ANALYZING WELDING AND MECHANICAL PROPERTIES OF BUTT JOINTS FOR MILD STEEL (MS) BY ARC AND TIG WELDING

A thesis
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of
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APPROVAL

This is to certify that the project "**Analyzing Welding and Mechanical Properties of Butt Joints for Mild Steel (MS) by Arc and TIG Welding'',** By Md. Abdullah Al Rubel, ID: BME1502006396; Md.Ziaur Rahman Sarkar, ID: BME1903019198; Md. Nazmul Huda, ID: BME1902018127;Shafiqul Rasel ,ID:BME1903019055;Ananda Debnath,ID: BME1903019146; has been carried out under our supervision. The project has been carried out in partial fulfillment of the requirements of the degree of Bachelor of Science (B.Sc.) in Mechanical Engineering of years of 2023 and has been approved as to its style and contents.

Signature of the Supervisor

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DECLARATION

We, hereby, declare that the work presented in this project is the outcome of the investigation and research work performed by us under the supervision of **Niloy Sarkar,** Assistant Professor Department of Mechanical Engineering, Sonargaon University (SU). We also declare that no part of this project and thesis has been or is being submitted elsewhere for the award of any degree.

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ABSTRACT

The Arc welding and the tungsten inert gas (TIG) welding method most commonly used to weld ferrous metals, nonferrous metals, and other metals since it is simple, easily implemented, and achieves consistent high-quality welds. In this study, butt joints produced between two Mild steel (MS) have been achieved by using Arc welding with E6012 electrode and TIG welding with ER4047 filler metal. In there analyzing welding and mechanical properties of Butt-welding joints with two types of test like 1. Destructive Test 2. Non-Destructive Test. Destructive weld testing, as the name suggests, involves the physical destruction of a completed weld to evaluate its strength and characteristics. In there the testing procedure is conducted to understand a specimen's material behavior, strength, quality of the welded joint, and the skill of the welder by Tensile Strength test, Impact test, Nick break test, Face bend test, Root bend test, Side bend test and Hardness test. This type of testing involves breaking a sample fillet weld that is welded on one side only. These samples have a load applied to its unwelded side and welded side, typically in a press, tension, breaking and the load is increased until the weld fails. In this experiment Non-destructive testing (NDT) is analysis technique used by industry to evaluate the properties of a material, component, structure or system for characteristic differences or welding defects and discontinuities without causing damage to the original part.

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Chapter 1

Introduction

1.1: Background of the project and state of the art

Welding is a fabrication process whereby two or more parts are fused together by means of heat, pressure or both forming a join as the parts cool. Welding is usually used on metals and thermoplastics but can also be used on wood. The completed welded joint may be referred to as a weldment.

The basic purpose of welding is to join two elements together with a firm connection. Welders typically work with metal or thermoplastic and use durable filler material to bind them together

Welding establishes strong, durable, and permanent joint links. It is a simple process that results in a great finish. The technique, when used with filler material, produces a stronger weld than the base material.

Types of welding are:

Gas Metal Arc Welding (GMAW/MIG), Gas Tungsten Arc Welding (GTAW/TIG), Shielded Metal Arc Welding (SMAW), and Flux Cored Arc Welding (FCAW). The three most common welding types are – Arc, MIG and TIG welding. Shielded Metal Arc Welding (Stick) is the most popular welding process. It is the most versatile and uses the simplest equipment. The small light electrode and holder can be used in very tight places or reach several hundred feet away from the welding power supply.

1.2: Objectives

1. To study the primary purpose of weld inspection is to reveal the weld quality and discontinuities in the weld, knowing if the objectives are met.
2. To study discontinuities are known as welding defects, and they cause premature weld failure due to added stress concentrations or reduction of strength within the welded component.
3. To check the integrity of the weld (the join between two or more metals) by weld testing is carried out .
4. To ensures adequate safety and soundness, and helps provide quality assurance
5. An error in the welding process may damage weld metals significantly resulting in the loss of strength, durability, and failure of the structure.
6. These welding testing methods like visuals inspection and others are an assurance that products are secure for the intended use.
7. They ensure to meet the set standards for smooth sailing without many errors and possible extra expenses.
8. The tensile and face, Root and Side bending tests are destructive as the test specimens are loaded until they give out, to gain the desired information.
9. The Impact test is done in order to quantify the impact energy of the different microstructure in the weld metal as far as possible; the equipment will be operating at upper shelf temperature where brittle fracture is not a risk.
10. Nick break test is used this thesis to determine the quality of weld.
11. In this thesis we can try find out which welding joint is more useful.

Chapter 2

Literature Review

2.1 Arc Welding

Arc welding is a type of welding process using an electric arc to create heat to melt and join metals. A power supply creates an electric arc between a consumable or non-consumable electrode and the base material using either direct (DC) or alternating (AC) currents.

2.2 The four main types of welding are

1. Gas Metal Arc Welding (GMAW/MIG)
2. Gas Tungsten Arc Welding (GTAW/TIG)
3. Shielded Metal Arc Welding (SMAW)
4. Flux Cored Arc Welding (FCAW)

These types of welding involve the creation of an electric arc between an electrode and the metal being welded. The electric arc provides heat to fuse the metals together. A power supply is used to generate the arc, which can either use an alternating current (AC) or a direct current (DC).

2.3 Advantages of arc welding

- Affordable cost for equipment and doesn't need much due to the lack of gas.
- Portability is very easy to transport.
- Versatile and works well on metal that's dirty Shielding gas not necessary, meaning the process can be completed in all types of weather (including wind or rain)
- Arc welding can deliver extremely strong bonds even between thin metals. The construction industry uses arc welding to guarantee strong, sustainable connections within buildings, bridges, and other infrastructures. Other industries that use arc welding are the oil and gas industry and the power industry.

The arc welding process uses an electrical arc that forms between an electrode and the base metal to generate a temperature of around 6,500 degrees Fahrenheit.

TIG welding is often considered the strongest weld since it produces extreme heat, and the slow cooling rate results in high tensile strength and ductility. MIG is also an excellent candidate for the strongest type of weld because it can create a strong joint.

Arc Welding involves open circuit (when not welding) voltages which are typically from as low as 20 volts to as high as 100 volts. The voltage inside welding equipment is commonly much higher: from 120 volts to 575 volts or more.

The arc temperature is much higher than that of an oxyacetylene flame. In addition, the arc is kept in intimate contact with the base metal, so there is efficient transfer of heat. In electric resistance welding, the metal itself is the heat source.

Iron-based metals such as steel and stainless steel tend to work with the highest number of techniques compared to others. Low carbon mild steel acts as one of the most weld able metals available. Its composition includes low amounts of elements that can decrease the risk of a failed weld

Arc welding, including gas shielded arc welding, is broadly divided into two types: consumable (fusible) electrode type and non-consumable (non-fusible) electrode type depending on whether the welding rod/wire melts in the process or not.

For most uses the E6012-13 is a good all-around electrode choice. It can be used to weld sheet metals, heavy plates, and just about anything in between. But there is one catch! When it comes to arc welding electrodes, always use class A electrodes and preferably name brand manufacturers.

In electrode welding, contact between the rod electrode and work piece ignites the arc. This creates a short circuit for a fraction of a second between the two poles, meaning that current can then flow. The arc burns between the work piece and the electrode. This creates the required fusion heat.

2.4 Electrodes

Six types of welding electrodes are uses--

- Consumable Electrodes.
- Non-consumable Electrode.
- Low hydrogen carbon steel electrode.
- Mild Steel Electrode.

- Mild Steel Electrode (Non-ISI grade)
- Stainless Steel Electrode.

Arguably the most popular stick electrode today is the low-hydrogen E7018, which produces quality welds with excellent toughness and high ductility. It's used for welding metals with an increased risk of weld bead cracking under certain conditions, like vibratory stress.

There are mainly two types of electrodes, namely reactive and inert electrodes. A reactive electrode is an electrode which actively participates in the reaction. Some reactive electrodes include zinc, copper, lead, and silver. An inert electrode is a type of electrode which does not participate in a chemical reaction.

2.5 Arc Welding Machine

An arc welding machine is a device used for fusing metals. The machine emits an electrical arc from an electrode which melts metal or supplies filler into a joint between two pieces of metal. To produce the temperatures up to 3,600ºC needed to fuse metals, arc welding machines consume significant quantities of energy.

Fig2.1: A Arc Welding Machine

2.6 TIG Welding

Tungsten Inert Gas (TIG) welding, also known as Gas Tungsten Arc Welding (GTAW) is an arc welding process that produces the weld with a non-consumable tungsten electrode. Tungsten inert gas (TIG) welding became an overnight success in the 1940s for joining magnesium and aluminum.

The normal gas for TIG welding is argon (Ar). Helium (He) can be added to increase penetration and fluidity of the weld pool. Argon or argon/helium mixtures can be used for welding all grades. In some cases, nitrogen (N_2) and/or hydrogen (H_2) can be added to achieve special properties.

The most important applications for TIG welding are pipeline and pipe welding. It is, however, used in many industries, such as aviation and aerospace and sheet metal industries when welding particularly thin materials and special materials such as titanium.

2.6 Benefits

- Greater control: One area of TIG welding that helps to increase control is the tungsten electrode used to create the electrical arc.
- Versatility: TIG welding is a very versatile method of welding for a few different reasons.
- Welds don't need cleaning post-welding.
- Lack of speed. ...
- Higher cost associated with TIG.
- TIG welding is often considered the strongest weld since it produces extreme heat, and the slow cooling rate results in high tensile strength and ductility. MIG is also an excellent candidate for the strongest type of weld because it can create a strong joint
- DC is used for TIG welding Mild Steel/Stainless material and AC would be used for welding Aluminum. The TIG welding process has three options of welding current based upon the type of connection. Each method of connection has both advantages and disadvantages.

2.7 Difference between TIG and MIG

- MIG uses a solid wire that is machine-fed to the weld area while TIG uses a non-consumable electrode and a hand-held filler rod to form the weld. These differences mean that MIG and TIG welding processes have their own advantages and disadvantages and preferred applications.
- Offering high quality, versatility and longevity, TIG is the most commonly used stainless steel welding process. This welding process creates a low heat input, which makes it perfect for thin material.
- The tungsten electrode is at the core of TIG welding. At 3380 degrees Celsius, tungsten has the highest melting point of any pure metal in the periodic table. This means the electrode can emit an arc that heats and liquefies the work piece without itself melting away.
- During a TIG welding process, the arc current and arc voltage were 50A and 60V respectively, when the welding speed was 150,mm/min. In another process, the TIG welding is carried out at a welding speed of 120mm/min at the same are voltage and heat input to the material so that weld quality remains the same

2.8 TIG welding suitable for

TIG welding is suitable for all types of carbon steels, low-alloy steels, alloyed stainless, nickel alloys, aluminum and its alloys, copper and its alloys, titanium, magnesium, and other nonferrous alloys. The use of an infusible electrode makes TIG welding particularly suited for metals only a few millimeters thick. The most common metals that are fused together by TIG welding are titanium, aluminum, and stainless steel. Most often, it's used on thin segments of stainless steel.

In the TIG welding process the arc is formed between a pointed tungsten electrode and the work piece in an inert atmosphere of argon or helium. The small intense arc provided by the pointed electrode is ideal for high quality and precision welding.

