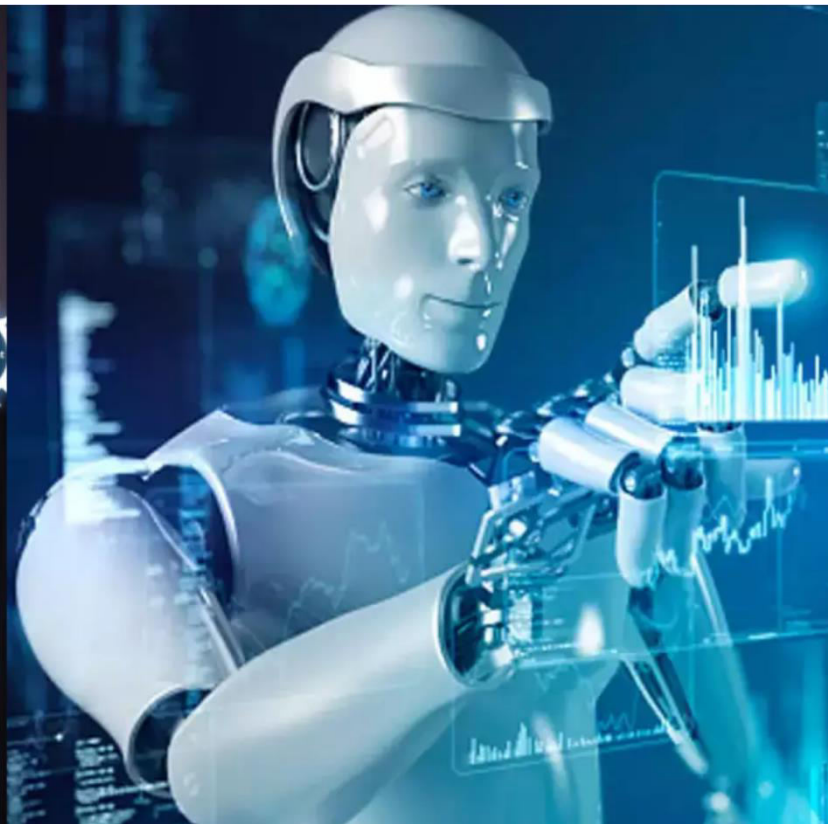




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Comparative Evaluation of Welding Defects in TIG and MIG Joints using Non-Destructive Testing (NDT) Methods

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ABSTRACT: This study investigates the influence of varying welding currents and voltages on the formation of defects in Tungsten Inert Gas (TIG) and Metal Inert Gas (MIG) welded joints. Mild steel plates were welded using both TIG and MIG processes, with controlled adjustments to voltage and current settings. The resulting weldments underwent comprehensive non-destructive testing (NDT) using a suite of techniques, including visual inspection, liquid penetrant testing, ultrasonic testing, radiographic testing, and magnetic particle testing. The application of these complementary NDT methods aimed to identify, characterize, and quantify the types and prevalence of welding defects in both TIG and MIG welds produced under different electrical parameters. The findings offer a comparative analysis of the nature and frequency of defects associated with specific voltage and current settings, providing valuable insights into optimizing welding parameters for enhanced weld quality and defect minimization. The interpreted results contribute to a deeper understanding of the relationship between welding conditions and defect formation, ultimately aiding in the selection of appropriate welding practices and NDT techniques to ensure the structural integrity of welded components.

KEYWORDS:

TIG and MIG Welding, Welding defects, Non-Destructive Testing (NDT), Welding voltage and current

I. INTRODUCTION

Welding is a critical fabrication process used to permanently join metals through the application of heat, pressure, or both. The integrity of welded joints is essential across industries such as construction, automotive, aerospace, and shipbuilding. Among the widely used techniques, Tungsten Inert Gas (TIG) and Metal Inert Gas (MIG) welding are known for their versatility and application-specific strengths. TIG welding offers precise, high-quality welds using a non-consumable tungsten electrode and inert shielding gas, making it ideal for thin materials and critical components. MIG welding, using a consumable wire electrode and shielding gas, is preferred for thicker materials and high-production environments. Despite their advantages, both processes are susceptible to welding defects due to factors such as improper parameters, operator skill, material type, and environmental conditions. Common defects include porosity, cracks, incomplete fusion, spatter, and lack of penetration, which compromise weld strength and reliability. Non-Destructive Testing (NDT) plays a key role in defect detection without damaging components. Techniques like Visual Testing (VT), Ultrasonic Testing (UT), Radiographic Testing (RT), Magnetic Particle Testing (MT), and Liquid Penetrant Testing (PT) are employed to detect and evaluate surface and subsurface flaws.

