INVESTIGATION OF WELD TEST USING COLD METALTRANSFER ON AUSTENITIC STEEL

A PROJECT REPORT

Submitted by

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INTERNAL EXAMINER **EXTERNAL EXAMINER**

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ABSTRACT

Joining of similar metals has found its use extensively in power generation, electronic, nuclear reactors, petrochemical and chemical industries due to environmental concerns, energy saving, high performance, cost saving. However efficient welding of similar metals has posed a major challenge due to difference in mechanical of the materials to be joined under a common welding condition. This causes a steep gradient of the mechanical properties along the weld. A variety of problems comeup in similar welding like cracking, large weld residual stresses, migration ofatoms during welding causing stress concentration on one side of the weld, compressive and tensile stresses, stress corrosion cracking, etc. To overcome thiscauses there are required to study the effect of welding process parameter on mechanical property.

The aim of this research is to investigate the tensile strength properties of similar metal welding of SS304 using Cold Metal Transfer (CMT) process with SS316L as a filler material by optimizing the welding parameter. The experimental results were obtained corresponding to the effect of different welding current, different welding speed and different gas pressure on ultimate tensile strength of butt joint.

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CHAPTER 1

INTRODUCTION

This project focuses on investigating the use of the Cold Metal Transfer (CMT) welding process on SS304 austenitic steel. SS304 is a commonly used stainless steel alloy known for its excellent corrosion resistance, low carbon content, and high-temperature strength. The CMT welding process is a relatively new technology that combines short-circuiting and spray transfer to join metals with a consumable electrode fed into the weld pool using a precise, controlled motion.

The objective of this project is to evaluate the mechanical properties of the weld produced using the CMT process on SS304 steel through impact and tensile tests to determine the weld's strength, ductility, and toughness. The results of these tests will be used to assess the suitability of the CMT process for joining SS304 steel and to compare its mechanical properties with other welding processes.

The significance of this project lies in its contribution to the development of new welding technologies that offer improved efficiency, lower heat input, and better mechanical properties. This project's findings will help researchers and manufacturers determine the viability of using the CMT welding process on SS304 steel and its potential to replace traditional welding methods. Ultimately, this research will provide insights into the optimal use of CMT welding and its potential to revolutionize the welding industry.

1.1 BACKGROUND OF WELDING

The history of joining metals goes back several millennia. The earliest examples of this come from the Bronze and Iron Ages in Europe and the Middle East. The ancient Greek historian Herodotus states in The Histories of the 5th century BC that Glaucus of Chios "was the man who single- handedly invented iron welding".

The Middleages brought advances in forge welding, in which blacksmiths pounded heated metal repeatedly until bonding occurred. In 1540, Vannoccio Biringuccio published De la pirotechnia, which includes descriptions of the forging operation. Renaissance craftsmen were skilled in the process, and the industry continued to grow during the following centuries.

Sir Humphrey Davy produced an electric arc using two carbon electrodes powered by a battery. This principle was subsequently applied to weld metals. Resistance welding finally developed in the year 1885 by Elihu Thomson. Acetylene gas was discovered in 1836 by Edmund Davy, but it could not be used in welding application due to lack of a proper welding torch. When the require welding torch was invented in 1900, oxy- acetylene welding became one of the most popular type of welding mainly due to its relatively lower cost. However, in the 20th century it lost its place to arc welding in most of the industrial applications.

Advance welding techniques like Plasma Arc Welding, Laser Beam

Welding, Electron Beam Welding, Electro- Magnetic Pulse Welding, Electro gas welding, Ultrasonic Welding, etc. are now being extensively used in electronic and high precision industrial applications.

1.2 TYPES OF WELD JOINTS

The welding joint geometry can be classified primarily into five types. This is based on the orientation between the material surfaces to be joined.

1.2.1 Butt joint

A butt weld, or a square-groove, is the most common and easiest to use. Consisting of two flat pieces that are parallel to one another, it also is an economical option. It is the universally used method of joining a pipe to itself, as well as flanges, valves, fittings, or other equipment.

1.2.2 Corner joint

A corner weld is a type of joint that is between two metal parts and is located at right angles to one another in the form of a L. As the name indicates, it is used to connect two pieces together, forming a corner. This weld is most often used in the sheet metal industry and is performed on the outside edge of the piece.

1.2.3 Edge joint

Edge welding joints, a groove type of weld, are placed side by side and welded on the same edge. They are the most commonly replaced type of joints due to build up accumulating on the edges. They are often applied to parts of sheet metal that have edges flanging up or formed at a place where a weld must be made to join two adjacent pieces together.

1.2.4 Lap joint

This is formed when two pieces are placed a top each other while also over lapping each other for a certain distance along the edge. Considered a fillet of a welding joint, the weld can be made on one or both sides, depending upon the welding symbol or drawing requirements. It is most often used to join two pieces together with differing levels of thickness.

1.2.5 Tee joint

The Tee Weld Joint is formed when two bars or sheets are joined perpendicular to each other in the form of a T shape. This weld is made from the resistance butt welding process. It can also be performed by Extrusion Welding.

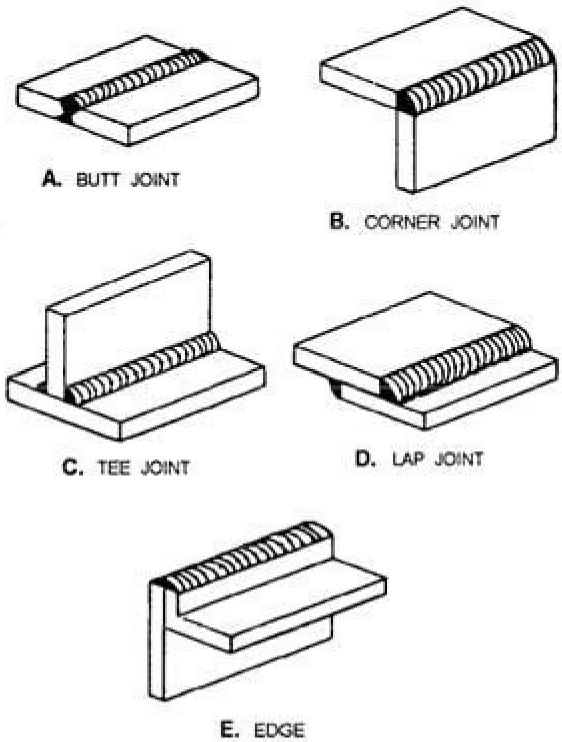

Figure 1.1 Types of welding joints.

1.3 METALLURGY OF WELDED JOINTS

Metal is heated over the range of temperature up to fusion and followed by cooling ambient temperature. Due to differential heating, the material away from the weld bead will be hot but as the weld bead is approached progressively higher

temperatures are obtained, resulting in a complex micro structure. The subsequent heating and cooling results in setting up internal stresses and plastic strain in the weld.

