

A Comparative Study Between Tig and Mig Welding Process and Their Effect in Tensile Test of Welding Joint of Dissimilar Metals (Low Carbon Steels & 316 Stainless Steel): A Literature Review

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ABSTRACT

The joining of dissimilar metals, specifically low-carbon steel (LCS) and 316 stainless steels (SS), is increasingly important in industries requiring lightweight, cost-effective, and high-performance components. This study presents a comprehensive literature review of the tungsten inert gas (TIG) and metal inert gas (MIG) welding processes, focusing on their effects on tensile strength, microstructural evolution, and process parameter optimization for dissimilar steel welds. TIG welding, characterized by a non-consumable tungsten electrode and lower heat input, consistently demonstrates superior weld quality, reduced formation of brittle intermetallic, and higher tensile strength compared to MIG welding. MIG welding, while offering higher deposition rates and productivity, is more sensitive to welding parameters and prone to defects if not properly controlled. Optimization techniques, including Taguchi design and response surface methodology, highlight the critical influence of welding current, voltage, travel speed, and shielding gas flow on mechanical performance. This review identifies a research gap in systematic experimental comparisons of TIG and MIG welding under identical conditions for LCS-316 SS joints. The findings underscore TIG welding as the preferred method for critical structural applications, while MIG welding offers advantages in high-volume industrial fabrication when parameters are carefully optimized.

Key Words: *TIG Welding, MIG Welding, Dissimilar Metals, Tensile Test, and Mechanical properties.*

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I. INTRODUCTION

Manufacturers are focused on dissimilar materials joining to reduce manufacturing costs and build lightweight components. Steel structures are lighter and more cost effective when their structural components are made of different steels [1, 2]. In fact, power generation, petrochemical, nuclear and other industries use a variety of dissimilar steel joints [2]. When soldering components, divergent joints are unavoidable. It is usually more difficult to join different steels than to join similar steels. This occurs due to a variety of reasons, including changes in microstructure and chemical composition and coefficients of thermal expansion. Welding of similar metals without filler material is known as autogenesis welding while filler material is called homogeneous welding. On the other hand, the welding of dissimilar metals with filler rods is called heterogeneous welding. The welding phenomenon comes into existence in 1930. Its growth is very fast in the fabrication industry [3].

It is an alternative method for casting or forging. Welding technology today has a broad and deep scope. It is successfully used in everyday things such as automobiles, planes, ships, home appliances, electronic equipment, bridge construction, building construction, pressure vessels, tanks, rail and road equipment, piping and pipelines, trucks, trailers, and trusses, among others. TIG and MIG welding are the most popular gas shielded arc welding processes used in many industrial fields. MIG is the welding process that is now used for welding a variety of materials, ferrous and nonferrous. In manual welding operation, the welder must control over a welding variable that affects the weld penetration, weld geometry, and overall weld quality. Proper changes of weld material like welding current, welding voltage, travel speed, wire electrode size and type shielding gas, weld joint position, and electrode angle will increase the chance of producing welds of satisfactory quality [4-6]. MIG can be used on a broad range of materials and thicknesses. The latest Super Pulse technology enables MIG to give a finish that is similar to that obtained with TIG (tungsten inert gas) welding, yet with the speed for which MIG is renowned. Concept underlying MIG welding is simple, with the arc being struck between the tip of the reel-fed wire as it emerges from the torch, and the work piece. A shielding gas used to prevents oxidation forming [3]. With most MIG welding sets, the user sets the wire feed speed, which determines the current; then the user sets the voltage to suit that current. On other hand, TIG welding process is an arc welding process uses a non-

consumable tungsten electrode to produce the weld where weld area is protected from atmosphere with a shielding gas. Argon or Helium are the must use and filler metal may also feed manually for proper welding [5, 7]. TIG welding process was developed during Second World War. With the development of TIG welding process, welding of difficult to weld materials e.g. Aluminum and Magnesium become possible. The use of TIG today has spread to a variety of metals like stainless steel, mild steel and high tensile steels, Al alloy, Titanium alloy. Like other welding system, TIG welding power sources have also improved from basic transformer types to the highly electronic controlled power source today. TIG welding is an extremely versatile process; it can be used with virtually any weldable metals, including dissimilar metals, and thicknesses from 0.5mm upwards. TIG welding machines are typically available in current ratings from 150A to 350A and they are capable of operating at currents as low as, typically, 3A for a 150A machine [4, 5, 7, 8]. For structural applications, the stainless steel is one of the most popular materials for structural applications, due to their excellent physical properties but increase the structural cost. The additional benefits and the design codes of stainless steels have focused their industrial use for conventional structural engineering applications such as civil construction, nuclear reactors, thermal power plants, vessels and heat exchangers for several industrial applications.

