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Effects of Root Opening on Welding Speed, Hardness, Root Penetration and Tensile Strength using E7018 Welding Electrode by Weaving Technique on E250 Plates

by

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A THESIS

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DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING

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The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a thesis entitled "**Effects of Root Opening on Welding Speed, Hardness, Root Penetration and Tensile Strength using E7018 Welding Electrode by Weaving Technique on E250 Plates**" submitted by Winner Shrestha in partial fulfillment of the requirements for the degree of Master in Energy System Planning and Management.

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ABSTRACT

The weldability of E 250 mild steel plates which are extensively used in penstock pipes of hydropower depends upon different parameters like welding current, voltage, travel speed, electrode angle and other parameters. Mostly, E7018 electrode is used for welding by Shielded Metal Arc Welding (SMAW) process. Root opening is the gap between the two metals in a butt joint that are to be welded. Welding performed in workshops are done in controlled and qualitative environment but during installation in field due to geological conditions like high slopes, difficulty in handling pipes in vertical tunnels and inclined tunnels the welding may not be performed as done in workshop but the design requirement is same. Four sets of samples are prepared by fitting two samples each of 300 mm length x 300 mm width x 10 mm thickness with root opening of 2 mm, 4 mm, 6 mm and 8 mm respectively with bevel angle of 60 degrees, single groove and root face of 2 mm. Welding has been performed by certified welder, accordance to ASME Section IX, with the use of E7018 electrode with 2.5 mm diameter by SMAW process and weaving technique.

The welding speed decreased while welding from 2 mm to 8 mm. The welding speed decreased from 81.31 mm/min to 76.23 mm/min, 66.58 mm/min and 55.54 mm/min at root opening of 2 mm, 4 mm, 6 mm and 8 mm respectively. Hardness of the material indicates the changes in property of the material after being welded. The hardness in weld metal increased from 125.6 HV to 127.3 HV, 136.8 HV and 139.2 HV and hardness in heat affected zone increased from 104.3 HV to 106.8 HV, 107.7 HV and 108.6 HV at root opening of 2 mm, 4 mm, 6 mm and 8 mm respectively. Complete root penetration of 10 mm was found while welding in root opening of 4 mm whereas minimum root penetration of 8.8 mm, 8.1 mm and 6.9 mm was found while welding with root opening of 2 mm, 6 mm and 8 mm respectively. The root penetration decreased with an increase of root opening. With the increase in root opening, heat input has to be increased. As, the experiment is carried in constant current and voltage, the heat input required for 6 mm and 8 mm root opening is less causing less root penetration in welds. There is no effect in minimum required tensile strength of welded zone when welding is performed by E7018 welding electrode in E250 grade materials by weaving technique varying the root opening from 2 mm to 8 mm. The rupture is found to be in parent metal in all the samples.

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ABBREVIATIONS

AC	Alternating Current
CE	Carbon Equivalent
dB	Decibel
DC	Direct Current
DCEN	Direct Current Electrode Negative
DCEP	Direct Current Electrode Positive
HAZ	Heat Affected Zone
HB	Hardness Brinell
HRB	Hardness Rockwell B
HRC	Hardness Rockwell C
HV	Hardness Vickers
IS	Indian Standard
MPa	Mega Pascal
NDT	Non-Destructive Testing
SMAW	Shielded Metal Arc Welding
UT	Ultrasonic Testing
UTM	Universal Testing Machine
Masl	Meters Above Sea Level
LP	Lack of Penetration
LF	Lack of Fusion

CHAPTER ONE: INTRODUCTION

1.1 Background

Welding is the process of joining metals or other materials to form a single set with the application of heat. Welding is extensively used in production of pressure vessels, pressure pipes, petroleum storage tanks, petroleum transport pipes, earth moving equipment, automobiles, turbines. The long route of pipes required for water or petroleum products are formed by welding the individual pipes. Complex shapes required for specific work are formed by welding the individual parts.

Shielded metal arc welding (SMAW) is mostly used as welding process all over the world where the electrodes are covered with the flux which protects the molten weld pool from the surrounding atmosphere. The electrode produces an arc and provide enough energy to melt the electrode in order to join two metals.

The principle of SMAW is based on the electric circuit. The electric arc produced between the workpiece and electrode melts the electrode and fills the gap between the materials that are to be welded. During this course, the electrode or filler material is consumed as forms the molten weld pool in the gap and joins the materials. The gap between the two metals that are to be joined is known as root opening.

The equipments required for SMAW process are easily available and versatile to use. Almost all types of materials can be arc welded by suitable selection of filler materials for any size of thickness down to 2 mm. Similarly, arc welding can be performed at any position. (Wilhelmsen Ships Service)

1.2 Context of Nepal

Penstock pipes are the major components in hydropower projects as it conveys water under pressure. The long length of penstock pipes and the required diameter of pipes are manufactured and installed by welding process. There are different types of materials used for penstock pipes of hydropower depending upon the pressure, project location, chemical properties and physical properties of the materials. The major properties for design of penstock pipes are its yield strength and the ultimate tensile strength.

Weldability characteristics are also important for selection of penstock pipes. The quality of welding is dependent upon different factors which are follows:

- Material grades of the penstock pipes
- Ambient temperature
- Selection of filler material (electrode)
- Preheating of the materials
- Welding parameters like welding current, voltage, root gaps, inter pass temperature

As per the context of Nepal hydropower projects are being developed in higher altitude location with high pressure head. The projects are being developed around the altitude of 3000 masl with the pressure head up to 1000 m. Generally, materials with yield strength of 250 MPa were being used previously but with construction of a greater number of projects and increase in project heads more high strength materials i.e., material grades with yield strength of 350 MPa and 450 MPa are being used to decrease the thickness of penstock materials.

With the use of high-grade materials, the welding of these high-grade materials also becomes important as the results may be catastrophic if the welding quality is poor. The welding may be poor due to following factors:

- Welding performed by unqualified welder or welding operator
- Improper selection of welding parameters
- Not performing of non-destructive tests

1.3 Problem Statement

Welding is extensively used in hydropower sector for Nepal for fabrication and erection of penstock pipes and hydraulic gates. Penstock pipes are the major components to withstand the pressure of the water and welding is the important factor to be considered. IS 2062 E 250 is the major used steel in hydropower projects in Nepal and welding is performed by SMAW process. Tensile strength is the major part considered in design of penstock pipes to withstand pressure (American Society of Civil Engineers, 2012). Similarly, the hardness of the material after welding is also the important property to be checked prior to the crack development in the weld.

The root opening has been defined as non-essential variable which means the change in root opening can be proceeded without the requalification of WPS (The American Society of Mechanical Engineers, 2019). The root opening of 0 to 3 mm must be maintained for single V- groove weld of butt joint for SMAW weld with tolerance of +2 mm and -0 mm (American Welding Society, 2000).

There has been extensive research in the optimization of welding parameters like welding current, polarity, electrode angle, welding speed, welding voltage, electrode diameter and temperature for achieving the optimum tensile strength and hardness but there is scarce information regarding the effect of root opening on tensile strength and hardness in the SMAW process. Welding performed in workshops are done in controlled and qualitative environment but during installation in field due to geological conditions like high slopes, difficulty in handling pipes in vertical tunnels and inclined tunnels the welding may not be performed as done in workshop but the design requirement is same. Hence, increase in root opening of weld may affect the weld properties.

Similarly, during design of penstock pipes, the diameter of pipes may be so small that inside welding is not possible to carry which in turn requires proper root opening for complete joint penetration of weld metal till bottom of butt joints. Hence research is necessary to find the effect of different root openings on tensile strength, hardness of the weld metal, parent metal, base metal and root penetration of weld.

1.4 Objectives

1.4.1 Main Objective

Study effects of root opening on welding speed, hardness, root penetration and tensile strength using E7018 welding electrode by weaving technique on E250 plates

1.4.2 Specific Objectives

- Measurement of welding speed for 2 mm, 4 mm, 6 mm and 8 mm root openings
- Effect of root opening on hardness of weld metal zone, heat affected zone and parent metal of welded sample
- Effect of root opening on root penetration of the welded sample using ultrasonic testing
- Effect of root opening on tensile strength of welded sample and location of rupture in the welded sample.

1.5 Limitations

- Chemical analysis is not performed
- Grain structure at weld zone is not analyzed
- If the strength parameter of material differs from standard, then result may vary
- If the parameter referenced taken from previous researcher’s changes, then the results may vary.

CHAPTER TWO: LITERATURE REVIEW

2.1 Mild Steel

Steel is an alloy of iron and certain percentage of carbon. The other elements are also present in the mixture of iron and carbon which affects the physical and chemical properties of the steel. With the increase in carbon content the hardness of the metal increases whereas the ductility decreases. With the increase in hardness, it becomes difficult to weld.

Mild steel can be machined and complex shapes can be formed with proper physical and mechanical properties at much lower cost. The general percentage of carbon in mild steel is between 0.05% to 0.35%. (Mst Nazma Sultana, 2014)

Mild steel is extensively due to its major following properties:

- High machinability
- High weldability
- Ductility
- High Tensile Strength
- High toughness

2.2 Welding Joints

SMAW process forms the strong joint by welding different mild steels. The covered filler materials produce the arc and provide heat for melting of filler materials. The flux or covering around the electrode produces the shield and protects the weld pool of metals from being oxidized. This also protects the molten metal from effects of sudden drop of temperature from weld pool temperature to the ambient temperature.

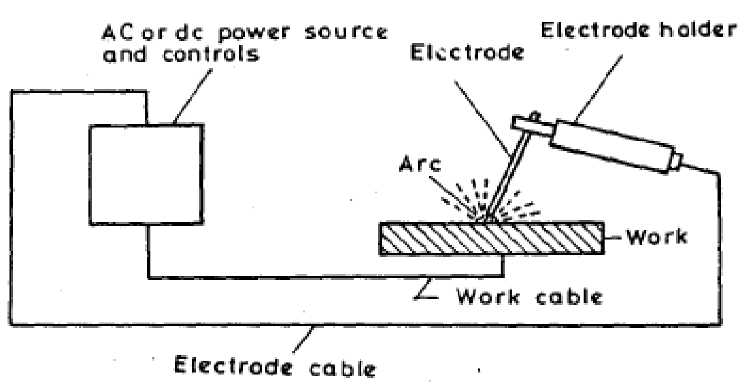

Figure 2.1: Schematic diagram of SMAW welding (Parmar, 2005)

The welding may be differentiated as butt welding and fillet welding according to the position of plane of placement of weld materials. If the two pieces are kept in same plane and ends are joined then it is called as butt welding whereas if the two pieces are perpendicular then it is called fillet welding. The butt weld joint design may be single groove or double groove.

2.3 Heat Affected Zone

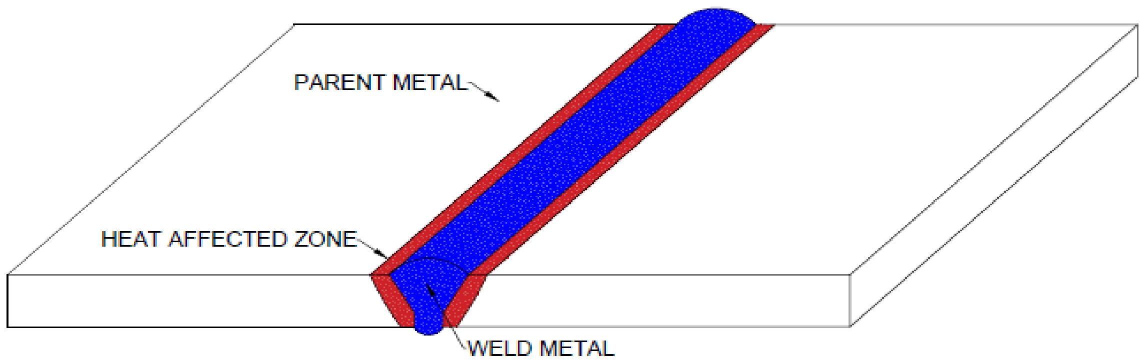

Figure 2.2: Butt joint showing of weld metal zone, heat affected zone and base metal

A heat affected zone (HAZ) is formed by the impact of continuous cooling and heating cycle produced by an arc. In the HAZ of the weld part, it is heated up to the temperature at which the base metal melts and is the output of effect on the microstructure of base metal. When the steels are welded, significant microstructural changes take place in HAZ which affect the mechanical and physical properties altering the service behavior of the weld.

The weld joint design forms the major part of welding along with the other welding parameters. Root spacing, root face and groove angle are the important factors to be considered during weld joint design of butt welding.