2.9 TIG Welding Machine

Tungsten Inert Gas (TIG) welding, also known as Gas Tungsten Arc Welding (GTAW) is an arc welding process that produces the weld with a non-consumable tungsten electrode. Tungsten inert gas (TIG) welding became an overnight success in the 1940s for joining magnesium and aluminum.

Fig 2.2: A TIG welding Machine

2.10 Working principle of arc welding process

Arc welding is welding using the heat of an arc as a heat source. In arc welding, positive voltage is applied to the electrode (welding rod/wire) and negative voltage is applied to the base material. This makes an arc occur from the base material to the electrode.

2.11 Working principle of TIG welding process

Tungsten Inert Gas (TIG) welding uses the heat generated by an electric arc struck between a non-consumable tungsten electrode and the work piece to fuse metal in the joint area and produce a molten weld pool

2.12 There are five basic welding joints

1. Butt joint welding.

2. Tee joint welding.

3. Corner joint welding.

4. Lap joint welding.

5. Edge joint welding.

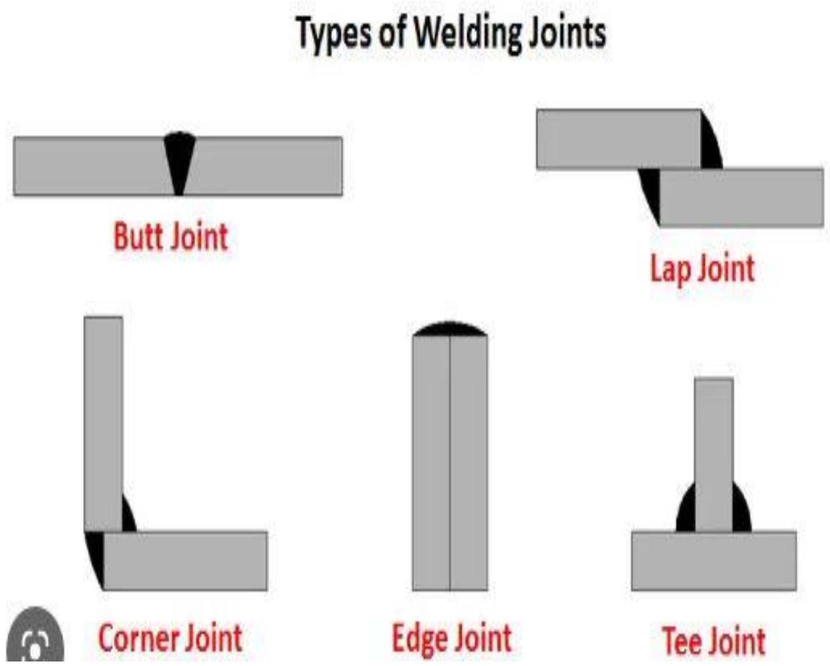


Fig 2.3: Types of Joint

2.13 Butt joint welding

Butt welding is the principal method for creating a join between two ends of material. This can include but is not limited to various metals, plastics and other materials.

The joint is formed simply by placing two pieces of metal end-to-end and then welding along the join. Importantly, in a butt joint, the surfaces of the work pieces being joined are on the same plane and weld metal remains within the planes of the surfaces.

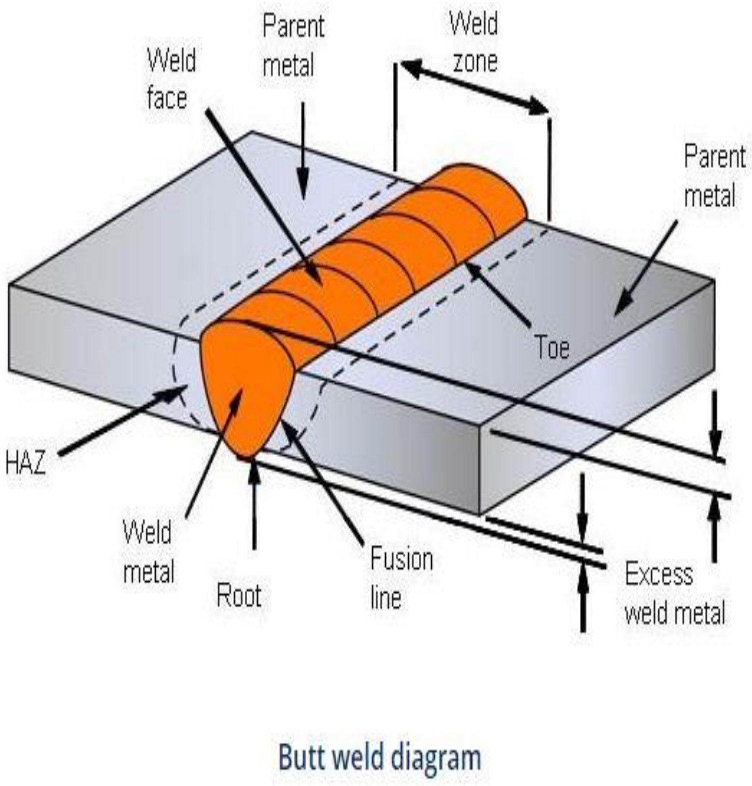


Fig 2.4: Butt weld

A butt weld is one of the simplest and versatile types of weld joint designs. The joint is formed simply by placing two pieces of metal end-to-end and then welding along the join. Importantly, in a butt joint, the surfaces of the work pieces being joined are on the same plane and weld metal remains within the planes of the surfaces. Thus, works pieces are nearly parallel and do not overlap, unlike lap joints, for example**.**

Depending upon the thickness of the metal pieces, different types of grooves can be prepared. Groove preparation is also called weld edge preparation and is necessary for thicker metals. Examples of types of grooves, depending upon their shape are V groove, J groove, and U groove. Groove design changes depending upon full penetration or partial penetration weld requirements. Groove welding can be carried out using different types of welding - whether manual, mechanized or automated processes. Thin sheets are usually welded without any weld edge preparation; such joints are referred as square butt joint.

Butt joints can be welded using arc welding, resistance welding and high energy beam welding and it can even be part of a brazing operation. At the start, weld pieces can be held together with a tack weld, which is a temporary joint that ensures components stay in a proper alignment while the butt welding is performed. Pre-heating might be required for joining parts at the butt joint area. Butt welding is commonly employed in various industry sectors varying from piping systems, automotive, energy, power, etc.

As mentioned earlier, various types of butt-welding joints are named for their particular shape. The different types of joints include single V, double V, single and double bevel, single and double U, single and double J joints, square butt joints and even combinations of these. The simplest of these, with regards to alignment, is the square butt weld.

In all cases, the welds are performed with the pieces end-to-end with the thickness of the parent metal. To control distortion of the welded assembly, it is important to control weld penetration by using a double penetration joint design.

For butt welds, depending upon various factors, there is typically a gap of about 2 to 3mm (1/8”) between the work pieces, which is called a root gap. The gap is to ensure that the filler metal fully penetrates the joint. If the gap is too small or too large, it will produce weld defects.

2.13.1 Advantages

Butt welds provide several advantages, including:

- High strength with complete fusion
- Easy to machine
- Distortion control
- Easy to inspect
- Disadvantages

2.13.2 There are some disadvantages such as

- Welding geometry can limit applications
- Fixturing or backing may be required
- Sensitive to faying surface conditions

2.14 The testing procedure for welded joints

Welds can be tested by destructive and non-destructive techniques. Most production is tested by use of non-destructive methods. The most common non-destructive tests to check welds are Visual Inspection, Liquid Penetrant, Magnetic Particle, Eddy Current, Ultrasonic, Acoustic Emission and Radiography. And most common destructive tests to check welds are Tensile Strength Test, Impact Test, Nick break test, Face Bend Test, Root Bend Test, Side Bend Test and Hardness Test Etc.

2.15 Destructive Weld Testing

The present article covers an introduction to destructive weld testing, various methods of destructive testing, their applications, and their significance. Destructive weld testing, as the name suggests, involves the physical destruction of a completed weld to evaluate its strength and characteristics. The testing procedure is conducted to understand a specimen's material behavior, strength, quality of the welded joint, and the skill of the welder.

Destructive weld testing is frequently used for the following applications:

- Welding procedure qualification
- Sampling inspection
- Research inspection
- Welder performance qualification testing
- Failure analysis work

2.15.1 Destructive Weld Testing Methods

Methods of destructive weld testing typically involve sectioning or breaking the welded component and evaluating various mechanical and physical characteristics. Check out some of the most common methods for executing a destructive weld test below.

2.16 Shaper Machine

Shaper, metal-cutting machine in which the work piece is usually held in a vise or similar device that is clamped to a table and can be manually operated or power driven at right angles to the path of a chisel like cutting tool with only one cutting edge held on the end of a reciprocating ram.

Fig 2.5: A Shaper machine

2.17 Milling Machine

Milling machine, device that rotates a circular tool that has a number of cutting edges symmetrically arranged about its axis; the work piece is commonly held in a vise or similar device clamped to a table that can move in three perpendicular directions.

Fig 2.6: A Milling Machine

2.18 Process of Arc welding

1. Understand the process of shielded Metal Arc Welding

An electric arc is formed at the tip of the welding rod when a current passes across an air gap and continues through the grounded metal which is being welded.

Welding machine. This is the term used to describe the machine which converts 120–240-volt AC electricity to welding voltage, typically 40-70 volts AC, but also a range of DC voltages. It generally consists of a large, heavy transformer, a voltage regulator circuit, an internal cooling fan, and an amperage range selector. The term welder applies to the person doing the welding. A welding machine requires a welder to operate it.

Leads or Welding leads. These are the insulated copper conductors which carry the high amperage, low voltage electricity to the work piece that is being welded.

Rod holder is the device on the end of the lead that holds the electrode, which the person welding uses to accomplish the welding task.

Ground and ground clamp. This is the lead that grounds, or completes the electrical circuit, and specifically, the clamp that is attached to the work to allow the electricity to pass through the metal being welded.

Amperage, this is an electrical term, used to describe the electrical current supplied to the electrode.

DC and reverse polarity. This is a different configuration used in welding with an arc/electrode system, which offers more versatility, especially in overhead welding applications and for use welding certain alloys that do not weld easily with AC voltages. The welding machine that produces this current has a rectifier circuit or has the current supplied by a generator, and is much more expensive than a typical AC welder.

Electrodes. There are many specialized welding electrodes, used for specific alloys and types of metals, such as cast or malleable iron, stainless or chromyl steel, aluminum, and tempered or high carbon steels. A typical electrode consists of the wire rod in the center covered with a special coating (flux)which burns as the arc is maintained, consuming oxygen and producing carbon dioxide in the weld area to prevent the base metal from oxidizing or burning away in the arc flame during the welding process. Here are some common electrodes and their uses:

E6011 electrodes are a mild steel electrode with a cellulose fiber coating. The first two numbers in the electrode identification is the tensile strength, measured in pounds per square inch times 1,000. Here, the yield of the electrode would be 60,000 PSI.

2. Gather the tools and materials begin welding:

This means the welding machine, electrodes, cables and clamps, and the metal to be welded.

3. Set up a safe work area, preferably with a table constructed of steel or other non-flammable material.

4. Prepare the metal to be welded

Fig2.7: Electrodes

5. Attach clamps to hold metal pieces together:

Locking type pliers, "C" clamps, a vice, or spring loader clamps will usually work. For special projects, you may find you will have to adapt different techniques to secure the work pieces until they are joined.

