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ABSTRACT

The main objective of industries of reveal with manufacturing better quality product at low cost and increase productivity. Tig welding is most vital and common operation use for joining of two similar or dissimilar parts with heating the material or applying the pressure by using the filler material for increasing productivity with less and cost constrain. The tig welding parameters are the most important factors affecting the quality, productivity and cost of welding. The purpose of this study is to propose a method decide near optimal setting of the welding process parameters in tig welding. This project shows the influence of welding current, arc voltage and gas flow rate on strength of stainless steel and mild steel material during welding. A taguchi orthogonal array, signal to noise ratio and analysis of variance are employed to investigate the welding characteristics of dissimilar joint and optimize the welding parameters.

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SYMBOLS AND ABBRIVATIONS

AC - Alternating Current
ANOVA - Analysis of Variance
ANSYS - Analysis System
ASME - American Society of Mechanical Engineers
ASS - Austenitic Stainless Steel
ASSHAZ - Austenitic Stainless Steel Heat Affected Zone
ASTM - American Society for Testing and Materials
CC - Continuous Current
CCGTA Welding - Continuous Current Gas Tungsten Arc
DC – Direct Current
DCEN - Direct Current Electrode Negative
DCEP - Direct Current Electrode Positive
DCRP - Direct Current Reverse Polarity
DOE - Design of Experiments
DOP - Depth of Penetration
EBW - Electron Beam Welding
FCAW - Flux Cored Arc Welding
FRW - Frictional Welding
FZ - Fusion Zone
GFR – Gas Flow Rate
GMAW - Gas Metal Arc Welding
GTAW - Gas Tungsten Arc Weld
HAZ - Heat Affected Zone
LBW - Laser Beam Welding
MSS - Martensitic Stainless Steel
PC - Pulsed Current
PCGTAW - Pulsed Current Gas Tungsten Arc Welding
PM – Parent Metal
RMS - Root Mean Square
SMAW - Shielded Metal Arc Welding
SS - Stainless Steel
S/N – Signal to Noise Ratio
WZ – Weld Zone

CHAPTER 1
INTRODUCTION

1.1 Welding

Welding is a fabrication process that fastens or joins the materials, by the use of heat and pressure thereby causing fusion action. When an adequate amount of pressure is applied, the joint area can be welded together and the material also gets softened by application of heat which is different from other metal joining techniques, operating from lower temperature such as brazing and soldering, which do not melt the base metal. Additionally, the filler material gets melted to the joint to form the weld pool which cools to form a joint that can be as strong or even stronger, than the base material. The concept of welding first developed in the middle ages, till 19th century the requirement of metal joining was carried out in some forms to meet the industrial requirements. Before this, two metal objects were joined together by the process of forge welding. There are potentially large numbers of possible weld geometries, which are commonly inspected by ultrasonic techniques.

The properties of welding are as follows:

- Weld metal has different composition and thermal history to base metal
- Welding heat modifies adjacent base metal Heat Affected Zone (HAZ)
- Variation in strength, ductility and corrosion resistance across welds.
- Welding process can be classified into various categories based on the below mentioned requirements.
- Fusion welding or pressure welding depends on the application of heat. Pressure welding involves no application of heat.
- Fusion welding can be classified based on the operating temperature as low and high. Generated heat is used to develop low temperature it is called low temperature welding similar to brazing and soldering. Further methods in fusion welding are meant for high temperature applications.
- Other classifications in Fusion welding with respect to heat generation are, resistance welding, gas welding, thermit welding and electric arc welding.
- Classification with respect to type of joint produced can be called as spot welding, butt welding, seam welding and lap joint welding

It is important to note that the various defects which are encountered during welding need to be rectified to ensure the weld quality. Some of the most commonly identified defects are cracking, lack of fusion, incomplete penetration, porosity, and slag inclusion which has been shown in Figure 1.1

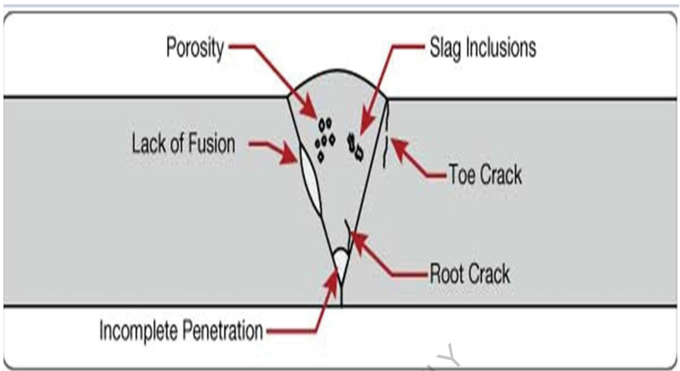

Figure 1.1.Welding Defects

It is important to ensure below conditions to achieve quality of welds

- A source of energy to create union by Fusion or Pressure.
- A method for eliminating surface irregularities.
- A method for protecting metal from atmospheric contamination.
- Control of weld metallurgy.

1.1.1 Importance of welding

Welding is used as a fabrication process across all industries irrespective of the size of industry. The activity involves fabrication and subsequent post production activities mainly rework in case if any above said issues encountered in the products. The process is efficient, economical and dependable for metal fusion. Welding process has got applications in special areas like air, underwater and in space in addition to the other industrial applications.

1.1.2Applications of welding

- Welding finds its applications in the wider area like automobile industries, construction of ships, submarines, pressure vessels, offshore structures, storage tanks, oil, gas, water pipelines, girders, press frames and water turbines, etc.
- The process is used in critical applications like the fabrication of fission chambers of nuclear power plants.
- Rapid progress in exploring the space has been made possible by new methods in welding and the various researches related with welding metallurgy. The aircraft industry cannot meet the enormous demands for aircrafts, fighter and guided planes, space crafts, missiles and rockets without welding.
- A large contribution made to the public from welding application by making home need products like refrigerators, dishwashers, kitchen cabinets and other similar items.
- It is also used in the applications of fabrication and repair of farm, oil machinery, manufacturing of jigs and fixtures, furnaces, mining, boilers, railway wagons and coaches, Automotive vehicle body building, automotive parts, earth moving machinery, submarines, underwater construction and repair.

1.2 Gas tungsten arc welding

Gas Tungsten Arc Welding formerly known as Tungsten Inert Gas Welding (TIG). Gas Tungsten Arc Welding (GTAW) is one of the simple processes, having low operating cost and provides greater control over the welded part than other processes, such as gas metal arc welding, shielded metal arc welding, etc. This method allows stronger and higher quality weld joint. However, the main problem arises during welding of metals due to degradation in mechanical and metallurgical properties of the welded metal joints. This is mainly in terms of its tensile strength and ductility, after it has been welded. GTAW is commonly used to weld stainless steel in both similar and dissimilar configuration. The gas tungsten arc welding (GTAW) process is based on the electric arc established between a non-consumable tungsten electrode and the material to be welded. Part of the heat generated by the electric arc is added to the material to be welded and thereby generating the weld pool. The weld pool is protected from air contamination by a stream of an inert gas (Ar or He) or a mixture of gases. This process is also known as tungsten inert gas (TIG), although small amounts of non-inert gases could be taken along with shielding mixtures, such as hydrogen or nitrogen. Autogenous GTAW welding performing in the absence of filler metal and mainly for making lean square edge sections (2mm) while V and X type edge 5 preparations are needed in thicker sections. Filler metal addition is required in such cases. This process is extensively used for welding lesser thickness of parts with stainless steel, aluminum, magnesium or titanium alloys as well as pieces of carbon and low alloy steels. The filler metal is supplied from a filler wire and is similar to the metals to be welded. Welding without filler metals by GTAW can also be done, where welding of close fit joints is required. In general AC power supply is preferred for aluminum and magnesium since the clean-up activity of AC eliminates oxides and enhances the weld quality. DC power supply is also possible. The cost involves towards inert gas usage results this operational cost more than SMAW, but it provides welds with very high quality and surface finish. The basic diagram of GTAW is shown in Figure 1.2