Depending upon the slope of temperature gradient three distinct zones as shown in Figure 1.6 can be identified in welded joint which are:

I. Base Metal
II. Heat Affected Zone(HAZ)
III. Weld Metal

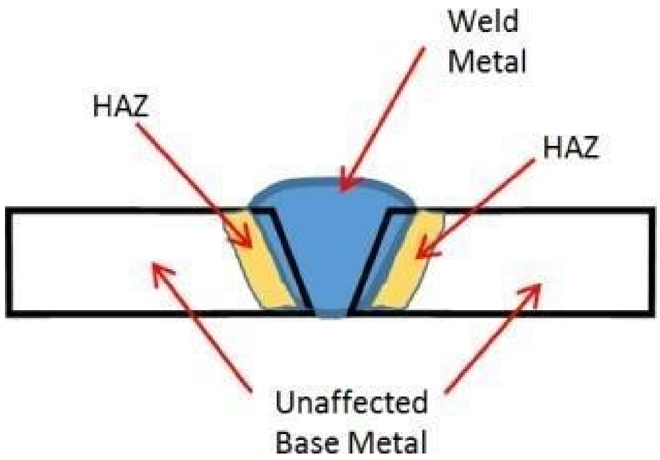

Figure 1.2 Metallurgy of welded joints.

A joint produced without a filler metal is called autogenous and its weld zone is composed of re-solidified base metal. A joint made with a filler metal is called weld metal. Since central portion of the weld bead will be cooled slowly, long columnar grains will developed and in the out ward direction grains will become finer and finer with distance.

The ductility and toughness decreases away from the weld bead. However strength increases with the distance from the weld bead. The original structure in steels consisting of ferrite and pearlite is changed to alpha iron. The weld metal in the molten state has a good tendency to dissolve gases which come into contact with it like oxygen, nitrogen and hydrogen. during solidification, a portion of these gases get trapped into the bead called porosity. Porosity is responsible for decrease in the strength of the weld joint. Cooling rates can be controlled by preheating of the base metal welding interface before welding.

The heat affected zone is within the base metal itself. It has a micro structure different from that of the base metal after welding, because it is subjected to elevated temperature for a substantial period of time during welding. In the heat affected zone, the heat applied during welding recrystallises the elongated grains of the base metal, grains that are away from the weld metal will recrystallises into fine equiaxed grains.

1.4 COLD METAL TRANSFER WELDING (CMT)

CMT is a subset of gas metal arc welding. It works by reducing the weld current and retracting the weld wire when detecting a short circuit, resulting in a drop- by-drop deposit of weld material.

Cold Metal Transfer (CMT) is a welding method that is usually performed by a welding robot. The CMT machine detects a short circuit which sends a signal that retracts the welding filler material, giving the weld time to cool before each drop is placed. This leaves a smooth weld that is stronger than that of a hotter weld. This works well on thin metal that is prone to warping and the weld burning through the material.

Welding wire is fed through the system that is controlled by a computer, the computer adjusts things such as wire feed, welding speed, and amps going through the wire.

Cold metal transfer (CMT) process is a highly developed version of Metal Inert Gas/ Metal Arc Gas (MIG/MAG) arc welding process with a precise process control and low heat input to the base material. It is a revolutionary of welding techniques, inclusive of welding techniques and its application. CMT is not only completely new process but also allow application that are as yet completely unexplored.

A typical CMT welding electrical signal cycle can be defined as the period required to deposit a droplet of molten electrode into the weld pool. The analysis of current and voltage waveform is essential to study the energy distribution of different phases in droplet transfer process. The cycle is divided into three phases as follows:

I. The peak current phase
II. The background current phase
III. The short circuiting phase

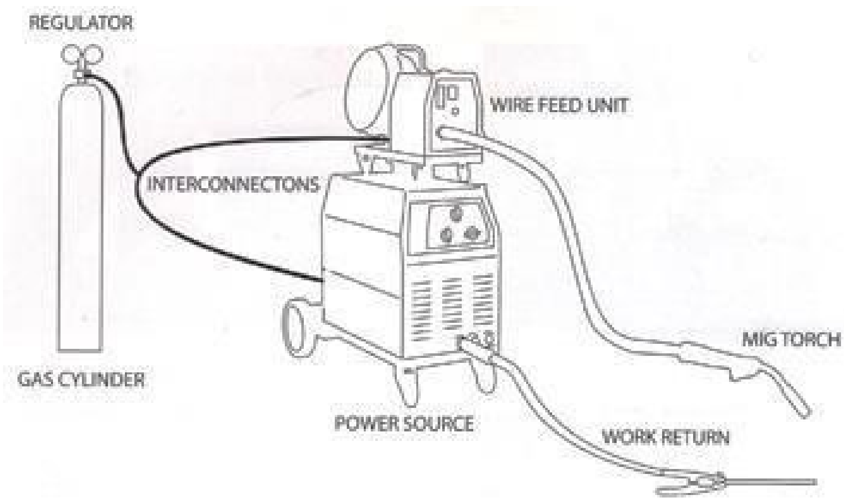

Figure 1.3 Schematic diagram of CMT welding machine.

1.4.1 Types of CMT welding

Cold Metal Transfer Pulse

CMT Pulse uses direct current electrode positive (DCEP) polarity throughout. This means that approximately 70% of the heat in the arc will be taken by the electrode side and 30% will be taken by the workpiece.

Cold Metal Transfer Advanced

CMT Advanced welding process uses a type of alternating current. This effectively means that the welding arc's heat distribution changes directions because the polarity of the current is constantly alternating. This allows for even cooler welding than the original CMT Pulse process. Since the alternating current keeps the weld and the workpiece much cooler, the user can afford to turn up the wire feed speed thus allowing for higher deposition rates, which usually means faster welding.

Cold Metal Transfer Pulse Advanced

This uses an alternating current just as CMT Advanced does. The primary difference between these two processes is that only the pulses of the sequence have a positive polarity. Since most of the heat is then concentrated toward the electrode, the filler metal is deposited much easier to bridge gaps in joints, thus keeping the workpiece cooler during the deposition. This process is specifically tailored to fix bridge gaping.

Cold Metal Transfer Dynamic

This process is designed to weld thicker plate. It increases the rate of the wire extension-retraction cycle thus allowing for higher wire feed speeds and consequently, higher deposition rates. This allows for greater penetration into the weld joint, which is ideal for thicker plate. This process stands outside of the original intention of cold metal transfer in general, in that it is not designed for cladding.