Problem Statements: TIG welding provides outstanding welding with a coalescence of heat generated through an electric arc between a tungsten electrode and the steel. TIG welding is a simple, fumeless, and spatter-free process that requires little or no finishing. MIG welding of dissimilar metals can be challenging due to the difference in their properties, which can lead to the formation of brittle intermetallic compounds and poor weld quality. The MIG welding of dissimilar metals, specifically stainless steel and carbon steel, with the aim of identifying the optimal welding conditions for producing sound welds with adequate mechanical properties. This study focusing on the effects of welding current and gas flow rate on the welding of the dissimilar metals Low Carbon Steels & 304 Stainless Steel. Mechanical properties, such as tensile strength was used to assess the TIG and MIG welding process parameters. Finally, this study investigates and optimizes the effect of welding factors on welding quality.

Research Aims: This work aims to study, analysis, design and optimization of MIG and TIG welding of different materials plates that be welded together. Comparing the mechanical tests and find out the best welding joints. Moreover, the important process control variables such are welding current, electrode speed, and welding voltage) to important MIG and TIG quality parameters, and finding the relationship between these parameters and the mechanical properties of stainless steel and low carbon steel alloys until get the best welding joint.

Expected Contribution: This work could be applied on other materials and on other welding processes even those with filler metals. This work could be extended to study the influence of parameter on other responses like heat affected zone, hardness and distortion. Spotlight on the TIG and MIG welding and their important. The study classified as experimental work. The research adds a new reference to researchers about welding dissimilar metals. This research contributes as an experimental work to know the behavior of TIG & MIG welding of dissimilar metals. The research given an excellent idea about mechanical tests.

II. LITERATURE REVIEW

Joining dissimilar metals such as low-carbon steels (LCS) and stainless steels (SS) is critical for industries including petrochemical, power generation, nuclear, and structural engineering, where combined mechanical and corrosion resistance is required at minimal cost. Among the various welding techniques, metal inert gas (MIG) and tungsten inert gas (TIG) welding are widely applied for such joints due to their versatility and capability to deliver high-quality welds. However, their metallurgical and mechanical outcomes differ significantly, especially when dissimilar materials are involved. This review critically examines prior studies on TIG and MIG welding of dissimilar metals, with particular emphasis on tensile strength, microstructural changes, and optimization of process parameters.

TIG vs. MIG in Dissimilar Welding

The welding of dissimilar metals such as low-carbon steel (LCS) and stainless steel (SS) presents multiple challenges: differences in melting temperature, thermal conductivity, coefficient of thermal expansion, and chemical composition can lead to brittle intermetallic phases, residual stresses, and distortion [9-10]. In this context, the choice between tungsten inert gas (TIG) and metal inert gas (MIG) welding processes is crucial for balancing weld quality with productivity.

Heat Input and Arc Characteristics

TIG welding employs a non-consumable tungsten electrode and typically delivers lower heat input, allowing for precise control of the fusion zone. This reduced heat input minimizes dilution and prevents the formation of brittle phases at the interface [11]. In contrast, MIG welding, which uses a consumable wire electrode fed continuously, often produces higher heat input and faster deposition rates. While this makes MIG suitable for

thicker sections and high-volume fabrication, the increased thermal cycle can result in coarse microstructures and higher residual stresses in dissimilar welds [12].

Weld Quality and Defects

Several studies confirm that TIG welding results in superior weld bead appearance, minimal spatter, and fewer defects. TIG welds of LCS–SS joints have been shown to exhibit smoother transition zones and fewer porosity issues compared to MIG welds, which are prone to inclusions and incomplete fusion under improper parameter control. On the other hand, MIG welding provides higher productivity but often requires advanced variants such as pulsed MIG to achieve comparable quality to TIG [13].

