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Analysis of Welding Characteristics of Two Dissimilar Metal (FSS 409 & ASS 304) Using TIG Welding

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Abstract
The TIG welding of stainless steel sheets is influenced by numerous factors. Because of practical constraints, four defining traits were taken into account during the experimental investigation. When selecting the parameter values, the qualities of the materials and the industry-available equipment for experimentation were taken into account. A study was done on the hoarding pipe welding process that is now in use. The design of experiments technique was used to plan the experiments. Ideal welding conditions were shown to increase penetration depth, hardness, and ultimate tensile strength. The best parameter selection was confirmed by destructive and nondestructive mechanical testing. When ideal conditions were employed throughout the welding process, the joint tensile strength and hardness of stainless steel ASS304 were increased by 10.56% and 7.36%, respectively. Ultrasonic testing was utilized to check the integrity of the welded joints and search for internal flaws. TIG welding employs a non-consumable tungsten electrode to create the arc, whereas MIG welding uses a consumable wire electrode fed through a wire feeder. MIG welding employs the wire electrode as both the arc source and the filler, as opposed to TIG welding, which calls for the manual addition of a separate filler metal. The usual gas for TIG welding is argon (Ar). Helium (He) can be introduced to increase the penetration and fluidity of the weld pool. You can weld with argon or argon/helium mixtures in all grades. Sometimes nitrogen (N2) and/or hydrogen (H2) are added to obtain specific properties.
Keywords: *TIG Welding Process, Ferritic Stainless Steel 409, Corrosion Resistance, Heat Resistance*

1. Introduction
Welding is the technique of joining dissimilar metal parts to create a continuous metallic connection. In this process, the connecting metals or nonmetals can melt using a thermal source such a gas flame, electric arc, or laser. Next, the filler metal is employed. Put another way, "welding" is the technique of applying heat to two or more surfaces to form a nearly seamless connection. This arc welding method that produces the weld using a non-consumable electrode is also known as gas tungsten arc welding or tungsten inert gas welding. [1-3] Combining thin and medium thickness materials, stainless steel sheets, and situations where weld metal metallurgical control is crucial are all good uses for the pulsed GTAW technique. With the increasing use of mechanized welding, the selection of welding process parameters and welding method must be increasingly exact in order to ensure that high-quality weld bead parameters are obtained at a low cost and with high repeatability. [4-6] TIG welding is the most effective method of welding stainless steel. When these steels were initially being developed for use in cutlery, they were referred to as "TIG" (Tungsten Inert Gas Welding) Stainless. Originally used to refer to these steels generally, the word is now used to describe a wide range of steel grades and kinds for applications that call for resistance to oxidation or corrosion. Stainless steels are employed because of their exceptional toughness and general resistance to corrosion. Austenitic stainless steel (300 series) is the most commonly utilized variety because it is ductile and readily molded into the required geometries. To create alternating layers of martensitic and austenitic structures, they can also be casehardened if extreme

toughness and resistance to surface wear are needed. However, compared to other ferrous alloys, their application is limited due to their higher initial cost and susceptibility to intergranular (IGC) corrosion and pitting. To explore these localized corrosion occurrences in structural parts of interest, a cell was designed to perform polarization (spot) tests on metallic surfaces within predefined zones. At the moment, a number of processing problems affect the quality and properties of the welded output. Connection, during the welding process of the grade 304 structural components. Issues such as cracking, carbide precipitation phase, and sigma phase can considerably lower this welded joint's mechanical properties. Choosing the right material and welding settings is crucial to managing the aforementioned issues. [7-10] To decrease welding flaws and obtain improved mechanical qualities, it is necessary to determine the optimum current as one of the parameters for TIG welding on 304 stainless steel [16–20] Research has been done on how welding current affects the tensile characteristics, fracture, microstructure, and morphology of welded joints made of 304 stainless steel. This study suggests the ideal TIG welding process settings for 304 stainless steel tubing. To increase productivity during production and development, the chemical composition % (by weight) of the work piece material is recorded. High-quality industrial systems can be designed with the help of the Taguchi philosophy? In order to achieve the intended outcomes, the Taguchi technique integrates DOE with parametric process optimization. An orthogonal array (OA) provides a set of well-balanced (minimum experimental runs) tests, and the optimization's objective functions are Taguchi's signal-to-noise ratios (S/N), which are logarithmic functions of the desired output. This approach facilitates data analysis and optimal outcome prediction. The Taguchi method evaluates the best parameter selections by using the signal-to-noise ratio, a statistical performance metric.

