Mekanika: Majalah Ilmiah Mekanika

Evaluating the Influence of Environmental Factors and Parameters on Advancements in Welding and Joining Processes: A Review

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Abstract

This review article presents a comprehensive overview of welding, including its environmental influence, common welding failures, welding parameters, and predictions of development regarding welding and corrosion. The quality and integrity of welds can be significantly affected by environmental factors such as temperature, humidity, and atmospheric contaminants. Moreover, welding failures can occur due to various reasons, such as improper welding techniques, inadequate preparation, corrosion, or material defects, leading to structural weaknesses and compromised joint integrity. Furthermore, notable progress has been achieved in welding system technology, encompassing automation, robotics, and real-time monitoring. These advancements underscore the vital role of welding parameters in transforming control, precision, and productivity within the welding process. The integration of innovative welding systems has led to improved welding efficiency, reduced human error, and increased overall process reliability. This review consolidates knowledge from diverse sources, making it a valuable resource for researchers, practitioners, and industries involved in welding.

1 Introduction

Welding is a combination of two or more components using material or without additives with high heating. There is a failure in the welding process that may occur and change the metallurgical properties due to heating. Gas Metal Arc Welding (GMAW) and Shielded Metal Arc Welding (SMAW) are welding processes that are often used in construction work or joining steel materials. To increase durability, strength, and safety, especially on steel construction materials, an analysis of welded joints is carried out to determine any changes in properties that have occurred during the welding process. Ibrahim et al. [1] have researched using the GMAW technique with arc voltage and welding speed parameters obtained changes in structural properties due to heating on microstructural analysis. Gemme et al. [2] also researched Friction Stir Welding. They found that there were failures caused by sub-surface defects that were generated afterward by abnormal agitation and softening of the heat-affected zone in excessive heat.

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Welding is a process of joining two or more metal parts by applying heat, pressure, or both. For instance, Friction Stir Welding (FSW) is a solid-state welding technique that involves a non-consumable rotating tool that creates friction between the workpieces, generating heat [3]. The heat softens the metal, allowing the tool to traverse along the joint and create a weld. Welding quality is affected by various environmental factors, such as temperature, humidity, wind, dust, and corrosion [4-6]. These factors can cause defects in the welds, such as cracks, porosity, lack of fusion, and distortion. Welding failure can have serious consequences for the safety and performance of the welded structures and components. Therefore, it is important to monitor and control the welding environment and to use appropriate welding techniques and materials. The development of welding systems aims to improve welding quality and efficiency by using advanced technologies, such as automation, robotics, sensors, artificial intelligence, and additive manufacturing [7-9]. These technologies can help reduce human errors, optimize welding parameters, enhance weld inspection and evaluation, and create complex and customized shapes. It is important to choose appropriate welding parameters to get the best quality welding results, such as the arc current and arc voltage, environmental influence, and the causes of the failure of the weld joint must be considered. Therefore, environmental influences and the process of occurrence of faults in welding joints are crucial issues in this study.

One specific real-world application of welding that correlates with the subject of discussion, especially in ship structures, is the construction and repair of large-scale marine vessels, such as cargo ships, tankers, and cruise liners. The ship structure welding is a critical process that must consider the environmental influences discussed in this review, such as temperature, humidity, and atmospheric contaminants. Ships operate in a variety of marine environments subjected to varying weather conditions and exposure to corrosive saltwater [10]. These environmental factors can have a significant impact on the quality and integrity of ship welds. Understanding the environmental influence on welding is essential in shipbuilding in order to optimize process parameters and ensure the reliable quality of welds [11]. Proper welding techniques and preparation are critical to ensuring the strength and durability of the ship's structure, as welding failures can result in compromised joint integrity and structural weaknesses, jeopardizing the safety of the vessel and its crew. Welding is a critical aspect that must be addressed in this comprehensive review article. The welding, for instance, in ships and maritime structures requires special attention due to the unique challenges posed by marine environments. The quality and integrity of ship welds are of utmost importance as they directly impact the safety and longevity of vessels at sea. Ship welding is heavily influenced by environmental factors, such as saltwater exposure, corrosive elements, and constant movement [12]. Understanding the environmental impact of ship welding is essential for optimizing process parameters and ensuring reliability, such as welds in maritime structures. The welding technology review is urgently needed because it highlights how these advancements can significantly reduce human errors, optimize welding parameters, improve weld inspection and evaluation, and enable the creation of intricate and tailored shapes.

This study aims to conduct a thorough investigation of existing literature, with a focus on the interconnections between welding, environmental influences, welding failures, and welding parameters. Furthermore, ongoing studies investigate welding failures, structural changes, and material testing. As highlighted in this study, improving the strength and safety of construction steel is prioritized for fundamental support in the sector.

