s1-028

Research Article

Open Access

Effect of Three Poles Magnet on Weld Bead Characteristics in Autogenous GTA Welding Process on S355J2+N Steel

Prem Raj* **and J.S. Gill**

Department of Mechanical Engineering, Sant Longowal Institute of Engineering and Technology, Sangrur, Punjab, India

***Correspondence to:**
Prem Raj
Department of Mechanical Engineering, Sant Longowal Institute of Engineering and Technology, Sangrur, Punjab, India.
E-mail: premraj0911@gmail.com

Received: November 24, 2022
Accepted: April 03, 2023
Published: April 05, 2023

Citation: Raj P, Gill JS. 2023. Effect of Three Poles Magnet on Weld Bead Characteristics in Autogenous GTA Welding Process on S355J2+N Steel. *NanoWorld J* 9(S1): S139-S143.

Published by United Scientific Group

Abstract

The present study analyses combined effect of magnetic fields obtained by two types of magnetic configurations (NSN and SNS) on weld bead characteristics and microhardness in GTAW. For this analysis, a newly designed three-poles (E-type) electromagnet was installed to generate a combination of two symmetrically transverse external magnetic fields. Material selected for the experiment is high strength low alloy (HSLA); S355J2+N grade with 10 mm thickness. It was observed from the results that the symmetrically transverse magnetic fields are capable to enhance the weld bead appearance, weld width, shape, and microhardness. It was also observed that for different values of excitation current, magnetic fields generated with both configurations viz., NSN and SNS provide overall greater bead width, and higher penetration shape factor in comparison to specimens welded with conventional GTA welding. The configurations NSN and SNS of the E-type magnet provide improvement in penetration shape factor by 61.5% and 58%, respectively. These configurations are found to be more suitable for the purpose of weld cladding and hard facing. Whereas the microhardness can be improved by 6.7% and 8.2% under the magnetic configurations NSN and SNS, respectively.

Keywords

Gas tungsten arc welding, Three poles magnet, Magnetic fields, Weld bead characteristics

Introduction

Gas-tungsten arc (GTA) welding is performed to melt and join the two similar or dissimilar metals with the help of an electric-arc struck between the non-consumable tungsten electrode and the work surface under the shielding of inert gas. It is suitable for applications in manufacturing industries such as the shipbuilding, auto industry, and aerospace due to precision and high weld quality [1].

Weld bead characteristics, microstructure, mechanical properties are influenced by the arc force and arc shape which further depend upon the welding variables which includes arc voltage, welding current, arc travel speed, electrode to work surface distance, gas flow rate, etc. The arc pressure and heat input are quite less in GTA welding at low-level of current which results in lower penetration depth and lesser width of bead. Reducing the welding speed is a conventional solution to increase the depth penetration and bead width. Though, lowering the welding speed causes higher amount of heat accumulation and reduced welding efficiency which consequently leads to reduction in the strength in HAZ region due to coarsening of grains [2].

In recent years, research and development has increased and still going on strong due to the requirements and need to reduce energy consumption and better welding efficiency and performance characteristics. Many researchers have experimented on advanced developed methods such as hybrid arc welding, activated-gas tungsten arc (A-GTA) welding, and in recent, employing magnetic field in various arc welding to obtain better weld bead characteristics and performance for a specified welding variable.

The direction of current in GTA welding is along length of electrode which set up a magnetic field circumferentially to electrode and in the plane of the work surface that results in poor weld quality [3]. In order to counteract the influence of these magnetic field, Brown and co-authors implemented a magnet in 1962 to the welding processes to analyse the impacts of magnetic field on weld materials and obtained favourable results [4]. The externally applied magnetic field can also be used to adjust the arc pressure and arc shape, to refine grain size, improve solidification rate of weld molten pool, improve mechanical properties and overall weld bead quality [5]. Shakya et al. [1] employed both side electromagnets in GTAW process to produce combination of two co-axial magnetic field and observed that conical shape of arc was deformed into compressed elliptical shape and consequently enhancement in bead width. Pathak et al. [6] investigated the influence of intensity and frequency of magnetic field on weld bead characteristics and mechanical (tensile and impact) properties and they found the improvement in weld bead and weld joint strength. Chohan [7] used TIG welding process equipped with an external magnetic field and observed that solidification rate changes with magnetic field which results in the uniformity and refinement of grain size which leads to change in the microhardness.