2. Consequences of TIG Welding Process

The hazards of TIG welding

TIG welding creates a wide range of potential safety risks. Radiation, welding smoke, and electric shock provide the biggest threats. There could be risks prior to, during, or following welding.

The process of TIG welding

TIG, often known as gas tungsten arc welding (GTAW), is an acronym for tungsten inert gas. The procedure feeds current into the welding arc using a non-consumable tungsten electrode. Tungsten and the weld puddle are shielded and kept cool by an inert gas, usually argon.

Temperature is used in TIG welding

Up to 19000°C of extremely high temperatures are produced during the TIG process. [11] The TIG arc merely generates heat; if more material is needed to finish a weld, it can be added automatically or manually in the form of consumable filler wire.

2.1. Ferritic Stainless Steel 409

Ferrite grade 409 stainless steel has good mechanical qualities and is resistant to corrosion at high temperatures. It is frequently referred to as chromium stainless steel and is used in weldable applications such as automotive exhaust system. Highly stabilized versions of grade 409 steels, including grades S40920, S4092, and S40910, are also offered. The inclusion of niobium, titanium, or both in the steel composition ensures the stability of these grades.

2.2. Corrosion Resistance

The exceptional resistance to exhaust gas and atmospheric corrosion of grade 409 stainless steels outperforms that of martensitic grades with 12% chromium and 3CR12. However, compared to grade 430 steels with 17% chromium, the corrosion resistance is lower. [12] Grade 409 steels can mildly corrode on their surface, which restricts their use as decorative materials.

2.3. Heat Resistance

Grade 409 stainless steels offer scaling resistance at temperatures up to 675°C during continuous operation, and up to 815°C under intermittent conditions. These temperatures pertain to specific service environments.

2.4. Heat Treatment

Grade 409 steels are annealed at temperatures between 790 and 900°C, and air cooling is then applied. Grade 409 steels do not become harder after thermal treatment.

2.5. Welding

Prior to welding, grade 409 steels need to be

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preheated to 150–260°C. While grade 309 electrodes or filler rods are highly advised by AS 1554, grade 430 and 409 filler rods and electrodes can be used while welding grade 409 steels.6. In order to reduce grain growth, care should be used while welding grade 409 steels.

2.6. Properties of FSS 409 Steel

Excellent resistance to corrosion, particularly against oxidation and scaling in hot environments. Excellent creep resistance and strength at high temperatures less costly than stainless steel that is austenitic Figure 1 shows the tig welding through using dissimilar metal SS409 & ASS304

Figure 1 TIG Welding Through Using Dissimilar Metal SS409 & ASS304

3. Applications

Automotive exhaust system

FSS 409 is frequently utilized in the production of vehicle exhaust systems because of its affordability, heat resistance, and resistance to corrosion. The steel is resistant to both high temperatures and the corrosive atmosphere caused by exhaust gasses.

Heat exchangers

FSS 409 can withstand moderately corrosive environments and elevated temperatures, making it an ideal material for use in heat exchangers due to its corrosion resistance and thermal stability.

Fuel filtration system

In fuel filtration systems, where corrosion resistance is essential, ferritic stainless steel, such as FSS 409, is utilized. Over time, the filtering system's integrity is preserved in part by the steel's ability to withstand corrosion.

