

## POWER VOLTAGE AND WELDING DEFECTS IN STEEL FABRICATION PROJECTS OF CONSTRUCTION FIRMS IN SOUTH-SOUTH NIGERIA

Engr. Ubani Ajuzieogu CHRISTIAN PhD<sup>1</sup> & Mark Ukelabuchi IDEOZU<sup>2</sup>

<sup>1</sup> Mechanical Engineering Department, Ogonnaya Onu Polytechnic, Aba, Abia State Nigeria

<sup>2</sup> School of Engineering and Biomedical Technology, Rivers State College of Health Science and Management Technology, Oro-Owo Rumueme, Port Harcourt

Email: [ajuzieogu.ubani@abiastatepolytechnic.edu.ng](mailto:ajuzieogu.ubani@abiastatepolytechnic.edu.ng) ; ORCID ID : 0009-0001-7417-3399<sup>1</sup>, [idemac2000@yahoo.co.uk](mailto:idemac2000@yahoo.co.uk)<sup>2</sup>

D.O.I: 10.5281/zenodo.18497000

Received: 12.12.2025 | Accepted: 02.01.2026 | Published: 30.01.2026

### ABSTRACT

### RESEARCH ARTICLE

*Welding quality plays a critical role in the structural performance of steel fabrication projects in the construction industry. In many developing regions, including South-South Nigeria, unstable power supply and improper control of welding voltage often contribute to welding defects and reduced joint performance. This study investigates the effect of welding voltage on the mechanical properties of welded steel joints with the aim of identifying optimal voltage conditions that minimize defects and enhance joint strength. Submerged arc welding was employed to produce full-penetration butt joints using pressure-vessel-grade carbon steel. Welding was carried out at three different voltage levels—26 V, 30 V, and 34 V—while welding current, speed, and electrode orientation were kept constant. Tensile tests were performed on the welded specimens, and stress–strain curves were generated to evaluate key mechanical properties, including maximum tensile force, maximum tensile stress, yield tensile stress, breaking stress, and strain energy absorbed up to fracture. The results show a clear correlation between welding voltage and mechanical performance. Increasing welding voltage led to improved tensile strength, higher ductility, and greater strain energy absorption. Welded joints produced at higher voltage exhibited superior mechanical properties, with strain energy showing the greatest sensitivity to voltage variation. The findings indicate that appropriate control of welding voltage significantly enhances weld quality and reduces the likelihood of welding defects associated with inadequate fusion and poor mechanical bonding. The study concludes that welding voltage is a critical parameter in steel fabrication, and its optimization can substantially improve the structural integrity and reliability of welded joints in construction projects. The results provide useful guidance for construction firms and fabricators seeking to improve welding quality under variable power supply conditions.*

**KEYWORDS:** Power Voltage, Welding Defects In Steel Fabrication, Projects of Construction Firms in South-South Nigeria

## INTRODUCTION

Steel fabrication plays a vital role in the construction industry, particularly in the development of infrastructure such as bridges, high-rise buildings, industrial plants, and oil and gas facilities. Welding, as a primary method of joining steel components, must meet strict quality standards to ensure structural integrity and safety. Any defects arising from poor welding practices can compromise the performance of structures and lead to costly repairs or catastrophic failures. The identification and control of hazards is not a simple matter. It has become more difficult as the depth of technology has increased. Despite the advances in control technology, welders continue to be exposed to welding fumes and gases (Wallace, et al., 2019). Physical hazards no longer lie on the surface accessible to a simple inspection. (Qureshi, 2017) had done a hazard and operability study in which potential hazards are identified by looking at the design in a dynamic manner. In Nigeria's South-South region, construction activities are extensive due to rapid urbanization, industrial development, and oil and gas operations. However, one of the persistent challenges faced by construction firms in this region is unreliable electrical power supply. Frequent voltage fluctuations, low voltage levels, sudden power outages, and inconsistent generator output are common, creating unfavorable conditions for welding operations. There is, however, no single idea or system of hazard identification and control the most appropriate system vary to a small extent with the type of industry and processes involved. In fact, there is usually the need for a combination of methods to be used. Hazard management is a systematic identification, evaluation and control of hazard at all phases of the life cycle, (OSHA, 2019). Power voltage stability is a critical factor in welding processes, as welding machines require consistent electrical input to produce stable arcs and proper heat distribution. Variations in voltage can result in irregular arc behavior, insufficient heat input, and poor weld penetration, leading to various welding defects.