The present experimental work is an attempt to study the further improvement in weld bead profile and mechanical properties by grain refinement in GTA welding process with the effect of externally employed transverse magnetic fields. To conduct the present study, a new technique using E-type magnet with variable poles such as north (N)-south (S)-north (N) (designated as NSN) and south (S)-north (N)-south (S) (denoted by SNS) has been deployed. The experimental results obtained with and without magnetic fields for bead width (w), penetration depth (d), penetration shape factor (w/d) and microhardness are revealed in this present study.

Materials and Methods

Material selected for the experiment is high strength low alloy (HSLA) steel; S355J2+N with dimensions of 150 × 50 × 10 mm. S355J2+N steel is reported suitable for applications in wind and waterpower plant, power generation, pressure vessels, pipes, mining equipment's, shipbuilding and offshore structures [8]. S355J2N can withstand an impact energy of 27 J at -20 °C.

The experimental set up consisted of applying external magnetic field to conventional GTAW set up as shown in figure 1. As shown in figure 1, welding table was mounted on the welding manipulator which is driven by a drive motor. Speed controller controls forward and backward movement of the welding table. An additional direct current (DC) power source with a current range of (0 - 6 A) was coupled with

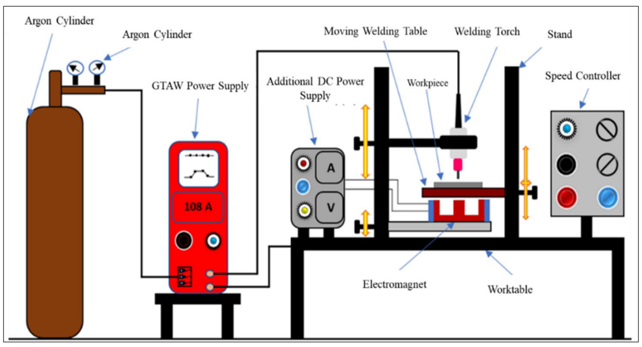


Figure 1: Schematic diagram of the experimental setup with E-type electromagnet.

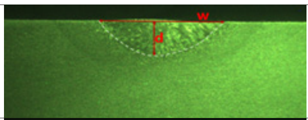
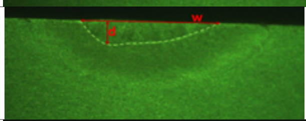
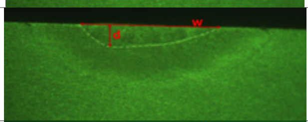
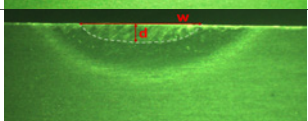
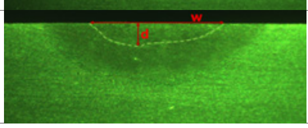
coils terminals to excite the three poles (E-type) electromagnet which resulted into generation of electromagnetic fields. Two magnetic configurations, north (N)-south (S)-north (N) (designated as NSN) and south (S)-north (N)-south (S) (designated by SNS) are obtained by conversion the directions of DC power supply where N and S denote north and south pole respectively. The magnetic field intensity represented by (B) was recorded with the help of Gaussmeter. The lines of magnetic fields act on arc in the transverse direction to weld which construct combination of two symmetrically transverse magnetic fields. Bead on plate experiments were performed to analyze the weld bead characteristics by using automatic autogenous GTA welding process equipped with electromagnet. The three poles (E-type) magnet were installed below the workpiece so that magnetic field intensity applied on arc and the molten pool completely. Welding parameters used in the experiment were welding current (150A), welding speed (10 cm/min), gas flow rate (14 L/min), arc length (3 mm), and the excitation current (I_m = 0 - 6 A). The experiments were carried out using two magnetic configurations (NSN and SNS) at different values of exciting current (I_m = 0 to 6A at the step interval of 1A). In this experimentation, both welding torch with tungsten electrode of 3 mm diameter and the electromagnets were held stationary while the specimens and worktable was moving at uniform welding speed of 10 cm/min. Argon (99% pure) was used for shielding gas with flow rate 14 L/min. The extraction of specimens was done by means of low temperature cutting process. A standard metallurgical method was used to prepare these specimens, and then they were etched using a Nital solution made up of 2% nitric solution. A macroscope was used to take macro-graphs of bead profiles and a 'welding penetration analysis system' software was used to calculate the dimensions of the bead (bead width and penetration depth) and are presented in table 1. In table, S_1 shows the bead geometry of the welded specimen using conventional GTA welding process while S_2 - S_7 and S_8 - S_{13} show the bead geometry under magnetic field with magnetic configurations NSN and SNS, respectively.