1.4.2 CMT welding process

CMT welding has an exceptionally stable arc. The pulsed arc is made up of a base current phase with a low power and a pulsing current phase with high power without short circuits. This leads to almost no spatter being produced. (Spatter are droplets of molten material that are generated at or near the welding arc.).

In the pulsing current phase, the welding droplets are detached in a targeted manner via a precisely dosed current pulse. Because of this process, the arc only introduces heat for a very brief period during the arc-burning phase. The arc length is detected and adjusted mechanically. The arc remains stable, no matter what the surface of the workpiece is like or how fast the user welds. This means CMT can be used everywhere and in every position.

The CMT process physically resembles MIG welding. However, the big difference is in the wire feed. Rather than continuously moving forward into the weld pool, with CMT, the wire is retracted the instant current flows. The weld wire and a shielding gas are fed through a welding torch, the electricity arcs between the weld wire and the welding surface – this causes the tip of the weld wire to liquefy and to be applied to the welding surface. CMT uses automatic activation and deactivation of the heating arc to systematically heat and cool the weld wire while bringing the wire into and out of contact with the weld pool many times per second. Because it uses a pulsing action instead of a continuous stream of power, CMT welding generates only one-tenth of the heat that MIG welding does. This reduction in heat is CMT's greatest benefit and is why it's called "Cold" metal transfer.

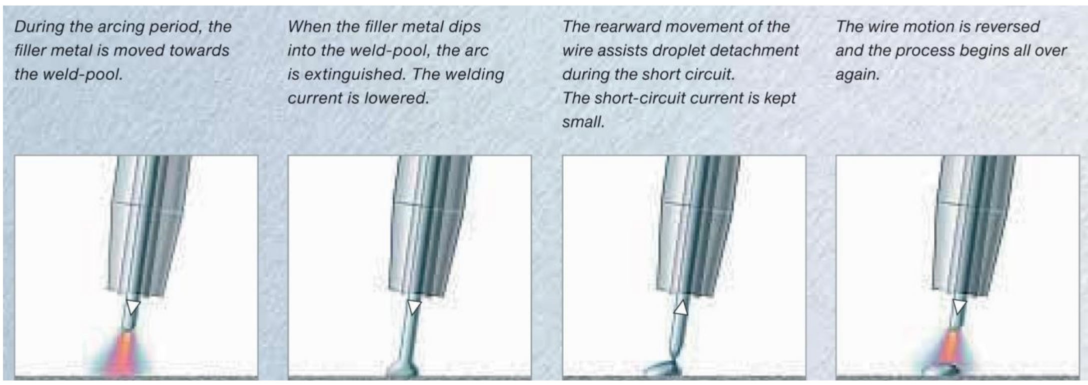

Figure 1.4 CMT welding process

1.4.3 Uses of CMT welding

Cladding

Fronius originally developed this process for cladding. Cladding is the joining of two similar metals. This is not achieved easily with other welding processes that produce more heat. Due to the extreme precision that Cold Metal Transfer Welding provides, neither of the joint members will overheat, and consequently, the bonding between the two metals is much more controllable.

Electronics

CMT, because of its extreme precision as compared to regular MIG welding, is one of the best choices for electronic enclosures, especially when the components are particularly sensitive. The low heat input is less likely to warp the enclosure during its construction than regular MIG welding. On the other hand, TIG welding, while adept to handle such a sensitive task, comes short in the efficiency department. This makes CMT an ideal process for this application.

Automobile

CMT has become a favorite application for many automobile manufacturers, including Tesla. This is especially the case when aluminum is primarily used to create the structure of the vehicle. The Tesla Model S is made from aluminum. After creating the main panels for the body of the vehicle using aluminum sheets put through die presses, they join the panels using fasteners, epoxy, and also cold metal transfer welding.

Why CMT welding is preferred

In the welding process, heat from the welding torch heats up the workpiece and a feed wire in the torch, melting them and fusing them together. When the heat is too high, the filler can melt before reaching the workpiece and cause drops of metal to splatter onto the part. Other times, the weld can quickly heat the workpiece and cause distortion or in the worst cases, holes can be burnt into your part.

The most commonly used types of welding are MIG and TIG welding. These both have a much higher heat output compared to Cold Metal Transfer (CMT) welding.

In our experience, TIG and MIG welding is not ideal for joining light gauge sheet metal. Due to the excessive amounts of heat, there is warping and meltback, particularly on stainless steel and aluminum.

1.6 SS304 CHARACTERISTICS AND APPLICATIONS

1.6.1 Characteristics

- Alloy 304 is a chromium-nickel molybdenum austenitic stainless steel developed to provide improved corrosion resistance to Alloy 304 in moderately corrosive environments.
- Alloy 304 resists atmospheric corrosion, as well as, moderately oxidizing and reducing environments. It also resists corrosion in polluted marine atmospheres.
- Alloy 304 is non-magnetic in the annealed condition, but can become slightly magnetic as a result of cold working or welding. It can be easily welded and processed by standard shop fabrication practices.
- Alloy 304 performs well in sulphur containing service such as that encountered in the pulp and paper industry. The alloy can be used in high concentrations at temperatures up to 120°F (38°C).
- Alloy 304 can be readily welded by most standard processes.
- A post weld heat treatment is not necessary.

1.6.2 Applications

- Pulp and paper equipment
- Heat exchanger
- Dyeing equipment
- Film processing
- Equipment
- Pipeline

1.7 WELDING PROCESS VARIABLES

Weld quality and weld deposition rate both are influenced very much by the various welding parameters and joint geometry. Essentially a welded joint can be produced by various combinations of welding parameters as well as joint geometries.

These parameters are the process variables which control the weld deposition rate and weld quality. The weld bead geometry, depth of penetration and overall weld quality depends on the following operating variables.

- Welding Current
- Welding Voltage
- Welding Speed
- Contact Tube-to-Work Distance(CTWD)
- Electrode Size
- Arc Travel Speed
- Welding Position
- Gas Flow Rate
- Shielding Gas Composition

Welding Position: The wire electrode's position affects weld bead shape and penetration more than arc voltage and travel speed. Two travel angles define wire electrode position.

Gas Flow Rate: Proper gas flow ensures a uniform shield for the molten metal, preventing contamination and increasing efficiency. Flow rates vary and should be selected based on the application.

Shielding Gas Composition: Shielding gas protects the arc and molten weld pool from oxygen and nitrogen, preventing weld deficiencies. Gas composition affects arc characteristics, mode of metal transfer, penetration, weld bead profile, speed of welding, cleaning action, and weld metal mechanical properties. Argon and argon-helium mixtures are used for non-ferrous metals, while argon and carbon dioxide are used for carbon steel.

