



# **Comparative Evaluation of Welding Defects in SMAW, TIG and MIG of Dissimilar Metal Joints Using NDT Methods**

**Muhammed Jihans NP<sup>1</sup>, Umersahil KC<sup>2</sup>, Anfaaz C<sup>3</sup>, Vaishakh C<sup>4</sup>, Abhiram K<sup>5</sup>**

Graduate Students, Dept. of ME, AWH Engineering College, Calicut, Kerala, India<sup>1-4</sup>

Assistant Professor, Dept. of ME, AWH Engineering College, Calicut, Kerala, India<sup>5</sup>

**ABSTRACT:** Welding is a fundamental joining process used in various engineering industries; however, the formation of defects significantly affects the strength and reliability of welded joints, especially in dissimilar metal combinations. This study presents a comparative evaluation of welding defects in Shielded Metal Arc Welding (SMAW), Gas Metal Arc Welding (MIG), and Gas Tungsten Arc Welding (TIG) processes for dissimilar metal joints of mild steel and stainless steel. Non-Destructive Testing (NDT) methods such as Dye Penetrant Testing (PT), Radiographic Testing (RT), and Ultrasonic Testing (UT) are employed to detect surface and internal defects. The results indicate that TIG welding produces the least defects due to better control over heat input, while SMAW shows higher defect formation due to manual operation and slag inclusion. MIG welding provides moderate performance. The study highlights the importance of selecting appropriate welding techniques and inspection methods to ensure weld quality and structural integrity

**KEYWORDS:** Welding Defects, SMAW, MIG, TIG, Dissimilar Metals, NDT, PT, RT, UT.

## **I. INTRODUCTION**

Welding is one of the most essential fabrication processes used in modern engineering industries for permanently joining metallic components. It plays a crucial role in sectors such as construction, automotive, aerospace, shipbuilding, and power generation, where the strength and reliability of joints directly influence the safety and performance of structures. With the advancement of technology, there is an increasing demand for joining dissimilar metals in order to combine desirable properties such as strength, corrosion resistance, and cost efficiency.

However, welding dissimilar metals presents significant challenges due to differences in their chemical composition, thermal conductivity, melting temperature, and coefficient of thermal expansion. These variations can lead to the formation of undesirable metallurgical structures and increase the likelihood of defect formation during welding. As a result, achieving a sound and defect-free joint becomes more complex compared to welding similar metals.

Various welding processes such as Shielded Metal Arc Welding (SMAW), Gas Metal Arc Welding (MIG/GMAW), and Gas Tungsten Arc Welding (TIG/GTAW) are commonly used for joining metals. Each of these processes differs in terms of heat input, shielding mechanism, level of automation, and operator control. These differences significantly influence the type and severity of defects formed in the welded joint

.During the welding process, several types of defects may occur due to improper process parameters, contamination, or operator errors. Common welding defects include cracks, porosity, slag inclusions, lack of fusion, lack of penetration, and undercut. These defects can adversely affect the mechanical properties of the joint, such as strength, toughness, and fatigue life, thereby reducing the overall reliability of the structure.

To ensure the quality and integrity of welded joints, it is essential to detect and evaluate these defects without causing damage to the component. This is achieved through Non-Destructive Testing (NDT) methods, which allow inspection of both surface and internal discontinuities. Among the various NDT techniques, Dye Penetrant Testing (PT) is used for identifying surface defects, Radiographic Testing (RT) is effective in detecting internal volumetric defects, and Ultrasonic Testing (UT) is used to locate and size subsurface flaws.

In this context, the present study focuses on the comparative evaluation of welding defects in SMAW, MIG, and TIG welded dissimilar metal joints using NDT methods. The objective is to analyze the nature and severity of defects associated with each welding process and to determine the most suitable technique for producing high-quality welds with minimal defects. This study provides valuable insights into the relationship between welding processes and defect formation, thereby aiding in the selection of appropriate welding methods for industrial applications.