Results and Discussion

Influence of external transverse magnetic fields on width and penetration depth of weld bead

Comparison study of the bead width and penetration obtained on conventional GTA welding and GTA welding with assisted external magnetic field are illustrated in table 1. When excitation current, I_m is 0 A (i.e., without the application of magnet), bead width and penetration depth obtained are 4.61 mm and 1.43 mm, respectively. The measurement results of width and penetration of bead for all values of excitation current (i.e., I_m = 1 A, 2 A, 3 A, 4 A, 5 A, and 6 A) under both magnetic configurations NSN and SNS is illustrated by graphical represented in figure 2. It was examined that both the configurations alter the bead appearance and bead shape. It was noticed from the figure that with the application of both the magnetic configurations, the width of bead increases, and penetration depth decreases for whole values of excitation current (except I_m = 5A) as compared with conventional GTA welding process. It may be due to the fact that the E-type elec-

Table 1: Weld bead geometry with and without magnetic fields.

Sample	Bead Geometry	Bead Width, w (mm)	Penetration Depth, d (mm)	Penetration Shape Factor (w/d)
S_1		4.61	1.43	3.22
S_2		5.14	1.42	3.61
S_3		5.44	1.05	5.18
S_4		4.70	1.14	4.12
S_5		5.19	0.62	8.37
S_6		5.51	1.03	5.34
S_7		5.66	1.08	5.24
S_8		5.09	0.92	5.53
S_9		5.30	0.88	6.02
S_{10}		4.64	0.95	4.88
S_{11}		5.28	0.68	7.76
S_{12}		5.98	1.46	4.07
S_{13}		4.73	0.83	5.69

tromagnet form a combination of two symmetrically transverse magnetic fields which increase the thrust force on arc in the direction perpendicular to weld and can radiate the arc to disperse to greater surface area at work surface and normal to welding direction and it reverse the Margoni and Lorenz forces which leads to a wider bead and less penetration [1, 9]. The maximum bead width and corresponding penetration depth achieved under NSN configuration is 5.66 mm and 1.08 mm, respectively at I_m = 6 A and under SNS is 5.98 mm and 1.46 mm at I_m = 5 A. Results suggest that, in comparison to results obtained without a magnet, these magnetic configurations produced overall less penetration depth and higher bead width. Larger width and smaller penetration depth of weld are advantageous for weld overlays applications which consequently leads to reduction in dilution.

Influence of external transverse magnetic fields on penetration shape factor

Penetration shape factor is the proportion of width and penetration depth of weld bead. It affects metallurgical and mechanical characteristics of welds. Effect of E-type magnets on penetration shape factor is presented in table 1 and in figure 2 also. It was revealed from figure that penetration shape factor achieved without magnetic field is 3.22 which is lowest value as compared to the penetration shape factor obtained under both magnetic configurations for whole ranges of excitation current (viz., I_m = 0 A - 6 A). It is due the higher magnetic field intensity that leads spread of arc to larger surface area and shallow penetration as already explained. The maximum penetration shape factor obtained with configuration NSN is 8.37 at I_m = 4 A which is approximately 61% higher than that achieved (3.22) without magnetic field due to wider bead width (5.19) and shallow penetration (0.62). The maximum penetration shape factor obtained with configuration SNS is 7.76 at I_m = 4 A which is approximately 58% higher than that achieved (3.22) without magnetic field due to wider bead width (5.28) and shallow penetration (0.68). These configurations are quite favourable for weld overlays because wider bead width and shallow penetration are preferred. The optimum penetration shape factor is very important as wider bead width and lesser penetration alter the mechanical and metallurgical properties.