Electrode Size: Electrode diameter affects weld bead configuration, depth of penetration, bead width, and travel speed. Smaller diameters have more penetration, while larger diameters create a wider weld. The electrode size chosen depends on the workpiece's thickness, desired penetration, weld profile and deposition rate, welding position, and cost.

Arc Travel Speed: Travel speed controls the rate of the arc along the workpiece. Slower speeds increase heat input, weld penetration, and weld metal deposit, resulting in a wider bead contour. If the travel speed is too slow, poor fusion, lower penetration, porosity, slag inclusions, and a rough, uneven bead may occur.

CHAPTER 2

LITERATURE SURVEY

“Cold Metal Transfer (CMT) Welding Technology: A Review" by Wei Gao and colleagues (2018) provides an overview of the CMT welding process, a relatively new welding technology that has been gaining popularity in recent years. The article discusses the advantages of the CMT process, including low heat input, minimal spatter, and high-quality welds. The authors also review the process parameters that can affect the quality of the weld, such as wire feed rate, arc voltage, and travel speed. Additionally, the article highlights some of the applications of the CMT process, such as welding thin materials and similar metals. This review article is an excellent resource for anyone interested in learning about the CMT process and its potential applications.

"Effect of welding parameters on microstructure and mechanical properties of SS304 austenitic stainless steel joints by Cold Metal Transfer (CMT) welding" by S. N. Das and colleagues (2016) focuses on the effect of welding parameters on the microstructure and mechanical properties of SS304 steel joints welded using the CMT process. The study found that the heat input, wire feed rate, and travel speed had a significant impact on the weld's microstructure and mechanical properties. The authors concluded that the CMT process produced high-quality welds with good mechanical properties when appropriate welding parameters were used. This study provides valuable information for anyone looking to optimize the CMT process for welding SS304 steel.

"Investigation of cold metal transfer (CMT) welding process for joining austenitic stainless steel" by A. H. Ahsan and colleagues (2021) explores the feasibility of the CMT process for joining austenitic stainless steel. The authors conducted a series of experiments to evaluate the mechanical properties of SS304 steel joints welded using the CMT process. The study found that the CMT process produced welds with excellent mechanical properties, including high strength and ductility. The authors concluded that the CMT process has the potential to replace traditional welding processes for joining austenitic stainless steel. This study highlights the potential of the CMT process as a viable alternative to traditional welding methods.

"Investigation of mechanical properties and microstructure of AA6061 aluminum alloy joint welded by CMT and GMAW processes" by M. A. Bahrami and colleagues (2017) compares the mechanical properties and microstructure of AA6061 aluminum alloy joints welded using the CMT and Gas Metal Arc Welding (GMAW) processes. The study found that the CMT process produced joints with improved mechanical properties, including higher strength and ductility, compared to the GMAW process. The authors attributed these improvements to the CMT process's ability to control heat input and minimize spatter. This study demonstrates the potential of the CMT process for welding aluminum alloys.

"Microstructural and mechanical characterization of stainless steel 304 joined by cold metal transfer (CMT) welding process" by R. Singh and colleagues (2018) investigates the microstructure and mechanical properties of SS304 steel joints welded using the CMT process. The study found that the CMT process produced welds with improved mechanical properties, including higher strength and toughness, compared to traditional welding processes. The authors attributed these improvements to the CMT process's ability to minimize heat input and reduce thermal distortion. This study provides valuable insights into the potential of the CMT process for welding SS304 steel and highlights the benefits of using this technology over traditional welding methods.

Impact toughness and microstructure of low carbon austenitic stainless steel welded by cold metal transfer (CMT) process" by T. A. Khalid and colleagues (2019) investigates the impact toughness and microstructure of low carbon austenitic stainless steel welded using the CMT process. The authors conducted a series of experiments to evaluate the mechanical properties of the welds and to analyze the microstructure using electron microscopy techniques. The study found that the CMT process produced welds with good impact toughness and a refined microstructure. This study provides valuable insights into the potential of the CMT process for welding low carbon austenitic stainless steel.

"Influence of welding parameters on the mechanical properties of MIG welded austenitic stainless steel" by M. Prasad and colleagues (2015) investigates the effect of welding parameters on the mechanical properties of MIG (Metal Inert Gas) welded austenitic stainless steel. The authors conducted a series of experiments to evaluate the impact of various welding parameters such as welding speed, voltage, and wire feed rate on the tensile strength, hardness, and microstructure of the welds. The study found that the welding speed and voltage significantly affected the mechanical properties of the welds, while the wire feed rate had a minor effect. The authors concluded that optimized welding parameters can produce MIG welded austenitic stainless steel with good mechanical properties. This study provides valuable insights into the optimization of MIG welding parameters for austenitic stainless steel.

CHAPTER 3

METHODS AND MATERIALS

3.1 FRONIUS TPS 4000

The TransSynergic (TS) 4000 and TS 5000 and TransPulsSynergic (TPS) 2700, TPS 3200, TPS 4000 and TPS 5000 power sources are fully digitised microprocessor-controlled inverter power sources. The modular design and potential for system add-ons ensure a high degree of flexibility. The devices can be adapted to any specific situation. The TransPuls Synergic 2700 features an integral 4-roller drive. There is no longer an interconnecting hosepack between the power source and wire-feed unit. Its compact design makes the TPS 2700 particularly suitable for mobile applications. All models except the TS 4000/5000 are multiprocessor devices: - MIG/MAG welding - TIG welding with touchdown ignition (excluding CMT power sources) -Manual metal arc welding

3.1.1 Functional principle

The central control and regulation unit of the power sources is coupled with a digital signal processor. The central control and regulation unit and the signal processor control the entire welding process. During the welding process, the actual data is measured continuously and the device responds immediately to any changes. Control algorithms ensure that the desired target state is maintained.

This results in: -

- A precise welding process.
- Exact reproducibility of all results.
- Excellent weld properties.

3.1.2 Applications

The devices are used in workshops and industry for manual and automated applications with classical steel, galvanised sheets, chrome/nickel and aluminium. The integral 4-roller drive, high performance and light weight of the TPS 2700 power source make it the ideal choice for portable applications on building sites or in repair workshops.

The TS 4000/5000 and TPS 3200/4000/5000 power sources are designed for: -

- Automobile and component supply industry
- Machinery and rail vehicle construction
- Chemical plant construction
- Equipment construction
- Shipyards, etc.

Figure 3.1 Fronius TPS 4000 MIG

Figure 3.2 Control System of Fronius TPS 4000

3.1.3 Fronius RCU 5000i

The RCU 5000i remote control is intended for the operation of all power sources in the TransSynergic/TransPuls Synergic series. All functions available on the power source can be retrieved using the RCU 5000i. In addition, further functions are available such as optimisation of welding characteristics. Connection to the power source takes place via a LocalNet plug. The RCU 5000i remote control unit is equipped with an LCD. In conjunction with a clearly laid-out menu, this makes for a user-friendly device.