2 Environmental Influence

Environmental conditions in the welding process are factors that cause failure of the welded joint. If not controlled, it will cause nitrogen gas content, which can cause porosity defects, so that it is susceptible to cracking, which results in poor strength and toughness tests on steel welding [13]. Several studies have been conducted to determine the effect of various environmental conditions during the welding process. Jang et al. [14] improved the Gas Metal Arc Welding (GMAW) technique for A15083-O aluminum alloys. Also, strength and toughness behaviors were examined for four different compositions of argon and helium gas, and four conditions temperature, +25 °C, -30 °C, -85 °C, and -196 °C. Tensile testing at the temperature test of +25 °C to -85 °C did not significantly but increased rapidly at -196 °C. The lower the test temperature possible, the higher the elasticity of the alloy [14]. However, the strain tends to increase as the test temperature decreases, indicating that the aluminum material can be used at extremely low temperatures. The various components of the shielding gas did not have a significant effect on the mechanical properties, but in general, the best analytical performance was shown for the Ar33% + 67%He mixture. Table 1 shows prior studies related to the environmental influence of welding systems.

Table 1. Prior studies related to the environmental influence of welding system

Authors	Application	Country	Remark
Atkins et al. [13]	Shielded Metal Arc Welding (SMAW)	USA	This study aimed to assess the susceptibility to hydrogen-induced cracking in the fusion zone of single-pass weld deposits fabricated through four distinct welding processes with equivalent levels of diffusible hydrogen.
Jang et al. [14]	Gas Metal Arc Welding (GMAW)	South Korea	The strength and elongation of the material were not affected much by the test temperature in the range of +25 °C to -85 °C, but they increased significantly at −196 °C. The shielding gas composition also had a minor impact on these properties.
Abbasi et al. [15]	Friction Stir Welding (FSW)	Iran	Mg_2Si precipitates form in the microstructure under all welding conditions. The number of precipitates increases, while the size and spacing between them decrease when applying Friction Stir Vibration Welding (FSVW) and Under Water Friction Stir Welding (UWFSW). The precipitate size is approximately 57 nm, 36 nm, and 25 nm for UWFS, FSV, and FS welded specimens, respectively.
Shimpi et al. [16]	Friction Stir Welding (FSW)	India	Friction stir welding offers an efficient and cost-effective alternative method for joining thin plates and hollow pipes. Consequently, this same joining process can be utilized for joining thin shells and tanks in various applications such as automobiles, aerospace, and shipbuilding.
Rouhi et al. [17]	Friction Stir Welding (FSW)	Iran	A rotational velocity of 1250 rev min^{-1} and a linear speed of 40 min min^{-1} are the parameters that result in faultless welds for the AZ91C magnesium alloy.

AA6061-T6 was analyzed for microstructure and mechanical characteristics and then compared with conventional Friction Stir Welding. The result showed that Friction Stir Vibration Welding (FSVW) and Under Water Friction Stir Welding (UWFSW) can effectively reduce the size and interparticle distance of precipitates, and strength and ductility are higher than the conventional Friction Stir Welding. There is also a higher tensile based on the analysis that has been carried out. Furthermore, the tensile strength of the sample welded underwater is about double that of the original material (Figure 1), according to Rouhi et al. [17].

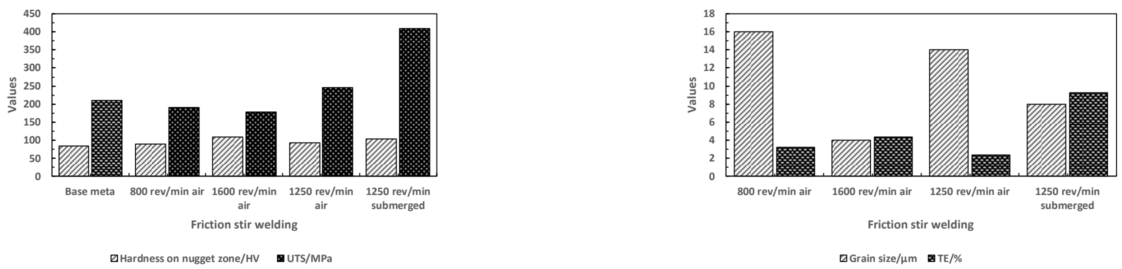


Figure 1. Samples welded in different environments based on research in [17]

Figure 2. Impact of welding conditions on the mechanical properties of joint zones based on research in [15]