The primary objective of this study is to identify and analyze common welding defects associated with TIG and MIG welding processes. Surface and internal flaws are detected using a range of non-destructive testing (NDT) techniques, including Ultrasonic Testing (UT), Radiographic Testing (RT), and Magnetic Particle Testing (MT). The overall goal is to assess the quality of welded joints by correlating the observed defects with welding parameters and procedural variations. The project focuses on the evaluation of weld quality in TIG and MIG welded joints, utilizing NDT data to explore defect patterns and determine root causes for improving welding performance and structural integrity.

II. LITERATURE REVIEW

Several studies have explored the effectiveness of various welding techniques and non-destructive testing (NDT) methods to ensure weld quality. Harshal Ashok Aglawe et al. (2015) [8] emphasized the advantages of ultrasonic phased array testing over traditional methods like radiography, demonstrating superior defect detection in weld joints. Patil Sachin S. and Naik Girish (2017) [1] addressed defect reduction in casting processes through systematic quality tools, including Ishikawa diagrams and simulation. Ogundimu et al. (2019) [5] compared TIG and MIG welds on stainless steel, concluding that TIG offered better mechanical performance, particularly at higher currents. Kamble Snehal et al. (2019) [9] reviewed ultrasonic NDT in casting inspection, highlighting its capabilities in defect and microstructural evaluation.

Mridul Gupta et al. (2021) [11] stressed the role of NDT in modern manufacturing for identifying discontinuities, advocating for increased automation to reduce human error. Naresh Kumar Wagri et al. (2022) [12] discussed machinability challenges in advanced materials and the role of heat treatment in improving performance indicators like tool life and surface finish. Lastly, Syed Rashedul Haque et al. (2023) [10] conducted a comparative study on TIG and MIG welding of mild steel, concluding that TIG yielded superior mechanical properties and fewer defects, underlining the need for optimal parameter selection for structural integrity.

III. EXPERIMENTAL SETUP

3.1 Selection of Base Material

Material for the sample to be welded was Mild steel. having composition as given in Table

C	Si	Mn	P	Fe
0.17%	0.20%	0.54%	0.16%	98.7%

Table 3.1 Composition of mild steel

3.2 Dimension of test specimen

Mild Steel plate of 7 mm thickness was cut with dimension of 200 mm x 100 mm with the help of hand-saw and grinding done at the edge to smooth the surface to be joined.

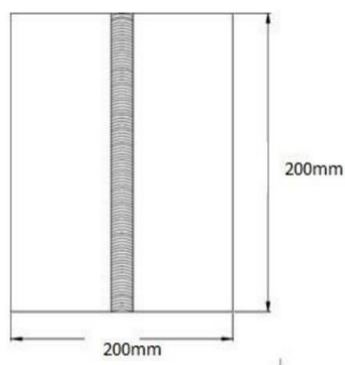


Fig 2.1 Dimension of test specimen

3.3 Process Parameters and Test specimens

The selection of welding variables should be made after determining the base metal. The key variables considered in the welding process include welding current and welding voltage, while other parameters are kept constant.

A total of six weld samples, comprising both TIG and MIG processes with varying current and voltage settings, were selected to evaluate and compare the quality of welds through systematic non-destructive testing methods.