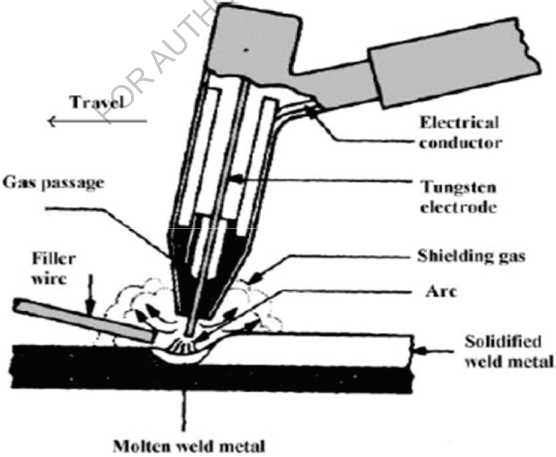

Figure 1.2 GTAW Basic Equipment

The GTA welding machine may be either AC or DC. The type of machine for particular GTA weld jobs depends on the materials to be welded. All the three types of welding current or polarities as mentioned in Figure 1.3 can be used for GTA welding. Each current has individual featured that it makes more desirable to achieve special conditions or with welding with specific types of metals. The major difference between the current will impact heat distribution and the presence or degree of arc cleaning. The heat distribution between tungsten electrode and work with each type of welding current has been shown in Figure 1.3

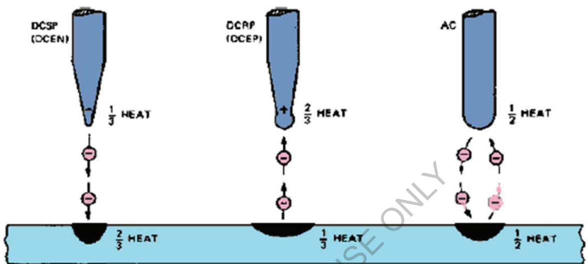

Figure 1.3 Heat Distributions between the Tungsten Electrodes

1.2.1 Electrode used in TIG welding

There are five types of electrode which are used in TIG welding and identified with their colour.

1).Pure Tungsten (W) (Green Colour).

2).1% Thoriated Tungsten (Yellow Colour).

3).2% Thoriated Tungsten (Red Colour).

4).Striped Tungsten (Blue Colour).

5).Zirconium Tungsten (Brown Colour).

1.2.2 Shielding Gases Used for TIG Welding

1) Argon.

2) Helium.

3) Mixture of Argon and Helium

1.2.3 Advantages

1).It produces no noises or very less noises.

2).The quality of weld produced by the TIG welding is far superior than other welding process.

3).Low sparks produces as very less filler metal is added.

4).No flux is required or added.

5).Smoke or fumes is not produced.

6).Welding can be done I all positions.

7).Especially good for welding thin sections

1.3 Stainless Steel

Stainless steel is essentially a low carbon steel which contains chromium at 10% or more by weight. It is this addition of chromium that gives the steel its unique stainless, corrosion resisting properties.

The chromium content of the steel allows the formation of a rough, adherent, invisible, corrosion resisting chromium oxide film on the steel surface. If damaged mechanically or chemically, this film is self-healing, providing that oxygen, even in very small amounts, is present. The corrosion resistance and other useful properties of the steel are enhanced by increased chromium content and the addition of other elements such as molybdenum, nickel and nitrogen.

There are more than 60 grades of stainless steel. However, the entire group can be divided into five classes. Each is identified by the alloying elements which affect their microstructure and for which each is named.

1.3.1 Benefits of Stainless Steel

Corrosion Resistance

Lower alloyed grades resist corrosion in atmospheric and pure water environments, while high-alloyed grades can resist corrosion in most acids, alkaline solutions, and chlorine bearing environments, properties which are utilized in process plants.

Fire and Heat Resistance

Special high chromium and nickel-alloyed grades resist scaling and retain strength at high temperatures.

Strength-To-Weight Advantage

The work-hardening property of austenitic grades, that results in a significant strengthening of the material from cold-working alone, and the high strength duplex grades, allow reduced material thickness over conventional grades, there for cost savings.

1.3.2 Properties

Stainless steel is defined as a ferrous alloy with a minimum of 10% chromium content. The name originates from the fact that stainless steel does not stain, corrode or rust as easily as ordinary steel. This material is also called corrosion resistant steel when it is not detailed exactly to its alloy type and grade, particularly in the aviation industry.

Stainless steels have higher resistance to oxidation (rust) and corrosion in many natural and man made environments; however, it is important to select the correct type and grade of stainless steel for the particular application.

High oxidation resistance in air at ambient temperature is normally achieved with additions of a minimum of 13% (by weight) chromium, and up to 26% is used for harsh environments. The chromium forms a passivation layer of chromium(III) oxide (Cr2O3) when exposed to oxygen. The layer is too thin to be visible, meaning the metal stays shiny. It is, however, impervious to water and air, protecting the metal beneath. Also, when the surface is scratched this layer quickly reforms. This phenomenon is called passivation by materials scientists, and is seen in other metals, such as aluminium. When stainless steel parts such as nuts and bolts are forced together, the oxide layer can be scraped off causing the parts to weld together. When disassembled, the welded material may be torn and pitted, an effect that is known as galling.

Table 1.1 Properties of stainless stail

Z	Maximum Value (S.I.)	Units (S.I.)	Minimum Value (Imp.)	Maximum Value (Imp.)	Units (Imp.)
Atomic Volume (average)	0.0072	m^3/kmol	421.064	439.371	in^3/kmol
Density	8.07	Mg/m^3	491.308	503.794	lb/ft^3
Energy Content	111	MJ/kg	9858.82	12025.6	kcal/lb
Bulk Modulus	152	GPa	19.435	22.0457	10^6 psi
Compressive Strength	310	MPa	24.6564	44.9617	Ksi
Ductility	0.51		0.3	0.51	NULL
Elastic Limit	310	MPa	24.6564	44.9617	Ksi
Endurance Limit	307	MPa	37.1296	44.5265	Ksi
Fracture Toughness	278	MPa.$m^{1/2}$	101.925	252.993	ksi.$in^{1/2}$
Hardness	2200	MPa	246.564	319.083	Ksi
Loss Coefficient	0.00148		0.00095	0.00148	NULL
Modulus of Rupture	310	MPa	24.6564	44.9617	ksi

Z	Maximum Value (S.I.)	Units (S.I.)	Minimum Value (Imp.)	Maximum Value (Imp.)	Units (Imp.)
Poisson's Ratio	0.275		0.265	0.275	NULL
Shear Modulus	82	GPa	10.7328	11.8931	10^6 psi
Tensile Strength	620	MPa	69.6181	89.9234	Ksi
Young's Modulus	205	GPa	27.5572	29.7327	10^6 psi
Glass Temperature		K			°F
Latent Heat of Fusion	285	kJ/kg	111.779	122.527	BTU/lb
Maximum Service Temperature	1198	K	1381.73	1696.73	°F
Melting Point	1673	K	2506.73	2551.73	°F
Minimum Service Temperature	0	K	-459.67	-459.67	°F
Specific Heat	530	J/kg.K	0.379191	0.410145	BTU/lb.F

Z	Maximum Value (S.I.)	Units (S.I.)	Minimum Value (Imp.)	Maximum Value (Imp.)	Units (Imp.)
Thermal Conductivity	17	W/m.K	24.3364	31.8246	BTU.ft/h.ft^2.F
Thermal Expansion	18	10^{-6}/K	27	32.4	10^{-6}/°F
Breakdown Potential		MV/m			V/mil
Dielectric Constant					NULL
Resistivity	81	10^{-8}ohm.m	69	81	10^{-8} ohm.m

1.3.3Commercial value of stainless steel

Stainless steel's resistance to corrosion and staining, low maintenance, relative inexpense, and familiar luster make it an ideal base material for a host of commercial applications. There are over 150 grades of stainless steel, of which fifteen are most common. The alloy is milled into sheets, plates, bars, wire, and tubing to be used in cookware, cutlery, hardware, surgical instruments, major appliances, industrial equipment, and building material in skyscrapers and large buildings. See "Use in sculpture and building facades", below, for more.