Aluminum testing was recently carried out using the friction stir welding method, which compared variations of Friction Stir Vibration Welding (FSVW) and Under Water Friction Stir Welding (UWFSW) [15]. Figure 2 illustrates the influence of various joining conditions on the mechanical performance of the Stir Zone (SZ). Based on the data presented in Figure 2, the underwater friction stir welding samples exhibit superior mechanical characteristics compared to friction stir welding and friction stir-vibration welding samples. Specifically, the UWFSW samples demonstrate a higher Ultimate Tensile Strength (UTS), Yield Strength (YS), elongation, and impact toughness. The FSW samples have a yield stress of 131 MPa, UTS of 214 MPa, elongation of 6.41%, and impact toughness of 9 J. The FSVW samples exhibit a yield stress of 144 MPa, UTS of 234 MPa, elongation of 9.55%, and impact toughness of 19 J. In contrast, the UWFSW samples display a yield stress of 158 MPa, UTS of 269 MPa, elongation of 15.21%, and impact toughness of 28 J [15]. Friction Stir Welding (FSW) is a welding technique with environmentally green technology that requires less energy and does not require flux or gas, so it is more environmentally friendly than conventional welding, as shown by Shimpi et al. [16] and Rouhi et al. [17].

3 Welding Failure

Problems in welded joints can spread new problems if there is no inspection. The execution welding process, parameters welding process, and design of the weld geometry are basic problems in welded joints. Determining the causes of the failure of the weld joint can be analyzed by light microscopy, material testing, stress analysis, and visual inspection, as shown by Somers and Pense [18]. Selection of steel quality also affects failure in welding, especially in steels joined together, which are very sensitive to fatigue, weld quality, and weld corrosion. Table 2 shows prior studies related to the welding failure.

Steel structure construction is widely used in the manufacture of bridges, towers, building construction, and others. There is a connection that is connected at each end to each other using bolts, rivets, or welding. These crisis structures often get loads that exceed their normal load and are required for long years with environmental conditions that produce fluctuating pressure, see Thomas [19]. As presented in the study, insufficient penetration in a weld, as depicted in Figure 3, can result in premature failure at stresses significantly lower than the intended design stress for the application. In such cases, fatigue cracks tend to initiate at the weld toe and propagate along the bead of the weld until fracture occurs. Hence, ensuring the quality of the weld is of utmost importance to produce durable and high-quality welds.

Stabryła and Dutka [20] researched welding failure of construction steel, which affects durability, strength, and safety. In Figure 4, there is a welding failure in the GMAW technique. Cracks are visible on the outside base material precisely in the heat-affected zone. It can occur due to changes in volume and consist of harder martensite, which is affected by heat. The study further reveals that attempts were made to attribute the cracking to the presence of atomic nitrogen in the structure, which could lead to aging, along with the high Carbon Equivalent Value (CEV).

However, the steel used in accordance with the certificate demonstrates low nitrogen content and adequate silicon and aluminum content, ensuring proper settling and resistance to aging. Additionally, the CEV value of 0.36% is significantly below the standard limit of 0.50%, indicating that the steel's chemical composition should not pose any welding issues. One possible cause of material failure is the application of an external load that exceeds the strength of the material [22-24]. This failure can compromise the integrity and performance of engineering components or structures [25-28].

Table 2. Prior studies related to the welding failure

Authors	Application	Country	Remark
Somers and Pense [18]	Gas Metal Arc Welding (GMAW)	United States	Typically, welding failures can be attributed to welding issues classified into five categories. These are failures resulting from improper weld geometrical design, failures resulting from inappropriately specified weld process parameters, failures resulting from incompatibilities of the materials being welded and the processes employed, failures resulting from improperly executed welds, and failures resulting from unanticipated service conditions.
Thomas [19]	Gas Metal Arc Welding (GMAW)	United Kingdom	Various variables, including the magnitude of notch root stress and the properties of the notch itself, influence weld fatigue life. Factors such as applied stresses, warping degree, residual stresses, weld geometry, and size, as well as the presence of any weld defects, impact the notch stress. Consequently, the local stress at a notch plays a crucial role in determining the fatigue behavior of a weld.
Stabryła and Dutka [20]	Metal Active Gas (MAG) welding	Poland	The utilization of an incorrect welding technique resulted in the presence of several welding defects, primarily incomplete fusions. Improper preparation for welding, such as excessive distance, potentially excessive thresholds, and lack of scarfing, also contributed to these issues.
Gemme et al. [2]	Friction Stir Welding (FSW)	Canada	The fatigue strength of FSW joints is determined by a competition between two failure mechanisms associated with the welding pitch. Initially, fatigue cracks can originate from the root of circular grooves left on the weld surface by the tool.
Saju and Velu [21]	Rotary Friction Welding (RFW)	India	A crack originated and propagated along the weld, with the Base Metals (BMs) exhibiting higher toughness compared to the Dissimilar Metal Welded Joints (DMWJs). The DMWJs demonstrated inferior crack growth resistance compared to the BMs. However, post-weld heat treatment improved both the Fracture Toughness (FT) and crack growth resistance in the DMWJ compared to the untreated DMWJ.