Applications

The RCU 5000i remote control unit is used

- For operating and programming the power sources, making pre-settings.
- In robot applications.
- For manual welding using power sources equipped with the "Remote" control panel.

Advantages

- Clear layout thanks to LCD
- Simple and logical operation
- 180 pre-programmed Synergic welding characteristics
- Welding characteristics can be optimised
- Easy to program jobs
- Up to 1000 jobs can be stored
- User access management using keycard
- Parameter monitoring thanks to QMaster function
- LocalNet connection
- USB interface for software updates

Figure 3.3 Fronius RCU 5000i

3.2 SHIELDING GAS

The primary purpose of shielding gas is to prevent exposure of the molten weld pool to oxygen, nitrogen and hydrogen contained in the air atmosphere. The reaction of these elements with the weld pool can create a variety of problems, including porosity (holes within the weld bead) and excessive spatter.

The shielding used in this experiment is 100 percent Argon Density of Argon- 1,784 Kg/m3

3.3 WORKPIECE DETAIL

In this study, SS304 were used as a base metal. Base metals were machined to rectangular samples with the following dimensions: 60mm x 100mm x 3mm. Standard Single Lap joint configurations (with a root face thickness of 1mm, a root gap of 1 mm, and with a 45 angle) were employed for the samples.

3.4 STAINLESS STEEL ALLOY (SS304)

304 stainless steel is a kind of Austenitic stainless steel, a lower carbon variant of 304 stainless steel. Both 304 and 304 stainless steels contain molybdenum, but 316L stainless contain more molybdenum than 304 stainless steel. Due to the addition of molybdenum in the steel, the overall performance of

304 steel is superior to that of 310 and 316 stainless steel.

304 stainless steel has a maximum carbon content of 0.03 amd can be used in applications where post-welding annealing is not possible and where maximum corrosion resistance is required. Since 304 stainless steel features better carbide precipitation resistance than 304 stainless steel, 304 can be continuously exposed to the temperature of 427˚C – 857˚C (800˚F - 1575˚F), where 304 is not advisable to. Though 304 features better corrosion resistance than 304, but its mechanical properties are not as good as 304.

Table 3.4 Composition of SS304 (Wt %)

Element	**C**	**Mn**	**P**	**S**	**Si**	**Cr**	**Ni**	**Mo**	**N**	**Fe**
SS304	≤ 0.03	≤ 2	≤ 0.045	≤ 0.03	≤ 1	18-20	10-14	2-3	≤ 0.1	Balance

Table 3.5 Mechanical properties of SS304

Grades	**Tensile Strength Ksi(Mpa), min**	**Yield Strength, ksi (Mpa)**	**Elongation, %**	**Hardness, Rockwell**
SS304	75(515)	30(205)	40	B82

3.6 PARAMETERS CONSIDERED FOR EXPERIMENT

Table 3.9 Input parameters considered for experiment

S.No.	**INPUT PARAMETER**
1.	Gas Flow Rate (Lit/min)
2.	Current (A)
3.	Welding angle (ø)
4.	Welding speed (mm/sec)

Table 3.10 Process parameter of metal Transfer

S.No	**Current (A)**	**Voltage (V)**	**Gas Flow Rate (Lit/min)**	**Welding speed (mm/sec)**	**Wire feed rate (m/min)**
1.	130	12.7	11	150	5.3
2.	140	17.3	12	200	3.5
3.	150	12.7	13	250	5.3
4.	160	14.6	14	300	5.8

3.6.1 Parameters

The wire feed rate, travel speed, and inter pass time. The effective area (EA) ratio, which represents the quality of the cross-section, and the height difference and deposit angle, which represent the uniformity of the deposit, are used to analyze the deposit quality.

A meta model based on GPR is formed based on output data acquired from these results.

The output data from the variation in major process parameters are included in the cost function for the optimization.

In the CMT welder, which uses a unity control system, current and voltage are synchronized andcontrolled simultaneously according to the wire feed rate. The wire feed rate is proportional to currentand voltage; thus, an increase in the wire feed rate indicates an increase in heat input.

In this study,the wire feed rate changes from 2.6 to 5.2 m/min, the corresponding voltage and current change from10.7 V and 100 A to 12.5 V and 160 A.

CHAPTER 4

CHARACTERIZATION AND TESTING

4.1 INTRODUCTION

This study investigates the microstructural properties and tensile strength characterization of the similar metal welding of a SS304, obtained by C welding with 316L fillers. And carrying out the corrosion test by using salt spray test. This includes testing of a material in a controlled corrosive environment which has been used to produce relative corrosion resistance information for specimens of metals and coated metals.

4.2 TENSILE TEST

Tensile Testing is a form of tension testing and is a destructive engineering and materials science test whereby controlled tension is applied to a sample until it fully fails.

This is one of the most common mechanical testing techniques. It is used to find out how strong a material is and also how much it can be stretched before it breaks. This test method is used to determine yield strength, ultimate tensile strength, ductility, strain hardening characteristics, Young's modulus and Poisson's ratio.

Tensile test was carried out on the similar weldments using Universal Testing Machine (UTM) obtained from the CMT welding techniques employing ERNiCr-3

Figure 4.1 Universal Testing Machine

4.2.1 Tensile Specimen Preparation

Tensile test specimens are prepared in a variety of ways depending on the test specifications. The most commonly used specifications are BS EN ISO 6892-1 and ASTM E8M. Most specimens use either a round or square standard cross section with two shoulders and a reduced section gauge length in between. The shoulders allow the specimen to be gripped while the gauge length shows the deformation and failure in the elastic region as it is stretched under load. The reduced cross section gauge length of specific dimensions assists with accurate calculation of engineering stress via load over area calculation.

4.2.2 Uses of Tensile Test

Tensile testing has a variety of uses, including:

- Selecting materials for an application Predicting how a material will perform under different forces
- Determining whether the requirements of a specification, contract or standard are met
- Demonstrating proof of concept for a new product
- Proving characteristics for a proposed patent
- Providing standard quality assurance data for scientific and engineering functions
- Comparing technical data for different material options
- Material testing to provide evidence for use in legal proceedings.

4.3 IMPACT TEST

Impact test, test of the ability of a material to withstand impact, used by engineers to predict its behaviour under actual condition. Many materials fail suddenly under impact under impact, at flaws, cracks, or notches.

The purpose of an impact test is to determine the ability of the material to absorb energy during a collision.

This energy may be used to determine the toughness, impact strength, fracture resistance or impact resistance of the material depending on the test that was performed and the characteristic that is to be determined. These values are important for the selection of materials that will be used in applications that require the materials to undergo very rapid loading processes Such as in vehicular collision.