6. Attach the ground clamp to the larger piece of stock that is being welded

Make sure there is a clean location so that the electrical circuit can be completed with minimal resistance at the ground location. Again, rust or paint will interfere with the grounding of your work piece, making it difficult to create an arc when you begin welding.

7. Select the correct rod and amperage range for the work

8. Hold the stinger in your dominant hand by the insulated handle, with the rod in a position so that striking the tip of it against the plate we are welding will be as natural a movement as possible.

9. Select the point where weld.

10. Strike the electrode against the surface of the metal, pulling it back slightly when you see an electric arc occur.

11. Clean finished weld

2.19 Process of TIG welding

The parameters that affect the quality and outcome of the TIG welding process are given below.

1) Welding Current:

Higher current in TIG welding can lead to splatter and work piece become damage. Again lower current setting in TIG welding lead to sticking of the filler wire. Sometimes larger heat affected area can be found for lower welding current, as high temperatures need to applied for longer periods of time to deposit the same amount of filling materials. Fixed current mode will vary the voltage in order to maintain a constant arc current.

2) Welding Voltage:

Welding Voltage can be fixed or adjustable depending on the TIG welding equipment. A high initial voltage allows for easy arc initiation and a greater range of working tip distance. Too high voltage, can lead to large variable in welding quality.

3) Inert Gases:

The choice of shielding gas is depends on the working metals and effects on the welding cost, weld temperature, arc stability, weld speed, splatter, electrode life etc. it also affects the finished weld penetration depth and surface profile, porosity, corrosion resistance, strength, hardness and brittleness of the weld material. Argon or Helium may be used successfully for TIG welding applications. For welding of extremely thin material pure argon is used.

Argon generally provides an arc which operates more smoothly and quietly. Penetration of arc is less when Argon is used than the arc obtained by the use of Helium. For these reasons argon is preferred for most of the applications, except where higher heat and penetration is required for welding metals of high heat conductivity in larger thicknesses. Aluminum and copper are metals of high heat conductivity and are examples of the type of material for which helium is advantageous in welding relatively thick sections. Pure argon can be used for welding of structural steels, low alloyed steels, stainless steels, aluminum, copper, titanium and magnesium. Argon hydrogen mixture is used for welding

of some grades of stainless steels and nickel alloys. Pure helium may be used for aluminum and copper. Helium argon mixtures may be used for low alloy steels, aluminum and copper

4) Process parameters used for A-TIG welding

Process parameters	Values
Electrode type -	W with 2% ThO2
Electrode diameter-	2.9 mm
Electrode vertex angle-	60°
Power supply type -	DCEN
Welding current-	220 A
Welding speed-	80 mm/min
Arc length	3mm
Shielding gas/Flow rate-	99.99% Pure Ar/10 l min−

4) Welding speed:

Welding speed is an important parameter for TIG welding. If the welding speed is increased, power or heat input per unit. Length of weld is decreases, therefore less weld reinforcement results and penetration of welding decreases. Welding speed or travel speed is primarily control the bead size and penetration of weld. It is interdependent with current. Excessive high welding speed decreases wetting action, increases tendency of undercut, porosity and uneven bead shapes while slower welding speed reduces the tendency to porosity

Chapter 3

Working Procedure

3.1 Sample Collection

For analyzing welding and mechanical characteristic of Arc and TIG welding joint, we need to collect MS metal. For all specimen we will cut out the metal from the pipe which is already used in the workshop by the shaper machine.

Fig 3.1: Specimen collected from this unused pipe

We will cut each sample into 12 inch long and 25-30 mm width by that shaper machine. Then cut each sample down the middle for V groove cutting so that we can welded that place.

3.2 Preparing all Welding joint samples for all Testing by Arc and TIG welding:

After cutting V notch or groove in the middle of all sample by Shaper machine then we will Arc and TIG welding followed the electrodes and filler metal by Arc and TIG welding Machine**.**

Fig: TIG welding processing

Fig3.2: Welding sample

Chapter 4

Tensile Strength Test

4.1 Tensile Strength Test Method of Arc Welding Joint

Tensile testing helps ensure that a weld meets the required levels of strength and ductility. Tensile testing is a destructive testing method that is done early when testing weld performance. This easy-to-perform assessment provides a wealth of information that is critical for selecting the best filler metal for an application. A sample of specified dimensions is loaded in tension until the point of failure. The sample piece is pulled apart to understand the strength, ductility and other characteristics of the weld. The test equipment calculates and displays the ultimate tensile strength [the maximum stress withstood before failure in pounds per square inch (psi) or megapascals (MPa), the yield strength (the stress where plastic deformation occurs in psi or MPa) and the percent elongation of the sample. The process involves creating a welded test plate, machining the plate to produce an appropriately sized test specimen, conducting the test and then analyzing results. Different base metals, joint designs and welding parameters can result in significantly different mechanical properties, even when using the same filler metal. For this reason, filler metal manufacturers and companies test plates in accordance with specifications that control all of these factors.

4.2 Common Types of Tensile Tests

- **All weld metal testing** — This involves testing only the weld metal of a sample welded test plate. It's a standard test for filler metals and in some procedure qualification processes. Note that all weld metal tensile bars may contain areas of the weld where dilution with the base metal has occurred; it may not be possible on all weld joint configurations.
- **Transverse tensile testing** — In this process, a tensile bar is extracted from the transverse axis of the plate (perpendicular to the axis of the weld). As a result, both the weld metal and base metal are tested, capturing the interaction between the two. It's a litmus test: It's definitive that the weld metal is

stronger than the base metal if the failure occurs in the base metal and vice versa. However, there are limitations to this type of testing. It is possible to extract ultimate tensile strength but not the yield strength or percent elongation (a measure of ductility) with a high degree of accuracy.

- **Longitudinal tensile testing** — This sample configuration involves testing a specimen that is extracted in the longitudinal axis of the weld. Depending on the joint design, a longitudinal tensile bar may contain both base metal and weld metal.

4.3 Universal Testing Machine (UTM)

Computerized Twin screw Universal Testing Machine to determine properties of Tensile & Elongation as per ASTM D 638 & ISO 527, Compression as per ASTM D 695 & Flexural (three-point bending), as per ASTM D 790 with auto stop, auto reverse facility & direct display of result through 32-bit micro controller having 4 lines and 20-character display. Suitable for checking all types of polymers, compounds, composite materials, fiber reinforced plastics (FRP) and polymeric materials.

Fig 4.1: Universal Testing Machine (UTM)

Before testing tensile strength test this machine, we have to machining this welding joint sample by a shaper machine. Both side machining or planning surface so that UTM machine can hold or grip this sample very tightly.

Fig 4.2: Stress & Strain curve

4.4 Breaking TIG joint

Fig4.3: Breaking Base metal zone(TIG)

4.5 Data Collection (TIG):

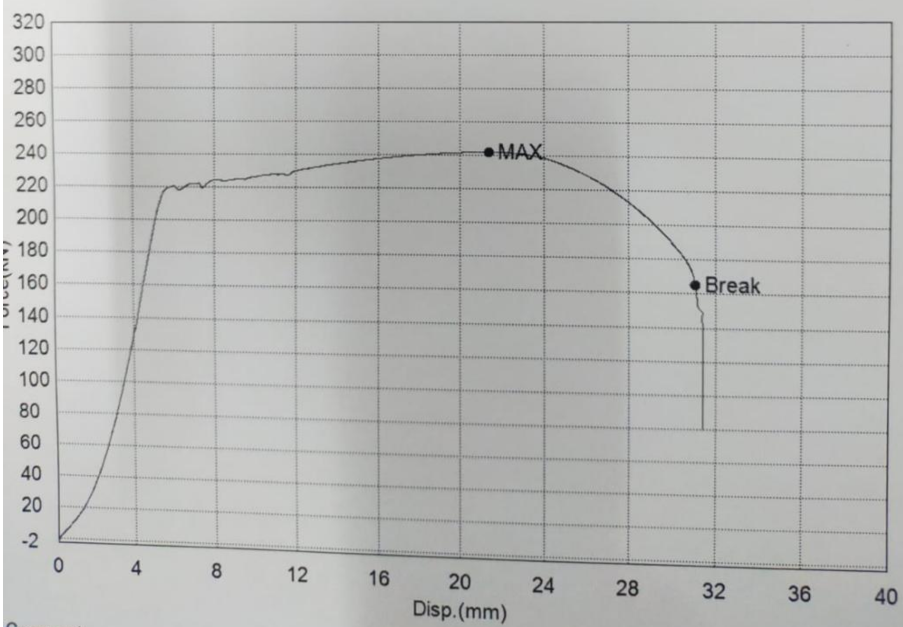
[illegible]		Test Type	Tensile
Test Mode	Single		
Speed	50mm/min	Shape	Plate
No of Batches:	1	Qty/Batch:	1

Name	Thickness	Width	Gauge_Length	Max_Force
Parameters				Calc. at Entire Areas
Unit	mm	mm	mm	kN
1 _ 1	11.7400	30.0000	100.0000	241.862

Name	Max_Stress	Max_Stroke	Max_Disp.	Max_Strain
Parameters	Calc. at Entire Areas	Calc. at Entire Areas	Calc. at Entire Areas	Calc. at Entire Areas
Unit	N/mm2	mm	mm	%
1 _ 1	686.717	21.3785	21.3785	21.3785

Name	Break_Force	Break_Stress	Break_Stroke	Break_Disp.
Parameters	Sensitivity: 10	Sensitivity: 10	Sensitivity: 10	Sensitivity: 10
Unit	kN	N/mm2	mm	mm
1 _ 1	165.473	469.826	31.0906	31.0906

Name	Max_Stroke Strain
Parameters	Calc. at Entire Areas
Unit	%
1 _ 1	21.3785

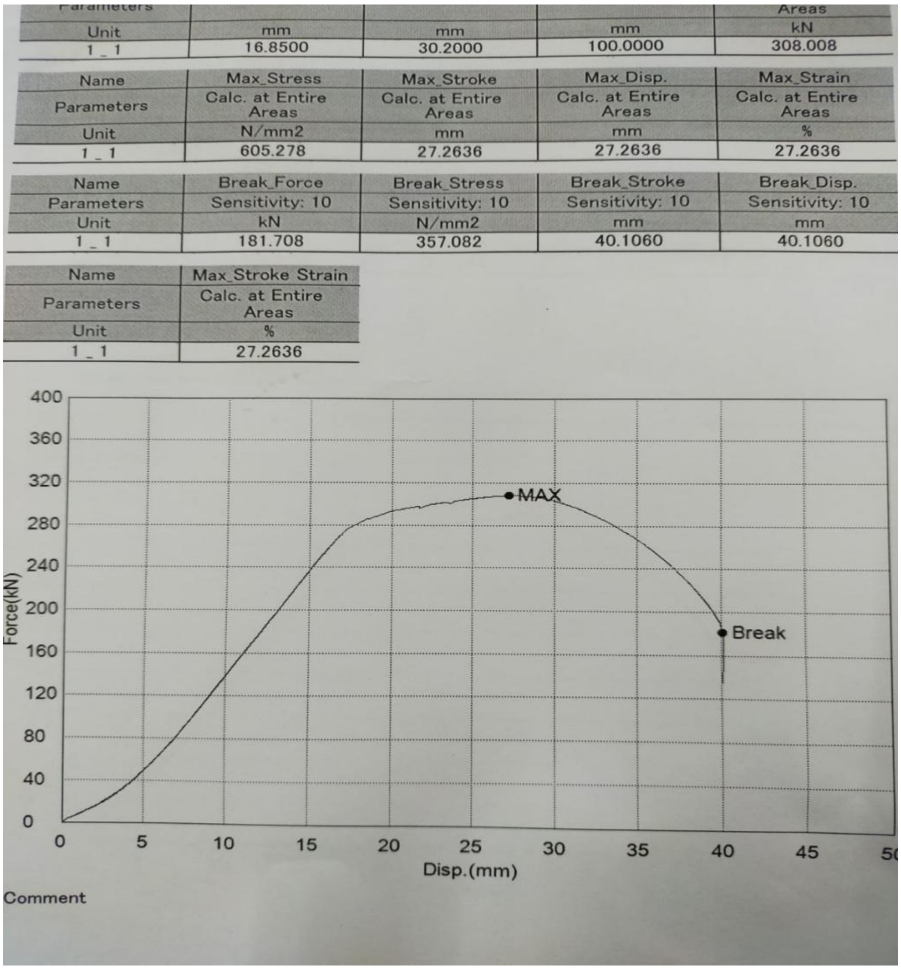


Comment

Fig 4.4: Stress& Strain curve (TIG)