Welding failures are common in marine engineering, particularly in ship structures. Researchers have delved into the evaluation of high cycle fatigue behavior in different types of welded joints used in ship hull structures. Hariprasath et al. [29] conducted a study that focused on flux-cored arc welded naval grade DMR249 A-grade steel joints, providing valuable insights into the stages of fatigue failure, ranging from crack initiation to propagation and final fracture. Understanding these stages is crucial for flux-cored arc welding of micro-alloyed naval-grade steel. Another study by Nathan et al. [30] examined the impact of tool rotational speed on the microstructure and mechanical properties of friction stir welded DMR249A high-strength low alloy steel butt joints for lightweight shipbuilding structures. Their findings showed that a specific Tool Rotational Speed (TRS) of 600 rpm resulted in the formation of lathe upper bainitic microstructure, leading to higher tensile strength and acceptable impact toughness properties in the joint. Moreover, Kožuh et al. [31] utilized Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray (EDX) analysis to identify inclusions sporadically present in the microstructure of the weld metal and the heat-affected zone. These inclusions, consisting of oxygen, calcium, aluminum, silicon, magnesium, and sulfur, were found to be a potential cause for pitting initiation in the weld metal/heat-affected zone.

Additionally, the corrosion of these regions might be attributed to the galvanic effect between inter-dendrite chromium-rich delta ferrite (21.09% Cr, 8.37% Ni) and nickel-rich austenite (15.72% Cr, 10.84% Ni), as presented in their study.

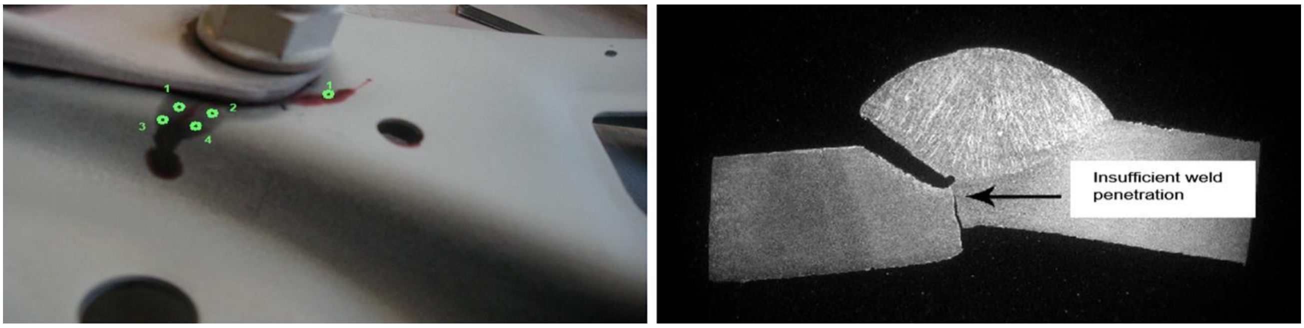


Figure 3. The construction joint failed as a result of insufficient weld penetration, leading to the initiation of a fatigue crack and subsequent fracture [19]

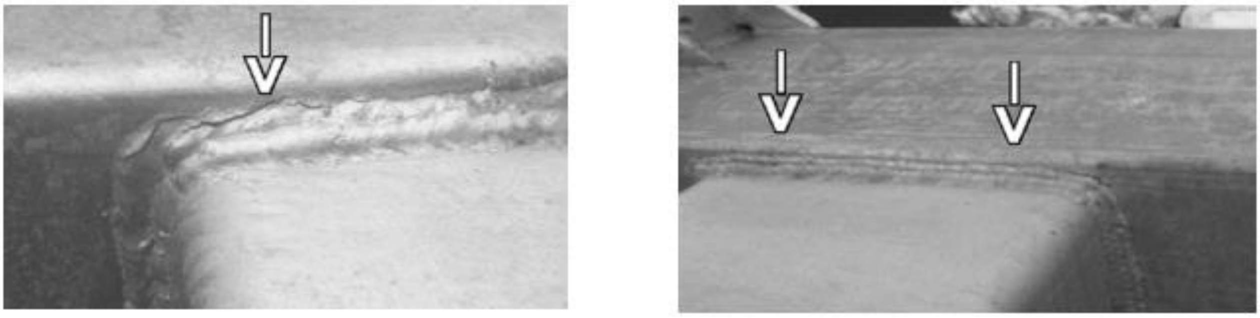


Figure 4. Cracking in the Heat Affected Zone (HAZ) circumferential weld [20]

As for treatments to improve the fatigue strength of welded joints in ship structures, burr grinding, Tungsten Inert Gas (TIG) dressing, and hammer peening have been identified as cost-effective options. However, it is essential to view these treatments primarily as remedial actions or repairs rather than as standard procedures for the design of new structures. Modifying the joint design during the initial stage is preferable to achieve the desired fatigue performance for the overall structure, as recommended in the study by Kirkhope et al. [32].