An impact test is used to observe the mechanics that a material will exhibit when it experiences a shock loading that causes the specimen to immediately deform, facture or rupture completely.

To perform this test the sample is placed in to a holding fixture with the geometry and orientation determined by the type of test that is used and then a known weight generally but not always in the shape of the pendulum is released

From the known height so that it collides with the specimen with a sudden force. This collision between the weight and the specimen generally result in the destruction of the specimen but the transfer of energy between the two is used to determine the fracture mechanics of the material.

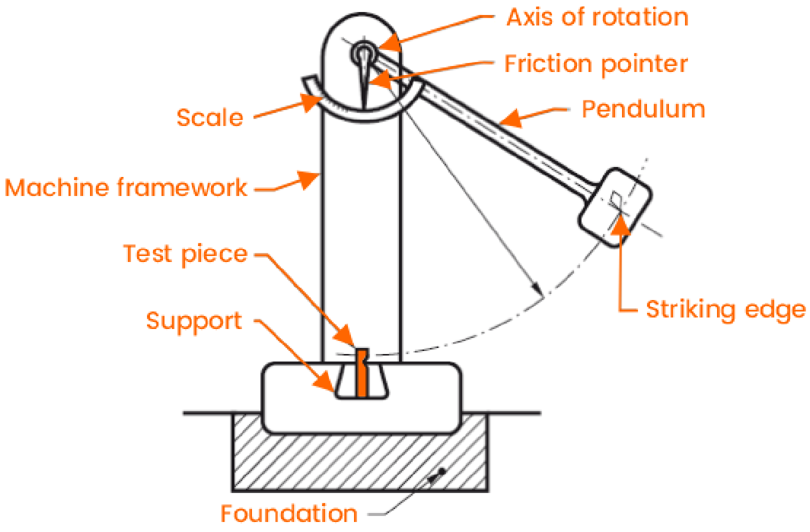

Figure 4.2 Impact Test Machine

4.3.1 Impact Test Specimen Preparation

Impact test specimens are prepared according to specific standards to ensure consistency and accuracy in the testing process. The most commonly used specimens for impact testing are the Charpy V-notch (CVN) and the Izod. The CVN specimen is a rectangular bar with a V-shaped notch machined on one side, while the Izod specimen is a rectangular bar with a notched or unnotched edge. Both types of specimens are typically made from a standard metal alloy, such as mild steel, and are machined to precise dimensions using a saw or milling machine.

After the specimens are machined, they are carefully cleaned to remove any dirt or debris that may affect the accuracy of the test results. The specimens are then placed in a temperature-controlled chamber to ensure that they are at the desired testing temperature. This is important because the impact properties of a material can vary significantly at different temperatures.

To conduct the test, the specimen is placed in a specially designed impact testing machine, which consists of a pendulum that is released from a specific height to strike the specimen. The amount of energy absorbed by the specimen during the impact is measured and used to calculate the material's impact strength. The machine is equipped with safety features, such as a safety shield, to protect the operator from flying debris in case the specimen fractures during the test.

4.3.2 Uses of Impact Test

- Impact tests measure the toughness and resilience of materials, especially metals.
- They help determine a material's ability to absorb energy under high stress.
- Impact tests can predict how a material will perform under certain conditions.
- They can identify potential weaknesses in a material.
- Impact tests are commonly used in industries such as construction, aerospace, and automotive.
- The tests are used to ensure the safety and reliability of materials and structures.

CHAPTER 5

RESULTS AND DISCUSSIONS

5.1 WELDED SAMPLE ANALYSIS

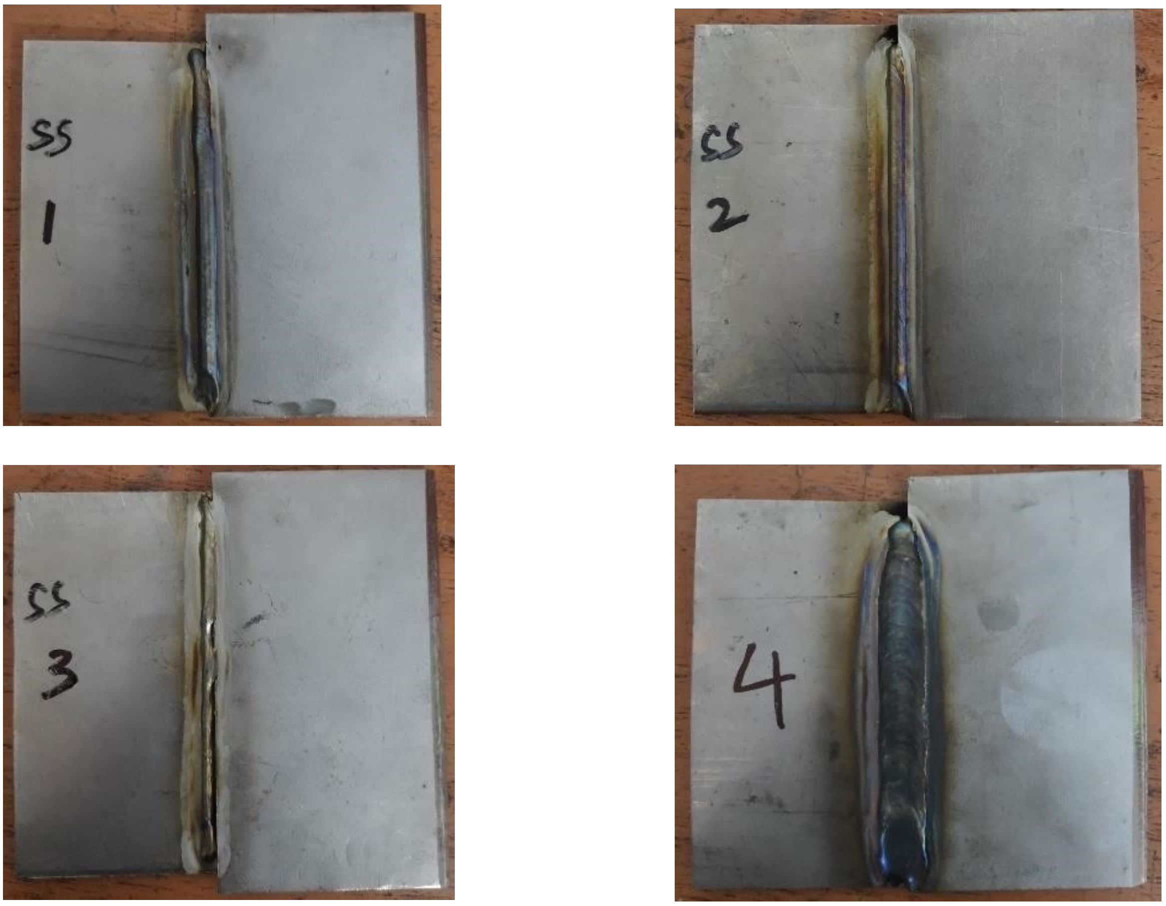

Figure 5.1 Welded Specimens

The macrograph of the weld sample is presented in Fig 5.1. It is observer that the surface of the welded plate is well and good. The welded zone is free from cracks of all the experimental runs is considered for micro-structural and tensile strength characterization.