4.6 Braking Arc joint

Fig4.5: Breaking Base metal zone (Arc)



Parameters				Areas
Unit	mm	mm	mm	kN
1 _ 1	16.8500	30.2000	100.0000	308.008

Name	Max_Stress	Max_Stroke	Max_Disp.	Max_Strain
Parameters	Calc. at Entire Areas	Calc. at Entire Areas	Calc. at Entire Areas	Calc. at Entire Areas
Unit	N/mm2	mm	mm	%
1 _ 1	605.278	27.2636	27.2636	27.2636

Name	Break_Force	Break_Stress	Break_Stroke	Break_Disp.
Parameters	Sensitivity: 10	Sensitivity: 10	Sensitivity: 10	Sensitivity: 10
Unit	kN	N/mm2	mm	mm
1 _ 1	181.708	357.082	40.1060	40.1060

Name	Max_Stroke Strain
Parameters	Calc. at Entire Areas
Unit	%
1 _ 1	27.2636

Fig 4.6: Stress& Strain curve (Arc)

Chapter 5

Impact Test

5.1 Impact Test Method of Arc and TIG Welding Joint

Impact testing is used to measure the impact toughness of the material used. This is described as the toughness and the ability of the material to absorb energy due to sudden loading. Toughness takes into account the ductility and strength of the material being tested.

Impact testing is required if the MDMT is below: -55°F, -48°C unless the above ratio is 0.35 or less, then its -155°F, -104°C.Impact Testing of metals is performed to determine the impact resistance or toughness of materials by calculating the amount of energy absorbed during fracture. The impact test is performed at various temperatures to uncover any effects on impact energy. Impact test not required/cannot be performed if the thickness is below 2.5mm.½ qualification thickness range with impact test is 9 to 18mm according to QW-403-6 (not 9 to 16mm). When there isn't impact test the qualified thickness range is 1,5 to 18 mm.

These tests try to obtain fundamental parameters: the plane strain fracture toughness, the energy release rate, the crack opening displacement, the crack-tip opening displacement, and the J integral. The most common impact test (Charpy) and fracture toughness test are briefly described below. The notch angle of the Izod impact test specimen is 45°

5.2 Testing Procedure

Before testing Impact test this machine, we have to machining this welding joint sample by a shaper machine in size of (10x10x55) mm Both side machining or planning surface.

After prepare (10x10x55) mm sample from arc and Tig welding joint. Then we making v-notch sample making by Milling Machine.

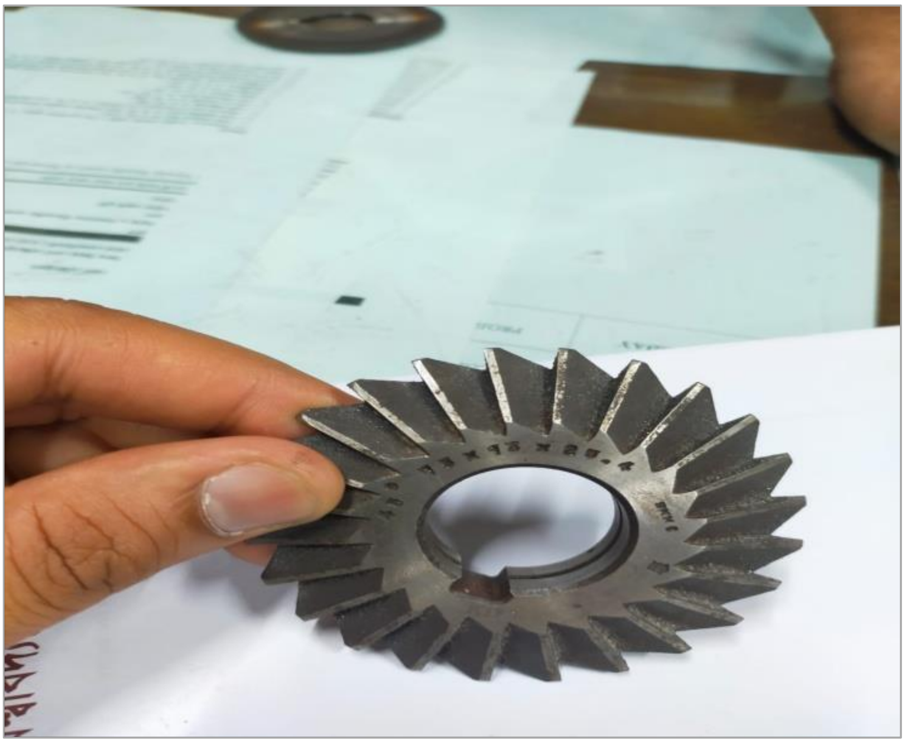


Fig5.1: 45° Angular Cutter

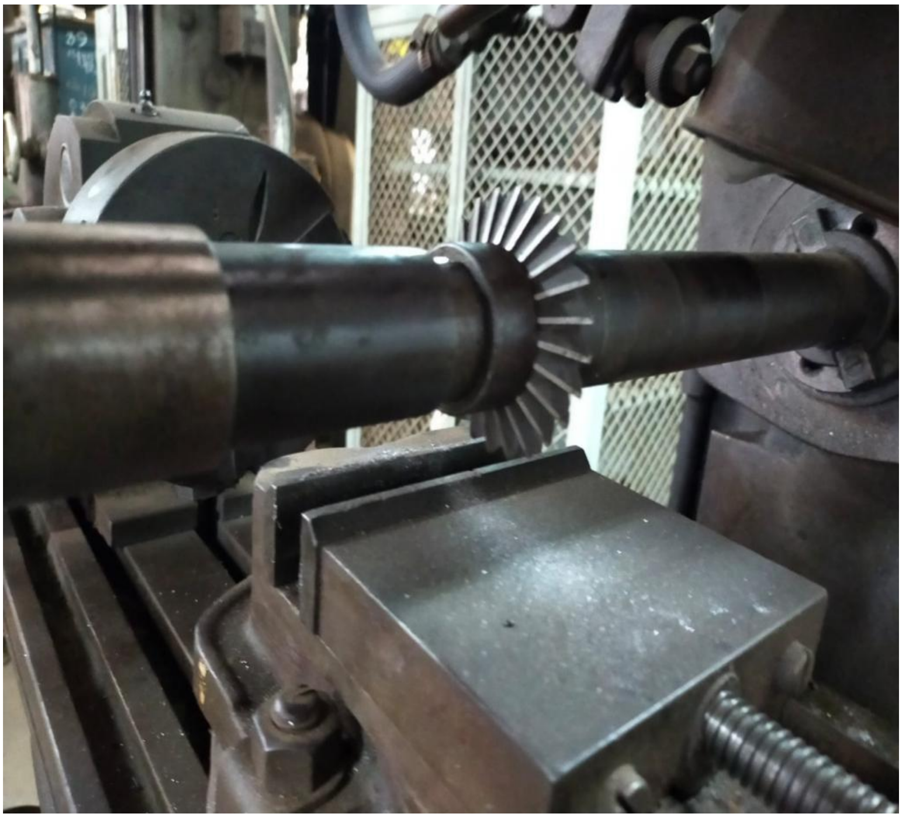


Fig5.2: Milling Machine

Fig5.3:45° angle Sample ready for Impact Test by Milling Machine

Fig5.4: Impact Test Machine

Fig5.5: Breaking after Impact test (Arc)

Fig5.6: Breaking after Impact test (TIG)

Chapter 6

Nick Break Test

To perform a nick break test, a specimen is prepared out of the weld metal. Stress concentrators are then machined into the specimen. The specimen is then broken and the fracture surface is observed at the conclusion of the nick break test.

6.1 Nick Break Test Method of Arc and TIG Welding Joint:

The Nick Break Test or Fracture is used to determine the quality of a weld, and involves breaking open the weld length-wise, and then visually inspecting the exposed weld interior for any internal imperfections such as lack of sidewall fusion, lack of inter-run fusion and porosity.

6.2 Common Types of Nick Break Tests:

A nick break test is a type of destructive testing that is used to evaluate the quality of a weld. To perform a nick break test, a specimen is prepared out of the weld metal. Stress concentrators are then machined into the specimen.

6.3 Procedure of testing:

For testing nick break sample at first we welded two sample .One for Arc welding and One for TIG welding test.

After completing welding by Arc and TIG welding then slot cutting all side of weld metal zone by a milling machine. This cutter is called slitting cutter.

Fig6.1: A Slitting Cutter

This Slitting Cutter size is 2mm thickness and 04-inch diameter.

Fig6.2: Milling Machine cutting with slitting saw cutter in Welded Face zone

Slot cutting size Face and Root Side zone id 1/16-inch depth and both side zone depth id 1/8 inch depth for breaking sample by UTM machine.
This depth size is depend welded metal thickness.

Fig6.3: Slot Cutting sample for braking

Fig6.4: Holding Sample for Nick break

Fig6.5: No crack is found (Arc welding joint)

Fig6.6: No crack is found (TIG welding joint)

Chapter 7

Test of Hardness

A hardness test is typically performed by pressing a specifically dimensioned and loaded object (indenter) into the surface of the material you are testing. The hardness is determined by measuring the depth of indenter penetration or by measuring the size of the impression left by an indenter.

There are several different types of hardness testers, including Vickers, Brinell, and Rockwell. All methods of hardness testing are based on the principle of applying a standard load through an indenter and measuring the penetration in terms of diameter/diagonal/depth of indentation.