3.1. Austenitic Stainless Steel 304

Austenitic stainless steels, or ASS304, are a class of stainless steels distinguished by a high concentration of nickel and chromium. Austenitic stainless steel, or ASS304, is the most popular variety and is renowned for having superior formability, weldability, and corrosion resistance. ASS304 is commonly utilized in sectors like food processing, chemical processing, and pharmaceuticals where resistance to corrosion is crucial. Numerous other industries, including aerospace, automotive, and construction, employ it as well. ASS304 is an extremely adaptable and sturdy material that works well in a variety of settings. It is a suitable option for uses requiring strength, toughness, formability, and resistance to corrosion.

3.2. Properties Corrosion Resistance

AISI 304 offers excellent corrosion resistance in a wide range of environments, including atmospheric conditions, fresh water, industrial atmospheres, and mild chemical environments. It owes its corrosion resistance to the presence of chromium and nickel in its composition.

3.3. Austenitic Structure

The austenitic crystal structure of AISI 304 imparts high toughness and ductility. This structure remains stable at both low and high temperatures, contributing to the steel's versatility.

3.4. Strength And Ductility

AISI 304 has good tensile strength and yield strength, providing a balance between strength and ductility. This combination of properties makes it suitable for forming and fabrication processes.

3.5. Formability

The steel exhibits excellent formability and can be easily fabricated into a variety of shapes, making it suitable for a wide range of applications in different industries.

3.6. Applications

Food Processing: Used in equipment and components for food processing and handling due to its corrosion resistance and hygienic properties.

Chemical Industry: Commonly employed in chemical processing equipment where resistance to corrosion from various chemicals is crucial.

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Medical Equipment: Used in the manufacturing of medical devices and equipment due to its biocompatibility and corrosion resistance. Applied in architectural structures, kitchen appliances, and decorative elements due to its aesthetic appeal and durability.

3.7. Issues In Dissimilar Metal Joining

The discontinuities in dissimilar metal joints (DMJ) develop mainly due to differences in various physical, mechanical, and chemical characteristics of parent metals; these discontinuities may appear in various forms such as unmixed zone (UMZ), segregation of alloying elements at joint interface, hard and brittle intermetallic compounds, the asymmetric joint between parent metals, skewed interfacial deformation, residual stress and distortion, large variation in mechanical and corrosion properties of the joint, and heat-affected zone (HAZ) on both sides of the joint (Kaushik and Dwivedi 2021a, 2022a

4. Mechanical Properties

Table 1 Represents the Mechanical Properties of Material

PROPERTY	409
Yield Strength, min. (ksi)	25
Tensile Strength, min. (ksi)	55
Elongation, min. (%)	20
Hardness, max. (Rb)	88

4.1. Physical Properties

Table 2 Represents the Physical Properties of Material

PROPERTY	409 DATA
Mechanical property requirements for annealed product as specified in ASTM A240 and ASME SA240.	0.279
Modulus of Elasticity, psi	32.0×10^6
Coefficient of Thermal Expansion, 68-212˚F, /˚F	6.5×10^{-6}
Thermal Conductivity, Btu/ft hr ˚F	13.2
Specific Heat, Btu/lb ˚F	0.11
Electrical Resistivity, Microohm-in	24.8

4.2. Chemical Composition

Table 3 Represents the Chemical Composition of Material

ELEMENT	409
Carbon	0.03
Chromium	10.5-11.7
Nickel	0.50
Manganese	1.00
Silicon	1.00
Nitrogen	0.030
phosphorous	0.040
Sulphur	0.020
Niobium	8 x (C+N) min / 0.15-0.50

Conclusion

Following conclusions are drawn in respect of MIG welding of AISI 409 Ferritic Stainless steel to AISI 316L austenitic stainless steel.

- The best result is obtained for the sample No.1 (Corresponding to current 100 A, flow rate 10 L/min and Nozzle to plate distance 9 mm) For this sample, ultimate tensile strength = 421.742 MPa and Yield strength = 266.322 MPa. The worst result in tensile testing has been obtained for the sample No. 6 (corresponding to current 112 a, gas flow rate 20 L/min and nozzle to plate distance 9 mm) for this sample yield strength 230.454 MPa and Ultimate tensile strength 345.678 MPa.
- Optimization of the process parameters has been done by using Taguchi-Desirability analysis; optimum parametric combination has been determined.

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