5.2 DEPOSITION RATE

Finding the deposition rate of the welded joint for nine samples.

Table 5.1 Deposition rate of the welding samples

EXP NO	Wire feed rate (m/min)	Deposition rate (g/min)	Ranking weld samples based ondeposition rate
1.	5.3	46.03	3
2.	3.5	30.4	6
3.	5.3	46.03	3
4.	5.8	50.38	2

5.3 TENSILE TEST

Tensile test was carried out on the similar weldments using Universal Testing Machine (UTM) obtained from the CMT welding techniques employing316L as filler is shown in Figure 4.14.

Figure 5.2 Welded zone which undergoes tensile test

Table 5.2 Tensile Test Results

Ex no	Gauge Width (mm)	Gauge Thickness (mm)	Original cross section (mm^2)	Ultimate Tensile Load(kN)	Ultimate Tensile Strength (N/mm^2 or Mpa)
1	5.94	2.93	17.40	7.81	488
2	5.93	2.94	17.43	5.62	400
3	5.95	2.92	17.37	5.16	390
4	5.95	2.93	17.43	12.01	560

5.3.1 Load vs Displacement

Load vs Displacement graph were obtained for the weldment is as shown in Figure 5.3

Loads are applied to a composite part using a force. This force can take different forms such as concentrated forces, pressure, and stress. The idea to focus on for a load controlled analysis is that the load changes incrementally while the tensile strength depends on the deposition rate of the material.