2.4 Welding Parameters

The quality of welding is imperative to the reliability and durability of weldment. The quality of welding depends on followings:

- Selection of welding parameters
- Design of weld joints
- Magnitude of residual stress and strain set up by welding heat
- Layout of welded joints

- Quality of parent metal
- Electrodes
- Performance of welding equipment
- Welding procedure followed
- Skill of the operator

There are different welding parameters affecting the weld quality. Current which is used in heating and melting the electrodes is called the welding current. The current produces the heat when arc is produced in during the welding period. The heat input in the metals is controlled by amount of current provided on it. Different amount of heat energy can be provided on the metal varying the amount of current. The arc voltage also affects the weld qualities. Arc length is altered with the change in arc voltage. With the increase in arc length, the process of heating and melting is decreased hence the temperature of weld also decreases as the arc is not in contact with the weld environment. This also decreases the rate of melting and heating. The diameter of electrode also effects the weld qualities. The diameter of the electrode must be according to the root opening. Similarly, the polarity affects the weld properties. Direct current electrode positive (DCEP) and direct current electrode negative (DCEN) are the polarities used in welding process. The welding speed also affect the weld properties which is one of the important factors to be considered. Groove angle also affects the weld properties. With the increase in groove angle, higher amount of weld pool is deposited which in turn provide the proper cooling rate increasing the tensile strength of the metal. The welding electrode angle affects the weld properties. With the increase in electrode angle, more heat is supplied to the weld pool which produces the homogeneous mixture forming proper and uniform mixture in the base material. (Baghel, 2022).

The boundaries of mass production of qualitative joints are limited by the weldability of the materials which can be susceptible to the defects in welding. For the good weldability, proper welding process, the physical and chemical composition of base material and filler material, the ambient temperature are the major factors to be considered. Heating of base material prior to welding can reduce the cooling rage, shrinkage stress, distortion in weld, cold cracking and hardening of heat affected zone. Similarly, this preheating removes the water content or moisture from the surface of metals which increases the proper fusion of filler metal and base metal. (Prasanta Majumder, 2020)

There are two types of polarity in DC, SMAW welding; Direct Current Electrode Positive (DCEP) and direct current electrode negative (DCEN). In DECP, the welding electrode lead is joined at the positive terminal of the welding machine and the work piece is joined to the negative terminal forming the electric circuit for flow of current. Similarly, in DCEN, the welding electrode lead is joined in negative terminal of welding machine and the work piece is joined to the positive terminal. DCEN produces the weld with higher tensile strength than the weld produced by the DCEP polarity. (Deepak Pathak R. P., 2020).

When the welding is performed by SMAW process in carbon steel by multi-layer welding, the ductility of the welded zone can be increased by welding the first layer by DCEN polarity and next layer by DCEP polarity. Similarly, if hardness is to be increased then the first layer shall be welded by DCEP polarity and next layer by DCEN polarity. (Abdulkareem Aloraier, 2021).

Shielded metal arc welding (SMAW) employs the use of carbon steel electrodes. The electrodes are selected according to the type of welding position of electrodes to be used, the covering types, polarities and mechanical properties of the weld metal. The welding electrodes can be in the form of rod or wire which can be made from metal or alloys. The welding electrode may or may not contain flux around it. The welding current flows through the electrode which provides the required amount of heat during welding.

The nomenclature of electrodes has its own classification as shown in figure 2.3, The letter "E" at the beginning stands for electrode. The first two digits, 70, specifies the tensile strength of at least 70 ksi of the weld metal. The third digit specifies position usability that will allow satisfactory welds to be produced with the electrode. For example, the "1" is 7018 means that the electrode can be used in all positions (vertical, horizontal, flat and overhead). The last digit taken together specifies the type of current which can be used while welding. It also provides the conformation regarding the type of covering of electrode. (American Welding Society, 1991)

The selection of type of welding electrode in dominant during the welding process. The strength of weld metals is guided by the selection of type of welding electrode. The electrode coating also effects the weld quality. The defects in the welding may initiate from the electrode types too. The mechanical properties like hardness, tensile strength and toughness are affected by the welding electrodes. (Azwinur, 2022).

Figure 2.3: E7018 Welding electrode

The heat input and filler material affect the tensile strength and hardness of the welded metals. The welding current and filler types also affect the hardness and tensile strength of the welded metals. With the increase in heat input, caused by increase in current, the tensile strength and hardness decreases when the other parameters like voltage, welding speed, etc. are kept at the optimum value. (Abdullah Modh Tahir, 2018). The diameter of welding electrode affects the tensile strength of the welded structures. The diameter of welding electrode is more dominant than the current in affecting the tensile strength of welds. The electrode diameter of 2.5 mm produces more tensile strength than the electrode diameter of 3.2 mm and 4.0 mm. (Mohd-Lair, 2021) Similarly, In E7018 the increase in current causes a decrease in hardness (Syukran, 2022).

When the welding is performed in high strength and high hardness materials formed from quenching and tempering, the softening in heat affected zone occurs which is caused by the selection of type of welding process and the type of welding electrode used. The welded joints which are formed by use of low hydrogen ferritic welding electrodes and SMAW process provides the superior transverse tensile and impact properties. (G Magudeeswaran, 2008). The microstructure of the welded joint can be improved in SMAW process by changing the chemical elements of the electrode coating, electrode types and protection of weld zone without further addition of equipments. (LS. Sisira K. Weerasekaralage, 2019).With the increase in welding ampere heat generation increases so melting of electrode become faster hence welding time decreases and welding speed was increases (Y, 2015).

2.5 Heat Input

Heat input in the weld depends upon the welding arc voltage, current, welding speed and the type of welding process used. The heat input is calculated as follows (Mohsen Amraei, 2019):

Heat Input (Q) = (η x V x I)/ (s x 1000)

Where,

Q is the amount of heat input in kJ/mm

η is the thermal efficiency of the welding process

V is the arc voltage in volts

I is the current in Ampere

V is the welding speed in mm/sec

2.6 Non-destructive testing

Nondestructive testing (NDT) is the process of performing the tests without affecting the physical nature of the test samples. The defects in the welded parts are identified without destroying the material. The inspection and evaluation shall be carried such that no damage is done on material without impairing the usefulness providing the vital information regarding characteristics and flaws in the welded joints. These NDT techniques are used to verify the finished products from the process of manufacturing of raw materials and fabrication. NDT techniques provides the information regarding the flaws present in the welded joints. These flaws are rejected or accepted according to the requirement of the specifications or standards. The flaws like porosity, incomplete penetration, cracks, incomplete fusion, etc. are identified by NDT at the definite location with its size. (J.R. Deepak, 2021).

Some of the nondestructive test methods include the following:

- Ultrasonic tests
- Radiographic tests

- Dye-penetrant tests (Liquid penetration tests)
- Magnetic particle tests
- Visual tests

The ultrasonic waves are introduced to the test samples at different frequencies in order to locate the position of internal defect in the ultrasonic testing method. When the sound beam is introduced towards the test samples, they are reflected at the point of defect or discontinuities. These reflected beams are detected in the screen are analyzed to find the presence the type of defects and their location.

The sound waves are generated at high frequencies in the range of 0.5 to 15 MHz in order to location the defects in the internal parts of welds. Ultrasonic tests work on the principle of receiving and quantifying the reflected waves (pulse-echo) or the transmitted waves (through-transmission). Out of the above systems pulse-echo method is usually used. This is because in the pulse echo method, the objects require to be accessed from single side only. In different applications, most of the times it may not be accessible from both sides of the test object which is shown in figure 2.4.

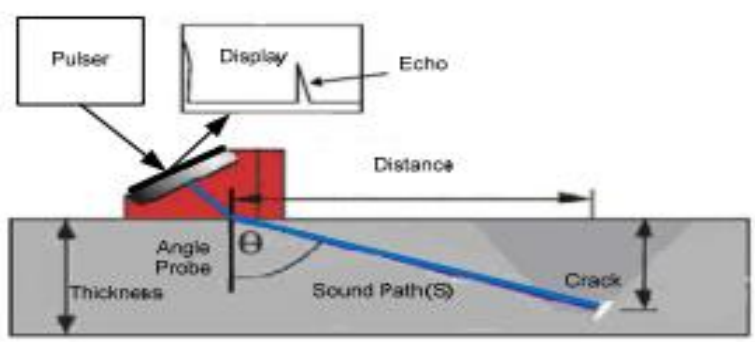

Figure 2.4: Pulse-Echo ultrasonic testing principle (Seyedtabaii, 2012)

The pulse echo method of ultrasonic tests contains the pulser/ receiver, transducer and the display screen. When the defects are found in the object, the part of energy present in the waves are reflected back from the location of defect. The mechanical energy present in the form of wave is converted to the electrical energy by the transducer. These electrical energies are shown in the screen in the form of echo and these echoes are interpreted to locate the position and size of the defects.

The major internal defects present in the welded joints are as follows:

- Incomplete fusion
- Incomplete root penetration
- Porosity
- Cracks
- Slag inclusions

A pulse echo type of equipment which can be operated in the frequencies of at least 1 MHz to 5 MHz must be used. These shall be facilitated with a stepped gain control in units of 2.0 dB or less. If the damping control is present in the equipment, then it can be used unless it reduces the sensitivity for the examination. (The American Society of Mechanical Engineers, 2019)

2.7 Hardness

Hardness is the physical property of the metals which shows its ability to resist the penetration and the abrasive wear. The changes in the microstructure of the metal can be shown by the measurement of hardness that are caused due to the welding. The hardness values depend upon the amount of heat supplied to the joints, type of welding process used, preheating or interpass temperature, thickness of the material and type of filler material used.

The service properties of weld zones can be related to the hardness. Not only the hardness of the weld zones, the maximum hardness of HAZ is also specified in order to provide proper requirement of hardness property. The hardness values of weldments need to be specified specially if the weld metals are exposed to the hydrogen bearing surroundings. Cracking can be caused if the high hardness metals are couples with the hydrogen. (Parmar, 2005)

The result of hardness test can be evaluated individually or its results can complement the results of the tensile test and bend tests of the welds. There are different types of hardness testing methods out of which Vickers, Brinell and Knoop hardness tests use the indentation area produced after applying certain amount of know load. Similarly, in the Rockwell test, the hardness is measured according to the depth of indentation produced under known load. The type of hardness measurement also depends upon the size and area of interest of weld locations like top of weld zone, face of the weld zone, root of the weld deposit area, heat affected zone and the base metal zone. Hardness measurement types also depend upon the strength of the material, type of data required and size of the welded joint. The Brinell test is used in heavy plates or large weld joints as it produces large indentation which is normally in the range of 2 mm to 5.6 mm. Vickers and Knoop test are generally used in hardness measurement of weld metal and HAZ as they produce less indentation in the sample object.

Hardness is normally measured in laboratory with the use of desk hardness testers. These testers use static loads for indentation. Welding performed in the field location cannot be tested by the use to stationary desk testes. So, for exterior hardness testing, universal portable hardness testers are used. These portable hardness testers use dynamic methods for indentation. These hardness testers allow the measured hardness to be converted to all other common hardness scales (HB, HV, HRB, HRC, HS). (Alam Vasko, 2019). If the hardness of the large structures or components in the field or site are to be measured then the samples need to be prepared by cutting the original components. During this course, the original components are damaged. Hence, this is not acceptable or impossible. Due to these issues, the portable hardness testers are developed to solve the above problems. (K V Gogolinskii, 2019)

The hardness of the weld metal depends upon the welding current. With the increase in current the hardness of the weld metal decreases. This is because with the increase in current the heat input provided in the weld zone and heat affected zone increases. With the increase in heat input hence the hardness decreases. Similarly, for same value of current the hardness is greater in weld zone compared to the heat affected zone. This is because the weld zone has the higher temperature compared to heat affected zone and parent metal. Higher the temperature, the cooling rate will be higher producing high hardness in weld zone. (Rudra Pratap Singh, 2020)

During welding process, different microstructural changes occur. With the increase in hardness of the weld zone cracks may develop hence the hardness up to 380 HV is allowed for the qualification of weld procedure so that cracks related to hydrogen are avoided. Similarly, the cracks may be developed at lower hardness due to sulphide stress, hence the maximum hardness value of 248 HV is allowed at root of weld joints. (Philippa Moore, 2015)

The hardness of the weld metal is increased with the increase in welding speed of electrodes. There is the increase in the yield strength and UTS with the increase in welding speed. Similarly, the sample welded at 20V shows a considerable increase in hardness as compared to the unwelded sample which decreased slightly above this voltage value. The yield strength and ultimate tensile strength of all the joints decreases with increased voltage. (Talabi, 2014).