Stainless steel is 100% recyclable. In fact, over 50% of new stainless steel is made from remelted scrap metal, rendering it a somewhat eco-friendly material.

1.3.4 Types of stainless steel

There are different types of stainless steels: when nickel is added, for instance, the austenite structure of iron is stabilized. This crystal structure makes such steels non-magnetic and less brittle at low temperatures. For higher hardness and strength, carbon is added. When subjected to adequate heat treatment these steels are used as razor blades, cutlery, tools etc.

Significant quantities of manganese have been used in many stainless steel compositions. Manganese preserves an austenitic structure in the steel as does nickel, but at a lower cost.

Stainless steels are also classified by their crystalline structure:

- Austenitic stainless steels comprise over 70% of total stainless steel production. They contain a maximum of 0.15% carbon, a minimum of 16% chromium and sufficient nickel and/or manganese to retain an austenitic structure at all temperatures from the cryogenic region to the melting point of the alloy. A typical composition is 18% chromium and 10% nickel, commonly known as 18/10 stainless is often used in flatware. Similarly 18/0 and 18/8 is also available. "Superaustenitic" stainless steels, such as alloy AL-6XN and 254SMO, exhibit great resistance to chloride pitting and crevice corrosion due to high Molybdenum contents (>6%) and nitrogen additions and the higher nickel content ensures better resistance to stress-corrosion cracking over the 300 series. The higher alloy content of "Superaustenitic" steels means they are fearsomely expensive and similar performance can usually be achieved using duplex steels at much lower cost.
- Ferritic stainless steels are highly corrosion resistant, but far less durable than austenitic grades and cannot be hardened by heat treatment. They contain between 10.5% and 27% chromium and very little nickel, if any. Most compositions include molybdenum; some, aluminium or titanium. Common ferritic grades include 18Cr-2Mo, 26Cr-1Mo, 29Cr-4Mo, and 29Cr-4Mo-2Ni.
- Martensitic stainless steels are not as corrosion resistant as the other two classes, but are extremely strong and tough as well as highly machineable, and can be hardened by heat treatment. Martensitic stainless steel contains chromium (12-14%), molybdenum (0.2-1%), no nickel, and about 0.1-1% carbon (giving it more hardness but making the material a bit more brittle). It is quenched and magnetic. It is also known as "series-00" steel.
- Precipitation-hardening martensitic stainless steels have corrosion resistance comparable to austenitic varieties, but can be precipitation hardened to even

higher strengths than the other martensitic grades. The most common, 17-4PH, uses about 17% chromium and 4% nickel.

- Duplex stainless steels have a mixed microstructure of austenite and ferrite, the aim being to produce a 50:50 mix although in commercial alloys the mix may be 40:60 respectively. Duplex steel have improved strength over austenitic stainless steels and also improved resistance to localised corrosion particularly pitting, crevice corrosion and stress corrosion cracking. They are characterised by high chromium (19-28%) and molybdenum (up to 5%) and lower nickel contents than austenitic stainless steels.

1.3.5 Stainless Steel Grades

- 200 Series-austenitic chromium-nickel-manganese alloys
- 300 Series-austenitic chromium-nickel alloys
- Type 301-highly ductile, for formed products. Also hardens rapidly during mechanical working.
- Type 303-Free machining version of 304 via addition of sulfur
- Type 304-the most common; the classic 18/8 stainless steel
- Type 316-the next most common; for food and surgical stainless steel uses; Alloy addition of molybdenum prevents specific forms of corrosion. Also known as "marine grade" stainless steel due to its increased ability to resist saltwater corrosion compared to type 304. SS316 is often used for building nuclear reprocessing plants.
- 400 Series-ferritic and martensitic chromium alloys
- Type 408-heat-resistant; poor corrosion resistance; 11% chromium, 8% nickel.
- Type 409-cheapest type; used for automobile exhausts; ferritic (iron/chromium only).
- Type 410-martensitic (high-strength iron/chromium).
- Type 416
- Type 420-"Cutlery Grade" martensitic; similar to the Brearley's original "rustless steel". Also known as "surgical steel".
- Type 430-decorative, e.g., for automotive trim; ferritic.
- Type 440-a higher grade of cutlery steel, with more carbon in it, which allows for much better edge retention when the steel is heat treated properly.

- 500 Series-heat resisting chromium alloys
- 600 Series-martensitic precipitation hardening alloys
- Type 630-most common PH stainless, better known as 17-4; 17% chromium, 4% nickel

1.3.6 Typical applications of stainless steel

Stainless steel is a versatile material. First used for cutlery it soon found its way into the chemical industry because of its corrosion resistant characteristics. Today corrosion resistance is still of great importance and slowly bust steadily the mechanical characteristics of the material are being recognised. It is material that keeps on finding its way into new applications on a close to daily bases. Below you will find a number of applications where stainless steel has proven itself through many years of reliable service

Cutlery and kitchenware

The most well known application stainless steels is probably for cutlery and kitchenware. The finest cutlery uses specially produced 410 and 420 for the knives and grade 304 (18/8 stainless, 18% chromium 8% nickel) for the spoons and forks. The different grades used such as 410/420 can be hardened and tempered so that the knife blades will take a sharp edge, whereas the more ductile 18/8 stainless is easier to work and therefore more suitable for objects that have to undergo numerous shaping, buffing and grinding processes.

Chemical, processing and oil & gas industries

Probably the most demanding industries that use stainless steels are the chemical, processing and oil & gas industries have created a large market for stainless tanks, pipes, pumps and valves as well. One of the first major success stories for 304 stainless steel was the storage of dilute nitric acid as it could be used in thinner sections and was more robust than other materials. Special grades of stainless have been developed to have greater corrosion resistance at a broad range of different temperatures. These are used in desalination plants, sewage plants, offshore oilrigs, harbour supports and ships propellers.

Food production

Also large amounts of stainless steel are used in food production and storage. The most commonly used grades are 304 and 316. In general, 304 is basically the workhorse grade while 316 is used in harsher environments. An important reason fur using stainless steels is not so much the corrosiveness of the food itself as well as the fact that the use of stainless allo0.39

ws for faster and more efficient cleaning. For example in ice cream production 316 is specified so that strong anti-bacteriological cleaning and rinsing systems can be used. One of the great advantages of stainless steel is that it imparts no taste to the food that it comes into contact with.

Architecture, building and construction

Architecture, building and construction is a growing market as many modern buildings use stainless steels for cladding, roofing and facades. Another thing is that the low maintenance cost and anti-vandal characteristics of stainless provides a growing market in public transport, ticket machines and street furniture. Stainless steels are used for construction purposes, as well. When reinforced concrete first started to be used it was considered that the carbon steel used would not rust, as cement, obviously derived from limestone, is alkaline. However, constantly using grit salt on bridges can change the pH to acidic thereby rusting the steel which expands and cracks the concrete. Stainless steel reinforcing bar, although initially expensive, is proving to have very good life cycle costing characteristics.

Medical applications

Especially clean melted stainless is used for medical implants and artificial hips. A great deal of medical equipment - such as orthopaedic beds, cabinets and examination machines - is made as standard from stainless because of its hygienic and easy-clean qualities. Pharmaceutical companies use stainless for pill funnels and hoppers and for piping creams and solutions.

