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Review and analysis of the Programmable Tungsten Inert Gas Welding Machine

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***Abstract*—**

The purpose of this study is to examine metal inert gas (MIG) and tungsten inert gas (TIG) welding processes. This study focuses on welding defects with various kinds of AISI-1020 mild steel welding joints when using metal inert gas (MIG) and tungsten inert gas (TIG). The impact of different process variables on mild steel welding was looked into. In this study, the main process parameters were changed, and destructive tests (tensile test) were used to examine the impact on hardness and impact strength. Yield stress, elastic stress, breaking stress, and breaking force were all measured during a tensile test. Additionally, non-destructive (NDT) testing was done.

Non-destructive testing was used for the liquid penetration and ultrasonic tests. The necessity of exceptional weld quality was also highlighted by a comparison of the two testing methods. The tensile test results for MIG welding are displayed in Fig. 12 and are 204.793 N/mm2 for yield, 27688 N/mm2 for elastic behavior, and 180 N/mm2 for breaking behavior. For MIG welding, the welding link was broken at 180 N/mm2. Figure 13 shows the TIG welding stresses as 313.633 N/mm2 for yield, 16506.2 N/mm2 for elastic, and 257.890

N/mm2 for breaking. At 257.890 N/mm2, the welding connection failed. AISI-1020 mild steel had a breaking stress of 420 N/mm2 prior to welding. Following welding, the breaking stress decreased to 257.890 N/mm2.

Shielded metal arc welding, gas metal arc welding, flux cored arc welding, submerged arc welding, electro slag welding, electron beam welding, and gas tungsten arc welding are just a few of the various welding techniques available for joining materials. The type of current, the thickness of the base materials, and the compositional range of the material to be welded are the main factors that influence the choice of welding. The most widely used gas shielding arc welding technique in many industrial domains is TIG welding.

The most crucial factors in determining arc stability, arc penetration, and defect-free welds are covered in this case study, including the power source, type of current, gas flow

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rate, electrodes, filer wire, TIG machine settings, and shielding gases.

Keywords: Programmable TIG welding, TIG welding parameters, Welding automation, Weld quality, Process optimization

I. INTRODUCTION

The sophisticated and incredibly effective Tungsten Inert Gas (TIG) Welding Machine is used to create precise and high-quality welds in a variety of industrial applications. This welding technique, also called Gas Tungsten Arc Welding (GTAW), creates an electric arc using a non-consumable tungsten electrode while shielding the weld area from atmospheric contamination with an inert gas like argon or helium. TIG welding is widely used in industries like aerospace, automotive, power plants, and fabrication because of its capacity to create strong, clean, and flawless welds [1].

A power supply unit, tungsten electrode, welding torch, shielding gas cylinder, regulator, and workpiece clamp are some of the key parts of the TIG welding machine. Depending on the kind of material being welded, the power supply can supply either direct current (DC) or alternating current (AC). While the inert gas shields the weld area from oxidation and contamination, the tungsten electrode creates the arc. The operator can precisely control the arc and apply heat to the workpiece with the welding torch [2].

An electric arc is created between the base metal and the tungsten electrode in order for the TIG welding machine to function. The extremely high temperature created by this arc melts the metal and creates a weld pool [3].

To strengthen the joint, a filler metal may occasionally be manually added. After cooling and solidifying, the molten metal creates a solid and long-lasting bond. High proficiency and appropriate control over variables like current, voltage, gas flow rate, and welding speed are necessary for the entire process [4].

The ability of TIG welding to create excellent welds free of smoke, slag, or spatter is one of its main benefits. This enhances the overall appearance of the weld and lessens the need for post-weld cleaning. Furthermore, TIG welding gives the operator great control over the welding process, enabling accurate and reliable results [Fig. 1]. It does, however, have certain drawbacks, including increased expense, slower welding speed, and the need for experienced operators [5].