Sample No.	Identification	Welding Process	Welding current	Welding voltage
1	WQT TIG V300	TIG	90	10-14
2	WQT MIG V150	MIG	120-150	22-26
3	WQT TIG V165	TIG	85	10-12
4	WQT MIG V100	MIG	100-120	17-20
5	WQT MIG V130	MIG	90-100	15-18
6	WQT TIG V100	TIG	75	9-11

Table 3.2 Specifications of welds

IV. RESULTS AND DISCUSSION

Six weld samples were evaluated using five non-destructive testing (NDT) methods to detect both surface and subsurface defects. The techniques employed included Visual Inspection, Liquid Penetrant Testing, Ultrasonic Testing, Radiographic Testing, and Magnetic Particle Testing. The following section presents the results of these evaluations.

4.1 VISUAL INSPECTION

Based on the visual inspection of the welded samples:

- **Spatter Formation:** Spatters were observed on samples 1, 3, and 5, indicating improper shielding or inconsistent arc control during the welding process.
- **Surface Discontinuities:** Sample 1 exhibited noticeable surface discontinuities along the weld bead, as highlighted in the red circle. This may be due to arc instability or poor cleaning of base metal.
- **Excess Reinforcement:** Excess weld reinforcement was identified in samples 4 and 5, suggesting improper control of filler deposition or travel speed.
- **Defect-Free Samples:** The remaining samples were found to be free from visible surface defects, indicating satisfactory welding parameters and technique for those specimens.



Fig 4.1 Visual inspection test sample 1 and 4.

Sample No.	Observed Defects	Remarks
1	Spatter, Surface Discontinuity	Visible weld imperfections; discontinuities may affect structural integrity
2	None	Weld appears visually sound and defect-free
3	Spatter	Minor surface spatter observed
4	Excess Reinforcement	Overfill at the weld bead; may require grinding or rework
5	Spatter, Excess Reinforcement	Surface spatter and excessive bead height noted
6	None	Weld is clean with no visible surface defects

Table 4.1 Visual inspection Results

4.2 LIQUID PENETRANT TESTING



Sample 1



Sample 2



Sample 3



Sample 4



Sample 5



Sample 6

Fig 4.2 Liquid Penetrant Testing Samples 1,2,3,4,5 and 6.

Sample No.	Defect type	Location	Possible cause	Severity
1	Linear	Weld toe & root	Small Cracks	Low
2	Linear	Weld centre & edges	Small Cracks	Low
3	Clustered Rounded	Spread on surface	Porosity	Moderate
4	Clustered Rounded	Spread on surface	Porosity	Moderate
5	Clustered Rounded	Surface-wide	Gas Porosity	Moderate-High
6	Linear	Weld toe & root	Cracks / Incomplete fusion	High

Table 4.2 Results of Liquid penetrant testing

4.3 ULTRASONIC TESTING

Out of six weld samples, three were found to be within the acceptable range, with defect indications falling below the DAC (Distance Amplitude Correction) line. Among these, two samples were TIG welded and one was MIG welded.



Fig 4.3 A Schematic Diagram Showing Echo Pattern. (The red line represents the DAC line any echo signal exceeding this line indicates a rejectable defect.)

Test Sample	Defect Depth (mm)	Defect Size (mm)	Amplitude (%)	Likely Defect Type(s)	Acceptance	Notes
1	6.4 - 17.1	3.1	25	Porosity	ACCEPTABLE	Small flaw, moderately reflective.
2	6.5	14.1	41	Undercut, crack, lack of fusion	ACCEPTABLE	Relatively large defect, strong echo.
3	5	4.3	45	Incomplete fusion, slag inclusion, crack, void	ACCEPTABLE	Moderate size flaw, strong signal.
4	N/A	5	Exceeds DAC	Lack of fusion, inclusion, crack, porosity	REJECT	Clear flaw indication exceeding DAC, larger/more reflective than acceptable. Defect is 70mm away from the edge.
5	3.82	5	Exceeds DAC	Porosity, lack of fusion, slag inclusions, cracks	REJECT	Two flaw indications exceeding DAC, unacceptable reflections.
6	4.21	5	Exceeds DAC	Porosity, lack of fusion, slag inclusion	REJECT	Significant peak crossing DAC, stronger than acceptable reflection.