Automotive

Cars are making increasing use of stainless steel, primarily for exhaust systems (grade 409) and catalytic converters, but also for structural purposes. With greater attention being made to achieving low long term maintenance costs, less environmental impact and greater concern with life cycle costs, the market for stainless steel continues to improve

CHAPTER 2

LITERATURE SURVEY

Welding is a process in which we join two similar or dissimilar metals or non metals by applying pressure or non pressure. Gas tungsten arc welding, GTAW, also known as tungsten inert gas welding, is an arc welding process that uses a non-consumable tungsten electrode for establishing an electric arc. Weld area is protected by shielding gases like argon or helium. It is generally used for welding hard-to-weld metals such as Stainless Steels, Magnesium, Aluminium, and Titanium. TIG welding is most commonly used to weld thin sections. For welding stainless steel we use direct current with negative electrode. Direct current with positive electrode is very less common and used rarely.

Prashant Kumar Singh al.This paper gives us a review on TIG welding for optimizing process parameters on dissimilar metals. Tungsten Inert Gas Welding of dissimilar material such as stainless steel and mild steel has the potential to hold good mechanical and metallurgical properties. I. U.

Abhulimen et al. This paper gives a prediction on weld quality using TIG welding. The technique we used here is Response Surface Methodology. Response surface methodology, based on the central composite face centered design was generated for the purpose of optimization of the weld quality.

K. M. Eazhil et at. In this paper, the Taguchi method is used for the Optimization of Tungsten Inert Gas Welding on 6063 Aluminum Alloy. The Taguchi method is used to optimize the pulsed TIG welding process parameters of 6063 aluminum alloy weld ments for maximizing the mechanical properties.

D. Devakumar et al. An attempt is made to review and unite the important research works done on TIG welding of stainless steel in past years, by various researchers. It has been discovered, that most of the works done, is on austenite steel, which is the most widely used type of stainless steel in the world. Main aim of this paper is to give a brief idea about the research works done in the past, on TIG welding of stainless steel by various researchers.

M. Zuber et al. Purpose of present work is to investigate the effect of oxide flux on welding of austenitic stainless steel 304L plates having thickness 8 mm its effect on welding distortion, ferrite number, hardness value and depth of penetration. SiO_2 is used as a flux in the form of powder mixed with the acetone and applied on bead plate without making a joint preparation and without addition of filler wire. The result showed that this technique can increase depth of penetration and weld aspect ratio resulting in lower angular distortion.

R. D. Kumar et al.In this paper, an attempt is made to reduce the effect of heat affected zone on strength by using Pulsed TIG welding process. This paper describes the optimization of process parameters like current, voltage, stand-off distance, pulse on time and off time & gas flow to improve weld quality. In this work Taguchi method is used to get the optimal parameters.

CHAPTER 3
METHODOLOGY

3.1 SELECTION OF MATERIAL

3.1.1 Stainless steel

Most stainless steels are considered to have good weld ability and may be welded by several welding processes including the arc welding processes, resistance welding, electron and laser beam welding, friction welding and brazing. For any of these processes, joint surfaces and any filler metal must be clean. The coefficient of thermal expansion for the austenitic types is 50% greater than that of carbon steel and this must be considered to minimize distortion. The low thermal and electrical conductivity of austenitic stainless steel is generally helpful in welding. Stainless steels are defined as iron base alloys which contains chromium not less than 10.5%. The thin layer of chromium oxide film which forms on the surface of a stainless steel provides corrosion resistance & prevents further oxidation. Most stainless steels are considered to have good weldability and may be welded by several welding processes including the arc welding processes, resistance welding, electron and laser beam welding, friction welding and brazing. For any of these processes, joint surfaces and any filler metal must be clean.

Table 3.1: Chemical Composition

Chemical Composition Limits									
Weight%	**C**	**Mn**	**Si**	**Cr**	**Ni**	**S**	**P**	**Mo**	**Cu**
316L	0.04-0.08	1.0-2.5	0.30-0.65	18-20	11-14	0.03 max	0.03 max	2-3	0.75 max

Table 3.2: Mechanical Properties

Material	Ultimate Tensile Strength		Offset Yield Strength 0.2 %		Elongation (%)
	Psi	MPa	psi	MPa	
ER 316 / ER 316L	84,100	580	58,000	400	38

3.1.2 Filler Materials

Filler metals are used for the plate thickness of 2 mm, having a chemical composition similar to that of the parent material. Filler metal diameter is available between 1.6 to 3.2 mm. In this research work 2.5mm diameter filler metal was used for initial tack and run welding since this 2.5mm diameter is more suitable to ensure proper penetration in the 1.2mm root between two plates.

When welding stainless steel to carbon steel, it is critical to pay attention to chemistry, mechanical properties and corrosion resistance to avoid potential trouble. For all three factors, choosing the right filler metal can help reduce concerns. Similar usage as 309, but the 0.04% maximum carbon content increases resistance to inter granular corrosion.

As an example, when joining 316L stainless steel to mild steel, the most commonly recommended filler metal is 316L. During the welding process, the weld becomes diluted with some of the stainless steel from one side of the joint and some of the mild steel from the other side, mixing of material from each side of the weld. The goal is to create a final weld deposit whose chemistry is compatible with each side of the weld joint. Using 316L filler metal achieves this goal when joining 316L stainless steel to mild steel.

Again, if there is uncertainty about the proper filler metal selection, remember to consult with a welding distributor or a filler metal manufacturer prior to attempting the dissimilar weld.

Matching the mechanical properties of each type of material is important, as well. Attaining a mechanical match is a function of having the correct chemistry and also a reflection of the heat created by the welding ure. As a general rule, when welding any stainless steel to carbon steel, the filler metal should match or slightly exceed the mechanical properties of the weaker of the two materials

The filler metals are used or consumed and become a part of the finished weld. The definition has been expanded and now includes electrodes normally considered non-consumable such as tungsten and carbon electrodes, fluxes for brazing, submerged arc welding, electro slag welding, etc. The term filler metal does not include electrodes used for resistance welding, nor does it include the studs involved in stud welding. The chemical composition of 316L electrode has been mentioned below in Table 3.8

Table3.3: Chemical Composition of 316L Electrode by % Weight

Weight%	C	Mn	Si	Cr	Ni	S	P	Mo	Cu
316L	0.04-0.08	1.0-2.5	0.30-0.65	18-20	11-14	0.03 max	0.03 max	2-3	0.75 max

Filler metals for welding stainless steels are produced as coated electrodes (AWS A5.4), solid and metal core wire (AWS A5.9) and flux core wire (AWS A5.22). Most electrodes are available with a lime coating (-15) (for use with DC only), a titanium coating (- 16) (for use with AC or DC) or a silica-titanium coating (-17) (for use with AC or DC mainly in the down hand or horizontal positions) and in the standard or low carbon variety. Most alloys which are available as coated electrodes are also available as either solid wire, metal cored wire or flux cored wire. A few are available only as coated electrodes. If a filler material of the correct match is not available, filler with higher alloy content normally should be used.

As mentioned previously, filler metal for austenitic stainless steels should match or exceed the alloy content of the base metal. If maximum strength properties and corrosion resistance are required for the application, a filler metal of matching or similar composition to the base metal should be used. For martensitic or semi austenitic base alloys, the weldment should then be given the full solution and aging heat treatment if feasible. If not, the components should be solution treated before welding, then given a post-weld aging treatment after welding. It is recommended that the austenitic precipitation hardening stainless steels not be heat treated after welding because of cracking problems. In fact, these alloys are difficult to weld for this reason and some are not able to weld. Nickel base and conventional austenitic filler metals can be used for these alloys, especially if high strength weld metal is not required.

3.2 Taguchi method

A Japanese scientist i.e. Genichi Taguchi, develop a technique on an orthogonal array. This method is widely used in manufacturing industries. The main objective of this method is to provide a high-quality product at very low cost to the producer (manufacturer). Taguchi developed an array for predict how different parameters affect the mean and variance of the process parameters. He made the method in such a way that each factor have equally weighted because each factor is evaluated independently of other factors, so that's why the effect of one factor does not affect the value of other factors [18] or we can it is statistically technique that allows us to improve the consistency of production. Taguchi method recognizes that not all factors that cause variability can be controlled. These uncontrollable factors are called noise. Taguchi designs try to identify controllable factors to evaluate variability that occurs and then determines optimal factor setting that minimize the process variability. A process designed with this goal will produce more consistent output and performance regardless of the environment in which it is used.