Influence of external transverse magnetic fields on microhardness

The values of Vickers microhardness in fusion zone (FZ)

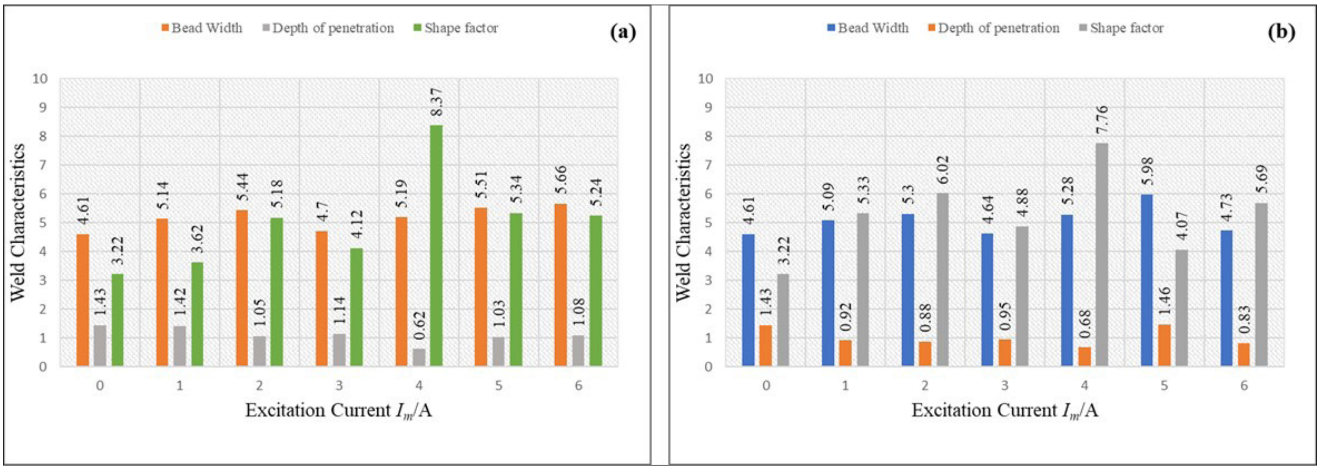


Figure 2: Graphical representation of weld bead width, depth of penetration and penetration shape factor with **(a)** configuration NSN and **(b)** configuration SNS.

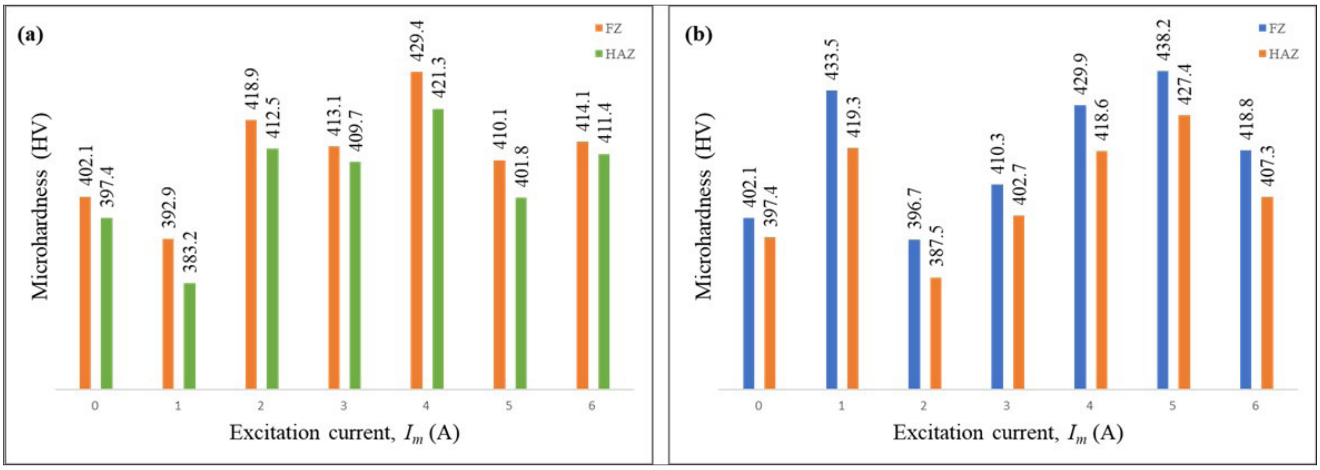


Figure 3: Microhardness with **(a)** configuration NSN and **(b)** configuration SNS.

as well as heat affected zone (HAZ) of the weld specimens with and without magnetic field were illustrated in figure 3. Microhardness values in FZ and HAZ of weld metal without application of magnetic field were 402.1 HV and 397.4 HV respectively while for the base metal it was found to be 187.5 HV. Maximum microhardness values in FZ and HAZ of the weld specimens obtained under the different magnetic fields corresponding to different values of excitation current for configurations NSN were noted to be 429.4 HV and 421.3 HV respectively, at I_m = 5 A and with configuration SNS were 438.2 HV and 427.4 HV respectively, at I_m = 5 A. It was observed from the graph that the overall trend obtained for microhardness values with different excitation current under both magnetic configurations was higher than that of without magnetic field. It may be due to the change of solidification rate with the application of magnetic fields that results in uniformity and refinement of grain size in microstructure of FZ and HAZ which in turns affects the microhardness [7, 10].