4 Welding Parameters

Modern information technologies such as the Internet of Things (IoT), big data, artificial intelligence, cloud computing, and intelligent manufacturing are transforming welding systems. These technologies enable Intelligent Welding Systems (IWS), which use computers to sense, learn, decide, monitor, and control various aspects of welding. IWS is attracting attention from both academic and industrial communities.

Industrial production lines rely heavily on welding processes and systems. Over the years, many welding operations that use handheld tools have been automated with welding systems that use industrial robots [33]. However, these welding robots are mostly preprogrammed machines with little or no intelligence. Modern welding processes are complex, with many parameters and a limited understanding of the process mechanism. Previous reviews have introduced and described several welding parameters effects, as summarized in Table 3. Ngo et al. [35] introduce a new method for improving the welding outcomes of a Gas Metal Arc Welding (GMAW) system using a decentralized control approach. The paper considers the GMAW system as two separate subsystems: the Power Source of GMAW (PS-GMAW) and the Wire Feed Unit (WFU). The paper proposes and applies sliding mode control and proportional control methods to control the welding current and voltage output for tracking the set value. As shown in Figure 5, the output welding current and voltage were stable after 3.5 seconds and closely matched the setting values throughout the welding process. The simulation results indicate that the output values were 110 A and 22 V, respectively. Friction stir welding of steel offers many benefits for various industrial sectors over traditional fusion welding methods.

Table 3. Prior studies related to the welding parameters effects

Authors	Application	Country	Remark
Chu and Tung [34]	Shielded Metal Arc Welding (SMAW)	Taiwan	The results of the experiments indicate that the proposed adaptive sliding mode controller for the automatic SMAW control system can not only substitute manual operations but also perform shielded metal arc welding effectively.
Ngo et al. [35]	Gas Metal Arc Welding (GMAW)	South Korea	The developed digital automatic GMAW system ensures that the welding values match the desired values, as demonstrated by the simulation and experiment results. Moreover, the quality of the welding line is guaranteed by the developed GMAW system.
Toumpis et al. [36]	Friction Stir Welding (FSW)	United Kingdom	The Charpy impact testing results and micro-hardness measurements show that the strength and hardness of the weld are not compromised by increasing the welding traverse speeds of FSW of steel, which enhances the competitiveness of this solid-state joining method.
Raimondi et al. [37]	Inertia Friction Welding (IFW)	United Kingdom	The spindle of the machine may have some runout due to the fabrication and assembly tolerances and the supporting elements' compliance.
Santos et al. [38]	Shielded Metal Arc Welding (SMAW)	Brazil	Designed AWS E70XX oxy rutile Ni-Mo low alloy electrodes can make welds with the properties needed for Class A welds according to the AWS D3.6 M code. These properties include ductility, mechanical strength, and toughness.