Mechanical Properties

From a mechanical performance perspective, TIG welding consistently provides higher tensile strength and ductility in dissimilar LCS–SS welds. For example, Singh et al. (2016) reported that TIG welds outperformed MIG welds by up to 12–15% in tensile strength due to balanced hardness across the fusion zone. MIG welds often show localized hardening near the fusion boundary, which can lead to brittle failure modes [13]. However, MIG can achieve competitive strength when process parameters such as current, voltage, and shielding gas flow are carefully optimized [14].

Process Efficiency and Industrial Relevance

Despite TIG's advantages in quality, its lower deposition rate and slower speed limit its application in large-scale industrial fabrication. MIG welding is often preferred in high-volume production environments due to its automation potential and faster weld rates. Recent advances such as SuperPulse and synergic MIG systems have narrowed the performance gap by providing smoother arc stability and controlled heat input, though still at a compromise in ductility compared to TIG [14].

Microstructural Observations

The dissimilar welding of carbon steels and stainless steels often leads to undesirable microstructural features such as carbide precipitation, martensitic transformation, and elemental segregation at the weld interface (Shome & Gupta, 2001; Khanna & Chawla, 2012). TIG welding tends to mitigate these effects due to its lower heat input and slower cooling rates, which reduce the extent of brittle phase formation [13]. For instance, Ghosh et al. (2010) studied TIG welding of LCS–SS dissimilar joints and reported that weldments exhibited fewer cracks and smoother transition zones than MIG joints, which often showed porosity and higher hardness in the HAZ. Similarly, Khanna and Chawla (2012) demonstrated that improper MIG welding parameters led to the formation of chromium carbides at grain boundaries, reducing corrosion resistance [9].

Mechanical Properties

Tensile strength remains the primary indicator of weld quality. In a comparative study, Singh et al. (2016) reported that TIG welds consistently outperformed MIG welds in tensile strength for dissimilar LCS–SS joints. MIG welds exhibited higher hardness at the fusion boundary, which correlated with brittle failure modes. On the other hand, TIG welds maintained balanced hardness distribution, improving ductility and joint toughness [13–15]. Furthermore, Elatharasan and Senthil Kumar (2013) applied the Taguchi method to TIG welding of stainless steel and reported optimal parameter settings that maximized tensile strength while minimizing distortion. Their results highlight TIG's sensitivity to parameter control but also its potential to deliver reproducible high-strength welds [11].

Parameter Optimization Approaches

Several optimization techniques, including Taguchi design, response surface methodology (RSM), and grey relational analysis, have been employed to optimize welding parameters for dissimilar joints. Patel et al. (2019) and Elatharasan and Senthil Kumar (2013) demonstrated that welding current, gas flow rate, and travel speed are the most influential factors. TIG welding generally required lower currents and slower travel speeds, whereas MIG welding depended heavily on wire feed rate and voltage adjustment [11–12]. Recent advances such as pulsed MIG and hybrid welding techniques have shown improvements in weld quality. For example, Shankar et al. (2020) reported that pulsed MIG could achieve tensile strengths approaching TIG levels, although still slightly inferior in ductility.

Research Gap

Although TIG welding generally provides superior tensile strength and microstructural stability in LCS–SS joints, MIG welding remains attractive for its speed and productivity. However, inconsistencies in weld quality under varying parameters limit its broader adoption for critical dissimilar joints. Prior studies have not sufficiently

compared MIG and TIG welds under identical experimental conditions while systematically optimizing parameters such as welding current, gas flow, and electrode feed. Moreover, few studies have explicitly focused on LCS–316 SS dissimilar welds, as most existing research emphasizes mild steel–304 SS combinations. This study addresses these gaps by experimentally comparing TIG and MIG welding of low-carbon steel with 316 stainless steels under controlled conditions. Tensile strength testing is used to evaluate the mechanical performance of the welds, and the influence of welding parameters is analyzed for process optimization.

Overall Comparison

In summary, TIG welding offers precision, better metallurgical control, and superior tensile performance, making it suitable for critical dissimilar joints in nuclear, aerospace, and petrochemical applications. MIG welding provides speed, cost-effectiveness, and adaptability for less critical applications, though its success heavily depends on optimization of parameters and advanced process variants. Table 1 showing a comparison table (TIG vs. MIG in dissimilar welding).