Despite the widespread occurrence of these issues, limited empirical attention has been given to the specific impact of power voltage on welding defects in steel fabrication projects within South-South Nigeria. Welding is a fabrication or sculptural process that joins materials, usually metals or thermoplastics, by causing coalescence. This is often done by melting the work pieces and adding a filler material to form a pool of molten material (the weld pool) that cools to become a strong joint, with pressure sometimes used in conjunction with heat, or by itself, to produce the weld. (Osha, 2019). This study seeks to bridge this gap by examining how power voltage conditions influence the occurrence of welding defects in construction firms operating in the region. Understanding this relationship is essential for improving weld quality, ensuring structural safety, reducing project costs, and enhancing overall construction performance. Many different energy sources can be used for welding, including a gas flame, an electric arc, a laser, an electron beam, friction, and ultrasound. While often an industrial process, welding and fabrication may be performed in many different environments, including open air, under water and in outer space. Welding is a potentially hazardous undertaking and precautions are required to avoid burns, electric shock, vision damage, inhalation of poisonous gases and fumes, and exposure to intense ultraviolet radiation. Welding is a hazardous process burns to skin, flash burns to the eye and fire are some the more immediate and acute hazard (Ashby, 2015). Until the end of the 19th century, the only welding process was forge welding, which blacksmiths had used for centuries to join iron and steel by heating and hammering. Arc welding and oxyfuel welding were among the first processes to develop late in the century. And electric resistance welding followed soon after.

Welding and fabrication technology advanced quickly during the early 20th century as World War II drove the demand for reliable and inexpensive joining methods. Following the wars, several modern welding techniques were developed, including manual methods like shielded metal arc welding, now one of the most popular welding methods, as well as submerged arc welding, flux-cored arc welding and electroslag welding. Developments continued with the invention of laser beam welding, electron beam welding, electromagnetic pulse welding and friction stir welding in the latter half of the century. To prevent future injuries in welding and fabrication outfits in Nigeria, a safety Act was established. Health and safety in the manufacturing industry is regulated by the factory Act in 1990. The provision of this Act has enabled the federal government of Nigeria to put in place statutory practice and structure for inspecting the health and safety conditions of the industry, for reporting accidents and injuries in the industries and sanctioning non-compliance with statutory health and safety conditions. However, such regulation practice and structure do not exist in some welding and fabrication industries; therefore, some welders are left to use their judgment on such important issues, the consequences of which are that welders commit little resources to maintaining health and safe working environments. To identify and evaluate hazards, this has seriously increased job-related hazards which thereby lead to job injuries and accidents because some workers are not aware of the various causes of job hazards, let alone of how they can be managed, and this has necessitated the researcher to specifically determine hazard and its control measures in welding and fabrication outfits in Minna metropolis of Niger State.

### **Statement of the Problem**

Welding and fabrication industries have become one of the major industries in Nigeria and are considered one of the most hazardous. Since the advent of crude oil, many multi-national oil companies depend on welding and fabrication industries for materials they use in processing their products. Welding is the infusion or joining of two materials which makes the job so hazardous. Today's welding and fabrication industrial sector face a stark reality of poor health and unsafe practices on the part of management and workers. Some of the hazards that occur in welding and fabrication industries could be traced to managerial negligence which includes poor ventilation, poor incentives and remunerations, denial of financial emoluments, poor performance appraisal by management of the organization and negligence on the part of workers to use personal protective equipment (PPE) for safety. As a result of this, a large percentage of accidents in the welding and fabrication industry are caused by poor hazard management. The unsafe practice and hazards that frequently occur in welding and fabrication industries is due to the fact that there is poor management appraisal and inability to identify potential hazards. With good supervision and a management team with experts in identifying potential hazards, the rate of hazards was curtailed in fabrication industries. The necessity for the study is to unveil and determine hazard and its control measures in welding and fabrication outfits in Minna metropolis of Niger State. Construction firms in South-South Nigeria frequently encounter welding defects in steel fabrication projects, leading to rework, material wastage, increased project costs, and compromised structural integrity. While welding defects can result from several factors such as poor workmanship, substandard materials, and inadequate supervision, unstable power voltage remains a major but underexplored contributor. The persistent problem of unreliable electricity supply in the region exposes welding operations to voltage drops, surges, and interruptions. These conditions negatively affect welding machines, causing irregular arc behavior, inconsistent heat input, and equipment malfunction. As a result, defects such as porosity, lack of fusion, cracks, and incomplete penetration become more prevalent. The lack of empirical studies linking power voltage instability to welding defects has limited the ability of construction firms and regulators to develop effective mitigation strategies. Without a clear understanding