Fig7.1: Hardness Test Machine with Sample

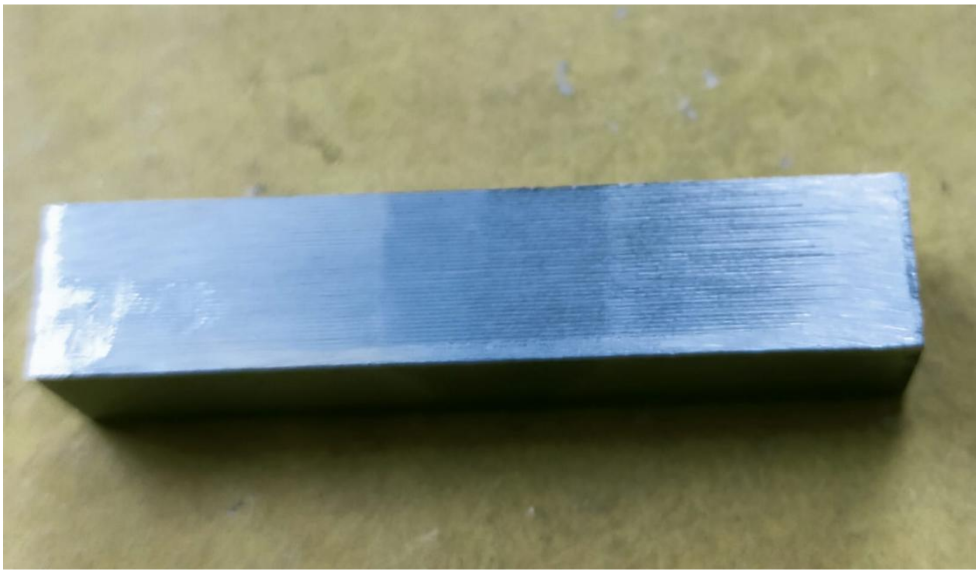


Fig:7.2 Prepared for Hardness Test

7.1 Calculation of Test of Hardness of Arc Welding Sample:

Base Metal=$\frac{2\times P}{\pi\times D\times(D-\sqrt{(D^2-d^2)}}$(Here,P=100kg,D=1.587mm,d=.841mm)

$$= \frac{2\times P}{\pi\times 1.587\times(1.587-\sqrt{(1.587^2-0.841^2)}}$$

=166

Heat Affected Zone= $\frac{2\times P}{\pi\times D\times(D-\sqrt{(D^2-d^2)}}$(Here,P=100kg,D=1.587mm,d=.80mm)

$$= \frac{2\times P}{\pi\times 1.587\times(1.587-\sqrt{(1.587^2-0.80^2)}}$$

=185

Welded Zone=$\frac{2\times P}{\pi\times D\times(D-\sqrt{(D^2-d^2)}}$(Here,P=100kg,D=1.587mm,d=.7651mm)

$$= \frac{2\times P}{\pi\times 1.587\times(1.587-\sqrt{(1.587^2-0.7651^2)}}$$

=204

7.2 Calculation of Test of Hardness of TIG Welding Sample:

Base Metal=$\frac{2\times P}{\pi\times D\times(D-\sqrt{(D^2-d^2)}}$(Here,P=100kg,D=1.587mm,d=0.78mm)

$$= \frac{2\times P}{\pi\times 1.587\times(1.587-\sqrt{(1.587^2-0.80^2)}}$$

=195

Heat Affected Zone= $\frac{2\times P}{\pi\times D\times(D-\sqrt{(D^2}-d^2)}$(Here,P=100kg,D=1.587mm,d=.80mm)

$= \frac{2\times P}{\pi\times 1.587\times(1.587-\sqrt{(1.587^2}-0.80^2)}$

=185

Welded Zone=$\frac{2\times P}{\pi\times D\times(D-\sqrt{(D^2}-d^2)}$(Here,P=100kg,D=1.587mm,d=.821mm)

$= \frac{2\times P}{\pi\times 1.587\times(1.587-\sqrt{(1.587^2}-0.821^2)}$

=175

Chapter 8

Face Bend Test

8.1 Define Face Bend Test:

This bend test determines the quality a weld at the face of a welded joint. The specimen normally is bent 180 degrees. Face bend tests are made with the weld face in tension;

8.2 Testing Procedure:

For testing Face bend sample at first, we welded two sample. One for Arc welding and One for TIG welding test.

After completing welding by Arc and TIG welding machine then machining Face and Rood side zone of welded metal by a Shaper machine.

Fig8.1: Face zone cutting by Shaper Machine

Fig8.2: 180◦ Bending machine

Then Pressure will be applied at 180-degree angle by A Hydraulic press machine keeping face side of welding joint

Fig8.3: After Face Bending test (Arc)

Fig8.4: After Face Bending test (TIG)

Chapter 9

Rood Bend Test

9.1 Define Root bend test:

This bend test determines the quality a weld at the root of a welded joint. The specimen normally is bent 180 degrees. Root bend tests are made with the weld Root in tension

9.2 Testing Procedure:

For testing Root bend sample at first, we welded two sample. One for Arc welding and One for TIG welding test.

After completing welding by Arc and TIG welding machine then machining Face and Rood side zone of welded metal by a Shaper machine.

Fig9.1: Root zone cutting by Shaper Machine

Fig9.2: 180◦ Bending machine

Then Pressure will be applied at 180-degree angle by A Hydraulic press machine keeping root side of welding joint

Fig 9.3: After Root Bending test (Arc)


Fig 9.4: After Root Bending test (TIG)

Chapter 10

Side Bend Test

10.1 Define Side Bend Test:

This bend test determines the quality a weld at the Side of a welded joint. The specimen normally is bent 180 degrees. Side bend tests are made with the weld Root in tension

10.2 Procedure:

For testing Side bend sample at first, we welded two samples. One for Arc welding and One for TIG welding test.

After completing welding by Arc and TIG welding machine then machining both sides not Face and root zone of welded metal by a Shaper machine in 12.50 mm wide

Fig 10.1: Reducing wide side zone cutting by Shaper Machine

Fig10.2: Prepared 12.50 mm thickness sample from Side bend test

Then Pressure will be applied at 180-degree angle by A Hydraulic press machine keeping thickness side of welding joint

Fig10.3: 180◦ Bending machine

Fig10.4: After Side Bending test

Chapter 11

Microstructure

A microscope is an instrument that can be used to observe small objects, even cells. The image of an object is magnified through at least one lens in the microscope.

Fig: Microscope Mchine

The main objective was to evaluate the better joint between MS prepared by ARC and TIG accordance to their impact, Tensile, nick break and bending strength.

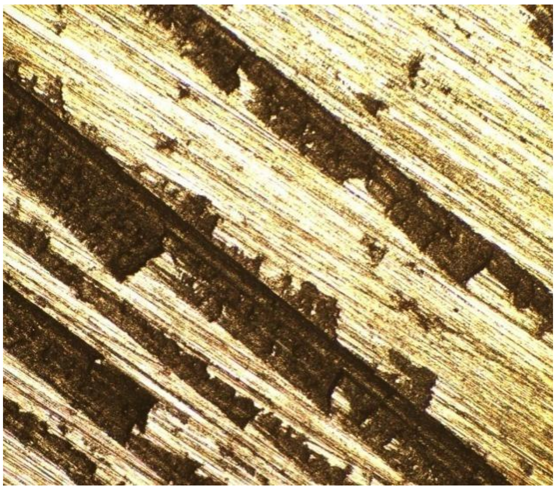


Fig 11.1 Optical micrographs of TIG welded zone at interfaces: -5x

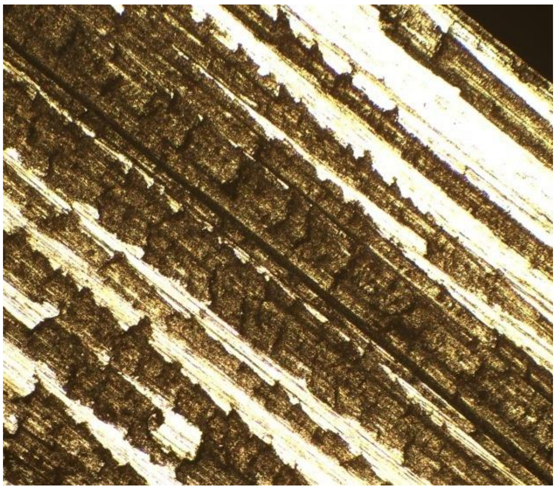


Fig11.2: Optical micrographs of TIG welded Heat Affected zone at interfaces: -5x

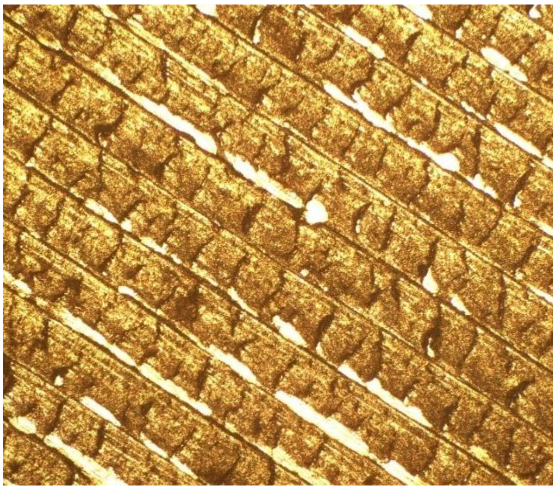


Fig:11.3 Optical micrographs of Arc welded zone at interfaces: -5x

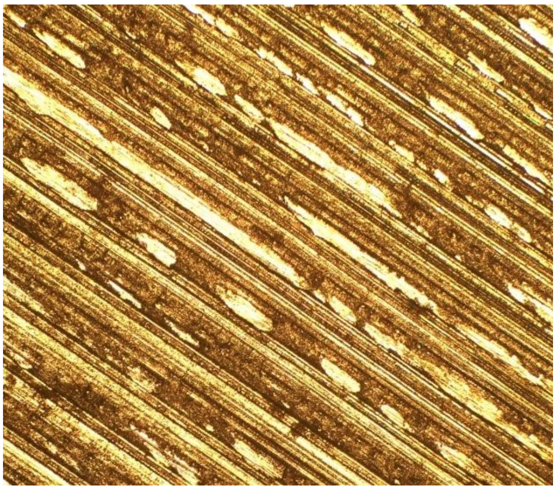


Fig:11.4 Optical micrographs of Arc welded Heat Affected zone at interfaces: -5x

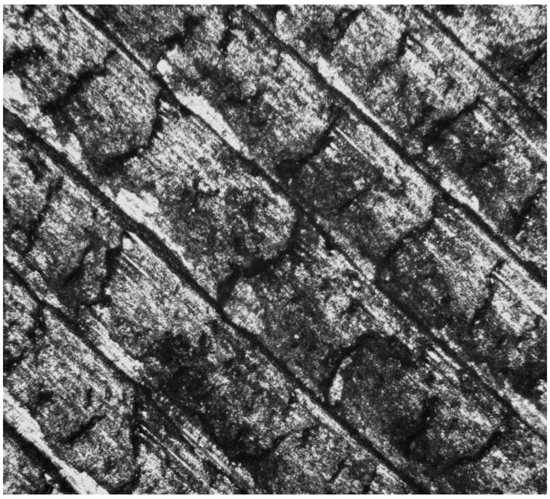


Fig: TIG welded zone at interfaces: -10x

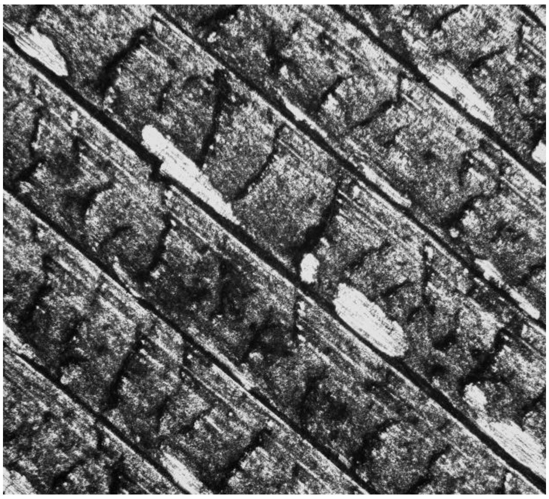


Fig: Arc welded zone at interfaces: -10x

This work represents a contribution to the study of the effect of shielded metal arc welding and TIG on MS. The microstructures in different zones are determined from the base metal to the weld metal. The microstructure of the center of weld zone is completely different from the heat-affected zone. The HAZ contains Widmannstetter ferrite, large grains of ferrite and colonies of pearlite. We have observed that bands of coarse grains grow along a certain preferred crystallographic direction. Moreover, we have found that maximum hardness values are situated in the area of weld metal and HAZ which indicates its specificity.