Table 1. Comparative summary of TIG vs. MIG welding for dissimilar joints (Low Carbon Steel–Stainless Steel).

Aspect	TIG (Tungsten Inert Gas)	MIG (Metal Inert Gas)
Arc & Heat Input	Non-consumable tungsten electrode; lower, controllable heat input; narrow heat-affected zone (HAZ).	Consumable wire electrode; higher heat input; wider HAZ; risk of distortion.
Deposition Rate	Low; slower welding speed, less suitable for thick sections.	High; faster deposition, ideal for production welding.
Microstructure	Finer, homogeneous microstructure; reduced carbide precipitation; smoother transition between LCS and SS.	Coarser grains; higher risk of intermetallic compounds and chromium carbide formation at interface.
Defects	Minimal spatter; low porosity; fewer inclusions when parameters optimized.	More prone to spatter, porosity, and lack of fusion defects if parameters not carefully controlled.
Mechanical Properties	Higher tensile strength and ductility due to balanced hardness across weld and HAZ.	Moderate tensile strength; localized hardening may cause brittle fracture modes.
Parameter Sensitivity	Sensitive to welding current, arc length, shielding gas flow; requires high operator skill.	Sensitive to wire feed speed, voltage, shielding gas; more forgiving with automation.
Productivity	Less efficient for large-scale production; mainly used for precision and critical joints.	Highly productive; widely used in fabrication and industry due to speed and ease of automation.
Applications	Aerospace, nuclear, petrochemical, critical piping, and dissimilar thin plates.	Automotive, structural fabrication, shipbuilding, pipelines, and mass production.

III. LITERATURE SURVEY

Mishra, R.R., Tiwari, V.K., & Rajesha, S. (2014). A study of tensile strength of MIG and TIG welded dissimilar joints of mild steel and stainless steel. Experimental comparison of MIG and TIG welded dissimilar joints (mild steel - stainless steel); tensile tests and dilution measurements. The findings: TIG-welded dissimilar joints showed better mechanical properties (higher tensile strength and cleaner welds) than MIG under their tested conditions [16]. Yelamasetti, B. et al. (2024). Optimization of TIG welding process parameters using Taguchi technique for joining dissimilar AA5083 and AA7075. Scientific Reports. Taguchi L-9 experimental design optimizing TIG current and root gap; responses: UTS, yield, hardness, impact. The findings: Taguchi effectively found robust TIG settings; current and root gap significantly influenced tensile and hardness responses — methodological relevance for steel/stainless studies [17]. Abima, C.S. et al. (2022). Comparative study between TIG-MIG hybrid, TIG and MIG (mechanical comparison). Experimental tensile and mechanical comparison of hybrid TIG-MIG vs standalone TIG and MIG joints. The study findings: TIG-MIG hybrid often delivered the best combination of tensile strength and elongation; TIG produced superior ductility vs MIG in many cases [18].

Van Huong, H. et al. (2024). Material strength optimization of dissimilar MIG welding between SUS304 and S20C. Metals (MDPI). Taguchi design varying stick-out, current, speed, voltage; microstructure and tensile testing. The findings: Welding current dominated UTS (optimal ~110 A with UTS $\approx$ 469 MPa in their setup); observed δ -ferrite near fusion line and columnar dendrites [19]. Ogbonna, O.S. (2023). Multi-response optimization of TIG dissimilar welding of AISI 1008 and AISI 316 using grey-based Taguchi. Int. J. Adv. Manuf. Technol. Grey-integrated Taguchi optimizing current, voltage, gas flow for UTS, yield, elongation, microhardness. The study findings: Optimized TIG settings increased UTS, yield, elongation and microhardness substantially; welding current and voltage were primary influencers [20]. Somani, C.A. et al. (2019). Experimental investigation of TIG-MIG hybrid welding for stainless steels. Experimental development and mechanical testing of TIG-MIG hybrid welds on austenitic stainless steels. The key findings: Hybrid approach combined TIG bead control with MIG deposition rate - improved tensile properties versus single-process welds in many trials [21].