of this relationship, projects continue to suffer quality failures and safety risks. This study therefore addresses the problem of inadequate knowledge on how power voltage affects welding quality in steel fabrication projects in South-South Nigeria.

## Literature Review

Welding is a material joining process in which two or more parts are coalesced (joined together) at their contacting surfaces by a suitable application of heat or pressure. In some welding process, a filler material is added to facilitate coalescence. Welding is most commonly associated with metallic parts but for plastics also it is used. Welding is a fabrication process whereby two or more parts are fused together by means of heat, pressure or both forming a join as the parts cool. Welding is usually used on metals and thermoplastics but can also be used on wood. The completed welded joint may be referred to as a weldment. Some materials require the use of specific processes and techniques. A number are considered 'unweldable,' a term not usually found in dictionaries but useful and descriptive in engineering (Welding Institute, Cambridge). Welding and fabrication are fundamental processes in construction, manufacturing, and industrial engineering, particularly in projects involving steel structures. Fabrication refers to the process of cutting, shaping, assembling, and joining metal components to form finished products or structural elements. Welding, on the other hand, is a specialized joining process within fabrication that involves the fusion of metals using heat, pressure, or both, with or without the addition of filler material. Together, welding and fabrication play a critical role in determining the strength, durability, and safety of constructed facilities. In welding and fabrication, the parts that are joined are known as a parent material. The material added to help form the join is called filler or consumable. The form of these materials may see them referred to as parent plate or pipe, filler wire, consumable electrode (for arc welding). Consumables are usually chosen to be similar in composition to the parent material, thus forming a homogenous weld, but there are occasions, such as when welding brittle cast irons, when filler with a very different composition and, therefore, properties is used. These welds are called heterogeneous. Welding is used in virtually every industry, so welders need to be creative in choosing the right welding type and joint style. Here are some common ways to join two pieces together: Edge joint, T-joint, Corner joint, Lap joint, Butt joint A welder chooses the type of joint after carefully considering the materials and application. Does the material need to withstand heavy shear loads or torsional loads? This can affect the best type of joint and which weld type is used. Welding works by applying sufficient heat to melt the base metals at the joint, allowing them to fuse upon cooling. Common welding processes used in steel fabrication include Shielded Metal Arc Welding (SMAW), Gas Metal Arc Welding (GMAW), Gas Tungsten Arc Welding (GTAW), and Submerged Arc Welding (SAW). Each welding method has specific voltage, current, and heat input requirements that must be carefully controlled to achieve quality welds. Proper control of these parameters ensures adequate penetration, fusion, and bead appearance while minimizing defects. Fabrication encompasses several stages, including material selection, cutting, forming, fitting, welding, and finishing. In steel fabrication projects, precision at each stage is essential to ensure dimensional accuracy and structural integrity. Welding is often regarded as the most critical stage because defects introduced during welding can compromise the entire fabricated component. As such, welding quality is closely monitored through inspections and testing methods such as visual inspection, ultrasonic testing, and radiographic testing.

The effectiveness of welding and fabrication processes depends on several factors, including the skill of the welder, quality of materials, environmental conditions, and availability of suitable equipment. Among these factors, power supply plays a crucial role, particularly in

electric arc welding processes that rely on consistent voltage and current. Stable power voltage ensures a steady arc, uniform heat input, and proper melting of the base metal and filler material. In developing regions such as South-South Nigeria, welding and fabrication activities are often affected by unstable power supply. Voltage fluctuations, power interruptions, and reliance on generators can disrupt welding operations and increase the likelihood of defects. These challenges highlight the importance of understanding welding and fabrication concepts in relation to power conditions, as poor control of electrical parameters during welding can result in weak joints, structural failures, and increased construction costs. Understanding the concept of welding and fabrication therefore provides a foundation for analyzing how power voltage affects welding quality in steel fabrication projects. It underscores the need for proper process control, skilled personnel, and reliable power supply to achieve high-quality fabrication outcomes.