Conclusion

The present work can be successfully employed for improving the weld bead profile, weld quality and weld efficiency. It was revealed that the bead width increases with the application of both the magnetic configurations for whole values of excitation current as compared to the bead width obtained welding without magnetic field. Maximum bead width observed in configurations NSN and SNS was 5.66 mm and 5.98 mm respectively while minimum depth of penetration observed in configurations NSN and SNS was 0.62 mm and 0.68 mm respectively. Penetration shape factors were improved in configurations NSN and SNS by 58% and 61% respectively with magnetic field. Higher penetration shape factor is quite favourable for weld overlays because wider bead width and shallow penetration are preferred. It was observed that the microhardness was improved with the NSN and SNS configurations by 6.7% and 8.2%, respectively.

Acknowledgments

The authors are very much thankful to the Department of Mechanical Engineering, SLIET, Longowal, Welding Metallurgy lab, Prof. A.S. Shahi, Mr. Varinder Singh and Mr. Paramjeet Shakya for continuous and unconditional support to carry out these experimental investigations.

Conflict of Interest

There is no conflict of Interest.

Credit Author Statement

Prem Raj: Methodology, Experimental investigations, Data collection, Writing - original draft preparation, Writing - review and editing, Supervision. All the authors read and approved the manuscript.

References

1. Shakya P, Singh K, Arya HK. 2022. Influence of magnets on arc shape and bead geometry in gas tungsten arc welding. *Mater Manuf Process* 38(4): 401-408. https://doi.org/10.1080/10426914.2022.2075890
2. Baskoro AS, Amat MA, Arisoni B. 2021. Study of cross-combination and square-combination configuration magnetic field on tungsten inert gas welding. *Int J Automot Mech Eng* 18(2): 8677-8686. https://doi.org/10.15282/ijame.18.2.2021.05.0661
3. Senapati A, Mohanty SB. 2014. Effects of external magnetic field on mechanical properties of a welded MS metal through metal shield arc welding. *Int J Eng Trends Technol* 10: 297-303.
4. Baskoro AS, Fauzian A, Basalamah H, Kiswanto G, Winarto W. 2018. Improving weld penetration by employing of magnetic poles' configurations to an autogenous tungsten inert gas (TIG) welding. *Int J Adv Manuf Technol* 99: 1603-1613. https://doi.org/10.1007/s00170-018-2552-2
5. Wu H, Chang Y, Lu L, Bai J. 2017. Review on magnetically controlled arc welding process. *Int J Adv Manuf Technol* 91(9-12): 4263-4273. https://doi.org/10.1007/s00170-017-0068-9
6. Pathak D, Pandey SP, Singh RP, Balu V. 2022. Influence of external axial magnetic field on shielded metal arc weld properties for high strength low alloy steel. *Mater Today Proc* 62: 2748-2754. https://doi.org/10.1016/j.matpr.2021.12.296
7. Chohan JS. 2021. Investigation of hardness and tensile strength in TIG welded specimens under influence of external electro-magnetic field. *Mater Today Proc* 37: 3498-3500. https://doi.org/10.1016/j.matpr.2020.09.394
8. Wallerstein D, Vaamonde E, Prada A, Torres EA, Urtiga Filho SL, et al. 2021. Influence of welding gases and filler metals on hybrid laser-GMAW and Laser-FCAW welds. *Proc Inst Mech Eng C J Mech Eng Sci* 235(15): 2754-2767. https://doi.org/10.1177/0954406220957053
9. Singh RP, Raghuvanshi D, Pal A. 2021. Effect of external magnetic field on weld width and reinforcement height of shielded metal arc welded joints. *Mater Today Proc* 38: 112-115. https://doi.org/10.1016/j.matpr.2020.06.107
10. Queiroz AVD, Fernandes MT, Silva L, Demarque R, Xavier CR, et al. 2020. Effects of an external magnetic field on the microstructural and mechanical properties of the fusion zone in TIG welding. *Metals* 10(6): 714. https://doi.org/10.3390/met10060714