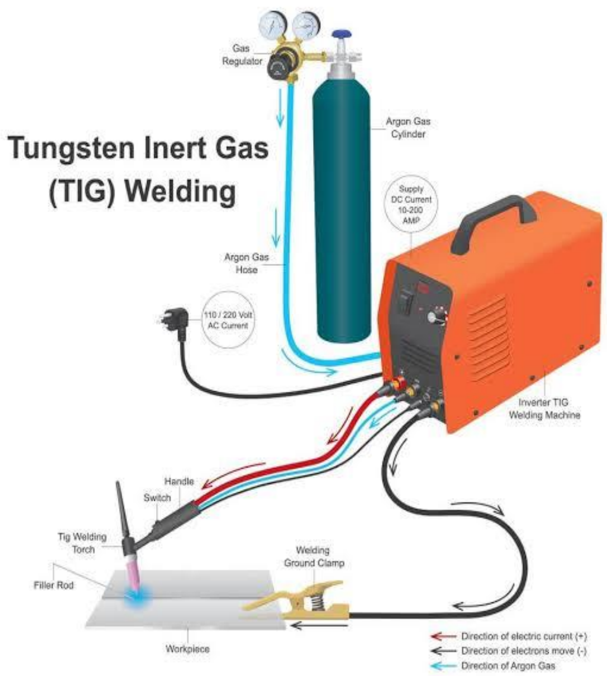

Fig. 1. Tensile Test Results for MIG Welded Joint

All things considered, the TIG welding machine is crucial to contemporary engineering and manufacturing procedures. It is a vital tool for industries where quality and dependability are crucial because of its capacity to create precise, strong, and clean welds. With the development of automation and technology [6].

II. Literature Review

Welding metallurgy is fundamental understanding of weld's heat transfer, solidification, phase transformation and microstructural development during welding process. All these factors have a significant effect on the quality and mechanical properties of the welded joints. The study of the physics of welding also provides insights into the physics of the arc process, heat generation, heat distribution and weld formation that are fundamental to the control of the welding process [7].

Various welding technologies and techniques have been innovated for higher productivity, better accuracy and weld quality for different manufacturing applications. TIG welding is one of these, as it is able to produce clean and precise welds with good control of the welding arc and heat input. Heat transfer and fluid flow phenomena strongly influence the weld pool behavior, directly influencing the shape, penetration, and geometry of the weld itself [8].

Various investigations have been aimed at optimizing the TIG welding parameters of various engineering materials. For low carbon steel, suitable combinations of the welding variables have been determined by statistical method like response surface methodogology. In the same way, both Taguchi and grey relational techniques have been used to select several weld parameters at the optimum level in order to optimize multiple weld parameters simultaneously [9].

Numerical modelling has also been investigated to predict weld geometry from the welding conditions. The models of heat transfer and fluid flow are available and can give relevant information about correlation between the process variables and weld pool dimensions. With these kinds of models, optimization methods can be used to provide this requested weld profile in a further reduction of experimental efforts [10].

Another factor of importance for TIG welding is the thermal and flow characteristics of the weld pool. This would facilitate the prediction of weld-pool behaviour and heat distribution if these properties like effective thermal conductivity and viscosity could be estimated accurately. These kinds of modelling can aid in maintaining the welding condition controlled and can enhance the reliability of the predicted weld characteristics [11].

From the experimental studies it was found that the mechanical property of TIG welded joints are greatly influenced by the parameters of the welding current, welding speed and filler related parameters. Optimal values of parameters have been achieved by optimization and performance of tensile properties have been improved. The results suggest that good choice of TIG welding parameters is necessary to obtain a good quality weld.

Better control of the welding process has led to even more process repeatability when using automated TIG welding. The optimization of automated welding parameters has been studied in order to improve the weld characteristics and keep the process consistency to stainless-steel joints. The use of pulsed current TIG has also been investigated with the pulse parameters affecting the weld penetration and other weld properties [12].

Focusing on the effect of the supporting and backing conditions during autogenous TIG welding has been the interest of more recent investigations. Different materials used in backing plates may have different heat dissipation, bead geometry, hardness, tensile strength and fracture properties. This shows that not only the main welding parameters but also the thermal circumstances of the surroundings during the welding process need to be taken into account [13].

Summarizing the present literature, it is found that the TIG welding performance depends mainly on the welding parameters, heat transfer, weld-pool behavior and thermal boundary conditions. Nevertheless, this leaves room for the design and testing of an arc programmable TIG welding machine that offers the facility for control and repeatability of the welding parameters. This work is therefore focused on the design, development and testing of a programmable TIG welding system to provide better control and repeatability in the welding process [14].

Factors Affecting TIG Weld Quality

The factors that influence the quality of a TIG welded joint are: electrical, thermal, material and operational. One of these is the welding current, which has a direct effect on the amount of heat the material will receive. However, a rise in current will lead to greater penetration and expansion of the molten pool. But overcurrent can result in an unnecessarily wide weld bead, excess penetration, distortion or even localized overheating. Hence, depending on the type of the material, thickness, electrode size and penetration desired, the current must be chosen.