The ultimate tensile strength and tensile strength also depends upon the number of welding passes and welding current. This is because with the increase in in current the heat input in the joints is increased. So, with the increase in heat input there is the decrease in tensile strength and vice versa. Hence, in order to gain higher tensile strength, lower heat input is recommended. (K.R. Jagtap, 2017)

2.8 Root Penetration and Tensile Strength

During the welding, the tensile strength of the weld region must always be greater than the tensile strength of the parent material. During the tensile test of welded samples, if the metal breaks away from the weld zone and the tensile strength hence received is above the minimum tensile strength specified then the procedure and electrode type will be accepted else the weld shall be rejected. In the case of rejected new sample shall be prepared and further tensile test shall be carried out. (Barry G. Bubar, 2011)

Weld bead geometry is accountable to obtain the optimum quality and strong welded joints. The shape and size of weld bead must be optimum to obtain proper mechanical properties. In order to obtain proper tensile strength and hardness the reinforcement height and penetration of weld must be optimized. (Deepak Pathak R. P., 2020).

With the increase in current the depth of penetration increases (Bijaya Kumar Khamari, 2019) The diameter of electrode and welding speed controls the height of reinforcement. Similarly, the electrode diameter affects the penetration of weld. Voltage also affects the hardness of the weld zone. So, electrode diameter and welding speed affects the weld bead dimensions (Rathi, 2020).

The distribution of residual stress is not affected by the shape of weld groove shape on the thin pipes (6 mm thick) and thick pipes (10 mm thick) during the welding performed of butt joints with double bevel groove. The increase in axial tensile strength is seen in the inner surface of double groove joints compared to the welding performed in single V and U butt joints (I. Sattari-Far, 2009)

Many research has been performed regarding welding current, voltage, welding speed, electrode diameter but the data related to root opening is limited and its effect on tensile strength and hardness is not defined.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Methodology

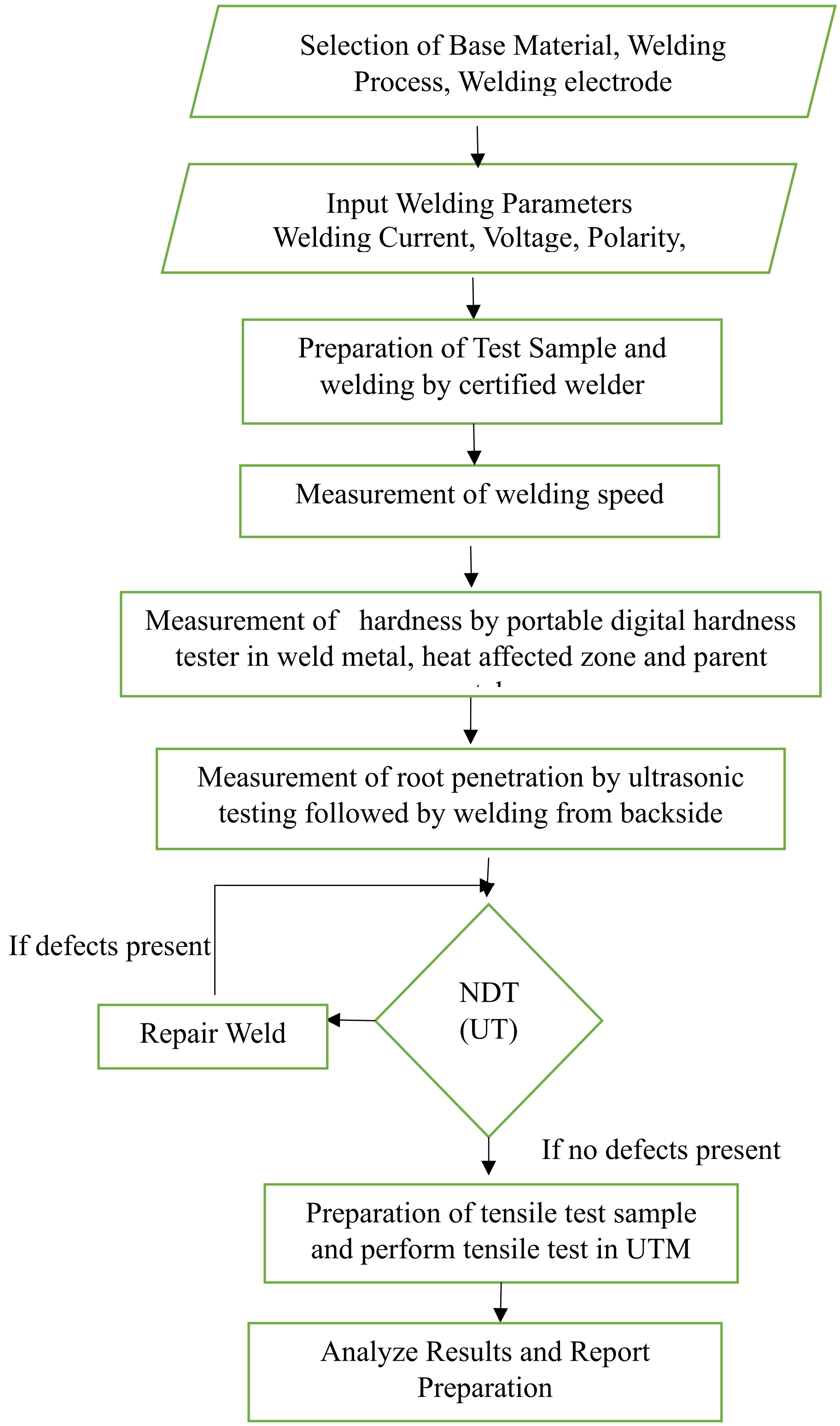

Figure 3.1: Research methodology

First of all, base material shall be selected with welding process and welding electrode. The welding parameters like welding current, voltage and polarity shall be fixed. Test samples shall be prepared and welded by certified welder according to ASME section IX. During the process of welding its speed shall be measured. After completion of welding from single bevel side, hardness shall be measured followed by measurement of root penetration by ultrasonic tests. After measurement of root penetration, if the defects are present, it shall be repaired and the sample shall be welded from back side of bevel face too. Again, ultrasonic tests shall be performed to check the defects present. If defects are present, it shall be repaired else it shall be proceeded for preparation of tensile test sample. The tensile test shall be performed and results shall be analyzed as shown in Figure 3.1.

3.2 Base Material

Mild Steel is selected for the experiment. E 250 material shall be selected with thickness of 10 mm for sample. E250 steels are suitable for welding, bolting, riveting structures and general engineering purposes. The carbon equivalent of E250 materials is 0.41. The individual content of carbon, manganese, Sulphur, phosphorous and silicon is given in Table 3.1. The minimum yield strength for 10 mm plates is 250 MPa and minimum tensile strength is 410 MPa as shown in Table 3.2 (Bureau of Indian Standards, 2011).

Table 3.1:Chemical composition of E 250 steel

Grade Designation	Quality	Ladle Analysis, Percent, Max					Carbon Equivalent (CE), Max
		C	Mn	S	P	Si	
E250	BR	0.22	1.50	0.045	0.045	0.4	0.41

Table 3.2: Mechanical properties of E250 steel

Grade Designation	Quality	Tensile Strength Min, MPa	Yield Stress Min, MPa			% Elongation
			T<20	T 20-40	T>40	
E250	BR	410	250	240	230	23

Where T stands for thickness

3.3 Welding Process

Shielded Metal Arc Welding (SMAW) welding is widely used for welding of metals. Tungsten Inert Gas (TIG) welding and Metal Inert Gas (MIG) are also used for welding purposes. TIG and MIG are used predominantly in workshop whereas SMAW welding is preferred in fields due to its convenient use.

Submerged Metallic Arc Welding (SMAW) process is selected for welding with direct current electrode positive (dcep). Three phase welding machine with capacity to produce 400 A of current is used for welding process. The welding shall be performed by the certified welder as per ASME Section IX (The American Society of Mechanical Engineers, 2019). Weaving technique shall be used while welding.

3.4 Welding Electrode

E 6013 and E 7018 are generally used in welding of common structural materials. E7018 contains less hydrogen compared to E6013. E7018 shows excellent performance in the properties of weld. (Santosh. S, 2018)

E7018 welding electrode with 2.5 mm diameter is selected for welding of the sample. The minimum tensile strength required for E7018 electrodes is presented in table 3.3 (American Welding Society, 1991).

Table 3.3: Tensile strength of E7018 welding electrode

AWS Classification	Tensile Strength		Yield Strength at 0.2 % Offset	
	ksi	MPa	ksi	MPa
E7018	70	482	58	399

The minimum tensile strength of E7018 electrode is 482 MPa and yield strength at 0.2 % offset is 399 MPa. This electrode meets all the requirement for welding as this electrode can be used in all the welding positions i.e. Flat, Vertical. Overhead and Horizontal Position. This electrode can be used only for direct current electrode positive. The welding electrode shall be heated up to 300°C for 2 hours in an oven prior to welding as per the manufacturer's recommendation. The electrode shall always be in oven during process of welding.

3.5 Welding Parameters

The root and different layers of the V groove joint for all four samples shall be welded at the constant current and voltage range. Previous researchers have found that the current and voltage have direct effect on the properties of weld hence, in order to get proper results of effect of root opening the current and voltage range are kept constant during welding at all four samples. The current at root pass shall be kept 70 A in order to provide complete penetration of weld. The current for second layer and third layer shall be increased to 85A and 90 A respectively in order to fill the weld and current for final layer shall be maintained 80 A in order to maintain proper weld reinforcement as shown in table 3.4.

Table 3.4: Current rating for individual weld passes

SN	Weld Layers	Current (A)	Voltage(V)
1	Root Pass	70	18-24
2	Second Layer	85	18-24
3	Third Layer	90	18-24
4	Final Layer	80	18-24

If the number of layers is increased during welding it shall be welded at the current of 85 to 90A with the voltage range of 18 to 24 volts.

3.6 Preparation of Samples

Eight pieces of 300 mm length and 300 mm width of sample are prepared from a long plate of thickness 10 mm. Two pieces of 300 mm by 300mm plates shall be fitted as shown in figure 3.2 with single V- groove and groove angle of 60 degrees forming a single sample.

Four sets of samples are made with two pieces (each of 300 mm width by 300 mm length) fitted together with different root opening as defined below:

- Sample A with root opening of 2 mm as shown in figure 3.3

- Sample B with root opening of 4 mm as shown in figure 3.4
- Sample C with root opening of 6 mm as shown in figure 3.5
- Sample D with rood opening of 8 mm as shown in figure 3.6