Table 4.3 Ultrasonic Testing

4.4 RADIOGRAPHIC TESTING

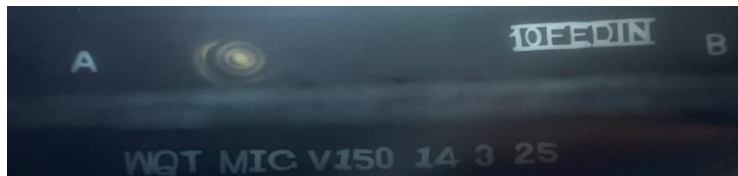
Radiographic Non Destructive Testing creates an image of the internal features, revealing flaws, defects, or variations in material density and thickness.

Volume 14, Issue 4, April 2025

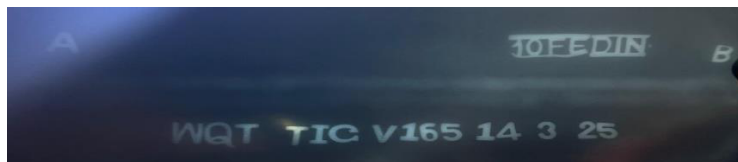
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Sample 1



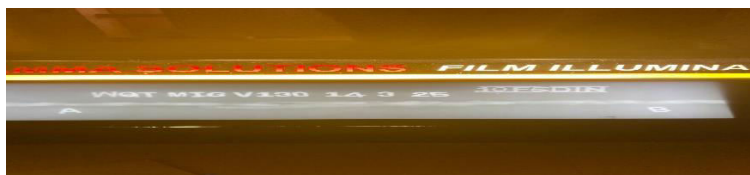
Sample 2



Sample 3



Sample 4



Sample 5



Sample 6

Fig 4.4 Images of Radiographic testing samples 1,2,3,4, 5 & 6.

Sl. No	Identification	Segment	Film Size	Observation	Remarks	Interpretation
1	WQT TIG V300	A-B	8" × 3"	Porosity	Acceptable	Porosity found, but within limits
2	WQT MIG V150	A-B	8" × 3"	Undercut	Acceptable	Undercut found, but acceptable
3	WQT TIG V165	A-B	8" × 3"	No significant defect	Acceptable	No significant defect – fully accepted
4	WQT MIG V100	A-B	8" × 3"	Lack of fusion	Reject	Lack of Fusion – Defective
5	WQT MIG V130	A-B	8" × 3"	Lack of fusion	Reject	Lack of Fusion – Defective
6	WQT TIG V100	A-B	8" × 3"	Lack of fusion	Reject	Lack of Fusion – Defective

Table 4.2 Results of Radiographic Testing

4.5 MAGNETIC PARTICLE TEST

Out of six weld samples tested using Magnetic Particle Testing (MPT), only three samples (1, 2, and 3) were found to be within acceptable limits, despite showing minor defects. The remaining three specimens (4, 5, and 6) were rejected due to significant lack of fusion, which is a critical welding defect.



Fig 4.5 Diagram of Magnetic Particle Testing

Specimen No.	Observed Defect	Status
1	Small porosity	Accepted
2	Undercut	Accepted
3	Small porosity	Accepted
4	Lack of fusion	Rejected
5	Lack of fusion	Rejected
6	Lack of fusion	Rejected

Fig 4.5 Results of Magnetic Particle Testing

High-quality welds with minimal defects can be achieved with TIG welding when performed correctly, as shown in sample 3, but MIG welding in this study exhibited a higher tendency for significant defects, especially lack of fusion (samples 4 and 5), a critical defect that demands careful control of welding parameters in both TIG and MIG welding, even though both processes can produce acceptable welds, as demonstrated by samples 1 (TIG) and 2 (MIG).

V. CONCLUSION

Both TIG and MIG welding have specific defect tendencies. TIG welds showed fewer defects but were prone to porosity and lack of fusion. MIG welding had more spatter, lack of penetration, and undercut. NDT methods effectively detected these defects. Proper parameters, training, and inspections are crucial for weld quality. TIG welding produced more acceptable results. MIG welding needs better process control and training to reduce defects like lack of fusion. Most issues arise from poor technique and parameter control. Focused training, optimized parameters, adherence to WPS (Welding Procedure Specification), and regular equipment calibration are essential.

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