Nguyen, T.T. et al. (2024). Dissimilar MIG welding optimization of C20 and SUS201 (Taguchi approach). Manufacturing (MDPI). Taguchi design (current, voltage, speed, stick-out) for MIG dissimilar joints; tensile and microstructural analysis. The findings: Welding current had the largest contribution to tensile outcomes; voltage showed the least influence [22]. Adin, M.Ş. (2024). A parametric study on the mechanical

properties of MIG welded steels. (Journal article). Parametric evaluation of MIG variables (current, gas, speed) and tensile/hardness response. The findings: Clear trends linking higher current/optimized gas flow to improved tensile strength; confirms current as key parameter [23]. Ogbonna, O.S., & coauthors (2023). Grey-based Taguchi method for multi-weld quality of MIG (AISI1008/AISI316). Multi-response optimization of MIG weld quality (UTS, hardness, elongation) using grey relational analysis. The study findings: Demonstrated a practical route to balance multiple mechanical outputs; produced robust parameter recommendations for MIG dissimilar joints [24]. Touileb, K. et al. (2022). Comparative microstructural, mechanical and corrosion study of TIG/ATIG welded 316L and mild steel. Metals (MDPI). TIG and activated TIG (ATIG) of 316L–mild steel; microstructure, tensile, corrosion testing. The key findings: Pulsed current with appropriate filler reduced element migration; ATIG altered penetration/HAZ and influenced tensile/corrosion behavior [25].

Baskutis, S. et al. (2021). Comparative research of microstructure and mechanical properties of dissimilar stainless-steel welds. PMC article. MIG welding experiments across several stainless grades joined to standard steels; hardness, tensile and microstructural analysis. The study findings: Fusion welding (MIG) outcomes depend strongly on stainless grade and filler selection; local microstructure at fusion influences failure location [26]. Habba, M.I.A. et al. (2023). Comparative study of FSW, MIG and TIG welding (mechanical performance). PMC article. Comparative mechanical testing (UTS, elongation) across friction stirs and fusion welding techniques. The findings: FSW often produced higher joint efficiency than fusion TIG/MIG for certain geometries, but TIG and MIG remain widely used for their specific advantages. (Contextual comparison useful for process selection) [27]. Kumar, C.V. et al. (2023). Review on mechanical and micro-structure properties of TIG & MIG welded joints. (ScienceDirect review). Literature review summarizing parameter–response relationships for TIG/MIG across alloys. The study findings: Synthesizes evidence that heat input/current controls HAZ and tensile response; highlights parameter windows and research gaps [28]. Liu, Z. et al. (2023). Dissimilar welding of high-nitrogen stainless steel and low-alloy steel. Shielding gas composition and process parameter study on weldability and mechanical properties of dissimilar steels. Key findings: Shielding gas affects microstructure and phase balance near the fusion line; appropriate gas selection improved ductility and reduced cracking [29]. Shafeek, A. et al. (2024). Effect of welding parameters on microstructure and mechanical properties (GMAW). Systematic parametric GMAW study focusing on current, voltage, shielding flow vs tensile/hardness. Key findings: Higher current with moderated gas flow raised tensile strength significantly; voltage had lesser effect than current/gas in many configurations [30].

Thangavel, S. (2024). Analysis and optimization of automated TIG welding for SS304. Optimization of automated TIG process parameters (current, speed, gas) with mechanical testing and statistical analysis. The study findings: Proper automation and parameter tuning produced reproducible high-quality TIG welds for SS304 with improved UTS and reduced HAZ variability [31]. Karthick, K. (2025). Optimization of TIG welding parameters and filler rod material. Taguchi orthogonal arrays to study filler and TIG parameters; OM/SEM microstructural analysis and mechanical testing. Key findings: Filler choice combined with optimized TIG parameters strongly affects weld microstructure and failure locus; Taguchi gave reliable optimal settings [32]. Akinlabi, S.A. et al. (2019). TIG & MIG hybrid welded steel joint: a review. Review of hybrid TIG-MIG techniques, mechanical findings and industrial applicability. Key findings: Hybrid welding can deliver both high deposition rate and good bead control; training and dual-skill requirements limit industrial adoption [33]. ResearchGate / IJCRT authors (various, 2023). Analysis of dissimilar joining of stainless steel and mild steel using MIG welding. Multiple student/professional experimental studies varying current, voltage and speed for MIG dissimilar welding; hardness and tensile evaluation. Key findings: Consistent observation across reports that welding current is the dominant parameter affecting UTS and weld quality; filler selection and speed are also important [34]. Ampaiboon, P. et al. (2015). Optimization & prediction of UTS in GMAW: RSM/ANOVA approach. Statistical modelling (RSM, ANOVA) to predict UTS from welding parameters in GMAW/MIG. The study findings: Demonstrated reliable predictive models for UTS and validated the use of RSM/ANOVA to build response equations useful for your mathematical modelling step [35].