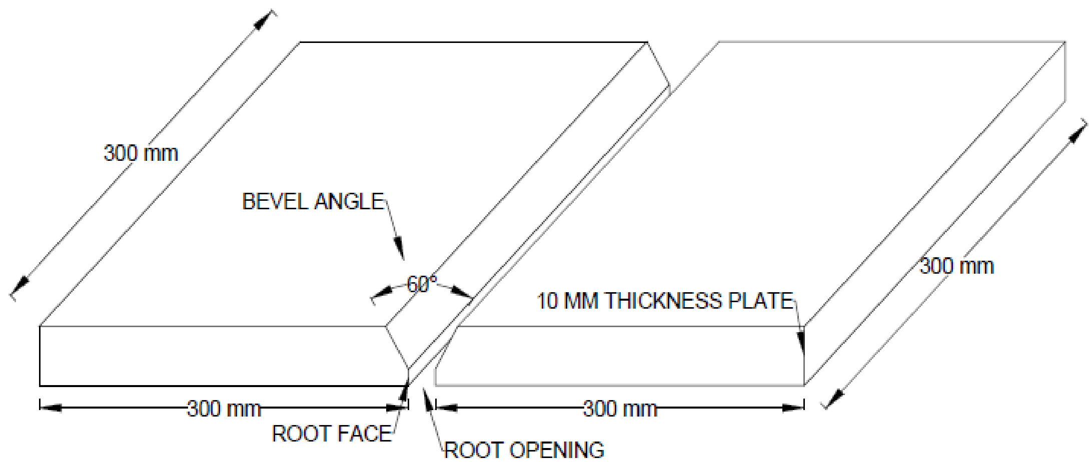

Figure 3.2: Sample preparation

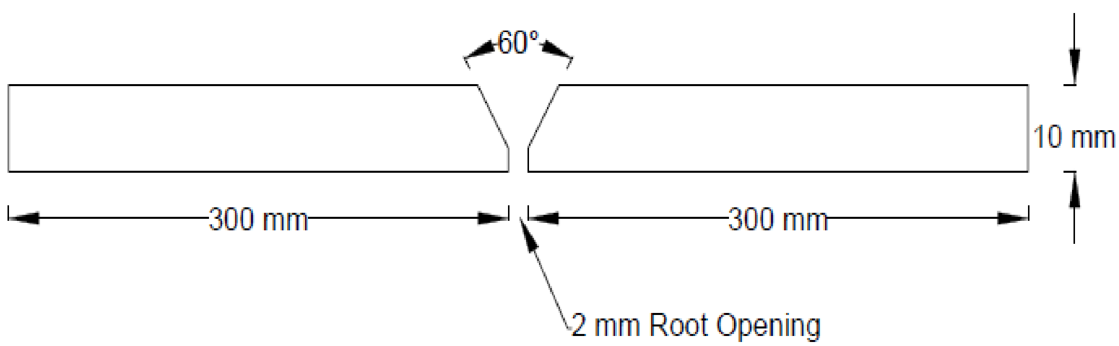

Figure 3.3: Sample A with root opening 2 mm

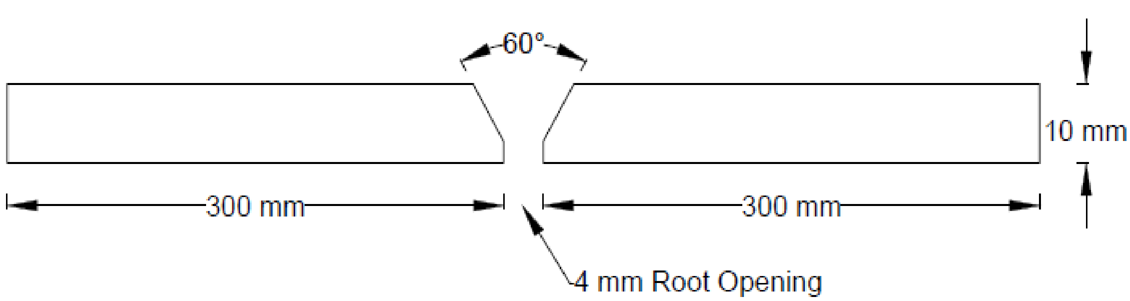

Figure 3.4: Sample B with root opening 4 mm

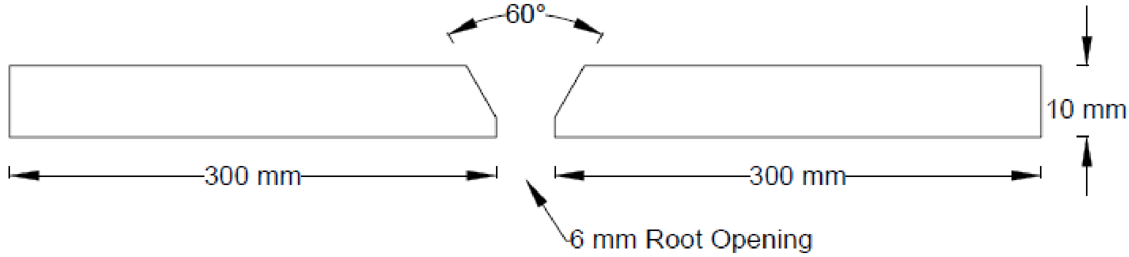

Figure 3.5: Sample C with root opening 6 mm

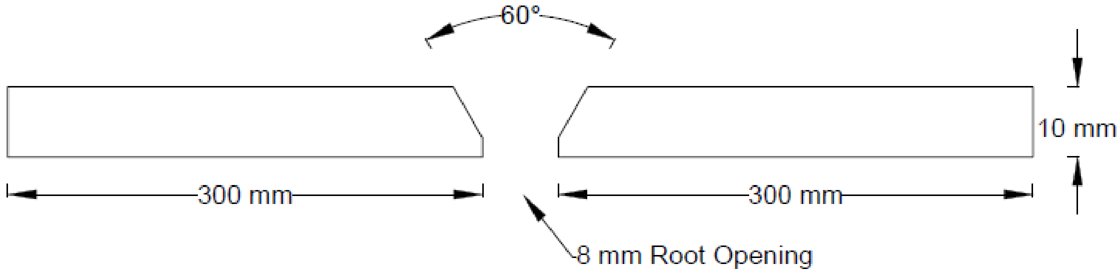

Figure 3.6: Sample D with root opening 8 mm

3.7 Welding of Test Samples

The welding of butt joint shall be done in multiple layers by use of 2.5 mm diameter E 7018 electrode by SMAW process. Weaving technique shall be used for welding in the sample as per the welding sequence shown in figure 3.7. During the weaving technique the electrode is moved in transverse direction along the motion of the weld. The welding shall be completed in four layers from one side.

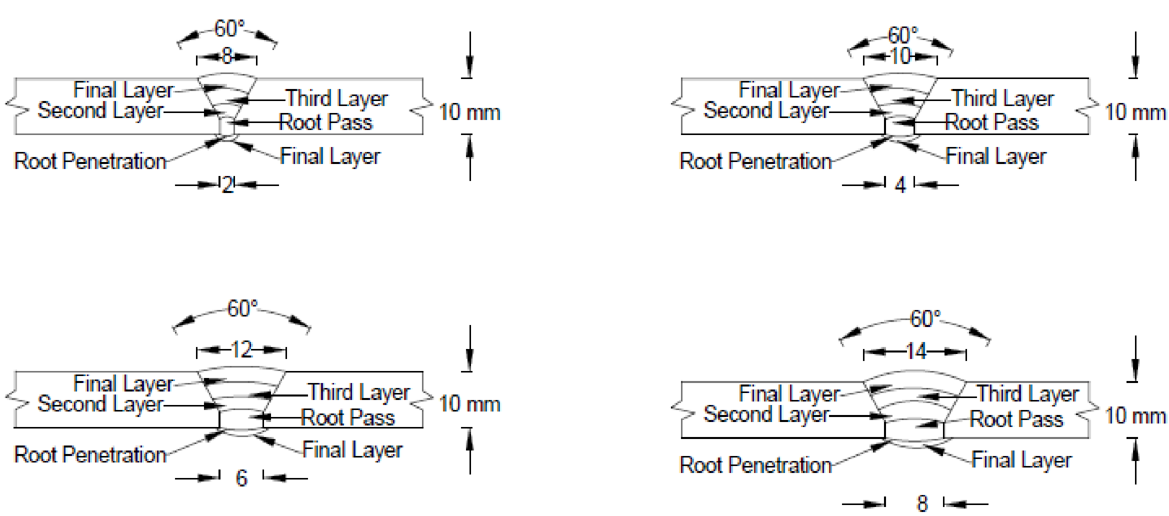

Figure 3.7: Weld layers for welding of test samples

3.8 Welding speed measurement

Welding speed shall be calculated by measuring the weld length and time taken to complete. The length and time shall be updated with consumption of each electrode. Welding speed for each layer shall be calculated.

3.9 Hardness Measurement

The welded samples shall be proceeded for hardness measurement. The hardness shall be measured by portable digital hardness tester based on Leebs hardness on the surface of weld metal, heat affected zone and parent metal as shown in figure 3.8. During a hardness test, an impact body with a spherically shaped tungsten carbide, silicon nitride, or diamond tip impacts, after being propelled to the specified velocity, the test surface from which it rebounds. The impact and rebound velocities are measured when the impact body is approximately 1 mm from the test surface. (ASTM International, 2019)

The leeb hardness number is a number equal to the ratio of the rebound velocity to the impact velocity pf a 3 mm or 5 mm (based on the type of impact device) diameter spherically shaped tungsten carbide, silicon nitride or diamond tipped impact body multiplied by 1000.

L= (Rebound Velocity/Impact Velocity) x 1000

The unit of leeb hardness number is HL. One or more suffix is added which provides the information of the type of impact device used. The leeb hardness number hence is converted to Vickers value and is noted at all points. MHT 170 model of portable hardness tester is used during this experiment. Calibration of equipment is done by making two impacts on a standardized test block. The leeb hardness instrument shall be considered verified if the individual readings fall with ± 6 HL units of the reference value.

The hardness shall be measured in five points of a single line. One point in weld zone, two points in heat affected zone of either side of weld and two points in either side of parent metal. First of all, the calibration of the hardness tester shall be done. The hardness of the calibration block is measured for testing the accuracy of hardness tester. After its confirmation according to the manufacturer's recommendation, hardness test shall be processed.

The hardness of weld metal shall be measured in center of the weld in weld metal zone. For the heat affected zone it shall be measured at point less than 5mm from the end point of weld and for the case of parent metal it shall be measured at a distance of 100 mm to 110 mm from the center of weld. The hardness shall be measured at the space of 25 mm along the direction of welding as shown in figure 3.9. The hardness of all four test samples shall be measured.

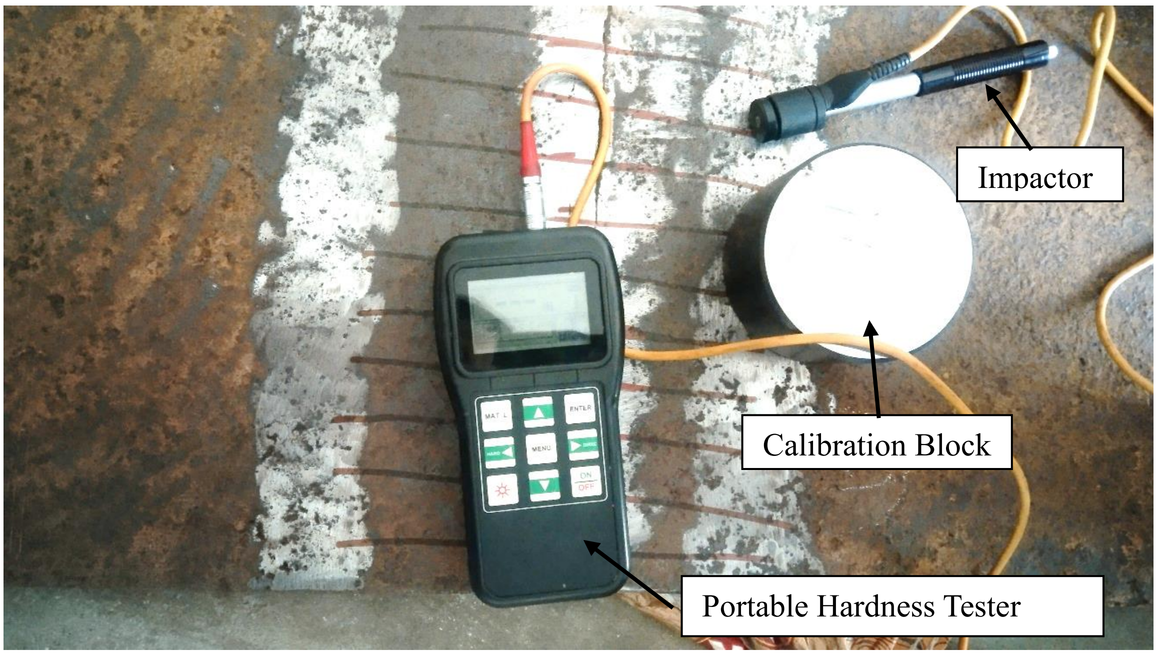

Figure 3.8: Calibration of digital hardness tester

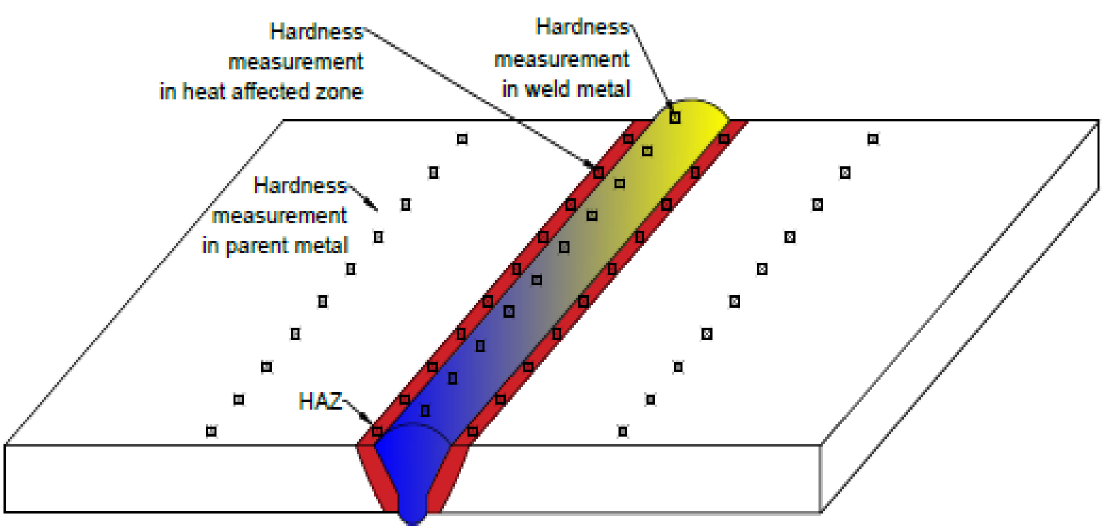

Figure 3.9: Hardness measurement points

3.10 Non-Destructive test of welds and measurement of root penetration

All the four samples after completion of welding shall be tested by using ultrasonic test. The welding shall be checked as per ASME Section V and the welding shall be accepted or rejected as per ASME Section VIII, Division 1 (The American Society of Mechanical Engineers, 2017). Root penetration shall be measured by use of pulse echo ultrasonic testing device as shown in figure 3.10. The reports of ultrasonic tests for root penetration are shown in **Appendix-3.** Similarly, all the welds shall be ultrasonically tested to check the presence of defects. The reports of ultrasonic tests of weld from bevel side is shown **Appendix-4**. After completion of measurement of root penetration, the weld shall be back chipped by grinding and hence welding shall also be performed from back side. The reports of ultrasonic tests for both side welding are shown in **Appendix-5**. The calibration certificate of the ultrasonic testing machine is shown in **Appendix-6.**

In case the defects are present then it shall be repaired. The defect shall be removed by grinding after which rewelding shall be done. The repaired sample shall be retested ultrasonically. After completion of all test then it shall be proceeded further for other process.