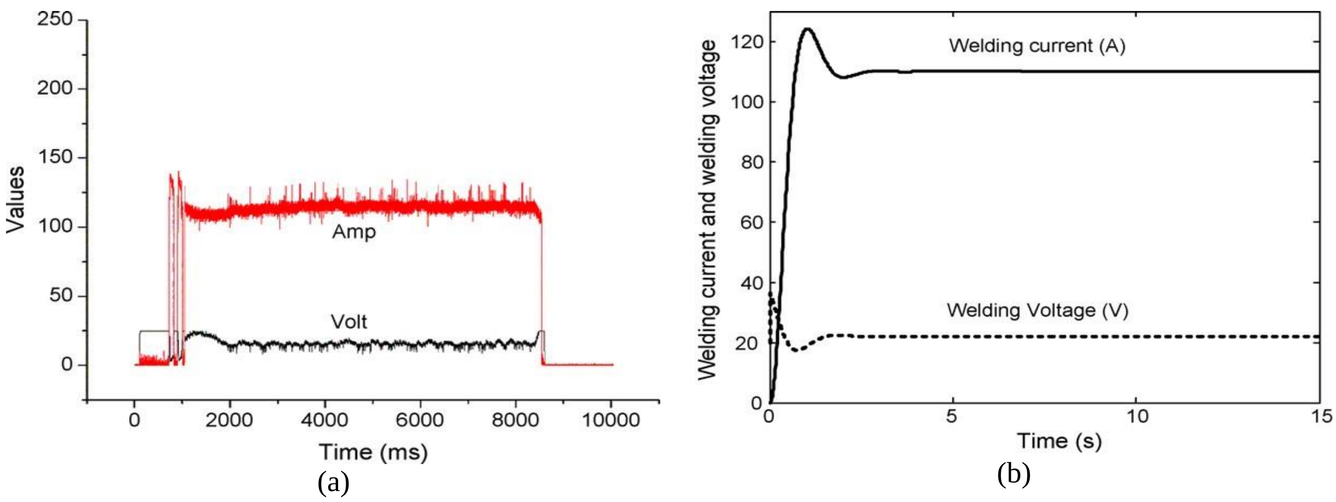
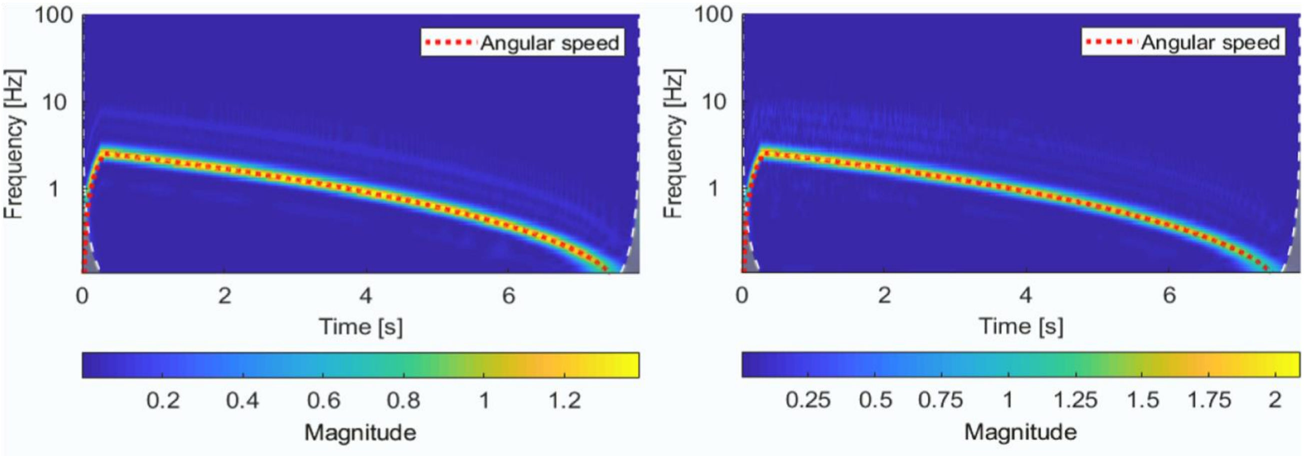


Figure 5. (a) Experimental results of developed GMAW, and (b) tracking current and voltage [35]

Toumpis et al. [36] established a process envelope for friction stir welding of DH36 Steel. It shows how increasing the welding traverse speeds can enhance the impact toughness of the weld and make the FSW of steel more competitive. Raimondi et al. [37] propose a new monitoring system that can measure the effects of the machine and the tooling on the Inertia Friction Welding (IFW) process in real-time. Furthermore, the output of a laser and a Linear Variable Differential Transformer (LVDT) was analyzed using a frequency spectrum, as shown in Figure 6.



(a) (b)

Figure 6. (a) Comparison between the scalograms of laser, and (b) LVDT with the angular speed of the spindle (dashed line) [37]

The development of welding systems has been a significant advancement in the field of manufacturing and engineering. Welding is the process of joining two or more metal parts by melting and fusing them. The welding system consists of various components, such as a power source, electrode, torch, filler material, shielding gas, and control unit. The manipulation of welding parameters can greatly influence quality and integrity of welded joints. Varied welding parameters can lead to diverse outcomes in terms of weld strength and structural integrity. Furthermore, the development of welding systems has been influenced by several factors, such as the demand for high-quality and durable products, the need to reduce production costs and time, the availability of new materials and technologies, and the environmental and safety regulations [37]. Some of the recent developments in welding systems include laser welding, friction stir welding, ultrasonic welding, and hybrid welding. These methods offer advantages such as high speed, precision, efficiency, and flexibility over conventional welding methods. Marine engineering has witnessed significant development in recent years [39-40]. However, they also pose some challenges, such as high initial cost, complex operation, and limited applicability. Therefore, further research and innovation are needed to overcome these limitations and improve the performance and reliability of welding systems.

5 Predictions of Development Regarding the Welding and Corrosion

The weld zone may be more susceptible to corrosion because of its different chemical makeup, residual stress, and metallurgical structure. To prevent corrosion of weld joints, the materials, filler metal, welding techniques, and finishing should be chosen carefully. However, even with these precautions, weld corrosion may still happen for various reasons.