3.3 Methodology

- Selection of base metals.
- Selection of process parameters.
- Preparation of samples for welding.
- Welding of samples.
- Specimen for tensile test & hardness test.
- Analyzing the result.

3.3.1 Base metals

Stainless steel

3.3.2 Process parameters

The selection of parameters of interest was base on study some research papers and experiment preliminary. The identified process parameters are given below:

1. Welding Current
2. Arc Voltage
3. Gas Flow Rate
4. Arc Travel Speed
5. Electrode Size
6. Electrode Extension
7. Electrode Position
8. Welding Position

The following process parameters are selected for the present work:

a) Welding Current (amp)

b) Arc Voltage (volt)

c) Gas Flow Rate (lt/min)

CHAPTER 4
EXPERIMENTAL SETUP AND METHODS

4.1 Welding Equipment and Accessories

In this experiment, TRIDENT 4009 make GTAW machine was used with 2 % thoriated tungsten electrode and manual welding technique with a root gap of 1.2 mm. The welding torch holds the non-consumable electrode assures the transfer of current to the electrode and the flow of shielding gas to the weld pool. Torches with the welding regimes up to 200A are gas cooled and those with continuous operation between 200 and 500A are water cooled. Gas cooled torch was used in the above arrangement. The shielding gas is directed on the puddle via a nozzle or cup which is concentric with the torch collet that holds the electrode [94]. The regulator is a device that reduces source gas pressure to a constant working pressure, independently of source pressure variations. During welding, welding gun was controlled manually and the filler rod was fed manually into the welding area. The effect of increasing the welding feed resulting reduced heat input. The GTAW of actual arrangement used in this research work is shown in Figure

4.1.1 Welding Accessories

Various welding accessories used in these experiments of similar and dissimilar welding with GTAW process have been presented for our better understanding. 4.1.2 Welding Torch The welding torch holds the non-consumable electrode, assures the transfer of current to the electrode and the flow of shielding gas to the weld pool. Torches with welding regimes up to 200Amp are generally gas-cooled and those with continuous operation between 200 and 500Amp are watercooled. Figure 4.3 shows a view of a water-cooled torch.

Figure 4.1 Gas Tungsten Arc Welding arrangemet (Original Image)

4.1.2 Welding Torch

The welding torch holds the non-consumable electrode, assures the transfer of current to the electrode and the flow of shielding gas to the weld pool. Torches with welding regimes up to 200Amp are generally gas-cooled and those with continuous operation between 200 and 500Amp are watercooled. Figure 4.3 shows a view of a water-cooled torch.

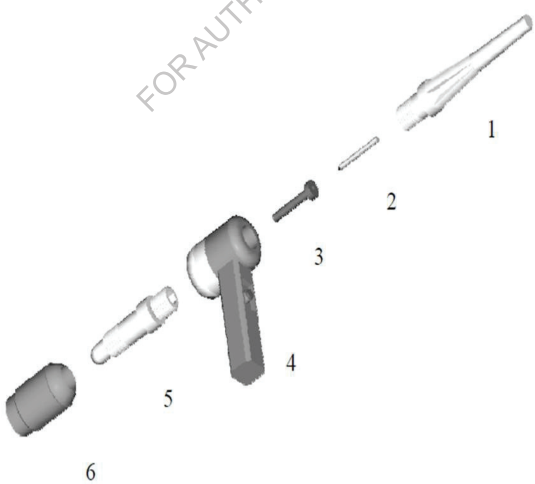

Figure 4.2 Exploded View of a Torch: Back cap-1 Electrode -2 Collet- 3 Handle-4 Collet body-5 Nozzle -6

4.1.3 Non-Consumable Electrodes

Non-consumable electrodes are composed of pure tungsten or tungsten alloys. Pure tungsten electrodes can be used with DC but are more sensitive to contamination, have lower service life-cycle and exhibit higher tip deterioration than alloyed electrodes. Non consumable electrodes can be used in welding of aluminum and magnesium alloys on AC.

Thoriated tungsten (2% ThO2) electrodes are widely used in industrial applications due to its excellent resistance to contamination, easy arc starting and stable electric arc. Concerns about safety, because thorium oxide is radioactive, led to the development of other electrodes containing small proportions (around 2%) of simple earth rare elements such as lanthanum, yttrium and cerium or even mixtures of several elements.

Nonconsumable electrodes have better operational characteristics than thoriated electrodes and can be used for welding carbon and stainless steels, nickel and titanium alloys. Zirconiated tungsten electrodes are excellent for AC due to its good arc starting, high resistance to contamination and small tip shape deterioration.

4.1.4 Shielding Gases

Shielding gases are used in GTAW to prevent atmospheric contamination of the weld metal. This contamination can produce porosity, weld cracking, scaling and even change the chemical composition of melted material. Besides shielding gas also has a large influence on the stability of the electric arc. Gases with low ionization potential facilitate the ignition of the electric arc and those with low thermal conductivity tend to increase the arc stability.

Argon is the most used shielding gas in GTAW. It has low ionization potential and is heavier than air, providing an excellent shielding of the molten weld pool. Furthermore, it is less expensive than helium, the other inert shielding gas used in the process. Argon is used in welding of carbon and stainless steels and low thickness aluminum alloys components.

For welding thick aluminum workpieces and other high conductive materials, such as copper alloys, helium is recommended because it has higher ionization potential than argon, needing higher voltage for arc initiation and maintenance, but producing higher heat input. Helium or helium/argon (30-80% Helium) mixtures allow increased welding speed and improved process tolerance. Mixtures of argon with up to 5% of hydrogen are frequently used for welding of austenitic stainless steels. Hydrogen increases arc-voltage and consequently heat input, increasing weld penetration and weld travel speed, as well improving weld appearance. Argon is also used as back side shielding gas, mainly in welding of stainless steels, aluminum alloys and reactive metals. Flow rates of shielding gases depend on weld thickness, being 4-10 L/min for argon and 10-15 L/min for helium, because it is lighter than argon, and consequently less effective in shielding. Gases with a purity of 99.995% are used in welding most of the metals, though reactive materials such as titanium need contaminant level less than 50 ppm.

4.1.5 Shielding Gas Regulator

The regulator is a device that reduces source gas pressure to a constant working pressure, independently of source pressure variations. Pressure reduction can be made in one or two stages. In this research work two stage Regulator was used to control the gas flow since regulator in two stages can give more stable output flow. A specially designed regulator attached with flow meter. The correct flow of argon to the torch is set by turning the adjusting screw on the regulator. The rate of flow depends on the kind and thickness of the metal to be welded

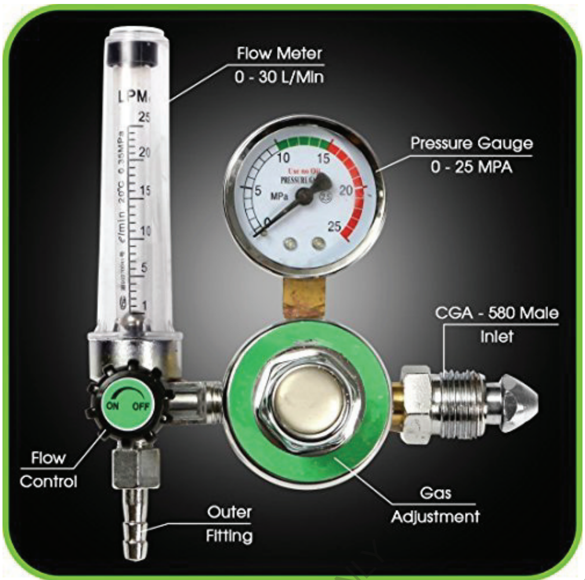

Fig 4.3: Argon Shielding Gas Regulator

4.2 GTAW Process Parameter

GTAW is regarded as a high quality process for welding thin metals using low travel speed and low electrode deposition rate, requiring highly skilled personnel in manual welding and greatly influenced by setting appropriate process parameters. Variants developed to seek to improve productivity, mainly deposition rate, penetration depth and welding speed.