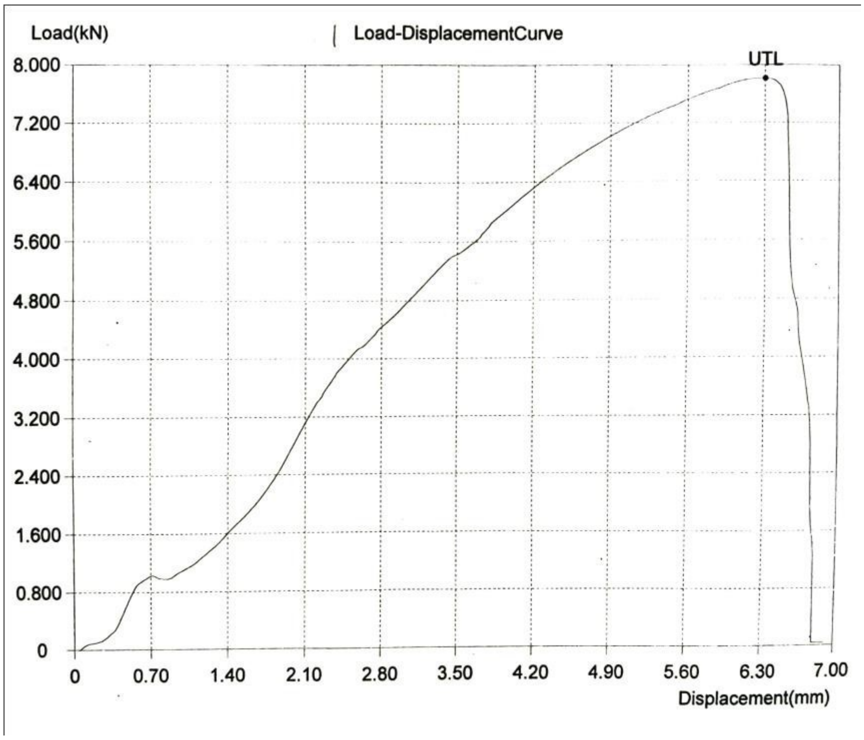

Figure 5.3 Sample 1 Load vs Displacement Graph

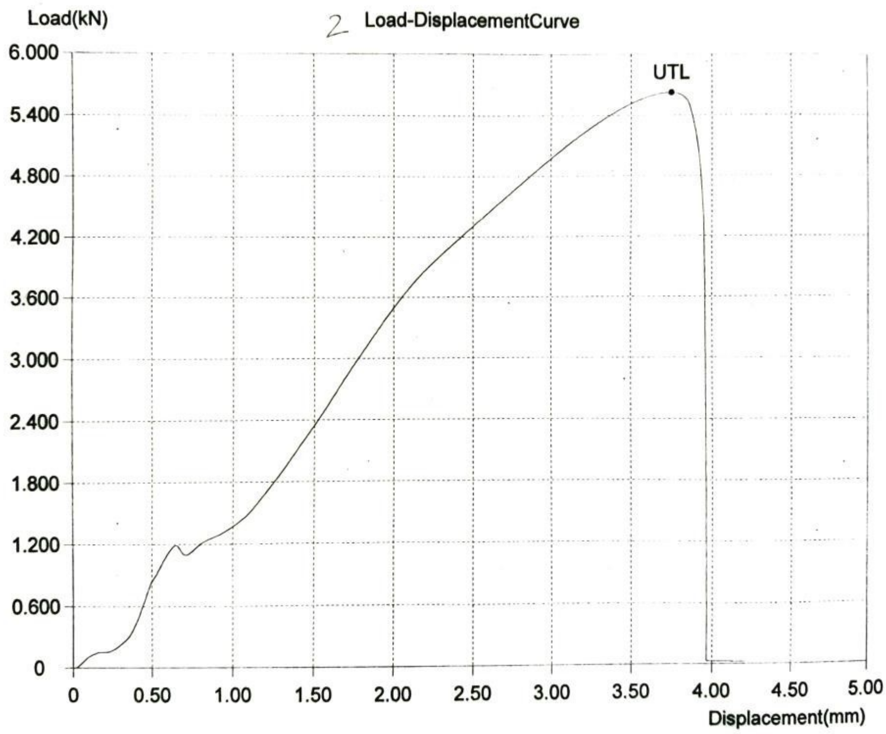

Figure 5.4 Sample 2 Load vs Displacement Graph

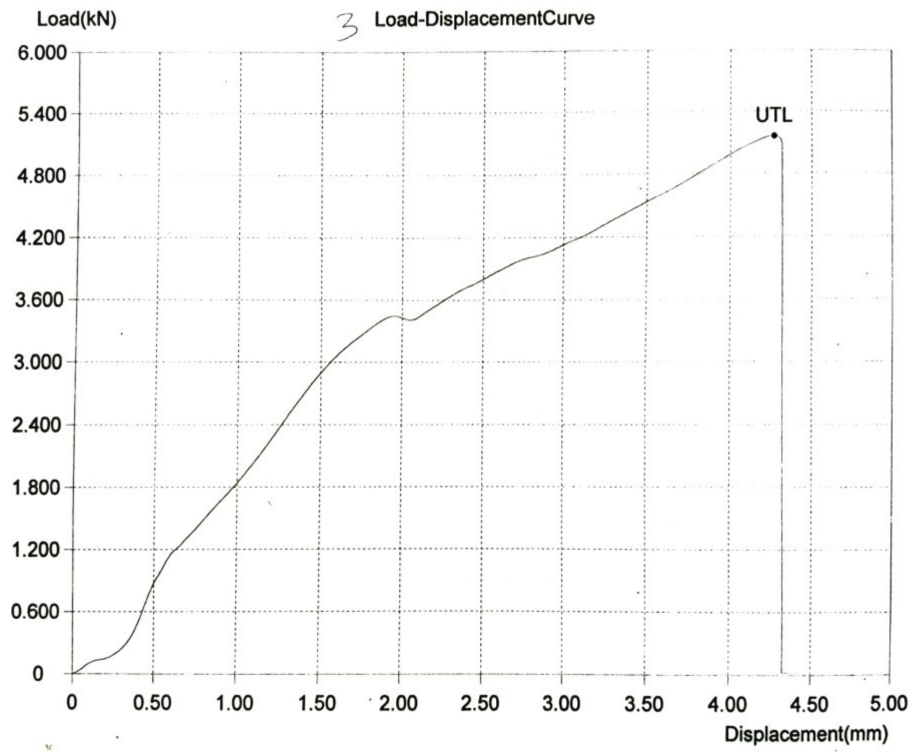

Figure 5.5 Sample 3 Load vs Displacement Graph

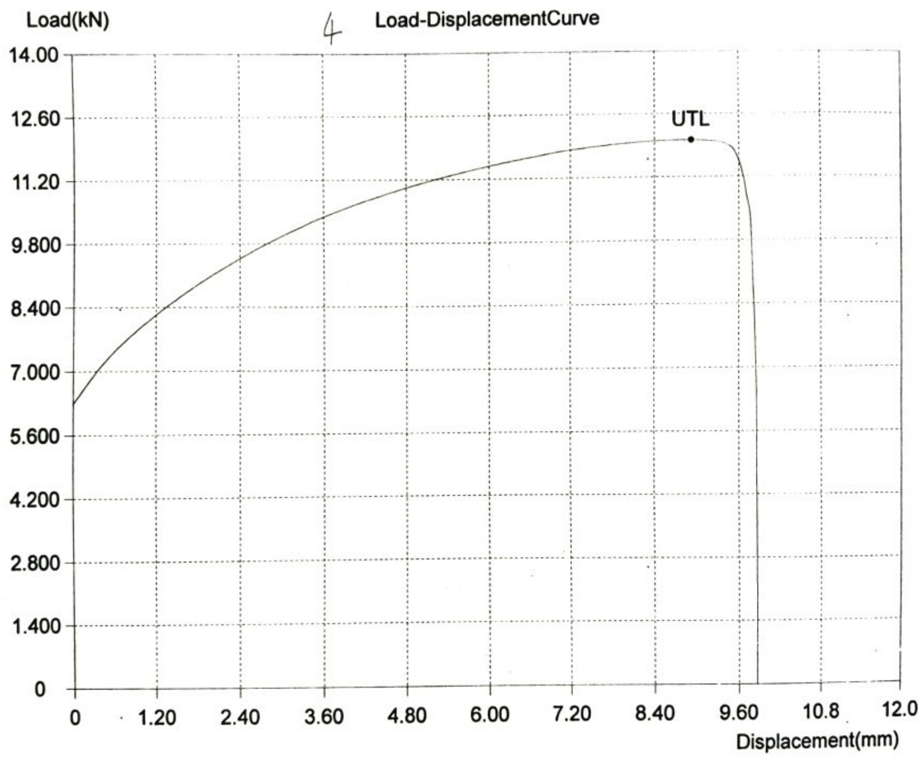

Figure 5.6 Sample 4 Load vs Displacement Graph

5.4 IMPACT TEST

Result of the CMT weld-ment clearly depicted that the fracture occurred at weld zone (WZ).

TEST TRAIL NO	IMPACT KJ
1	120
2	180
3	220
4	150

Figure 5.3 Impact Test Result

Figure 5.7 Welded zone which undergoes impact test.

CHAPTER 6

CONCLUSION

6.1 CONCLUSIVE SUMMARY

This study investigates the tensile strength and Impact strength characterization of the similar metal welding of stainless steel, SS304, obtained by CMT welding with 316L fillers.

The results of the study can be summarized as follows:

- Successful weldment obtained for all specimens in terms of macrostructure, without any lack of penetration, crack, spatter, etc.
- Tensile tests were carried out with respect to variation of gas flow rate, current and welding speed.
- The graph between load vs displacement were obtained respectively.
- The Experiment with parameter as current 120 A, welding speed 200 mm/min and gas flow rate 12 lpm has the maximum tensile strensth of 689 MPa by withstanding a load of 12.01 kN
- And the minimum tensile strength was obtained with experiment parameter as current 100 A, welding speed 300 mm/min, and gas flow rate 13 lpm with 297 MPa tensile strength by withstanding 5.16 kN
- And the experiment parameter with current 100 A, welding speed 300 mm/min, and gas flow rate 13 lpm used for experimentation should be avoided in further studies.
- The amount of deposition of weld metal in the lap joint directly affects the tensile strength of the lap joint.
- And the parameters varied in L9 orthogonal array affects the deposition rate of filler material thereby affecting the tensile strength of the joint.
- The results of the study will be very useful for the Original Equipment.

- Manufacturers (OEM) in producing equipment with bimetallic joints.

6.2 SCOPE FOR FURTHER RESEARCH

- Effect of other process parameters like Welding angle, Electrode size, Standoff distance etc, may be studied.
- Different design of experiment methodologies may be tried like taguchi's L27 orthogonal array etc….
- Optimization of process parameters can be done by using taguchi and other analysis methods.
- Thermocouple may be used to measure the temperature at different zonesHAZ and base metal.
- Alloy elements in the form of powder may be added in the stir zone Different types of joints can be tried.

In addition, further study into welding of similar alloys would provide a more thorough understanding of the capabilities of friction stir welding and possible applications for use. The temperature needs for each different material will be important to consider while welding similar alloys.

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