Other factors such as voltage in the welding process and arc length also affect the weld characteristics. The longer the arc is, the wider the heat spread is and the less concentrated, while shorter arcs mean that the heat is more concentrated around the joint so there is better control over it. Thus it is important to achieve relatively constant arc length for a consistently uniform weld profile. Another benefit of programmable systems is the ability to accommodate changes in arc length while manually welding which may vary the width and penetration of the weld bead.

The travel speed is also an important parameter. If the torch will be moving too quickly, the heat may not be reaching the joint and the joint could develop defects in areas related to incomplete fusion or insufficient penetration. However, if the travel speed is too fast, the heat input will be too high and could lead to an excessive HAZ being created, distorted, and/or larger penetration. An appropriate travel speed provides a balance between productivity and weld quality. Careful control of the flow rate of shielding gas is also required. As the flow rate becomes too low, the gases in the atmosphere may enter the molten weld pool, which will lead to an increased risk of oxidation and porosity in the welds. Too much gas can not be a good thing as it can draw troublesome turbulence to the area around the weld and disrupt the shielding environment provided by the gas. Therefore, the stability of the gas is important, along with the proper type of gas that is being used, in order to maintain integrity of the weld.

Other factors such as condition and geometry of the tungsten electrode also influence the arc behaviour. Contaminated or improperly prepared electrodes may result in unstable arc and weld formation, whereas a good electrode preparation maintains a focused and consistent arc. Furthermore, the condition of the base material is directly related to weld conditions. To reduce the likelihood of undesirable defects, oil, moisture, rust, paint and other contaminants should be removed from the parts prior to welding.

These parameters act on each other in complex ways, making TIG welding a process wherein it is necessary to monitor rather than adjust any one parameter. A key potential benefit is that with programmable welding equipment, there is scope to systematically control several parameters during the welding cycle. This makes it easier to repeat and set welding conditions for similar parts.

Programmability and Process Control

Programmable control is an important improvement to an old welding system, where welding was adjusted by hand. Conditions for a welding operation, such as weld type, are programmed and recreated during the next welding operation in a programmable system. When more than one part calls for similar joints, this method can be used to minimize the differences in welds.

The programmable machine can change welding current during various phases of the welding process, instead of keeping the current constant. Parameters can be varied during the arc starting, welding and ending processes depending on the criterion required. Such control offers increased flexibility in heat input control and allows for a reduced in-rush change in the heat conditions of the work-piece.

Programmable operation has several other advantages, one being repeatability. Even a good welder using hand tools might create little variation in travel speed, arc length or filler addition between two welding courses of operation. With such variations across many components, some may exhibit differences in appearance and mechanical properties of the welds. This manual dependency on process adjustment can be overcome with programmable control by repetition of the set process conditions.

Process control also offers benefits in the welding of thin material. Excessive heat input or change of thin sections may cause damage or burn through. Process parameters such as control current and programmed welding cycles can assist in keeping the heat input at the specified level for a range of values. This is also true of reducing the flow rate of current at the end of the weld, as this will reduce the size of undesirable end craters.

One other key area is integration of programmable welding equipment and automated/robotic systems. If the most important factors of welding torch movement and electrical parameters are coordinated, the welding process can be realized to become highly consistent. This is particularly useful when manufacturing an identical product, over and over again.

Programmability is no excuse for not having a technical knowledge though. Even after having set these parameters, the operator or welding engineer is still required to determine the proper values for material, thickness, joint design, electrode characteristics and shielding conditions to determine the appropriate parameters. A welding machine with the wrong setting can produce an undesirable welding setting time after time. Therefore, programmable technology should be considered a means of enhancing process control, not as a substitute for good welding procedure development.

III. Working of PAIRBM

The Tungsten Inert Gas (TIG) welding machine operates by creating an electric arc between the workpiece and a non-consumable tungsten electrode. The extremely high temperature created by this arc melts the base metal and, once solidified, creates a robust joint. Because the operator has total control over the heat input, arc length, and filler metal addition, TIG welding is one of the most accurate welding techniques. It is frequently utilized when high-strength, flawless, and clean welds are needed.
Depending on the kind of material being welded, either direct current (DC) or alternating current (AC) is supplied by the power source during the TIG welding process. The tungsten electrode is held in place by the welding torch because it has a very high

melting point and is resistant to being quickly consumed by the intense heat of the electric arc. An electric arc is created when the torch is brought close to the workpiece, and the arc temperature rises to the point where the metal at the joint is melted.