4.2.1 Power Sources

Power sources for GTAW are generally of the constant current type with drooping volt-ampere static curves, as illustrated schematically in Figure 4.3. Lightweight transistorized direct current power sources are currently used, being more stable and versatile than the old thyristor-controlled units [60]. In rectifier-inverter power sources, the incoming Alternating current is rectified and then converted into AC at a higher frequency than that of the mains supply, in the inverter. Afterward high voltage AC is transformed into low voltage AC suitable for welding, in the transformer, and then rectified.

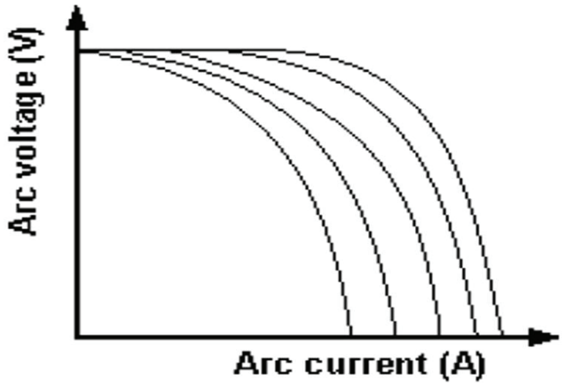

Figure 4.4 Arc Voltage Vs Current Voltage for GTAW

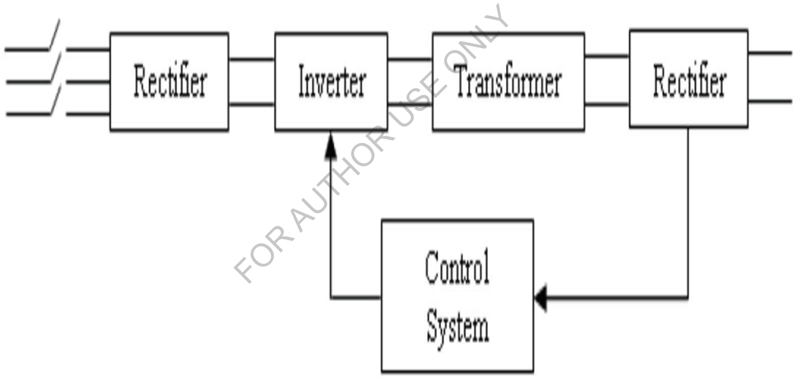

Fig 4.5 Inverter principles of power sources

The aim to increase the current frequency is to reduce the weight of the transformer and other components of the source such as inductors and capacitors. In arc welding processes some welding parameters exist that can affect the size, shape, quality and consistency of the weld. The major parameters that affect the weld include weld current, arc voltage, and travel speed.

4.2.2 Current

Current has a direct influence on weld bead shape, on welding speed and quality of the weld. Most GTAW welds employ direct current on electrode negative (DCEN) (straight polarity) because it produces higher weld penetration depth and higher travel speed than on electrode positive (DCEP) (reverse polarity). Besides, reverse polarity produces rapid heating and degradation of the electrode tip, because anode is more heated than cathode in gas tungsten electric arc.

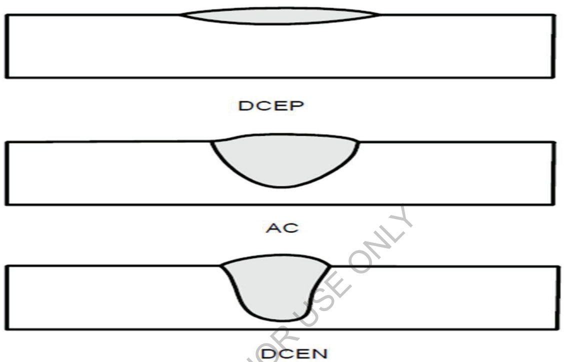

Figure 4.6 Effects of Current and Polarity on Weld Bead Shape

Reverse polarity may be of interest in welding aluminum alloys because of the cathodic cleaning action of negative pole in the work-piece, which impacts the removal of the refractory aluminum oxide layer. However alternating current is better adapted to welding of aluminum and magnesium alloys because it allows balancing electrode heating and workpiece cleaning effects. Weld penetration depth obtained with AC is in between depth obtained with DCEN and DCEP, as illustrated in Figure 4.5 The correct amperage for a certain electrode will depend on the size and classification of the electrode. Even the type of joint and welding position must be considered. The process requires sufficient electric current to melt both the electrode and a proper amount of base metal. Higher current will lead to deeper penetration. Using with high amperage may cause problems such as excessive spatter, electrode overheating and cracking.

4.2.3 Voltage

It is varied within narrower limits than welding current. It has an influence on the bead width and shape. Higher voltages will cause the bead to be wider and flatter. Extremely high arc voltage should be avoided, since it can cause cracking. The low arc voltage produces a stiffer arc that improves penetration. If the voltage is too low, a very narrow bead will result.

4.2.4 Welding Speed

The speed the electrode travels along the joint has a direct influence on bead shape, depth of fusion, cosmetic appearance and heat input into the base metal. Faster travel speeds produce narrower beads that have less penetration. This can be an advantage for sheet metal welding where small beads and minimum penetration are required. However, there is a tendency for undercutand porosity if the speed of the welding is too fast since the weld freezes quicker.

The effect of increasing the welding speed for the same current and voltage is to reduce the heat input. The welding speed does not influence the electromagnetic force and the arc pressure because they are dependent on the current. The weld speed increase impacts a decrease in the weld cross section area, and consequently penetration depth (D) and weld width (W) also decrease, but the D/W ratio has a weak dependence on travel speed.

These results suggest that the travel speed does not influence the mechanisms involved in the weld pool formation, it only influences the volume of melted material. Normal welding speeds are from 100 to 500 mm/min depending on current, material type and plate thickness.

4.2.5 Arc Length

The arc length is the distance between the electrode tip and the work piece. Arc length increases as the size of the electrode and amperage increase. Limiting arc length to the diameter of the core rod of the electrode is a good guideline. The arc length in GTAW is usually from 2 to 5 mm. If the arc length increases, the voltage to maintain the arc stability must increase, but the heat input to work piece decreases due to radiation losses from the column of the arc.

Consequently, weld penetration and cross section area of melted material decrease with increasing arc length.

4.3 TAGUCHI'S EXPERIMENTAL PROCEDURE

The main motive behind Taguchi method is to reduce variation in a process through robust design of experiment. The overall motive of the method is to give high quality product at low cost to the manufacturer. The experimental design given by Taguchi involves implying orthogonal arrays to organize the parameters affecting the process and the levels at which they give different values. In the place of having to test all possible combinations like the factorial design, the Taguchi technique tests pairs of combinations. This allows for the collection of the important data to find out which factors most affect product quality with a less amount of experimentation, thus saving time and resources. Study of ANOVA table for a given analysis helps to determine which of the parameters need control.