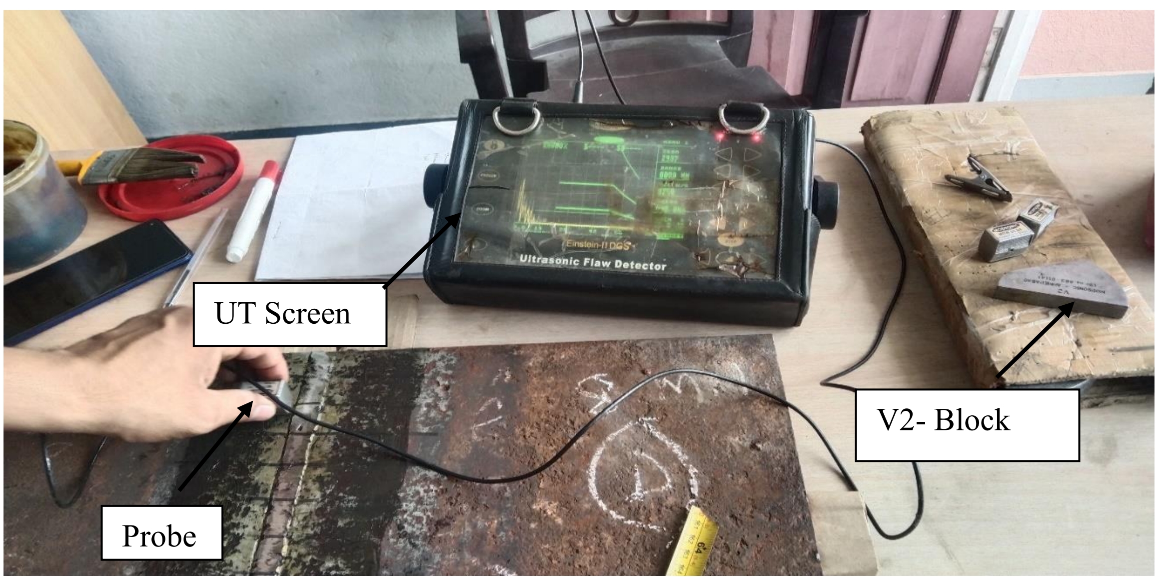

Figure 3.10: Ultrasonic testing of samples

3.11 Tensile Test of the Samples

The tensile test of welded test sample shall be proceeded further to inspect the tensile strength of welded sample and whether the sample shall break from the weld zone or the parent metal in all the samples. The tensile test shall be made as follows according to ASTM E8/E8M (ASTM) and tensile sample is prepared according to AWS B 4.0 as shown in figure 3.11. (American Welding Society, 2007)

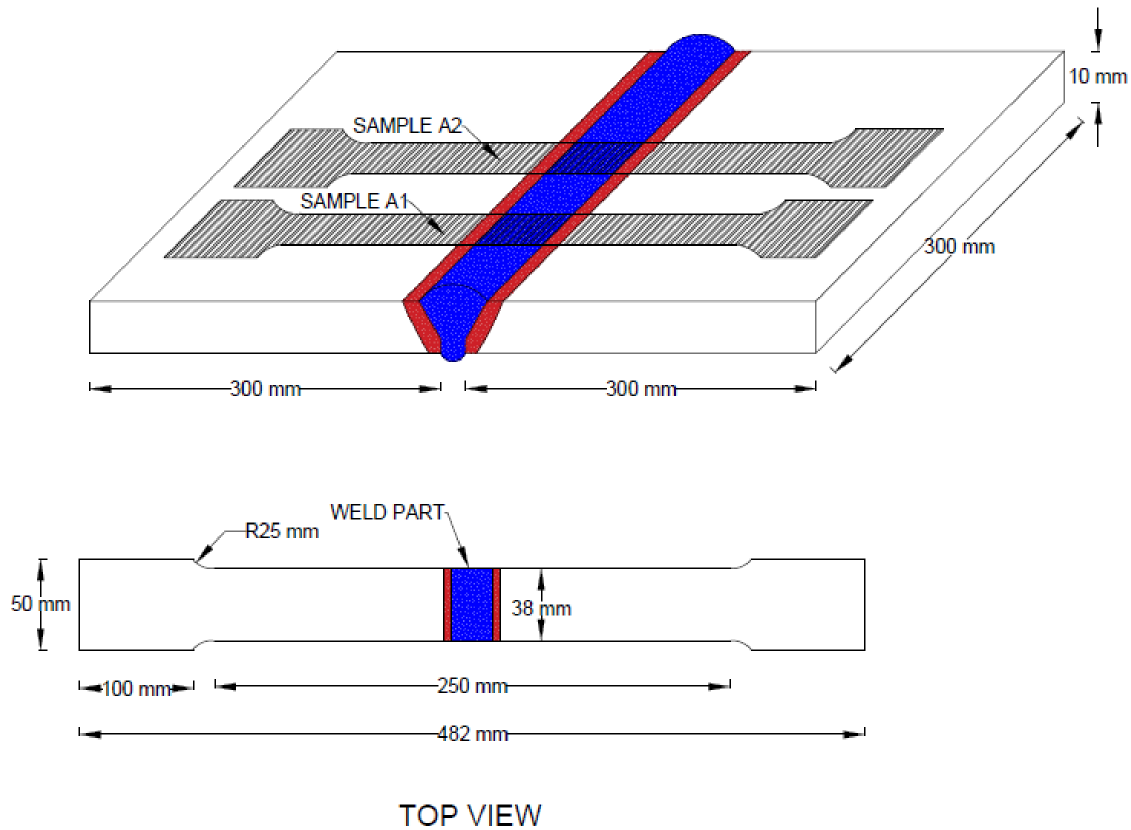

Figure 3.11: Tensile test sample

All the dimensions in figure 3.11 are in millimeters.

Two pieces of tensile test sample shall be taken from each set of welded samples. The tensile test sample shall as be described in above figure. Each welded sample shall be machine finished and uniform test sample shall be made. The weld zone shall be marked before tensile test.

The parallel reduced section shall be of 250 mm with grip length of 100 mm on both sides. The width of the parallel section shall be of 38 mm. Total of eight test samples shall be made for tensile test (2 each from different root opening samples). The naming of tensile test sample from sample A shall be named as A1 and A2. Similarly, the naming of tensile test sample from sample B, sample C and sample D shall be named as B1, B2, C1, C2, D1 and D2 respectively. The sample shall be cut in CNC flame cutting machine as shown in figure 3.12. This shall be further machine finished in milling machine as shown in figure 3.13. Tensile test shall be carried out in the Universal Testing Machine. The tensile strength of the test sample shall be measured and location of rupture shall be noted to confirm if the fracture is in the weld metal or in the parent metal.

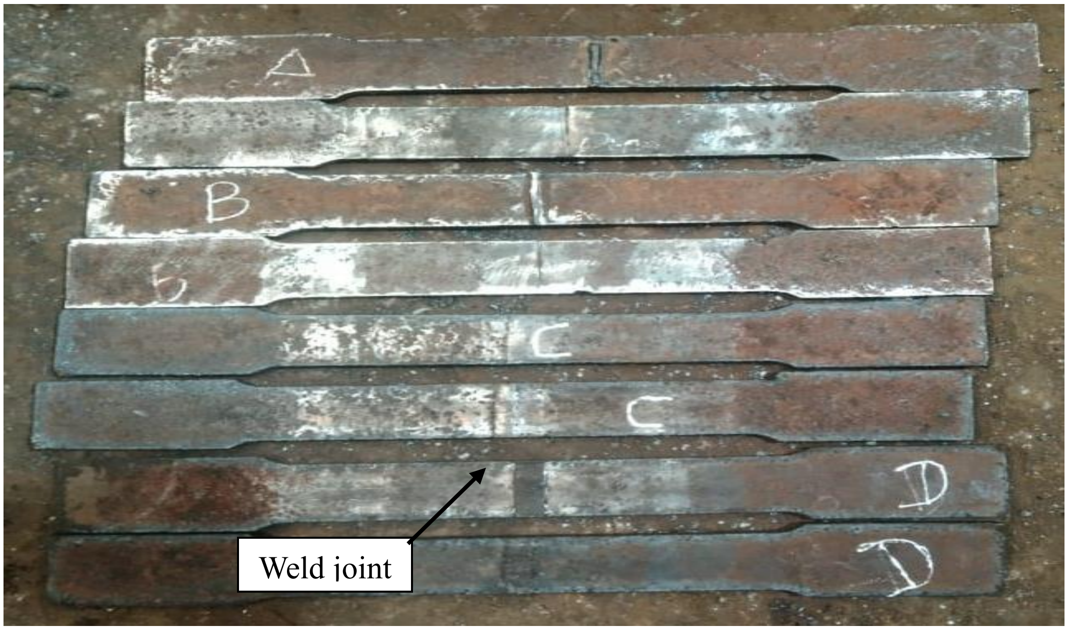

Figure 3.12: Cutting of welded sample by flame cutting in CNC machine

Figure 3.13:Tensile test samples preparation

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Measurement of Welding Speed

Welding speed was measured in each welding layer. The straight length of weld was taken after completion of each welding electrode. The time taken to complete each electrode was noted and hence the welding speed was calculated. The welding speed at root of sample A was 77.5 mm/min. Similarly, the welding speed was 82 mm/min, 82.25 mm/min and 83.5 mm/min in second layer, third layer and final layer of welding performed at sample A with the root opening of 2 mm as shown in table 4.1.

Table 4.1: Measurement of welding speed during welding of Sample A

SN	Weld Layer	Current	Voltage	Welding Length	Welding time	Welding Speed	Avg layer weld speed
		(A)	(V)	(mm)	(min)	(mm/min)	(mm/min)
1	Root Pass	70	20.6	85	1.12	76	77.50
2	Root Pass	70	20.6	85	1.09	78	
3	Root Pass	70	20.5	100	1.26	79	
4	Root Pass	70	20.5	50	0.65	77	
5	2nd Layer	85	21.6	90	1.09	83	82.00
6	2nd Layer	85	21.4	80	1.00	80	
7	2nd Layer	85	21.7	85	1.02	83	
8	2nd Layer	85	21.7	60	0.73	82	
9	3rd Layer	90	21.9	80	0.97	82	82.25
10	3rd Layer	90	22.2	85	1.03	83	
11	3rd Layer	90	21.3	80	0.97	82	
12	3rd Layer	90	22.8	80	0.97	82	
13	Final Layer	80	21.7	80	0.97	82	83.50
14	Final Layer	80	21.2	90	1.06	85	
15	Final Layer	80	20.7	90	1.06	85	
16	Final Layer	80	21.2	45	0.55	82	

The welding speed at root of sample B was 64.4 mm/min. Similarly, the welding speed was 77.5 mm/min, 81.5 mm/min and 81.5 mm/min in second layer, third layer and final layer of welding performed at sample B with the root opening of 4 mm as shown in table 4.2.