Chapter 12

Data Collection, Calculation Result and Remarks

12.1 Result of Tensile Strength Test

TIG Welding joint:

Name/Parameter	Unit
Thickness	11.7400 mm
width	30 mm
Gauge Length	100 mm
Max Force (Cal.at Entire Areas)	241.862 KN
Max Stress (Cal.at Entire Areas)	**686.717 N/mm2**
Max Stroke (Cal.at Entire Areas)	21.375 mm
Max Disp. (Cal.at Entire Areas)	21.375 mm
Max Strain (Cal.at Entire Areas)	21.375 %
Break Force (Sensitivity:10)	165.473 KN
Break Stress (Sensitivity:10)	469.826 N/mm2
Break Stroke (Sensitivity:10)	31.0906 mm
Break Disp (Sensitivity:10)	31.0906 mm
Max Stroke Strain (Cal.at Entire Areas)	21.3785 %

Table 1: TIG parameter table

Standard Used: API 1104

Test Name	Welding Metal	Welding Method	Breaking Strength(MPa)	Observation
Tensile Strength Test	MS	TIG	686.717	Specimen breaks outside the weld and fusion zone

Table2: TIG Result

Remarks:
Conforms to the requirement of the standard.

12.1.2 Tensile Strength Test

Arc welding joint:

Name/Parameter	Unit
Thickness	16.85mm
width	30.20mm
Gauge Length	100 mm
Max Force (Cal.at Entire Areas)	308.008 KN
Max Stress (Cal.at Entire Areas)	**605.278N/mm2**
Max Stroke (Cal.at Entire Areas)	27.2636 mm
Max Disp. (Cal.at Entire Areas)	27.2636 mm
Max Strain (Cal.at Entire Areas)	27.2636 mm %
Break Force (Sensitivity:10)	181.708 KN
Break Stress (Sensitivity:10)	357.082 N/mm2
Break Stroke (Sensitivity:10)	40.1060 mm
Break Disp (Sensitivity:10)	40.1060 mm
Max Stroke Strain (Cal.at Entire Areas)	27.2636 mm %

Table 3: Arc parameter table

Test Name	Welding Metal	Welding Method	Breaking Strength(MPa)	Observation
Tensile Strength Test	MS	Arc	605.278	Specimen breaks outside the weld and fusion zone

Table 4: Arc joint result

Remarks:
Conforms to the requirement of the standard.

12.2 Result of Impact test

Data Calculations:
Weight of the hammer=20.54 kg
Arm Length=0.825 m

Materials	**Weld Type**	**Depth of notch(mm)**
MS	Arc	2.13
MS	TIG	2.10

Table 5: Depth of notch

Weld Type	Type of specimen	Cross section below notch	Angle of rise, θ_1	Angle of fall, θ_2	Notch Impact Strength(J)
Arc	Notched	78.606	139	30	243.0
TIG	Notched	78.03	139	30	191.0

Table 6: Particulars of test

Standard Used: API 1104

Test Name	**Welding Metal**	**Welding Method**	**Temperature**	**Absorbed Energy (J)**
Impact Test	MS	Arc	-10°C	243.0
Impact Test	MS	TIG	-10°C	191.0

Table7 : Results of Arc and TIG

Remarks:
Conforms to the requirement of the standard.

12.3 Nick Break Test Result:

Standard Used: API 1104

Test Name	Welding Metal	Welding Method	Observation
Nick Break Test	MS	Arc	No gas pocket and slag inclusion found
Nick Break Test	MS	TIG	No gas pocket and slag inclusion found

Table 8: Observation table of nick break test

Remarks:

Conforms to the requirement of the standard.

12.4 Result of Hardness Test:

Arc Welding joint

Standard Used: BS 4515

Test Name	Welding Metal	Welding Type	Location	Measured Average Hardness(BHN) 100kg Load,1/16 inch dia. steel ball	Remarks
Hardness Test	MS	Arc	Base Metal	166	OK
			Heat Affected zone	185	OK
			Welded zone	204	OK

Table 9: Parameters and Measured table

TIG Welding joint

Standard Used: BS 4515

Test Name	Welding Metal	Welding Type	Location	Measured Average Hardness (BHN) 100kg Load,1/16 inch dia. steel ball	Remarks
Hardness Test	MS	TIG	Base Metal	195	OK
			Heat Affected zone	185	OK
			Welded zone	175	OK

Table 10: Parameters and Measured table

12.5 Result of Face Bend test:

Standard Used: API 1104

Test Name	Welding Metal	Welding Method	Observation
Face Bend Test	**MS**	**Arc**	**No crack was observed**
Face Bend Test	**MS**	**TIG**	**No crack was observed**

Table 11: Result of Face Bend test

Remarks:

Conforms to the requirement of the standard.

12.6 Result of Root Bend Test:

Standard Used: API 1104

Test Name	Welding Metal	Welding Method	Observation
Root Bend Test	**MS**	**Arc**	**No crack was observed**
Root Bend Test	**MS**	**TIG**	**No crack was observed**

Table 12: Result of Root Bend test

Remarks:

Conforms to the requirement of the standard.

12.7 Result of Side Bend Test:

Standard Used: API 1104

Test Name	Welding Metal	Welding Method	Observation
Side Bend Test	**MS**	**Arc**	**No crack was observed**
Side Bend Test	**MS**	**TIG**	**No crack was observed**

Table 13: Result of Side Bend test

Remarks:

Conforms to the requirement of the standard.

Chapter 13

Conclusion

In this paper, Arc & TIG welding joint between MS was successfully carried out and their properties Tensile Strength, Impact Strength, Nick break strength, hardness, Face bending strength, Root bending strength, Side bending strength and microstructure.

The following were the conclusions obtained.

1. Those samples welded at Arc & TIG found to have the maximum tensile strength. This is due to the minimum amount of internal stresses developed. The fine, equiaxed grain are uniformly distributed, in the welding region is the reason for better tensile properties.
2. Those samples welded at Arc & TIG found to have done in order to quantify the impact energy of the different microstructures in the weld metal and the HAZs to ensure that, as far as possible, the equipment will be operating at upper shelf temperatures where brittle fracture is not a risk.
3. In this paper, Nick break test is performed that there was no as slag inclusion, lack of fusion, incomplete penetration, porosity, etc in that butt weld.
4. The hardness was found to be highest for the sample welded joint. In all the samples hardness variations were observed.
5. The sample welded with 160A had more fine grains and is better suited for the higher tensile properties.
6. The Sample welded with Arc an TIG showed good Face, Root and side bending strength and it presented a low included angle.
7. Therefore, that all sample, Arc and TIG welded at high power showed better strength.

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Appendix:

All testing methods and result followed API 1104

Welding of Pipelines and Related Facilities

Pipeline Segment

API STANDARD 1104
NINETEENTH EDITION, SEPTEMBER 1999
ERRATA 1, OCTOBER 31, 2001

American Petroleum Institute

Helping You Get The Job Done Right.℠

5.6 TESTING OF WELDED JOINTS—BUTT WELDS

5.6.1 Preparation

To test the butt-welded joint, test specimens shall be cut from the joint at the locations shown in Figure 3. (See Section 13 for testing requirements for the flash welding procedure.) The minimum number of test specimens and the tests to which they shall be subjected are given in Table 2. The specimens shall be prepared as shown in Figure 4, 5, 6, or 7. For pipe less than 2.375 in. (60.3 mm) in outside diameter, two test welds shall be performed to obtain the required number of test specimens. The specimens shall be air cooled to ambient temperature prior to being tested. For pipe less than or equal to 1.315 in. (33.4 mm) in outside diameter, one full-section specimen may be substituted for the four reduced-section nick-break and root-bend specimens. The full-section specimen shall be tested in accordance with 5.6.2.2 and shall meet the requirements of 5.6.2.3.

5.6.2 Tensile-Strength Test

5.6.2.1 Preparation

The tensile-strength test specimens (see Figure 4) shall be approximately 9 in. (230 mm) long and approximately 1 in. (25 mm) wide. They may be machine cut or oxygen cut, and no other preparation is needed unless the sides are notched or are not parallel. If necessary, the specimens shall be machined so that the sides are smooth and parallel.

5.6.2.2 Method

The tensile-strength test specimens shall be broken under tensile load using equipment capable of measuring the load at which failure occurs. The tensile strength shall be computed by dividing the maximum load at failure by the smallest cross-sectional area of the specimen, as measured before the load is applied.

5.6.2.3 Requirements

The tensile strength of the weld, including the fusion zone of each specimen, shall be greater than or equal to the specified minimum tensile strength of the pipe material but need not be greater than or equal to the actual tensile strength of the material. If the specimen breaks outside the weld and fusion zone (that is, in the parent pipe material) and meets the minimum tensile-strength requirements of the specification, the weld shall be accepted as meeting the requirements.

If the specimen breaks in the weld or fusion zone and the observed strength is greater than or equal to the specified minimum tensile strength of the pipe material and meets the soundness requirements of 5.6.3.3, the weld shall be accepted as meeting the requirements.

If the specimen breaks below the specified minimum tensile strength of the pipe material, the weld shall be set aside and a new test weld shall be made.