4.3.1 Signal to noise

Taguchi method stresses the necessity of studying the response variation using the signal-to-noise ratio, resulting to decrease the effect of quality characteristic variation due to uncontrollable parameter. The S/N ratio can be used in three types:

1. Larger the better:

$SN_L = -10 \log[1/n \sum_{i=0}^{n} 1/yi2]$

2. Smaller the better

$SN_L = -10 \log[1/n \sum_{ii=0}^{n} y_i 2]$

3. Nominal the best

$SN_N = 10 \log [Y^2/S^2]$

Where,

n = Number of trials or measurement

yi = measured value

ȳ = mean of measured value

s = standard deviation

4.3.2 ANOVA (Analysis Of Variance)

The purpose of the analysis of variance (ANOVA) is to investigate which design parameters significantly affect the quality characteristic. This is accomplished by separating the total variability of the S/N ratios, which is measured by the sum of the squared deviations from the total mean S/N ratio, into contributions by each of the design parameters and the error. First, the total sum of squared deviations SST from the total mean S/N ratio nm can be calculated as,

$$SST = \sum(n_i - n_m)^2$$

Where,

n_i= S/N ratio of ith run or experiment.

n_m = total mean of S/N ratio

4.3.3 Selection of Orthogonal Array

In this research work, we have taken three parameters and three levels of each parameter. So, L9 orthogonal array has been selected. The array shown in table 5:

Table 4.1: Selection Of Othogonal Array

NO OF	CONTROL FACTORS		
RUNS	A	B	C
1	L1	L2	L1
2	L1	L2	L2
3	L1	L3	L3
4	L2	L1	L2
5	L2	L2	L3
6	L2	L3	L1
7	L3	L1	L3
8	L3	L2	L1
9	L3	L3	L2

Where A,B,C are process parameters & L1, L2, L3 are levels of each parameter.

CHAPTER 5

EXPERIMENTS AND RESULTS

Prepare of welding specimen To prepare the specimen of SS-316 dimension 300×100×2 mm were used. Experiments were designed by the Taguchi method using an L9 orthogonal array that was composed of three columns and 3 rows. This design was selected based on three welding parameters with three levels each. The selected welding parameters for this study were: Current, Wire feed rate and Gas flow rate. The S/N ratio for each level of process parameters is computed based on the S/N analysis. There are three categories of quality characteristic in the analysis of the signal-to-noise (S/N) ratio, i.e. the smaller-thebetter, the bigger-the-better and the nominal-the-better. In this experiment maximizing the tensile strength so Therefore, the optimal level of the process parameters is the level with the highest S/N ratio. Furthermore, a statistical analysis of variance (ANOVA) was also performed to indicate which process parameters are significant; the optimal combination of the process parameters can be predicted.

Table 5.1: Various Process Parameters

Parameters	Code	Level1	Level2	Level3
Current(amp)	A	70	80	90
Voltage(volt)	B	20	30	40
GFR(lt/min)	C	6	8	10

5.1 TESTING OF WELDED SPECIMEN

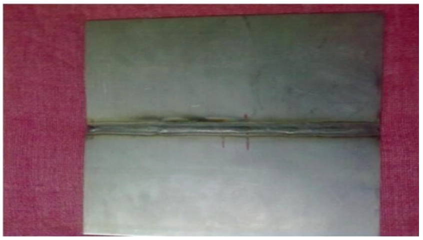

Fig 5.1: Actual Welding specimen with different parameters

5.2 Tensile test

Tensile Test The tensile test was done on UTM 400KN. A tensile test is also known as tension test & it is probably the most common type of mechanical test you can perform on material.

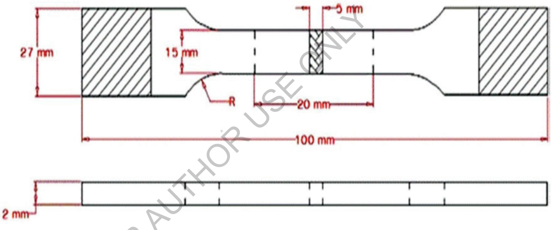

Figure 5.2 Tensile Test Specimen

Tensile tests are simple, less expensive, and fully standardized. By pulling on something, you will very quickly determine how the material will react to forces being applied in tension. By pulling material, you will find its strength along with how much it will elongate. One of the properties you can determine about a material is its ultimate tensile strength. This is the maximum load the specimen sustains during the test. The ultimate tensile strength may or may not equate to the strength at break. This all depends on what type of material you are testing brittle, ductile or a substance that even carries both properties. The test process involves placing the test specimen in the machine and applying tension to it until it fractures. During the application of tension, the elongation of the gauge section is recorded against the applied force.

Figure 5.3 UTM for Tensile Test

5.3 Hardness Test

This term may also refer to stiffness or temper or to resistance to scratch, abrasion, or cutting. It is property of a metal, which gives it the ability to resist being permanently deformed (bent, broken, or have its shape changed), when a load is applied. The metal with greater hardness it has greater resistance to deformation. In metallurgy hardness is defined as the ability of a material to resist plastic deformation.

Vickers Hardness Test

Vickers hardness is a measure of the hardness of a material, calculated from the size of an impression generates under load by a pyramid shaped diamond indenter. The diamond is pressed on the surface of material at loads ranging up to approximately 120 kilogram force and the size of the impression (not greater than 0.5 mm) is measured with the help of a calibrated microscope. The Vickers hardness number (HV) is calculated using the following formula:

$$HV = 1.854(F/D2)$$

With F being the applied load (measured in kilogram force) and D2 the area of the indentation (measured in square millimeters).

Fig 5.4: Hardness testing machine

The Vickers hardness should be reported like 800 HV/10, which means a Vickers hardness of 800, was obtained using a 10kgf force. Extremely accurate readings can be observed in this test, which is one of the major advantage of the Vickers hardness test and just single type of indenter is used for each and every type of metals or surface treatments.

CHAPTER 6
RESULT AND DISCUSSION

6.1 Tensile Test

Tensile testing has been done on the welded specimens. It was done on Universal Testing Machine (UTM). The value of tensile strength has been observed and then S/N ratio has been calculated manually as well as using software called MINITAB. The effect of each parameter on welding has been calculated and with the help of ANOVA, their percentage contribution is also evaluated. A figure shows the specimen of tensile test.

Tensile test before testing

Fig: 6.1 Tensile test before testing

Tensile test after testing

Fig: 6.2 Tensile test after testing

Calculation for S/N ratio

We know S/N Ratio for larger is better is:

$$SN_L = -10 \log[1/n \sum^{ni}_{=0} 1/y_i^2]$$

For 1st run:

n = 1 because we get the result in single trial

y = 266.507 (observed value)

So, S/N = -10 log (1/ 266.5072) = 48.5142

Similarly we calculate S/N Ratio for every run.

Table 6.1 Reading for tensile strength & S/N ratio:

Run	Arc current (amp)	Arc voltage (volt)	GFR(lt/min)	Tensile strength(mpa)	S/N ratio
1	70	20	6	266.507	48.51
2	70	30	8	296.519	49.44
3	70	40	10	244.898	47.78
4	80	20	8	262.905	48.39
5	80	30	10	315.726	49.99
6	80	40	6	301.321	49.58
7	90	20	10	247.299	47.86
8	90	30	6	277.311	48.86
9	90	40	80	238.896	47.56

Table 6.2 Responsetable for S/N ratio

Level	Arc current	Arc voltage	Gas flow rate
1	45.51	48.26	48.98
2	49.32	49.43	48.47
3	48.10	48.31	48.54
Delta	1.22	1.17	0.52
Rank	1	2	3

6.1.1Result Discussion of tensile Strength

The response tables show the average of each response characteristic (S/N rations, means) for each level of each factor. The tables include ranks based on Delta statistics, which compare the relative magnitude of effects. The Delta statistic is the highest minus the lowest average for each factor. Minitab assigns ranks based on Delta values: rank 1 to the highest Delta value, rank 2 to the second highest, and so on. Use the levels averages in the response tables to determine which level of each factor provides the best result. In our experimental analysis, the ranks indicate that current has the greatest influence on both the S/N ratio. The arc voltage has the next greatest influence, followed by gas flow rate. Hence, because our goal is to increase the tensile strength, we want factor levels that produce the highest mean. In Taguchi experiments, we always want to Maximize the S/N ratios and the means were maximized when the Current was 80, the Gas Flow Rate was 6 and the arc voltage was 30. Based on these results, we should set the factor at the calculated value.

Table 6.3 Response table for Means

Welding current	Level 2	80
Arc voltage	Level 2	30
Gas flow rate	Level 1	6

So, on the basis of these results we can say that Tensile Strength of stainless steel and mild steel will be higher when we will use Current at 80 A, Gas Flow Rate of 6 lt/min and Arc Voltage at 30 volt. So these are optimum welding parameters on which we can attain the higher tensile strength of Stainless Steel.

