

A Review on Magnetically Impelled Arc Butt (MIAB) Welding: Process Mechanisms, Modelling and Applications

G. Pugalvendhan¹, Dr. B. Anandavel², and Dr. K. Venkatesan³

¹PG Student, Department of Metallurgical Engineering, Government College of Engineering, Salem - 11

²Assistant Professor [Sr. Grade], Department of Metallurgical Engineering, Government College of Engineering, Salem - 11

³Head of the Department, Department of Metallurgical Engineering, Government College of Engineering, Salem - 11

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Abstract—Magnetically Impelled Arc Butt (MIAB) welding is a solid-state or near-solid-state joining process that uses a rotating electric arc driven by an external magnetic field to heat and forge pipe and tube ends. The process has gained significant industrial attention for its potential to replace conventional resistance, friction, and flash-butt welding in automotive, power, and defence applications. This review consolidates research on MIAB welding mechanisms, parameter optimization, finite-element modelling, metallurgical behaviour, and control strategies. Experimental and numerical studies consistently report that welding current and arc voltage dominate arc rotation and heating uniformity, while magnetic coil current and voltage exert secondary influence. Mechanical characterization demonstrates that MIAB joints exhibit high strength and ductility comparable or superior to base materials in steels, cast irons, and dissimilar combinations. Emerging developments in automatic control, genetic programming, and hybrid dissimilar applications reveal the process's scalability for high-pressure and corrosion-resistant structures. Remaining challenges include limited accessibility, complex magnetic field control, and lack of standardized qualification procedures. The review highlights the need for integrated modelling-control frameworks and process automation to enable MIAB welding's widespread adoption in next-generation manufacturing systems.

Index Terms—MIAB welding, magnetically impelled arc, solid-state welding, finite-element modelling, process parameters, dissimilar joining.

I. INTRODUCTION

Magnetically Impelled Arc Butt (MIAB) welding, also known as rotating-arc butt welding, is an advanced joining process developed in the 1970s to overcome limitations of resistance and friction welding for tubular components. It utilizes a direct-current (DC) arc between the pipe ends, rotated circumferentially by an external magnetic field, followed by axial forging to form a solid-phase joint.

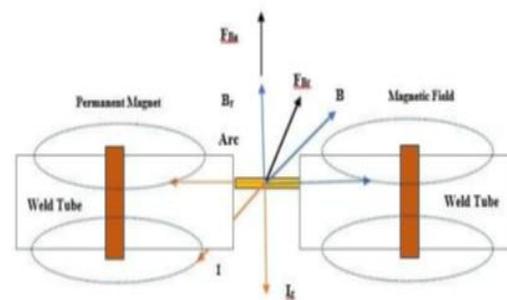


Fig.1. Principle of MIAB Welding

The absence of filler, shielding gas, or rotation of components makes MIAB a clean, rapid, and energy-efficient process suitable for high-strength steels and dissimilar materials. Recent advances in power-electronic control, electromagnetic modelling, and mechanical characterization have led to renewed academic and industrial interest in this technology.

II. MIAB WELDING FUNDAMENTALS

The MIAB process comprises three stages: arc initiation, magnetic arc rotation, and forging. The arc's circumferential motion ensures uniform heating of the tube ends before solid-state consolidation. Arc rotation speed (w) depends primarily on welding current, arc voltage, coil current, and coil voltage [6]. Excessive current leads to melting and expulsion, while insufficient current yields incomplete bonding. The proper combination of magnetic flux density and current–time control is crucial to achieving defect-free welds. Because the process operates without shielding gas or filler, the metallurgical integrity depends solely on heating uniformity, expulsion of oxide layers, and rapid solid-state bonding.

III. LITERATURE REVIEW

Experimental analyses by Arungalai Vendan et al. [6] and Garg et al. [10] quantified how electrical and magnetic parameters influence arc rotation and heating uniformity. Using laboratory MIAB modules, the researchers established that welding current has the strongest linear relationship with arc speed, followed by arc voltage. Coil current and voltage contribute comparatively little but control the magnetic flux density and thus the stability of arc motion. The results confirmed that stable arc propulsion is essential for symmetric thermal distribution and high weld quality. Vendan et al. [8] further optimized the process window for boiler-grade alloy steels (T11/T91), identifying that maintaining high transient current immediately before forging improves penetration and bead geometry. These studies provided the first systematic parameter maps for industrial MIAB operation. Finite-element modeling (FEM) has been central to understanding magnetic flux distribution and force generation during MIAB welding.

Manoharan et al. [7] developed a three-dimensional electromagnetic FEM using ANSYS to predict flux distribution across the inter-tube gap, revealing that flux density rises with coil current and decreases with gap width. Coil position relative to the weld center strongly affects field uniformity and, hence, arc stability.

Later work by Vendan et al. [4] integrated experimental validation with FEM predictions,

confirming the relationship between electromagnetic force and measured arc rotation speed.

Garg et al. [10] employed multi-gene genetic programming (MGGP) to predict arc speed from process inputs, demonstrating that data-driven symbolic regression can complement FEM for real-time control and optimization.

Sivasankari et al. [1] performed comprehensive testing on MIAB-welded T11 low-alloy steel tubes for high-pressure applications. The thermo-mechanically affected zone (TMAZ) exhibited grain refinement, bainitic/acicular ferrite transformation, and increased hardness. Welded specimens often showed higher tensile strength than base metal, with no internal defects when high arc currents were used.

Similarly, Vendan and Buvanashakaran [9] evaluated MIAB weld strength through tensile, bend, and impact tests, comparing results with flash-butt and induction-pressure welding.

Hassel et al. [3] extended mechanical analysis to dissimilar joints between L80 casing and duplex stainless steel, achieving sound metallurgical bonding and adequate corrosion resistance.

IV. RESEARCH GAPS AND FUTURE SCOPE

Despite substantial progress, several limitations restrict MIAB welding's broader adoption. Magnetic field optimization requires coupled thermal–mechanical simulation for predictive accuracy. Real-time sensing of arc speed and temperature is challenging; optical or electromagnetic sensors could enable closed-loop control. There is no dedicated international code or qualification procedure for MIAB, limiting certification. Research on non-ferrous alloys remains limited. Integration with robotic systems can enhance precision and repeatability for high-volume industries.

V. CONCLUSION

MIAB welding uniquely combines electromagnetic arc motion with solid-state forging to achieve high-quality tubular joints without filler or shielding. Research demonstrates that careful control of welding current and magnetic parameters yields defect-free welds with superior mechanical properties. FEM and data-driven models have advanced understanding of arc behavior, while adaptive control algorithms are

improving process consistency. Future progress depends on unifying modeling, sensing, and control, developing standardized qualification methods, and expanding research into new material systems.

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