5.6.3 Nick-Break Test

5.6.3.1 Preparation

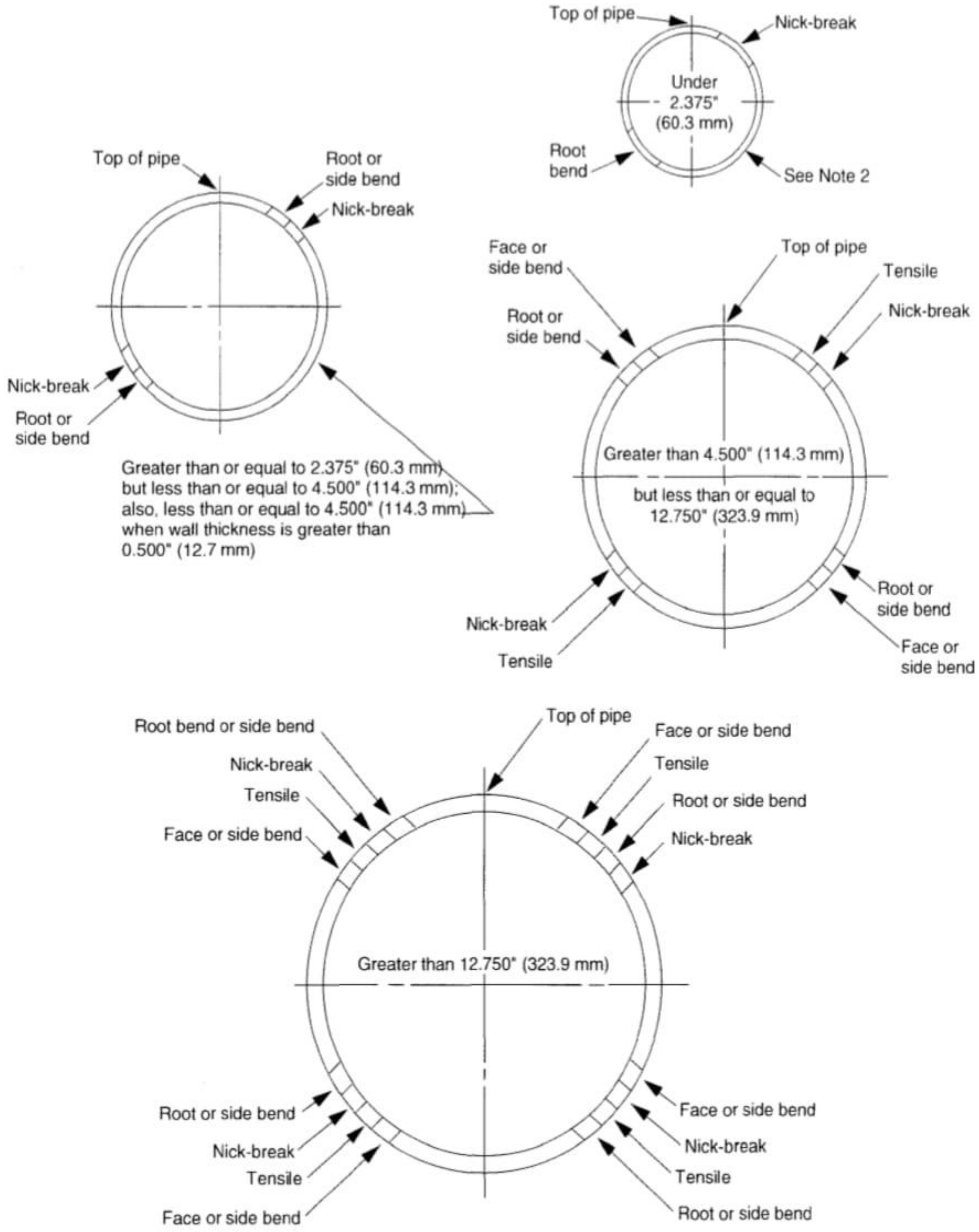
The nick-break test specimens (see Figure 5) shall be approximately 9 in. (230 mm) long and approximately 1 in. (25 mm) wide and may be machine cut or oxygen cut. They shall be notched with a hacksaw on each side at the center of the weld, and each notch shall be approximately $^{1}/_{8}$ inch (3 mm) deep.

Table 2—Type and Number of Test Specimens for Procedure Qualification Test

Outside Diameter of Pipe		Number of Specimens					
Inches	Millimetres	Tensile Strength	Nick-Break	Root Bend	Face Bend	Side Bend	Total
		Wall Thickness ≤ 0.500 inch (12.7 mm)					
< 2.375	< 60.3	0[b]	2	2	0	0	4[a]
2.375–4.500	60.3–114.3	0[b]	2	2	0	0	4
> 4.500–12.750	114.3–323.9	2	2	2	2	0	8
> 12.750	> 323.9	4	4	4	4	0	16
		Wall Thickness > 0.500 inch (12.7 mm)					
≤ 4.500	≤ 114.3	0[b]	2	0	0	2	4
> 4.500–12.750	> 114.3–323.9	2	2	0	0	4	8
> 12.750	> 323.9	4	4	0	0	8	16

[a]One nick-break and one root-bend specimen shall be taken from each of two test welds, or for pipe less than or equal to 1.315 inches (33.4 mm) in diameter, one full-section tensile-strength specimen shall be taken.

[b]For materials with specified minimum yield strengths greater than 42,000 psi (290 MPa), a minimum of one tensile test shall be required.



Notes:

1. At the company's option, the locations may be rotated, provided they are equally spaced around the pipe; however, specimens shall not include the longitudinal weld.
2. One full-section tensile specimen may be used for pipe with an outside diameter less than or equal to 1.315 in. (33.4 mm).

Figure 3—Location of Test Butt-Weld Specimens for Procedure Qualification Test

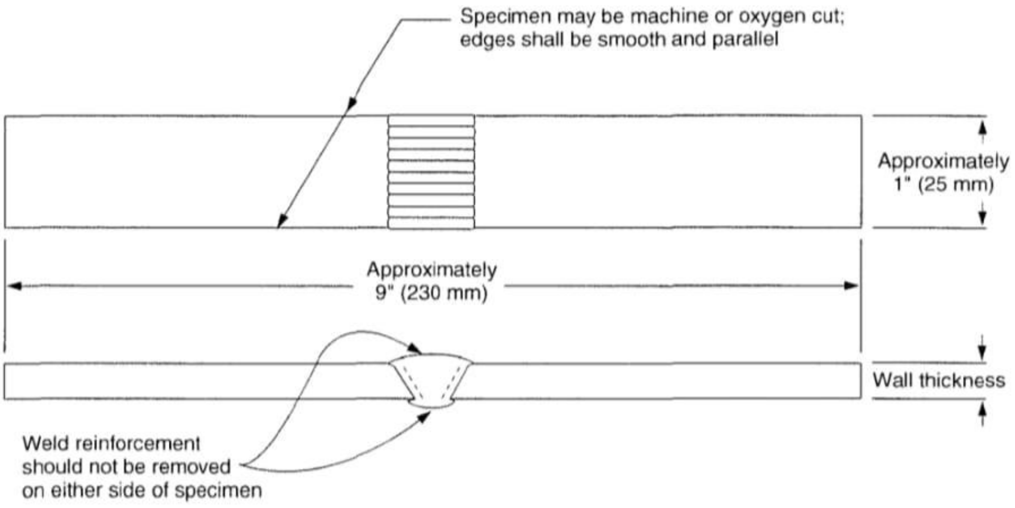


Figure 4—Tensile-Strength Test Specimen

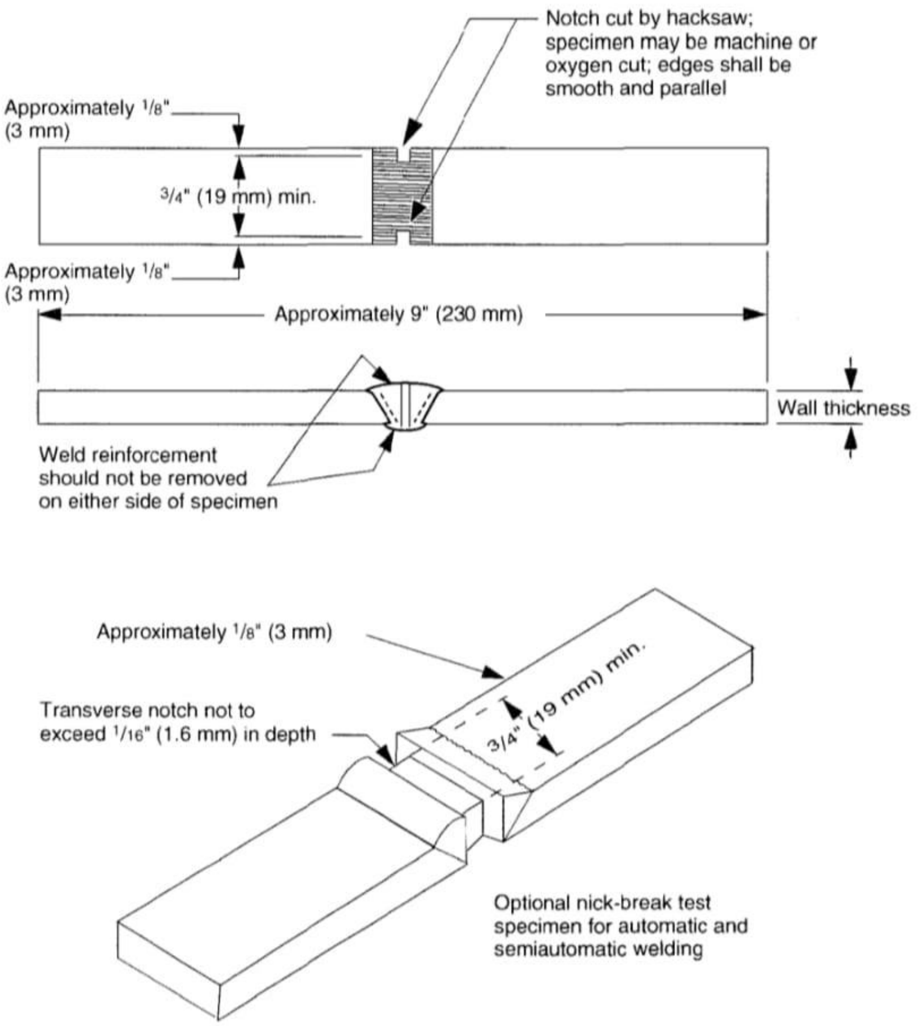


Figure 5—Nick-Break Test Specimen

Nick-break specimens prepared in this manner from welds made with certain automatic and semiautomatic processes may fail through the pipe instead of the weld. When previous testing experience indicates that failures through the pipe can be expected, the external reinforcement may be notched to a depth of not more than $^1/_{16}$ in. (1.6 mm), measured from the original weld surface.

At the company's option, nick-break specimens for qualification of a procedure using a semiautomatic or automatic welding process may be macro-etched prior to being nicked.

5.6.3.2 Method

The nick-break specimens shall be broken by pulling in a tensile machine, by supporting the ends and striking the center, or by supporting one end and striking the other end with a hammer. The exposed area of the fracture shall be at least $^3/_4$ in. (19 mm) wide.

5.6.3.3 Requirements

The exposed surfaces of each nick-break specimen shall show complete penetration and fusion. The greatest dimension of any gas pocket shall not exceed $^1/_{16}$ in. (1.6 mm), and the combined area of all gas pockets shall not exceed 2% of the exposed surface area. Slag inclusions shall not be more than $^1/_{32}$ in. (0.8 mm) in depth and shall not be more than $^1/_8$ in. (3 mm) or one-half the nominal wall thickness in length, whichever is smaller. There shall be at least $^1/_2$ in. (13 mm) separation between adjacent slag inclusions. The dimensions should be measured as shown in Figure 8. Fisheyes, as defined in AWS A3.0, are not cause for rejection.

5.6.4 Root- and Face-Bend Test

5.6.4.1 Preparation

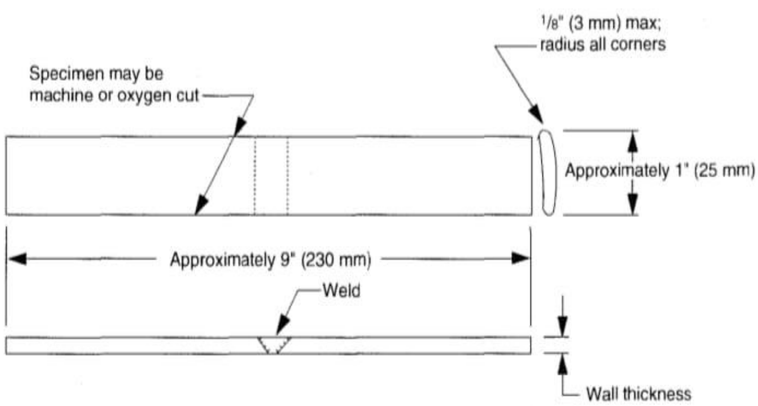
The root- and face-bend test specimens (see Figure 6) shall be approximately 9 in. (230 mm) long and approximately 1 in. (25 mm) wide, and their long edges shall be rounded. They may be machine cut or oxygen cut. The cover and root-bead reinforcements shall be removed flush with the surfaces of the specimen. These surfaces shall be smooth, and any scratches that exist shall be light and transverse to the weld.