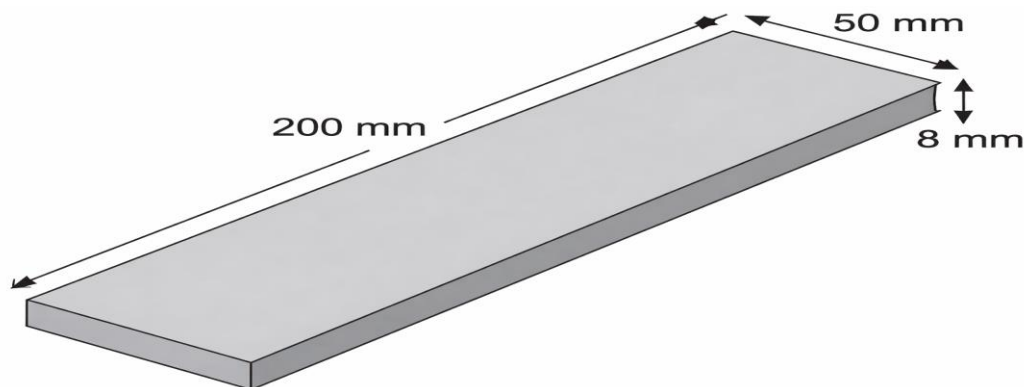
## II. MATERIALS AND METHODOLOGY

### A. Base Materials

The base materials selected for this study are Mild Steel and Stainless Steel (SS304). Mild steel offers good weldability and ductility, whereas stainless steel provides corrosion resistance and strength. The combination of these materials creates a dissimilar joint suitable for defect analysis.

### B. Sample Preparation

Plates of dimensions 200 mm × 50 mm × 8 mm were prepared. The edges were cleaned and properly aligned before welding. Proper surface preparation was carried out to remove contaminants.



### C. Welding Processes

The welding processes used in this study include:

- SMAW (Shielded Metal Arc Welding)
- MIG (Gas Metal Arc Welding)
- TIG (Gas Tungsten Arc Welding)

Appropriate welding parameters such as current, voltage, travel speed, and shielding gas were maintained for each process.

### D. Non-Destructive Testing Methods

#### 1. Dye Penetrant Testing (PT)

Used to detect surface defects such as cracks and porosity.

#### 2. Radiographic Testing (RT)

Used to identify internal defects like slag inclusion and voids.

#### 3. Ultrasonic Testing (UT)

Used to detect subsurface defects and measure defect depth.

## III. RESULTS AND DISCUSSION

The results obtained from the experimental investigation were analyzed using Non-Destructive Testing (NDT) methods, namely Dye Penetrant Testing (PT), Radiographic Testing (RT), and Ultrasonic Testing (UT), to evaluate both surface and internal defects in the welded dissimilar metal joints. The observations provide a clear comparison of defect characteristics associated with SMAW, MIG (GMAW), and TIG (GTAW) welding processes.

### [1] Dye Penetrant Testing (PT) Results – Surface Defect Analysis

The PT results revealed significant differences in the surface integrity of the welds produced by the three processes:

- **SMAW Welds:**

A large number of linear and rounded indications were observed, indicating the presence of surface cracks, porosity, slag inclusions, and undercut. The weld surface appeared rough and irregular, suggesting inconsistent heat input and manual operation.

- **MIG Welds:**

The PT inspection showed moderate surface defects, including scattered porosity and minor linear indications. The weld bead was comparatively smoother than SMAW, but still exhibited some inconsistencies due to variations in shielding gas flow and welding parameters.

- **TIG Welds:**

The TIG welds exhibited minimal surface defects, with only a few fine porosity indications. The weld bead was smooth, uniform, and well-defined, indicating better control over welding conditions and cleanliness.

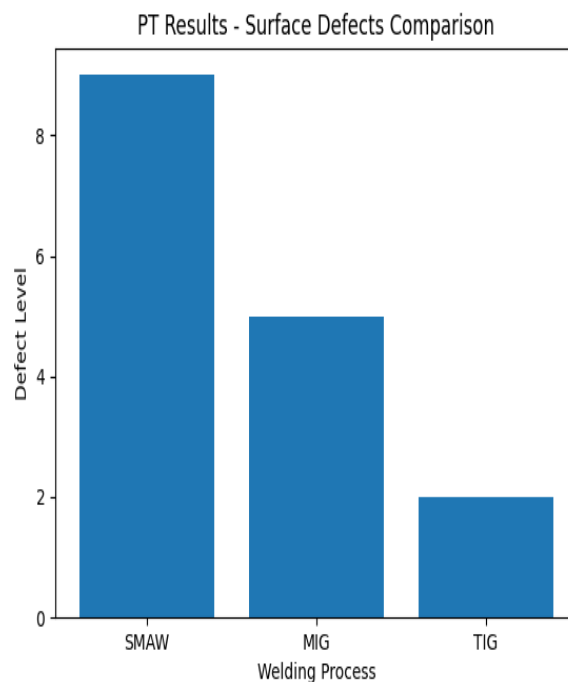


Fig 1: Comparison of Surface Defects (PT Results)

## [2] Radiographic Testing (RT) Results – Internal Defect Analysis

Radiographic examination provided insight into the internal structure and defect distribution within the welds:

- **SMAW Welds:**

RT images showed significant internal discontinuities, including slag inclusions, porosity clusters, and uneven fusion zones. These defects are primarily attributed to electrode coating, slag entrapment, and improper technique.