Table 4.2: Measurement of welding speed during welding of Sample B

SN	Weld Layer	Current	Voltage	Welding Length	Welding time	Welding Speed	Avg layer weld speed
		(A)	(V)	(mm)	(min)	(mm/mi	(mm/min)
1	Root Pass	70	21	60	1.02	59	64.40
2	Root Pass	70	21	70	1.10	64	
3	Root Pass	70	21.5	60	0.97	62	
4	Root Pass	70	21.5	60	0.83	72	
5	Root Pass	70	21.6	60	0.92	65	
6	2nd Layer	85	21.6	80	1.05	76	77.50
7	2nd Layer	85	21	80	1.03	78	
8	2nd Layer	85	21.7	80	1.02	78	
9	2nd Layer	85	22	65	0.83	78	
10	3rd Layer	90	24	80	1.02	78	81.50
11	3rd Layer	90	23.5	80	0.97	82	
12	3rd Layer	90	23.6	80	0.97	82	
13	3rd Layer	90	23.5	70	0.83	84	
14	Final Layer	80	20.2	80	1.10	73	81.50
15	Final Layer	80	20.7	85	1.06	80	
16	Final Layer	80	20.7	90	1.04	87	
17	Final Layer	80	20.1	50	0.58	86	

The welding speed at root pass of sample C was 57.83 mm/min. Similarly, the welding speed was 67 mm/min, 75 mm/min and 66.5 mm/min in second layer, third layer and final layer of welding performed at sample C with the root opening of 6 mm as shown in table 4.3.

Table 4.3: Measurement of welding speed during welding of Sample C

SN	Weld Layer	Current	Voltage	Welding Length	Welding time	Welding Speed	Avg layer weld speed
		(A)	(V)	(mm)	(min)	(mm/min)	(mm/min)
1	Root Pass	70	21.5	60	1.36	44	57.83
2	Root Pass	70	21.7	62	1.15	54	
3	Root Pass	70	21.1	50	0.85	59	
4	Root Pass	70	21.7	70	1.25	56	
5	Root Pass	70	21.1	80	1.20	67	
6	Root Pass	70	21.5	20	0.26	67	
7	2nd Layer	85	20.9	80	1.20	67	67.00
8	2nd Layer	85	20	80	1.22	66	
9	2nd Layer	85	20.7	80	1.18	68	
10	2nd Layer	85	22.2	80	1.20	67	
11	3rd Layer	90	21.8	90	1.23	73	75.00
12	3rd Layer	90	22.1	90	1.20	75	
13	3rd Layer	90	21.9	80	1.15	70	
14	3rd Layer	90	21.3	55	0.67	82	
15	Final Layer	80	21.7	120	1.90	63	66.50
16	Final Layer	80	20.2	90	1.30	69	
17	Final Layer	80	21.2	90	1.20	75	
18	Final Layer	80	21.5	10	0.17	59	

The welding speed at root of sample D was 34.13 mm/min. Similarly, the welding speed was 59.83 mm/min, 63.8 mm/min and 64.4 mm/min in second layer, third layer and final layer of welding performed at sample D with the root opening of 8 mm as shown in table 4.4.

Table 4.4: Measurement of welding speed during welding of Sample D

SN	Weld Layer	Current	Voltage	Welding Length	Welding time	Welding Speed	Avg layer weld speed
		(A)	(V)	(mm)	(min)	(mm/min)	(mm/min)
1	Root Pass	70	22.3	30	1.18	25	34.13
2	Root Pass	70	22.1	40	1.24	32	
3	Root Pass	70	21.7	40	1.20	33	
4	Root Pass	70	21.9	40	1.19	34	
5	Root Pass	70	20.9	45	1.20	38	
6	Root Pass	70	21.6	45	1.22	37	
7	Root Pass	70	21.5	30	0.77	39	
8	Root Pass	70	21.9	40	1.15	35	
9	2nd Layer	85	21.8	60	1.05	57	59.83
10	2nd Layer	85	20.5	70	1.11	63	
11	2nd Layer	85	21.4	70	1.11	63	
12	2nd Layer	85	20	20	0.33	61	
13	2nd Layer	85	21.3	65	1.08	60	
14	2nd Layer	85	20.7	22	0.40	55	
15	3rd Layer	90	21.5	70	1.12	63	63.80
16	3rd Layer	90	19.7	70	1.11	63	
17	3rd Layer	90	21.6	72	1.12	64	
18	3rd Layer	90	20.6	75	1.10	68	
19	3rd Layer	90	21	20	0.33	61	
20	Final Layer	80	21.1	70	1.13	62	64.40
21	Final Layer	80	21.2	80	1.13	71	
22	Final Layer	80	20.5	80	1.16	69	
23	Final Layer	80	20.9	50	0.75	67	
24	Final Layer	80	21.4	25	0.47	53	

The average welding speed for sample A with root opening of 2 mm was found to be 81.31 mm/min. Similarly, the welding speed decreased to 76.23 mm/min, 66.58 mm/min, 55.54

mm/min when the root opening was 4 mm, 6 mm and 8 mm consecutively as shown in figure 4.1.

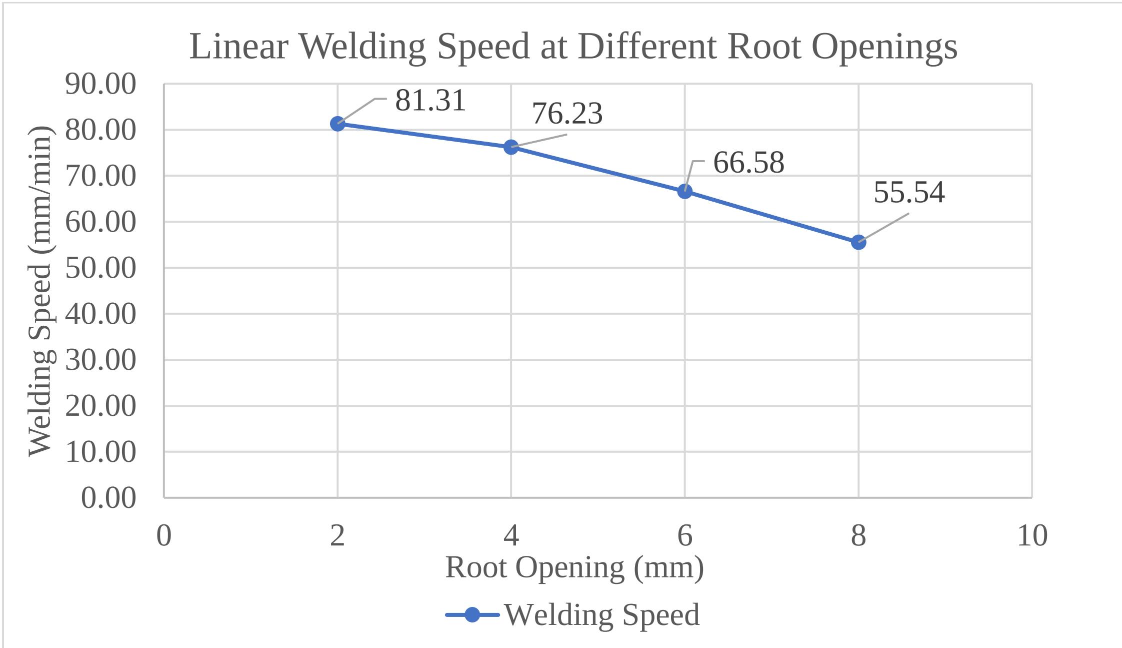

Figure 4.1:Welding speed at different root openings

The welding speed has inverse relationship with the heat input per unit length during welding. Hence, with the decrease in linear welding speed the heat input per unit length increases. But, during welding by weaving technique, the conventional straight length that has been accounted for welding speed may not be appropriate for speed calculation as there is the transverse movement of welding electrode. Hence, the inverse relation between speed and heat input per unit length may not be valid for welding performed by weaving technique.

4.2 Hardness Measurements

The hardness of the welded sample was measured in weld metal zone, heat affected zone and parent metal zone. Leebs hardness test was done by portable digital hardness tester and hardness unit was taken in HV converted by the portable hardness tester. Hardness was measured at the surface of the metal. The maximum hardness was found to be in weld metal followed by heat affected zone and parent metal. Similarly, the hardness increased in all weld metal, heat affected zone and parent metal while welding was done at increased root opening.

The effect of weaving leads to the considerable difference in the microstructures of HAZ. Similarly, the grain size of microstructure decreases in HAZ decreases with increase in root opening which is caused by the thermal fluctuation by reheating on the sidewall during weaving procedure. Therefore, the reheating can be recrystallized and then forms as a grain refinement (Jin-Hyeong Park, 2020). Fine grains are associated with high hardness hence with increase in root opening where the welding is performed by weaving technique the hardness increases.

The average hardness found in weld metal of sample A with root opening of 2 mm was 125.6 HV whereas the hardness in heat affected zone and parent metal was 104.3 HV and 96 HV respectively as shown in table 4.5.

Table 4.5: Measurement of hardness (HV) in Sample No A

SN	**Position of Measurement**	**Weld Metal**	**Heat Affected Zone**			**Parent Metal**			**Remarks**
			Left	**Right**	**Avg**	**Left**	**Right**	**Avg**	
1	25	138	98	102	100	86	88	87	
2	50	129	108	103	106	96	100	98	
3	75	125	104	97	101	97	101	99	
4	100	132	101	103	102	98	99	99	
5	125	131	102	99	101	94	98	96	
6	150	120	103	101	102	95	99	97	
7	175	119	104	109	107	96	101	99	
8	200	122	111	104	108	95	101	98	
9	225	123	102	100	101	99	99	99	
10	250	133	111	108	110	94	98	96	
11	275	116	110	107	109	96	101	99	
12	300	119	106	103	105	85	84	85	
Average		**125.6**			**104.3**			**96**	

The average hardness found in weld metal of sample B with root opening of 4 mm was 127.3 HV whereas the hardness in heat affected zone and parent metal was 106.8 HV and 96.2 HV respectively as shown in table 4.6. All the measurements have been taken at the top face of welded samples.

Table 4.6: Measurement of hardness (HV) in Sample No B

SN	**Position of Measurement**	**Weld Metal**	**Heat Affected Zone**			**Parent Metal**			**Remarks**
			Left	**Right**	**Avg**	**Left**	**Right**	**Avg**	
1	25	110	94	102	98	90	91	91	
2	50	139	124	107	116	97	96	97	
3	75	134	104	107	106	99	97	98	
4	100	127	103	102	103	99	97	98	
5	125	142	113	102	108	99	98	99	
6	150	142	105	97	101	92	98	95	
7	175	119	114	101	108	99	99	99	
8	200	117	108	100	104	98	97	98	
9	225	118	110	110	110	96	95	96	
10	250	139	110	118	114	94	96	95	
11	275	134	114	111	113	99	97	98	
12	300	106	100	99	100	89	91	90	
Average		**127.3**			**106.8**			**96.2**	

The average hardness found in weld metal of sample C with root opening of 6 mm was 136.8 HV whereas the hardness in heat affected zone and parent metal was 107.7 HV and 96.5 HV respectively as shown in table 4.7.

Table 4.7: Measurement of hardness (HV) in Sample No C

SN	Position of Measurement	Weld Metal	Heat Affected Zone (HAZ)			Parent Metal			Remarks
			Left	Right	Avg	Left	Right	Avg	
1	25	135	109	106	108	97	95	96	
2	50	139	108	109	109	95	93	94	
3	75	137	112	107	110	94	97	96	
4	100	142	109	102	106	96	96	96	
5	125	139	114	104	109	97	98	98	
6	150	135	105	109	107	96	95	96	
7	175	138	101	110	106	97	98	98	
8	200	130	112	100	106	94	98	96	
9	225	138	105	110	108	97	96	97	
10	250	137	108	118	113	95	98	97	
11	275	137	106	111	109	98	97	98	
12	300	135	102	99	101	95	96	96	
Average		**136.8**			**107.7**			**96.5**	

The average hardness found in weld metal of sample D with root opening of 8 mm was 139.2 HV whereas the hardness in heat affected zone and parent metal was 108.6 HV and 96.6 HV respectively as shown in table 4.8.