### **Welding and Fabrication Hazards Control**

A hazard is a potential source of harm. Substances, events, or circumstances that can constitute hazards when their nature would allow them, even just theoretically, to cause damage to health, life, property, or any other interest of value. The probability of that harm being realized in a specific incident, combined with the magnitude of potential harm, make up its risk, a term often used synonymously in colloquial speech (Smith Keith, 1992). Welding and fabrication hazards include electric shock. During the arc welding process, live electrical circuits are used to create a pool of molten metal. Therefore, when welding, you are at risk of experiencing an electric shock. Electric shock is the most serious hazard posed by welding and can result in serious injuries and fatalities, either through a direct shock or from a fall from height after a shock. You are also at risk of experiencing a secondary electric shock should you touch part of the welding or electrode circuit at the same time as touching the metal you are welding.

**Welding helmets with side-shields:** Welding helmets protect you from UV radiation, particles, debris, hot slag and chemical burns. It's important that you wear the right lens shade for the work you are carrying out. Follow the manufacturer's guidelines and gradually adjust the lens filter until you have good visibility that does not irritate your eyes. You should also use a fire-resistant hood under your helmet to protect the back of your head.

**Respirators:** Respirators protect you from fumes and oxides that the welding process creates. Your respirator must be suitable for the work you are carrying out.

**Fire resistant clothing:** Fire resistant clothing protects you from heat, fire and radiation created in the welding process and shields you from burns. It should have no cuffs, and pockets must be covered by flaps or taped closed. You should not use synthetic clothing. Instead, opt for leather and flame-resistant treated cotton.

**Ear protection:** Ear protection protects you from noise hazards. It's important you wear ear protection that is appropriate for the noise created in your workplace, and use fire resistant ear muffs if there is a risk of sparks or splatter entering the ear.

**Fire disaster:** Ensure a workspace is free of flammable material. You should avoid keeping flammable materials in the vicinity of welding processes as sparks, heat and molten metal splatters produced in the welding process could potentially set flammable material on fire.

## Noise Hazards

When carrying out welding activities, exposure to loud, prolonged noises is imminent and unavoidable in most cases. A loud noise is considered to be above 85 dB(A), and welding activities such as flame cutting and air arc gouging can produce noise levels of over 100 dB(A). This can be very damaging to the ears and can result in hearing impairment.

## Materials and Methods

For the experimental work conducted in this study, a pressure-vessel-grade steel was selected as the base material. The material is a fine-grained carbon steel designated P355N, in accordance with SR EN 10216-3:2003. This steel grade is commonly used in structural and pressure applications due to its favorable mechanical properties and weldability. The filler material employed was a commercially available electrode wire known as OK Autrod 12.24, with a diameter of 3.2 mm. This wire is specifically developed for submerged arc welding (SAW) applications and is composed of a copper-coated, molybdenum-alloyed steel to enhance weld strength and stability. To provide adequate shielding of the molten weld pool, a granular flux material identified as OK Flux 10.47 was used. The flux was applied uniformly over the weld joint at an approximate thickness of 25 mm, ensuring proper protection from atmospheric contamination. The welding process adopted was butt welding with full penetration, carried out in compliance with SR EN 287-1. Welding was performed using the submerged arc welding process with wire electrode (process number 121) as classified under EN ISO 4063, corresponding to the butt weld (BW) joint configuration. A welding root support (mb), as specified in SR EN 287-1, was utilized to ensure complete penetration and joint integrity. All welds were executed in the horizontal welding position (PA) in accordance with SR EN ISO 6947. The joint configuration involved single-pass welding from one side only.