- **MIG Welds:**

The radiographs indicated moderate internal defects, mainly in the form of porosity and occasional lack of fusion. Compared to SMAW, the defect density was lower, but still noticeable.

- **TIG Welds:**

TIG welds showed very minimal internal defects, with only occasional fine porosity. The weld region appeared dense and uniform, indicating good fusion and minimal contamination.

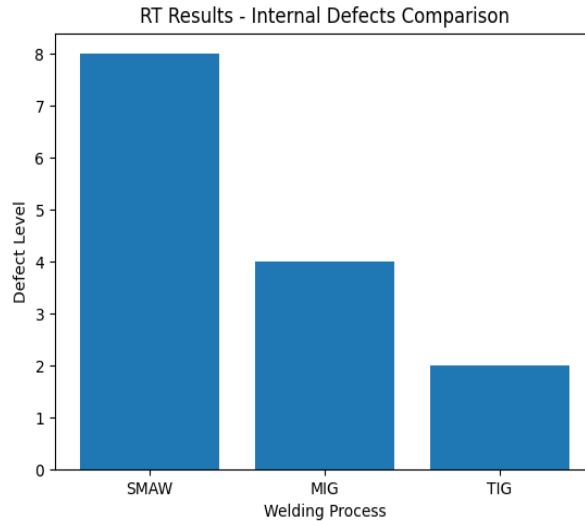


Fig 2: Comparison of Internal Defects (RT Results)

### [3] Ultrasonic Testing (UT) Results – Subsurface Defect Evaluation

Ultrasonic testing was used to detect subsurface and internal discontinuities and assess their severity:

- SMAW Welds:

UT signals indicated multiple reflections with higher amplitude, suggesting the presence of internal flaws such as inclusions and lack of fusion.

- MIG Welds:

Moderate echo signals were observed, indicating minor internal discontinuities such as small inclusions and porosity.

- TIG Welds:

UT results showed low-amplitude signals below the DAC curve, indicating absence of critical internal defects. Any detected discontinuities were minor and within acceptable limits.

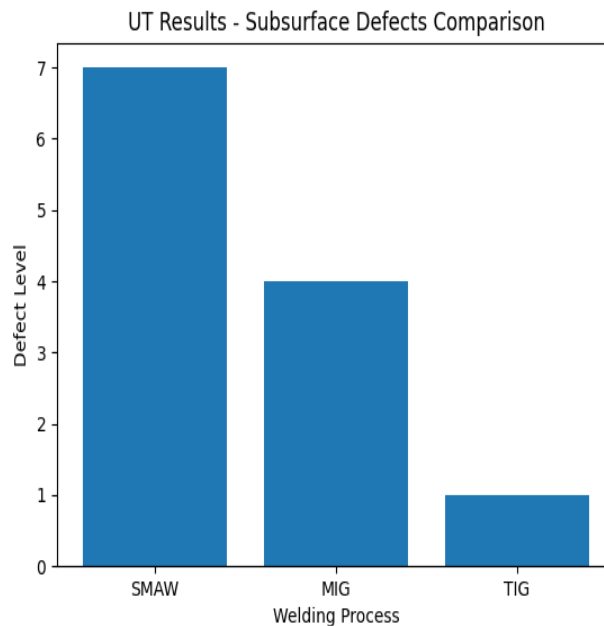


Fig 3: Comparison of Subsurface Defects (UT Results)

#### IV. COMPARATIVE ANALYSIS

The comparative analysis of the welded dissimilar metal joints was carried out by integrating the results obtained from Dye Penetrant Testing (PT), Radiographic Testing (RT), and Ultrasonic Testing (UT). This comprehensive evaluation provides a clear understanding of how different welding processes influence both surface and internal defect formation, ultimately affecting the overall weld quality.

##### Basis of Comparison

The three welding processes SMAW, MIG (GMAW), and TIG (GTAW) were compared based on the following parameters:

- Surface defect characteristics (PT results)
- Internal defect distribution (RT results)
- Subsurface flaw detection and severity (UT results)
- Overall weld bead appearance and uniformity

This multi-criteria approach ensures a reliable and holistic assessment of weld integrity.