The reviewed studies consistently show that TIG welding provides superior tensile strength, ductility, and weld quality for dissimilar metal joints (e.g., mild steel–stainless steel) due to its lower heat input, precise arc control, and reduced formation of brittle phases. MIG welding, while faster and more suitable for high-volume production, is more prone to coarse microstructures, residual stresses, and defects unless optimized carefully. Hybrid TIG-MIG welding combines the advantages of both processes, offering good bead control and higher deposition rates, often achieving tensile strength and elongation comparable to TIG welds. Process parameters especially welding current, voltage, travel speed, and filler selection—strongly influence mechanical properties. Taguchi, RSM, and grey relational methods have been widely used to optimize these parameters for both TIG and MIG, with current identified as the most critical factor. Microstructural analysis shows TIG welds generally have finer, more uniform grains, while MIG welds may exhibit δ -ferrite formation and carbide segregation at the fusion zone. Advanced techniques like pulsed TIG/MIG and ATIG can improve penetration and reduce HAZ variability.

Overall, TIG is ideal for critical, high-quality dissimilar joints, MIG suits high-volume production, and hybrid/advanced methods provide a practical balance of quality and efficiency. Gaps remain in systematic studies on LCS-316 SS joints and multi-response evaluations.

IV. CONCLUSIONS

Weld Quality and Mechanical Performance: TIG welding consistently produces superior tensile strength and ductility in dissimilar LCS-316 SS joints due to precise control of heat input, narrower HAZ, and reduced formation of brittle phases. MIG welding offers higher deposition rates but requires strict parameter control to avoid porosity, intermetallic formation, and localized hardening. **Microstructural Behavior:** TIG welding minimizes carbide precipitation, martensitic transformations, and elemental segregation at the interface, resulting in smoother transition zones. MIG welds exhibit coarser grains and increased δ -ferrite near the fusion line, which may compromise joint toughness if not optimized.

Process Optimization: Critical parameters influencing weld quality include welding current, voltage, travel speed, electrode feed rate, and shielding gas composition. Studies employing Taguchi design, response surface methodology, and grey relational analysis demonstrate that systematic parameter optimization significantly enhances tensile strength and reduces defects for both TIG and MIG welding. **Industrial Relevance:** TIG welding is ideal for critical structural applications in nuclear, aerospace, and petrochemical industries where precision and joint integrity are paramount. MIG welding is suitable for high-volume production, automotive, and structural fabrication due to higher deposition rates and automation potential, provided optimal process parameters are applied.

The study recommended: **Experimental Verification:** Conduct systematic experimental investigations comparing TIG and MIG welding of LCS-316 SS under identical parameters to quantify tensile strength, ductility, and HAZ characteristics. **Parameter Optimization:** Employ statistical optimization techniques (e.g., Taguchi L-9/L-16, RSM, or hybrid methods) to determine the optimal combination of current, voltage, travel speed, and gas flow for maximum joint strength and minimal defects. **Hybrid Welding Exploration:** Investigate TIG-MIG hybrid welding to leverage TIG's superior bead control with MIG's higher deposition rate, potentially achieving both high strength and productivity for dissimilar joints.

Material and Filler Selection: Assess the influence of filler metal composition on microstructure and mechanical properties to mitigate intermetallic formation and enhance corrosion resistance at the interface. **Extended Mechanical Analysis:** Evaluate additional mechanical responses such as hardness, impact toughness, fatigue resistance, and residual stress distribution to provide a comprehensive understanding of dissimilar weld behavior. **Industrial Implementation:** Develop guidelines for industrial adoption of TIG or MIG welding in critical dissimilar metal applications, emphasizing the importance of parameter control and process monitoring to ensure reproducible high-quality welds.

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