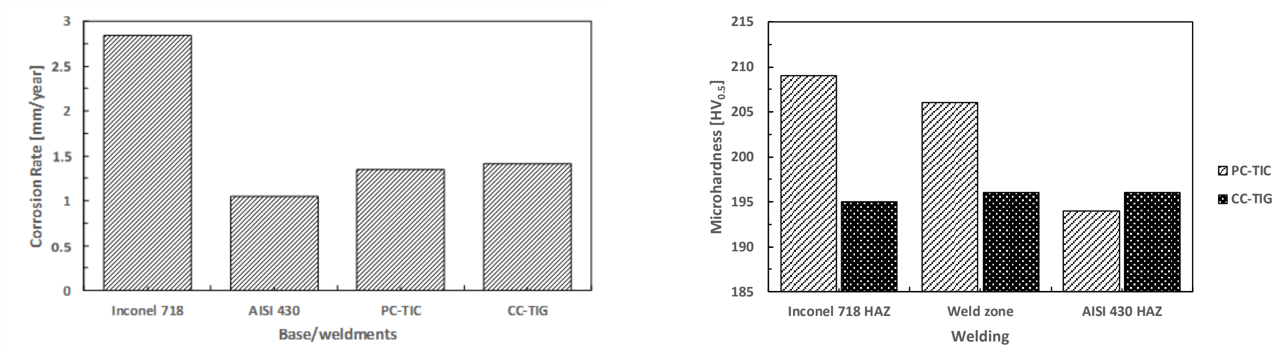
Chen et al. [41] recently conducted research focusing on the effects of Titanium (Ti) on the Microstructure, Mechanical Properties, and Corrosion Behavior of High-Strength Steel Weld Metals utilized in Offshore Structures. Their findings revealed that the weld metal's corrosion resistance increases with an increase in Ti content, ranging from 0.001 to 0.018 wt%. However, when the Ti content was increased to 0.022 wt%, the corrosion resistance of the weld metal deteriorated. In 2023, Yelamasetti et al. [42] investigated the metallurgical, mechanical, and corrosion behavior of pulsed and constant current Tungsten Inert Gas (TIG) dissimilar welds between AISI 430 and Inconel 718. The corrosion rate of the Pulsed Current Tungsten Inert Gas (PC-TIG) weldment was observed to be 1.35 mm/year, which is lower than that of the Constant Current Tungsten Inert Gas (CC-TIG) weldment (1.41 mm/year). The PC-TIG weldment exhibited improved corrosion resistance compared to the CC-TIG weldment and the base metal Inconel 718, as shown in Figure 7. Similarly, Ilman et al. [43] investigated the Metallurgical, mechanical, and corrosion characteristics of vibration-assisted gas metal arc AA6061-T6 welded joints. Their findings demonstrated that the application of mechanical vibration significantly increased the tensile strength of the welded joints by up to 83.3% higher when compared to the welds without vibration, with a frequency of

300 Hz. The strengthening mechanisms in the vibrated weld joints were primarily attributed to grain refinement in the weld metal region, involving columnar dendritic and equiaxed dendritic microstructures, which contributed to inhibiting fatigue crack growth in the weld metal.

Table 4. Prior studies related to the predictions of development regarding the welding and corrosion

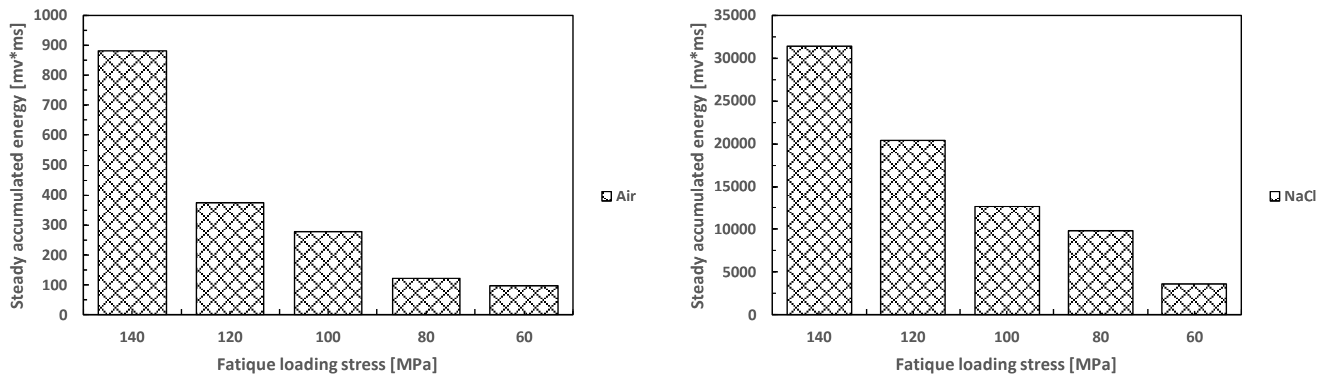
Authors	Application	Country	Remark
Chen et al. [41]	Shielded Metal Arc Welding (SMAW)	China	The addition of Ti had a significant impact on the microstructure, the oxide formation, the mechanical properties, and the corrosion resistance of the weld metal. The weld metal grains became finer as the Ti content increased. It resulted in higher tensile strength and corrosion resistance but lower impact properties.
Yelamasetti et al. [42]	Tungsten Inert Gas (TIG) welding	India	PC-TIG welding creates weldments with high mechanical performance, low corrosion susceptibility, and fine-grained structures at the root zones. These results have industrial relevance for assembling turbine discs and shafts.
Ilman et al. [43]	Gas Metal Arc Welding (GMAW)	Indonesia	The interdendritic regions of the weld joints that were assisted by vibration had less Mg_2Si and other intermetallic compounds, which lowered the chances of local galvanic cells and enhanced the corrosion resistance. The Heat Affected Zone (HAZ) and base metal might show similar corrosion behavior.
Ambade et al. [44]	Shielded Metal Arc Welding (SMAW)	India	The results show that the corrosion rate is higher for higher welding current. The SMAW weld joint has a higher corrosion rate than the GMAW and GTAW weld joints.
He et al. [45]	Friction Stir Welding (FSW)	China	Acoustic Emission (AE) energy, fatigue behavior, and evaluation technique of AZ31 welded joints are significantly affected by the corrosive environments. More AE events occur in corrosive environment due to the initiation, growth, and branching of cracks, resulting in higher AE energy accumulation than in air (non-corrosive environment). The corrosion fatigue limit of AZ31 welded joints in 3.5 wt% NaCl solution is about 50% lower than in air, indicating a high reduction rate.