Parameter	SMAW	MIG	TIG
Surface Defects (PT)	High	Moderate	Very Low
Internal Defects (RT)	High	Moderate	Very Low
Subsurface Defects (UT)	Moderate to High	Low to Moderate	Very Low
Weld Appearance	Rough, irregular	Fairly uniform	Smooth and uniform
Process Control	Low (manual)	Moderate	High
Overall Quality	Poor	Good	Excellent

Table .1 Comparative Summary Table

#### V. CONCLUSION

The comparative evaluation of welding defects using NDT methods demonstrates that the quality of welded joints is highly dependent on the welding process employed. TIG welding produces superior weld quality with minimal defects due to better control over welding parameters and shielding conditions. MIG welding offers a balance between productivity and quality, while SMAW is more prone to defects due to manual operation and slag formation.

The integration of PT, RT, and UT methods provides a comprehensive assessment of weld integrity by detecting both surface and internal defects. The study concludes that TIG welding is the most suitable process for dissimilar metal joints where high quality and reliability are required.

**REFERENCES**

1. Firmanto, H., Candra, S., Hadiyat, M. A., Triastomo, Y. P., & Wirawan, I. (2023). Tensile strength and microstructure of rotary friction-welded carbon steel and stainless steel joints. *Journal of Manufacturing and Materials Processing*, 7(1), 7. <https://doi.org/10.3390/jmmp7010007>
2. Scutelnicu, E., Iordachescu, M., Rusu, C. C., Mihailescu, D., & Ocaña, J. L. (2021). Metallurgical and mechanical characterization of low-carbon steel–stainless steel dissimilar joints made by laser autogenous welding. *Metals*, 11(5), 810. <https://doi.org/10.3390/met11050810>
3. Yang, L., Chuai, R., Cai, G., Xue, D., Li, J., Liu, K., & Liu, C. (2024). Ultrasonic non-destructive testing and evaluation of stainless-steel resistance spot welding based on spiral C-scan technique. *Sensors*, 24(15), 4771. <https://doi.org/10.3390/s24154771>
4. Giudice, F., Missori, S., Scolaro, C., & Sili, A. (2024). A Review on Fusion Welding of Dissimilar Ferritic/Austenitic Steels: Processing and Weld Zone Metallurgy. *Journal of Manufacturing and Materials Processing*, 8(3), 96. <https://doi.org/10.3390/jmmp8030096>
5. Soudy, A., Hoziefa, W., Fatahalla, N., & Hafez, K. M. (2024). Welding performance of carbon steel covered with 316L stainless steel using GTAW process. *Journal of Al-Azhar University Engineering Sector*, 19(72), 212–225. <https://doi.org/10.21608/aej.2024.278099.1638>
6. Ghorbel, R., Ktari, A., & Haddar, N. (2025). A new methodology for investigating the weld-joint microstructure and micro-hardness of the austenitic stainless steel clad plate made by SMAW-GTAW multi-pass welding process: Part II , Transition zone. *International Journal of Materials and Metallurgical Engineering*, <https://doi.org/10.1080/01694243.2025.2508765>
7. Deng, Y., Cao, K., Zhou, Y., Hu, L., Ou, Y., Zeng, J., & Li, Z. (2024). Effect of friction time on temperature distribution, plastic flow, microstructure, and properties in friction welding of 1045 carbon steel and AISI 430 ferritic stainless steel. *Journal of Materials Engineering and Performance*, 34, 3843-3858. <https://doi.org/10.1007/s11665-024-09410-w>
8. Presswood, R., Afshan, S., Meza, F., Baddoo, N., Shaheen, M., & Desnerck, P. (2024). Experimental study on the behaviour of austenitic stainless steel and carbon steel welded shear connectors. *Engineering Structures*, 321, 118930. <https://doi.org/10.1016/j.engstruct.2024.118930>
9. Mishra, V., Yuvaraj, N., & Vipin. (2024). Tribological behaviour of austenitic stainless steel-clad surface over low-carbon steel produced by Cold Metal Transfer welding process. *Transactions of the Indian Institute of Metals*, 77(6), 1639-1650. <https://doi.org/10.1007/s12666-024-03261-8>
10. Dhamothara Kannan, T., Sivaraj, P., Balasubramanian, V., Sonar, T., Ivanov, M., & Sathiya, S. (2024). Unsymmetric rod to plate rotary friction welding of dissimilar martensitic stainless steel and low carbon steel for automotive applications – Mathematical modeling and optimization. *International Journal on Interactive Design and Manufacturing (IJIDeM)*, 18, 1731-1759. <https://doi.org/10.1007/s12008-022-01193-51>



INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA



# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 9940 572 462  6381 907 438  [ijirset@gmail.com](mailto:ijirset@gmail.com)



[www.ijirset.com](http://www.ijirset.com)

Scan to save the contact details