5.6.4.2 Method

The root- and face-bend specimens shall be bent in a guided-bend test jig similar to that shown in Figure 9. Each specimen shall be placed on the die with the weld at mid span. Face-bend specimens shall be placed with the face of the weld toward the gap, and root-bend specimens shall be placed with the root of the weld toward the gap. The plunger shall be forced into the gap until the curvature of the specimen is approximately U-shaped.

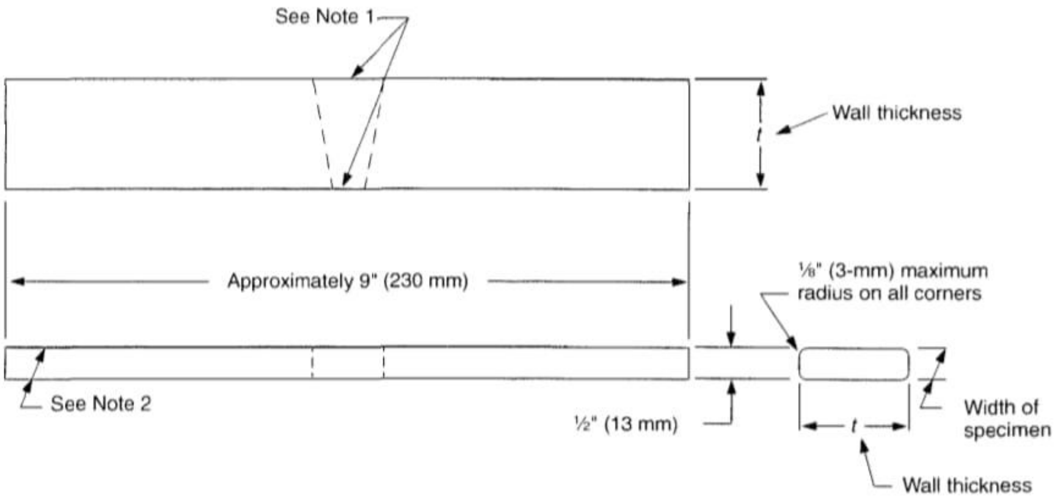
5.6.4.3 Requirements

The bend test shall be considered acceptable if no crack or other imperfection exceeding $^1/_8$ in. (3 mm) or one-half the nominal wall thickness, whichever is smaller, in any direction is present in the weld or between the weld and the fusion zone after bending. Cracks that originate on the outer radius of the bend along the edges of the specimen during testing and that are less than $^1/_4$ in. (6 mm), measured in any direction, shall not be considered unless obvious imperfections are observed. Each specimen subjected to the bend test shall meet these requirements.



Note: The weld reinforcement shall be removed from both faces with the surface of the specimen. The specimen shall not be flattened prior to testing.

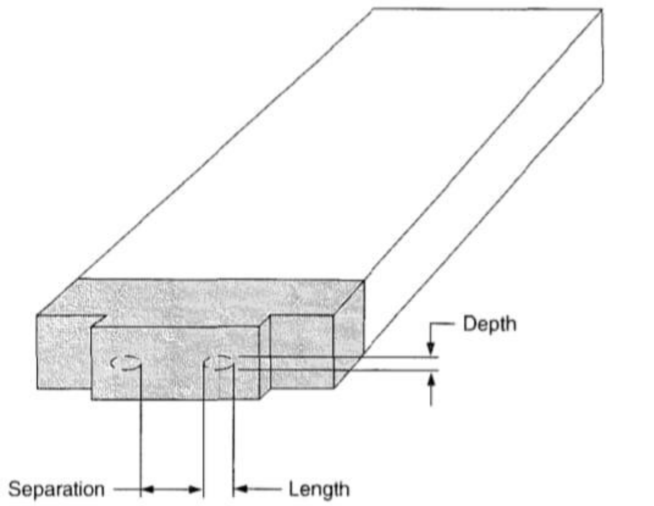
Figure 6—Root- and Face-Bend Test Specimen: Wall Thicknesses Less Than or Equal to 0.500 in. (12.7 mm)



Notes:

1. The weld reinforcement shall be removed from both faces flush with the surface of the specimen.
2. Specimens may be machine cut to a width of $^1/_2$ in. (13 mm), or they may be oxygen cut to a width of approximately $^3/_4$ in. (19 mm) and then machined or ground smooth to a width of $^1/_2$ in. (13 mm). Cut surfaces shall be smooth and parallel.

Figure 7—Side-Bend Test Specimen: Wall Thicknesses Greater than 0.500 in. (13 mm)



Note: A broken nick-break test specimen is shown; however, this method of dimensioning applies also to broken tensile and fillet weld test specimens.

Figure 8—Dimensioning of Imperfections in Exposed Weld Surfaces

5.6.5 Side-Bend Test

5.6.5.1 Preparation

The side-bend test specimens (see Figure 7) shall be approximately 9-in. (230-mm) long and approximately $^1/_2$-in. (13-mm) wide, and their long edges shall be rounded. They shall be machine cut, or they may be oxygen cut to approximately a $^3/_4$-in. (19-mm) width and then machined or ground to the $^1/_2$-in. (13-mm) width. The sides shall be smooth and parallel. The cover and root-bead reinforcements shall be removed flush with the surfaces of the specimen.

5.6.5.2 Method

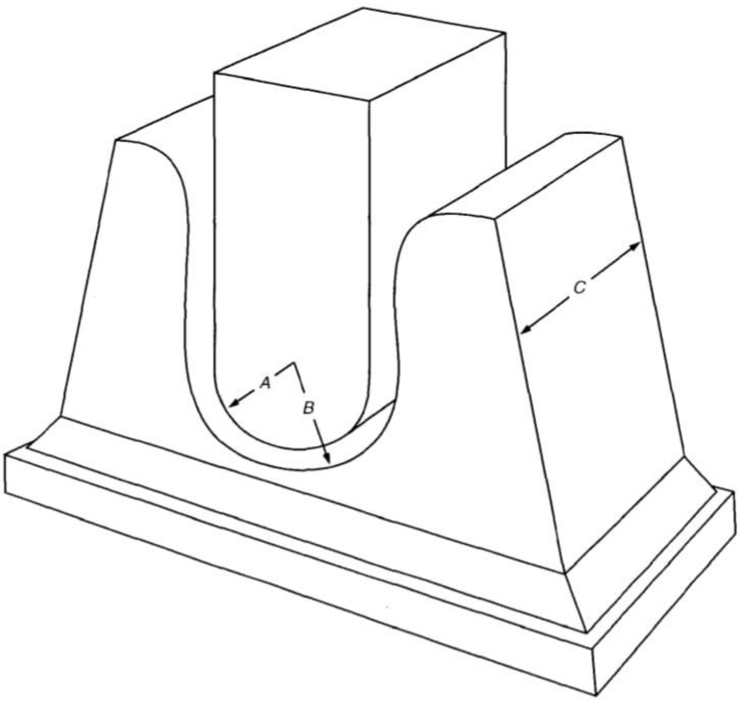
The side-bend specimens shall be bent in a guided-bend test jig similar to that shown in Figure 9. Each specimen shall be placed on the die with the weld at mid span and with the face of the weld perpendicular to the gap. The plunger shall be forced into the gap until the curvature of the specimen is approximately U-shaped.

5.6.5.3 Requirements

Each side-bend specimen shall meet the root- and face-bend test requirements specified in 5.6.4.3.

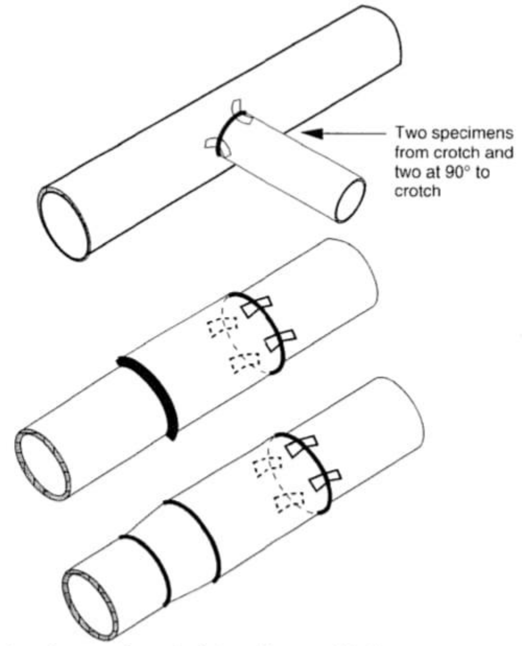
5.7 WELDING OF TEST JOINTS—FILLET WELDS

To weld the test joint for a fillet weld, a fillet weld shall be made to one of the configurations shown in Figure 10, following all the details of the procedure specification.



Note: This figure is not drawn to scale. Radius of plunger, $A = 1^3/_4$ in. (45 mm); radius of die, $B = 2^5/_{16}$ in. (60 mm); width of die, $C = 2$ in. (50 mm).

Figure 9—Jig for Guided-Bend Tests



Note: This figure shows the location of test specimens for joints with an outside diameter greater than or equal to 2.375 in. (60.3 mm). For joints with an outside diameter less than 2.375 in. (60.3 mm), specimens shall be cut from the same general location, but two specimens shall be removed from each of two test welds.

Figure 10—Location of Nick-Break Test Specimens: Fillet-Weld Procedure and Welder Qualification Test Welds

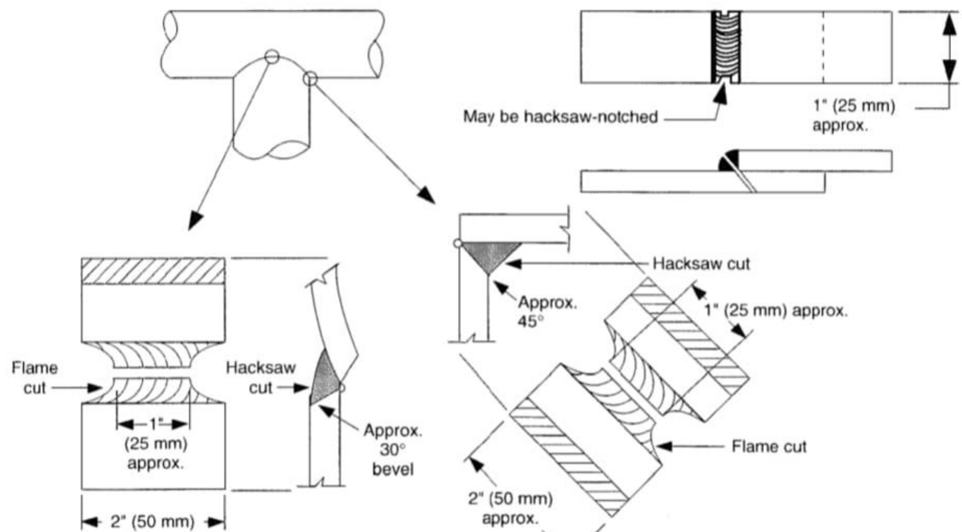


Figure 11—Location of Nick-Break Test Specimens: Fillet-Weld Procedure and Welder Qualification Test Welds, Including Size-to-Size, Branch-Connection Welder Qualification Test