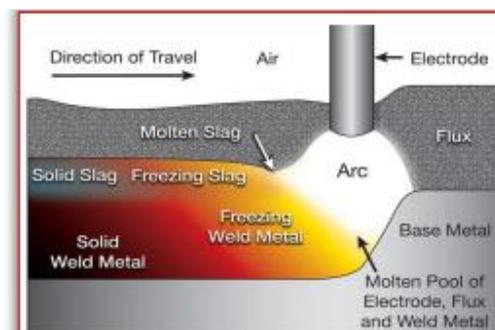


Figure 1. The process of submerged arc welding [7]

During the experimental program, welding was carried out under different voltage conditions while all other welding parameters were maintained constant. Figure 2 illustrates the welding process used to join two steel plates under varying voltage regimes. The constant welding parameters applied throughout all experimental runs were:

- Welding current: 480 A
- Welding speed: 60 cm/min
- Electrode angle: 90°

Three different welding voltage levels—26 V, 30 V, and 34 V—were investigated. For each voltage setting, four tensile test specimens were fabricated in accordance with BS EN 895:1995. From each voltage group, a representative stress–strain curve was selected and compared with those obtained from the other voltage conditions to evaluate the influence of welding voltage on mechanical performance.

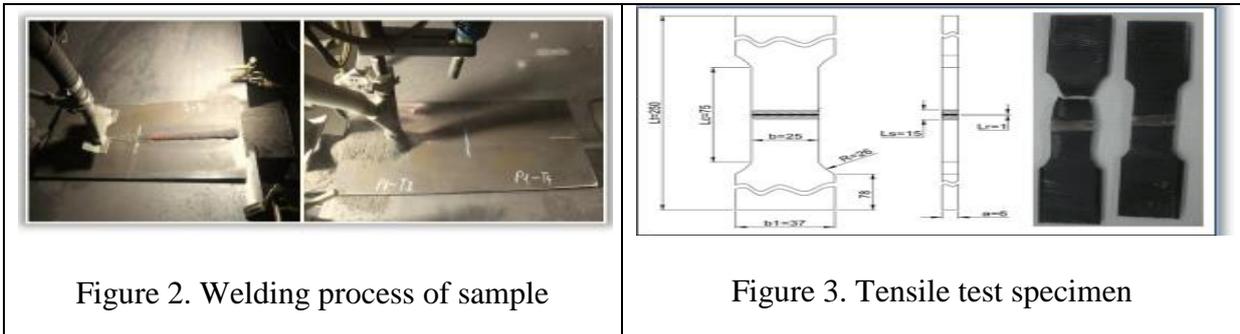


Figure 3 presents the schematic representation of the specimen geometry and dimensions used for tensile testing, along with images of a typical specimen before and after the tensile test.

### Data Analysis and Interpretation

The tensile tests conducted on the welded specimens generated experimental data that were processed to obtain stress–strain curves for each welding voltage condition. Figure 4 presents the representative stress–strain curves corresponding to welding voltages of 26 V, 30 V, and 34 V. A consistent upward shift of the curves is observed with increasing welding voltage, both along the stress axis and the strain axis. This indicates an overall improvement in the mechanical performance of the welded joints as the welding voltage increases. The stress–strain curves provided a basis for extracting key mechanical properties that characterize the strength and deformation behavior of the welded joints. These properties include maximum tensile force, maximum tensile stress, yield stress, and strain energy absorbed up to fracture. The numerical values obtained from the curves are summarized in Table 1.

**Table 1. Mechanical Properties of Welded Joints at Different Welding Voltages**

Mechanical Parameter	26 V	30 V	34 V	Unit
Maximum tensile force	62.31	66.97	79.74	kN
Maximum tensile stress	257.77	284.69	311.25	MPa
Strain at maximum stress	3.31	3.62	5.58	%
Breaking (fracture) stress	116.95	147.35	155.03	MPa
Strain at breaking stress	4.42	4.30	6.60	%
Yield tensile stress	42.13	207.33	220.49	MPa
Strain at yield stress	0.55	1.77	2.03	%
Modulus of elasticity	122,580	154,170	102,990	MPa
Strain energy absorbed up to fracture	476.74	812.25	1,491.49	kJ