6.1.2Analysis of Variance for S/N Ratio Tensile Strength

ANOVA is a statistically based, objective decision-making tool for detecting any differences in the average performance of groups of items tested. ANOVA helps in formally testing the significance of all main factors and their interactions by comparing the mean square against an estimate of the experimental errors at specific confidence levels.

Table 6.4Analysis of Variance for S/N Ratio Tensile Strength

Source	DOF	Seq. SS	Adj. MS	F	P	%
Current	2	0.04265	0.03622	4.02	0.199	22.46 %
Voltage	2	0.08344	0.04172	4.63	0.178	44.11 %
GFR	2	0.01524	0.00763	0.85	0.542	8.05 %
esidual Error	2	0.01801	0.00902			
Total	8	0.18914				

It can beobserved from the table that no parameter is significant for tensile strength up to 95% confidence level and welding current affect the tensile strength maximum 44.11% followed by arc voltage 22.46%. Gas Flow Rate has minimum affect only 8.05% and graph is shownbelow:

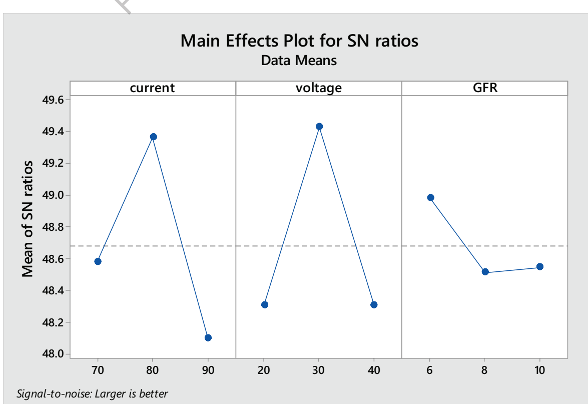

Fig: 6.3 Main Effects Plot for SN ratios of Tensile Strength

6.2 Hardness Test

This test has been done on the samples of welding prepared by TIG welding. Hardness of WZ (welding zone), HAZ (heat affected zone)has been observed and found out. Hardness test is done on Vickers Hardness Testing Machine. The micro-structure of each zone has also been observed and captured for better understanding. The samples were prepared accordingly and all 9 samples are tested for hardness. The 9 samples for hardness test are prepared on a mould of Bakelite Powder. We use Bakelite because of its high heat resistance ability.

Table 6.5 Hardness Reading and S/N Ratio

S n	Curr ent	Volt age	G F R	Hard ness WZ	Hardn ess PM	Hardn ess HAZ	S/N ratio
1	70	20	6	207.9	307.3	194.7	46.3571
2	70	30	8	219.6	296.0	196.3	46.8326
3	70	40	10	216.0	280.8	187.8	46.6891
4	80	20	8	218.4	280.4	178.1	46.7851
5	80	30	10	190.3	304.5	183.0	46.5888
6	80	40	6	199.8	284.1	164.9	46.0119
7	90	20	10	215.9	269.7	210.7	46.6851
8	90	30	6	217.0	280.1	201.4	46.292
9	90	40	8	216.8	272.5	212.0	46.7212

Tale 6.6 Response Table for S/N Ratio

Level	Current	Voltage	GFR
1	46.98	**46.92**	46.71
2	46.37	46.88	**46.99**
3	**47.15**	46.70	46.80
Delta	0.78	0.22	0.28
Rank	1.00	3.00	2.00

6.2.1 Results and Discussion of hardness Testing

The response table shows the average of each response characteristic (S/N ratio, means) for each level each factor. The tables include ranks based on Delta statistics, which compare the relativemagnitude of effects. The Delta statistic is the highest minus the lowest average for each factor. Minitab assigns rank based on Delta values; ranks 1 to the highest Delta value rank 2 to the second highest, and so on . Use the level averages in the response tables to determine which level of each factor provides the best result. In our experimental analysis for hardness of weld zone, heat affected zone (MS Plate) & heat affected zone (SS Plate), the ranks indicate that Gas Flow Rate has the greatest influence on the S/N ratio. The Current has the next greatest influence, followed by Wire Feed Rate. Here, because our global is to increase the weld ability by keeping the hardness at nominal value, we want factor levels that produce the highest mean.

In Taguchi experiments, we always want to maximize the S/N ratio. The level averages in the response tables show that the S/N ratio & Mean is maximized when the value of Current was 350 A, the Wire Feed Rate was 30 mm/min and the Gas Flow Rate was 35 L/min. Based on these results, we should set the hardnessat:

Table 6.7 Response Table for Means:

Current	Level 3	90
Voltage	Level 1	20
Gas Flow Rate	Level 2	8

Table 6.8 Analysis of Variance for Signal to Noise Ratio:

SOURCE	DOF	Seq. SS	Adj. MS	F	P	%
CURRENT	2	37.71	18.858	31.64	0.03	82.73 %
VOLTAGE	2	1.948	0.973	1.63	0.38	4.27 %
GFR	2	4.720	2.359	3.96	0.20	10.34 %
ERROR	2	1.192	0.596			
TOTAL	8	45.57				

6.2.2 Analysis of Variance for Signal to Noise Ratio

The analysis of variance was carried out at 95% confidence level. The main purpose of analysis of variance is to investigate the influence of deign parameters on Hardness by including that which parameter is significantly affected the quality characteristics. By use of ANOVA analysis the percentage contribution of welding current is 82.73 %, welding voltage of 4.27 % and gas flow rate of 10.34 % and the remaining are of errors. This error is due to human ineffectiveness and machine vibration. The purpose of ANOVA is to investigate which welding process parameters significantly affect the quality characteristics.Graph shows the correlation between different processparameters.

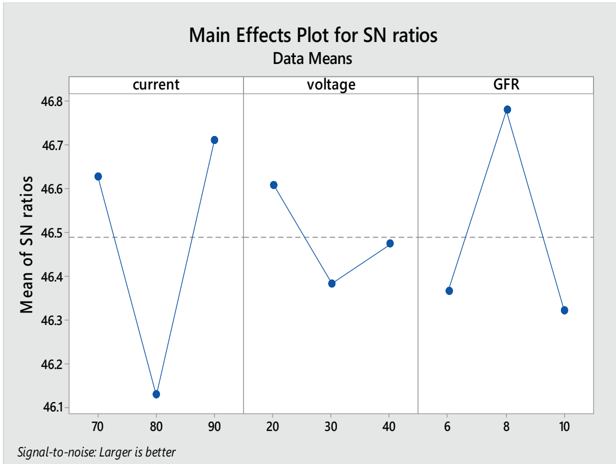

Fig: 6.4 Main Effects Plot for S/N Ratios of Hardness testing

CHAPTER 7
CONCLUSION

The purpose of the present research was to optimize the welding process parameters and find out their optimized values with the help of Tensile and Hardness testing of the welding samples. An important finding to emerge in this study is the values of the process parameters for maximum tensile strength and hardness. The use of L9 (3×3) orthogonal array with three control parameters allowed this study to be conducted with a sample of 9 work pieces. The study found that the control factors had varying effects on the tensile strength, arc voltage having the highest effect. Taguchi method has been very successful in designing high quality products and processes of many different fields. The present study can be concluding as follows:

1. Taguchi design of experiment technique can be very efficiently used in the optimization of welding parameters in manufacturing operations.

2. Optimum parameters setting for Tensile Strength is

The current parameter of level 2 value is 80 and contribution is 22.46%

The arc voltage parameter of level 2 value is 80 and contribution 44.11%

The Gas Flow Rate parameter of level 1 value is 1 and contribution 8.05%

3. Optimum parameters setting for Hardness

The current parameter of level 3 value is 90 and contribution 82.73%

The arc voltage parameter of level 1 value is 20 and contribution 4.27%

The Gas Flow Rate parameter of level 2 value is 8 and contribution 10.36%

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