Table 4.8: Measurement of hardness (HV) in Sample No D

SN	Position of Measurement	Weld Metal	Heat Affected Zone (HAZ)			Parent Metal			Remarks
			Left	Right	Avg	Left	Right	Avg	
1	25	139	110	112	111	94	97	96	
2	50	134	112	109	111	97	94	96	
3	75	131	111	115	113	97	96	97	
4	100	140	105	112	109	96	95	96	
5	125	141	106	115	111	95	94	95	
6	150	135	103	117	110	95	94	95	
7	175	137	103	109	106	98	99	99	
8	200	143	107	115	111	98	97	98	
9	225	142	104	109	107	95	94	95	
10	250	147	107	103	105	96	97	97	
11	275	136	109	102	106	97	97	97	
12	300	145	105	101	103	96	99	98	
Average		**139.2**			**108.6**			**96.6**	

The hardness value of weld metal increased from 125.6 to 127.3, 136.8 and 139.2 when the root opening increased from 2 mm to 4 mm, 6 mm and 8 mm respectively. The hardness value of heat affected zone increased from 104.3 to 106.8, 107.7 and 108.6 when the root opening increased from 2 mm to 4 mm, 6 mm and 8 mm respectively. The hardness value of parent metal increased from 96 to 96.2, 96.5 and 96.6 when the root opening increased from 2 mm to 4 mm, 6 mm and 8 mm respectively as shown in figure 4.2 and figure 4.3. Hence, with the increase in root opening and welding performed by the weaving technique the hardness of the material increases.

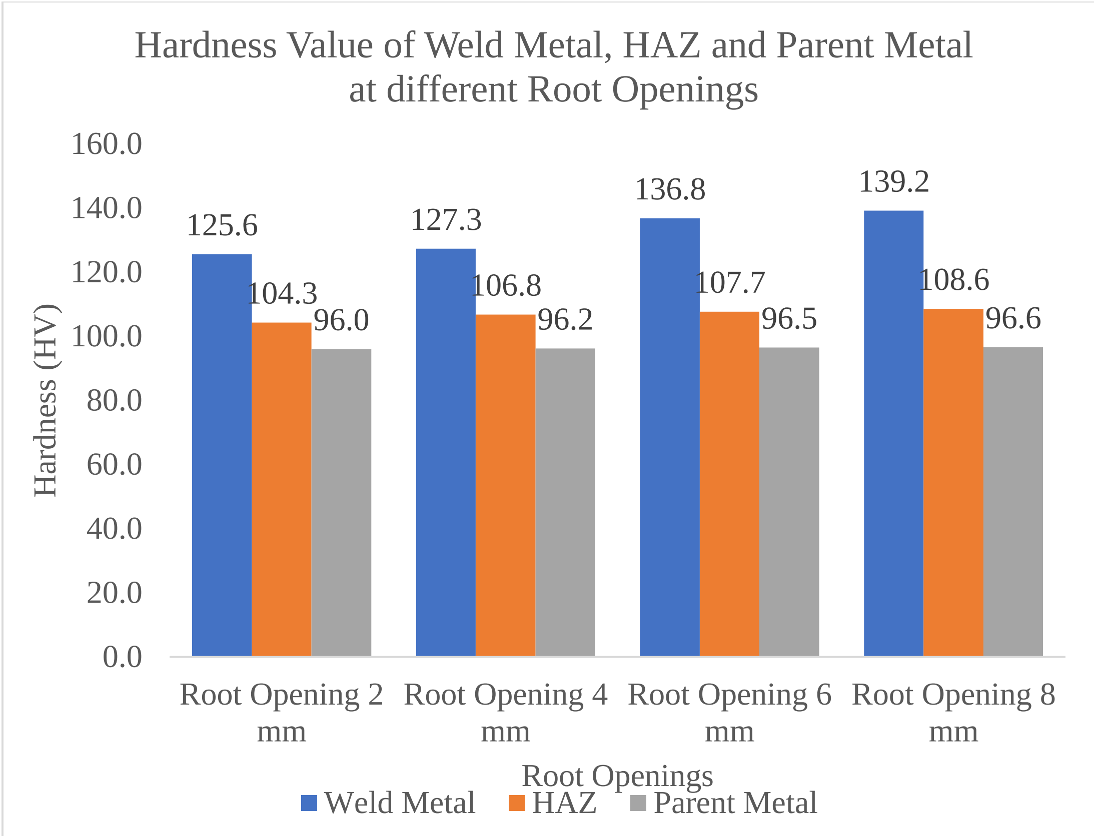

Figure 4.2: Hardness values at different point of WM, HAZ and PM

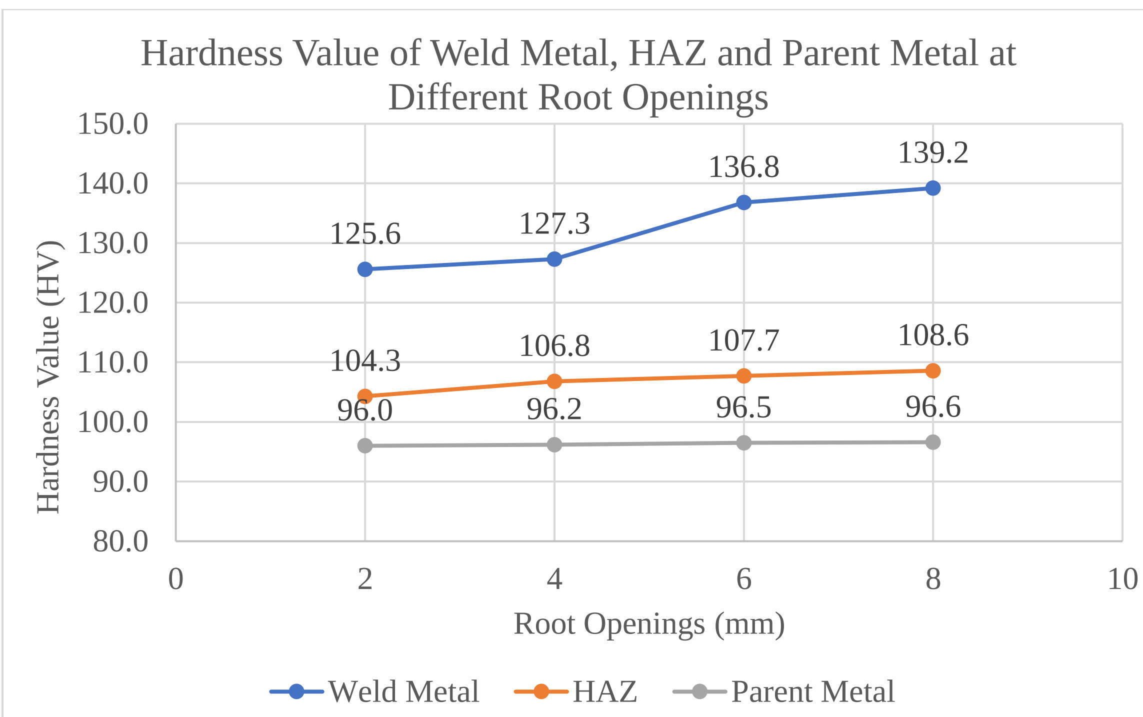

Figure 4.3: Hardness values at different root openings

4.3 Root Penetration

Root penetration was measured with the help of ultrasonic testing. Pulse echo equipment was used at frequency of 2 MHz with 60 degree and 70 degree probe with reference gain on 57 dB. Root penetration was measured for all the samples of Sample A, Sample B, Sample C and Sample D with root openings of 2 mm, 4 mm, 6 mm and 8 mm respectively.

The root penetration in first 90 mm of weld length in sample A of root opening 2 mm was 10 mm. The root penetration was only 9 mm from weld length of 90 mm to 170 mm. The root penetration was further decreased to 8.8 mm in 280 mm weld length as shown in figure 4.4.

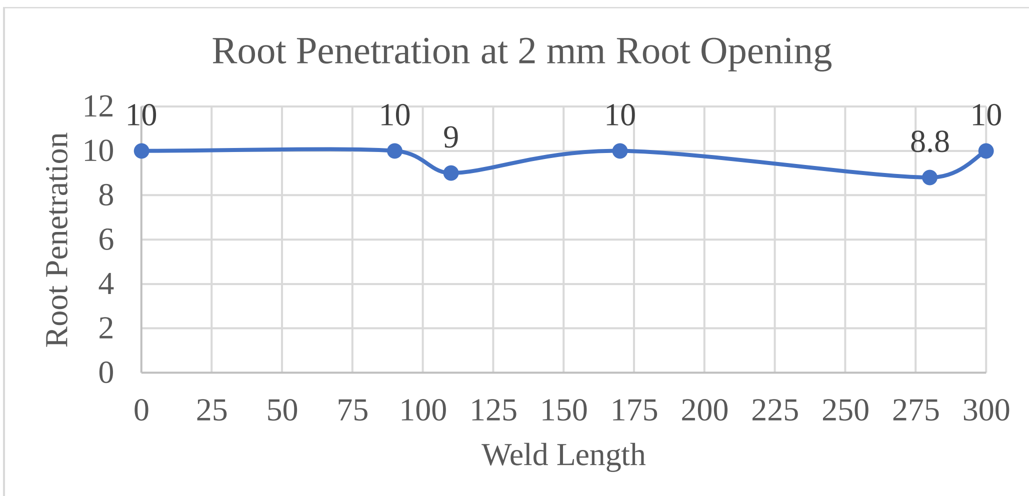

Figure 4.4: Root penetration at 2 mm root opening

Figure 4.5:Photographic representation of root penetration at 2 mm root opening

The root penetration in sample B with root opening of 4 mm was found to be complete with 10 mm from 0 mm to 300 mm weld length as shown in figure 4.6.