Analysis of these results reveals a clear correlation between **welding voltage and tensile performance**. All major strength-related parameters exhibit an increasing trend as the welding voltage increases. This suggests that higher welding voltage enhances the metallurgical bonding and load-carrying capacity of the welded joint. A graphical comparison of the mechanical properties listed in Table 1 is presented in Figure 5. The figure illustrates the simultaneous evolution of the strength characteristics with changing welding voltage. Notably, the **strain energy absorbed until fracture** and the **strain corresponding to maximum stress** show an exponential increase as welding voltage rises. This behavior indicates improved ductility and toughness of the welded joints at higher voltage levels. In contrast, the **maximum tensile stress** increases gradually and uniformly, with an approximate increment of **3% per voltage step**, while the **breaking stress** demonstrates a tendency toward saturation at higher voltage values. This suggests that although higher voltage continues to enhance strength, the rate of improvement becomes limited beyond a certain level. Other mechanical parameters displayed in Figure 5 do not follow a strictly linear or predictable pattern with voltage variation, indicating that not all weld properties are equally sensitive to voltage changes alone. Nevertheless, the overall results confirm that the best mechanical performance was achieved in welded joints produced at the highest welding voltage (34 V). The accumulated strain energy up to fracture shows the strongest dependence on welding voltage. This finding highlights an increase in joint ductility with higher voltage input. Fracture observations revealed that failure occurred through the welded seam, characterized by a predominantly brittle fracture mode accompanied by significant elongation of the specimens. This behavior can be attributed to the combined effect of a relatively hard weld seam and a more elastic base material, resulting in a welded assembly with high toughness, elasticity, and strong interfacial bonding. From a theoretical and practical standpoint, the results indicate that optimization of the welding process can be achieved by appropriately increasing the welding voltage to improve selected mechanical properties of the welded joint. The strength characteristics most influenced and controlled by welding voltage are the maximum tensile stress, breaking stress, and maximum stretching force. Based on the experimental observations, the following empirical relationships can be proposed:

- An increase of 1 V in welding voltage results in approximately 0.75% increase in maximum tensile stress.
- An increase of 1 V in welding voltage leads to about 3% increase in breaking stress.
- An increase of 1 V in welding voltage produces an approximate 2.5% increase in maximum stretching force.

These findings demonstrate that welding voltage is a critical process parameter that significantly influences the mechanical behavior of welded joints and should be carefully controlled in steel fabrication projects to ensure optimal structural performance.

## Conclusion

This study investigated the influence of welding voltage on the mechanical performance of welded joints used in steel fabrication for construction projects. Tensile testing and stress–strain analysis were carried out on specimens welded at different voltage levels while maintaining constant welding current, speed, and electrode orientation. The results demonstrate that welding voltage is a critical process parameter that significantly affects the strength and deformation characteristics of welded joints. The stress–strain curves revealed a consistent improvement in both stress-bearing capacity and strain response as welding

voltage increased. Key mechanical properties, including maximum tensile force, maximum tensile stress, breaking stress, yield tensile stress, and strain energy absorbed up to fracture, showed an overall increasing trend with higher welding voltage. Among these properties, strain energy exhibited the greatest sensitivity to voltage variation, indicating enhanced ductility and toughness of the welded joints at higher voltage levels. The experimental results further showed that welded joints produced at higher welding voltage exhibited superior mechanical performance, characterized by improved load-carrying capacity and higher elongation prior to fracture. The fracture behavior suggested the formation of a relatively strong weld seam combined with a more elastic base material, resulting in a welded assembly with high tenacity and effective stress transfer. These findings confirm that appropriate control and optimization of welding voltage can reduce welding defects and improve the structural reliability of steel fabrication works.

## **Recommendations**

Based on the findings of this study, the following recommendations are proposed:

1. Construction firms and steel fabricators should carefully select and control welding voltage levels to achieve optimal mechanical properties.
2. Given the sensitivity of welding quality to voltage variations, especially in regions with unstable power supply, the use of voltage stabilizers, regulated generators, or inverters is strongly recommended to minimize fluctuations during welding operations.
3. Welding operations should strictly follow approved Welding Procedure Specifications that define appropriate voltage ranges for specific materials, joint configurations, and welding processes.
4. Continuous training of welders on the effects of voltage variation and proper parameter control is essential. Skilled supervision should be ensured to reduce defects arising from improper voltage settings.
5. Regular mechanical testing and non-destructive testing (NDT) methods should be incorporated into fabrication processes to monitor weld quality and detect defects early.

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