Ambade et al. [44] investigated the effect of welding processes and heat input on the corrosion behavior of Ferritic stainless steel 409M. Ferritic stainless steel 409M was welded using Shielded Metal Arc Welding (SMAW), Gas Metal Arc Welding (GMAW), and Gas Tungsten Arc Welding (GTAW) at welding currents of 90A, 100A, and 110A in their study. Their findings revealed that the corrosion rate increased with higher welding currents. Moreover, the corrosion rate was observed to be higher in SMAW weld joints compared to GMAW and GTAW weld joints. In a separate study by He et al. [45], the corrosion fatigue Acoustic Emission (AE) characteristics and evaluation of friction stir welding joints of AZ31 magnesium alloy were investigated in a 3.5 wt% NaCl solution. The corrosive environment significantly influenced the AE energy, fatigue property, and evaluation method of AZ31 welded joints. In the corrosive environment, the accumulated AE energy was higher than that in a non-corrosive environment (air), owing to increased AE sources from crack initiation, propagation, and secondary crack generation. The corrosion fatigue limit of AZ31 welded joints in the 3.5 wt% NaCl solution was reduced by approximately 50% compared to that in air. The corrosion fatigue estimation model based on two lines was found to be appropriate because the corrosive environment accelerated or even eliminated the corrosion fatigue deformation process in each stage, as shown in Figure 8.



(a) (b)

Figure 7. The outcomes of corrosion tests conducted on the weldments of base/inconel 718 and AISI 430 based on: (a) Corrosion rate, and (b) Microhardness [42]



(a) (b)

Figure 8. Acoustic emission's energy gradually accumulates under varying fatigue loading stress: (a) Air, and (b) NaCl solution [45]

Corrosion occurring in the weld metal regions can have serious consequences, frequently resulting in significant structural failures. Mochizuki's study [46] demonstrated the effectiveness of an in-process control method in preventing fatigue and stress-corrosion cracking, which was supported by numerical analysis and actual experiments. This study looked into post-weld control methods, specifically water jet peening and TIG cladding. Water jet peening was effective in generating compressive residual stress on the surface, which improved resistance to fatigue and stress-corrosion cracking. Furthermore, it was found that cladding the weld with a corrosion-resistant material was effective in mitigating stress-corrosion cracking. The residual stress at the interface of the base metal was found to be within acceptable limits for stress-corrosion cracking.

6 Conclusions

Environmental influence, welding failure, welding parameters, and predictions regarding welding and corrosion are vital aspects of welding engineering. Environmental factors like temperature, humidity, corrosion, and stress impact weld quality and performance. For instance, high temperatures can cause thermal expansion and contraction, leading to residual stress and distortion. Welding failure arises from defects or errors during the welding process, causing cracks, fractures, or distortions. Advancements in welding systems aim to improve efficiency, safety, and reliability through technologies like laser welding, friction stir welding, robotics, sensors, and new materials. These interconnected aspects necessitate continuous research and innovation to optimize welding engineering for diverse applications. Future research should focus on optimizing welding systems for seawater conditions to enhance performance and reliability in order to advance marine engineering and address challenges like high costs and complex operations.

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