Simultaneously, the welding torch continuously supplies an inert shielding gas, typically helium or argon. This gas's primary function is to shield the hot electrode and the molten weld pool from airborne contaminants like moisture, nitrogen, and oxygen. The weld would experience flaws like oxidation, porosity, and poor fusion in the absence of this shielding gas. Additionally, the inert gas stabilizes the arc, facilitating a smoother and more precise welding process.

The right choice of process parameters also affects the TIG welding machine's performance. Arc voltage influences arc stability and weld shape, while welding current regulates the quantity of heat produced. To keep the weld pool safe throughout the procedure, the shielding gas flow rate needs to be appropriately maintained. The shielding effect could be disrupted by turbulence if the gas flow is too high, and atmospheric contamination could happen if it is too low. Similar to this, travel speed needs to be carefully regulated because too fast can result in weak welds and too slow can cause the material to overheat [Fig. 2].

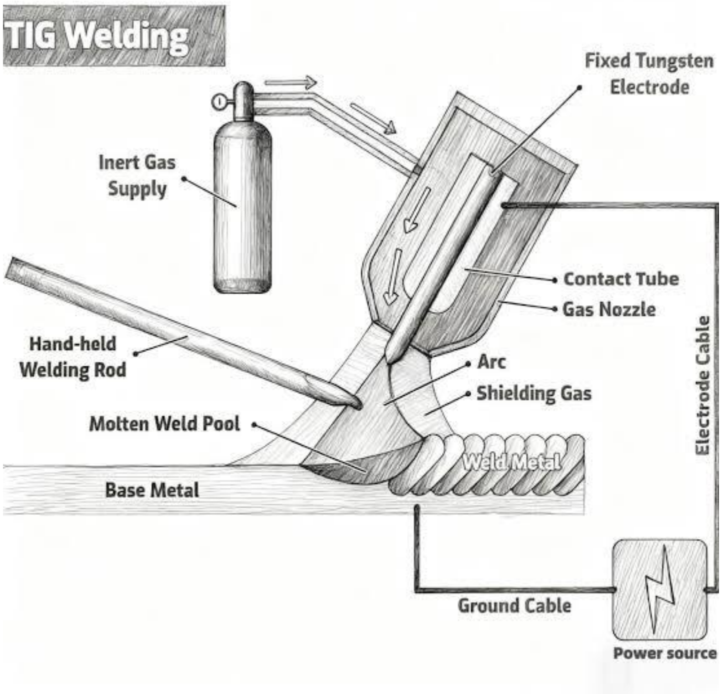

Fig. 2. Tensile Test Results for TIG Welded Joint

After welding, the molten metal cools and solidifies to form a strong and permanent joint. The operator's skill, the workpiece's cleanliness, and the precision of the machine settings all affect the final weld's quality. TIG welding offers much better control and better weld quality than MIG or other arc welding techniques, but it is typically slower. It is therefore favored in crucial applications where strength, accuracy, and aesthetics are equally crucial.

In general, the power supply, tungsten electrode, shielding gas, torch, and filler rod all work together to operate a TIG welding machine. The procedure creates clean, sturdy, and dependable joints while providing outstanding control over the weld pool. These benefits have made TIG welding a crucial procedure in today's manufacturing and fabrication sectors.

IV. CONCLUSION

This research paper presented the design, analysis, and working of the Tungsten Inert Gas (TIG) welding machine and evaluated its performance in terms of weld quality and mechanical properties. The study confirms that TIG welding is a highly efficient and precise welding technique capable of producing high-quality, clean, and defect-free welds. The use of a non-consumable tungsten electrode along with inert gas shielding ensures minimal contamination and excellent control over the welding process.

The analysis of process parameters such as welding current, voltage, and gas flow rate indicates that proper optimization is essential to achieve maximum strength and efficiency in welded joints. Experimental observations show that TIG welding provides better arc stability, deeper penetration control, and improved surface finish compared to conventional welding methods. However, it was also observed that the process requires skilled operation and involves higher initial cost and lower production speed.

Both destructive and non-destructive testing methods were used to evaluate weld integrity. The results highlight that although there is a slight reduction in mechanical strength compared to the base metal, the welded joints still maintain acceptable performance for industrial applications. Non-destructive testing techniques such as ultrasonic and liquid penetrant testing proved effective in identifying surface and internal defects.

In conclusion, TIG welding machines play a crucial role in modern manufacturing industries where precision, reliability, and quality are of utmost importance. Future advancements in automation and control systems can further enhance the efficiency and reduce the dependency on skilled labor, making TIG welding more accessible and cost-effective.

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