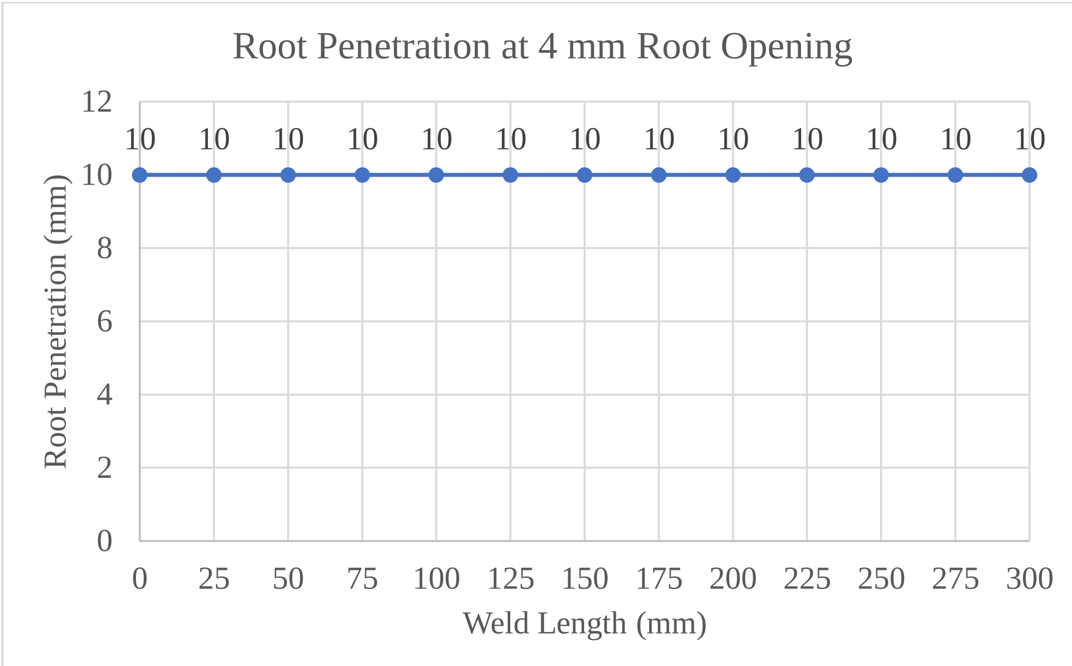

Figure 4.6:Root penetration data at 4 mm root opening

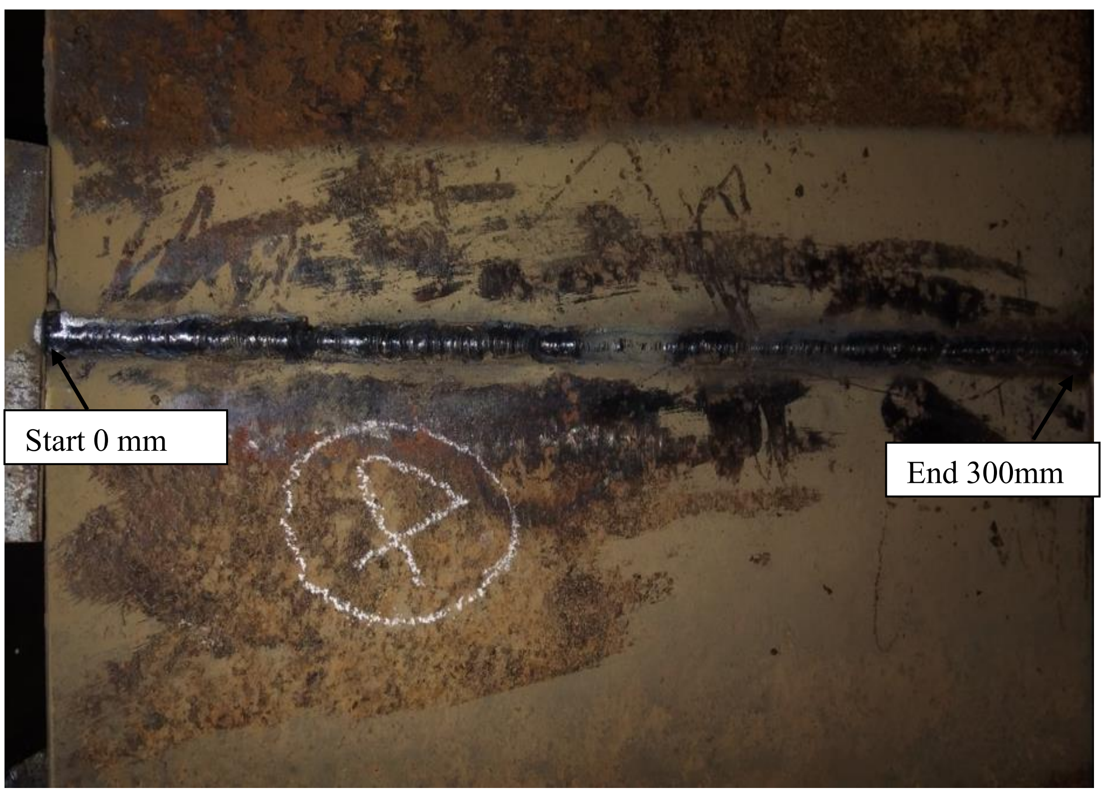

Figure 4.7:Photographic representation of root penetration at 4 mm root opening

The root penetration in sample C with root opening of 6 mm was found to be improper. Various variation was found in root penetration. The minimum root penetration of 8.1 mm was observed and at multiple locations there was no complete root penetration as shown in figure 4.8.

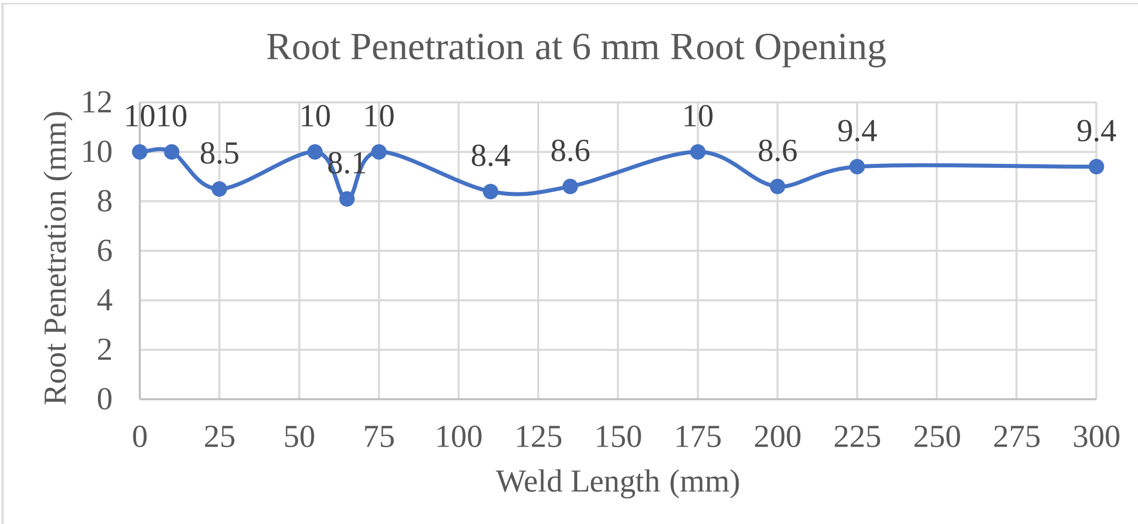

Figure 4.8:Root penetration data at 6 mm root opening

Figure 4.9:Photographic representation of root penetration at 6 mm root opening

The root penetration in sample D with root opening of 6 mm was also found to be improper. Various variation was found in root penetration. The minimum root penetration of 6.9 mm was observed and at multiple locations there was no complete root penetration as shown in figure 4.10.

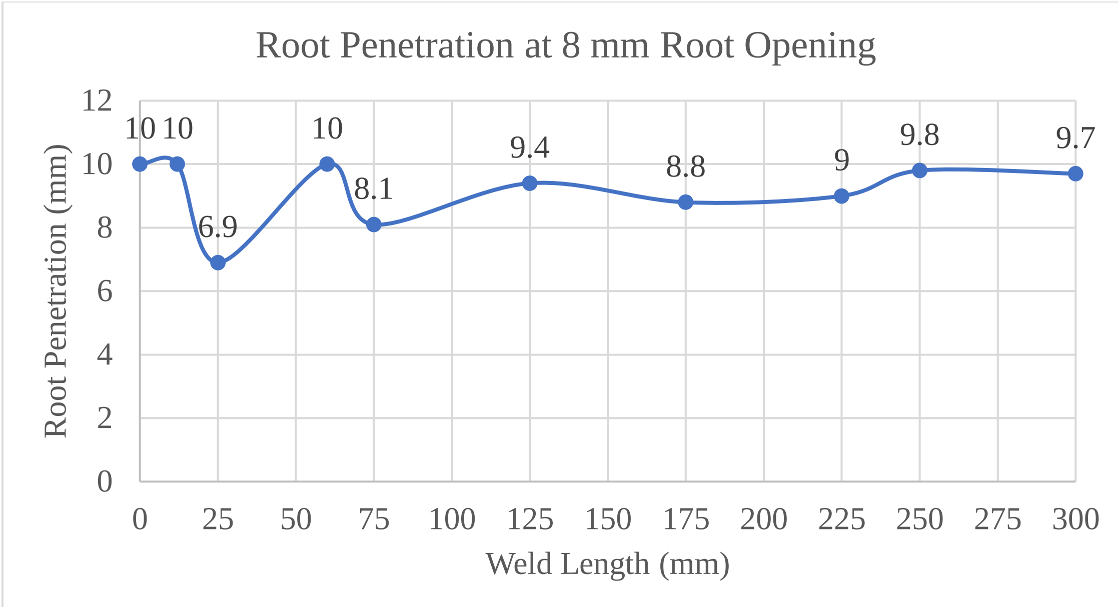

Figure 4.10:Root penetration in 8 mm root opening

Figure 4.11:Photographic representation of root penetration at 8 mm root opening

It was found that there is a complete root preparation in root opening of 4 mm whereas minimum root penetration of 8.8 was seen in root opening of 2 mm, 8.1 mm in root opening of 6 mm and 6.9 mm in root opening of 8 mm. It is seen that with the increase in root opening of butt weld joints, the penetration of weld becomes improper hence root penetration decreases.

4.4 Tensile Strength

Tensile strength of the samples was measured in the Universal Testing Machine manufactured by Shimadzu Seisakusho Limited in the Central Material Testing Laboratory of Pulchowk Campus. The thickness of each sample was measured at three points and corresponding width of sample was measured as shown in table 4.9.

Table 4.9: Measurement sheet for thickness and width of tensile test samples

SN	Sample	Thickness (mm)	Min Thickness	Width (mm)	Ref. Width (mm)	Remarks
1	A1	7.07	7.07	38.33	38.33	Root Opening 2 mm
2		7.62		38.01		
3		7.59		37.95		
4	A2	7.33	7.33	38.41	38.41	
5		7.47		38.15		
6		7.55		37.99		
7	B1	7.05	6.82	38.2	37.99	Root Opening 4 mm
8		7.19		38.07		
9		6.82		37.99		
10	B2	7.28	7.28	38.16	38.16	
11		7.74		38.07		
12		7.52		38.25		
13	C1	7.4	6.83	38.35	38.09	Root Opening 6 mm
14		7.45		38.04		
15		6.83		38.09		
16	C2	8.32	7.67	37.87	38.01	
17		8.75		37.79		
18		7.67		38.01		
19	D1	7.35	7.35	38.01	38.01	Root Opening 8 mm
20		7.52		38.15		
21		7.52		38.01		
22	D2	7	6.78	38.05	38.19	
23		7.13		38.11		
24		6.78		38.19		

Individual yield strength of samples A1, A2, B1, B2, C1, C2, D1 and D2 was obtained as listed in table 4.10.

Table 4.10: Yield Strength of different welded samples obtained from UTM

SN	Sample	Thickness (mm)	Width (mm)	Area (mm^2)	Yield Load(kg)	Yield Strength (N/mm^2)
1	A1	7.07	38.33	270.99	7,900.00	285.98
2	A2	7.33	38.41	281.55	7,600.00	264.81
3	B1	6.82	37.99	259.09	7,100.00	268.83
4	B2	7.28	38.16	277.80	7,900.00	278.97
5	C1	6.83	38.09	260.15	7,250.00	273.39
6	C2	7.67	38.01	291.54	8,600.00	289.38
7	D1	7.35	38.01	279.37	7,600.00	266.87
8	D2	6.78	38.19	258.93	7,300.00	276.57

The yield strength of sample A with root opening of 2 mm was 275.4 N/mm^2. Similarly, the yield strength was 273.90 N/mm^2, 281.39 N/mm^2 and 271.72 N/mm^2 of the sample B with root opening 4 mm, sample C with root opening 6 mm and sample D with root opening 8 mm respectively as shown in figure 4.12. The yield strength of all the welded samples were found to be above 250 N/mm^2.

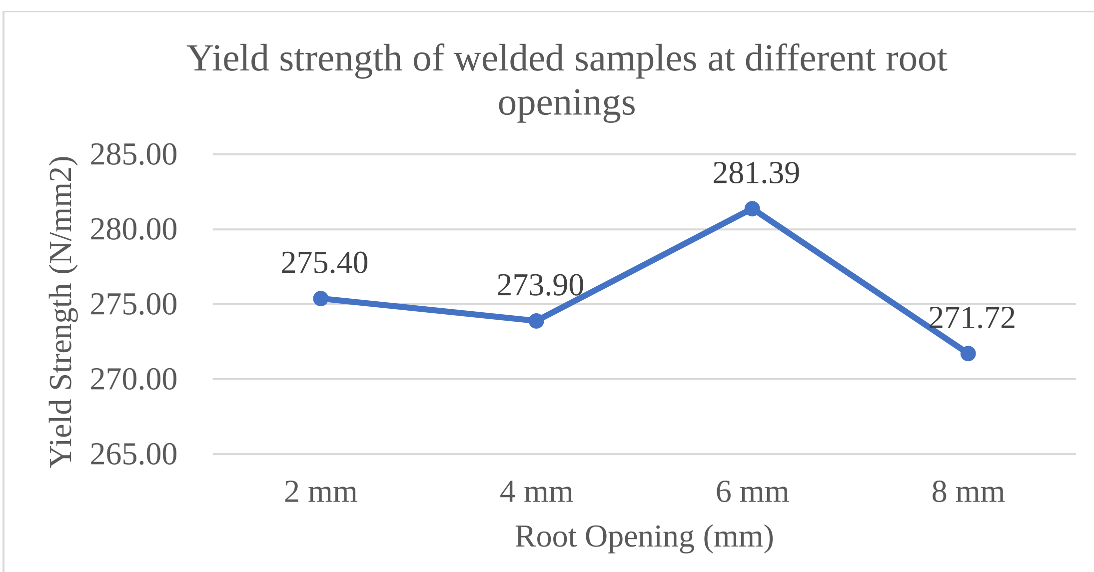

Figure 4.12: Yield strength of welded samples at different root openings

The tensile strength of samples A1, A2, B1, B2, C1, C2, D1 and D2 are obtained as shown in table 4.16. The tensile strength of sample A with root opening of 2 mm was 370.07 N/mm^2. Similarly, the tensile strength was 376.14 N/mm^2, 376.09 N/mm^2 and 370.04 N/mm^2 of the sample B with root opening 4 mm, sample C with root opening 6 mm and sample D with root opening 8 mm respectively as shown in figure in 4.13. All the samples ruptured from parent metal during tensile test as shown in figure 4.15. This means the effect of root opening is not seen in the welded part of the test sample done by E7018 electrode in E250 grade material.

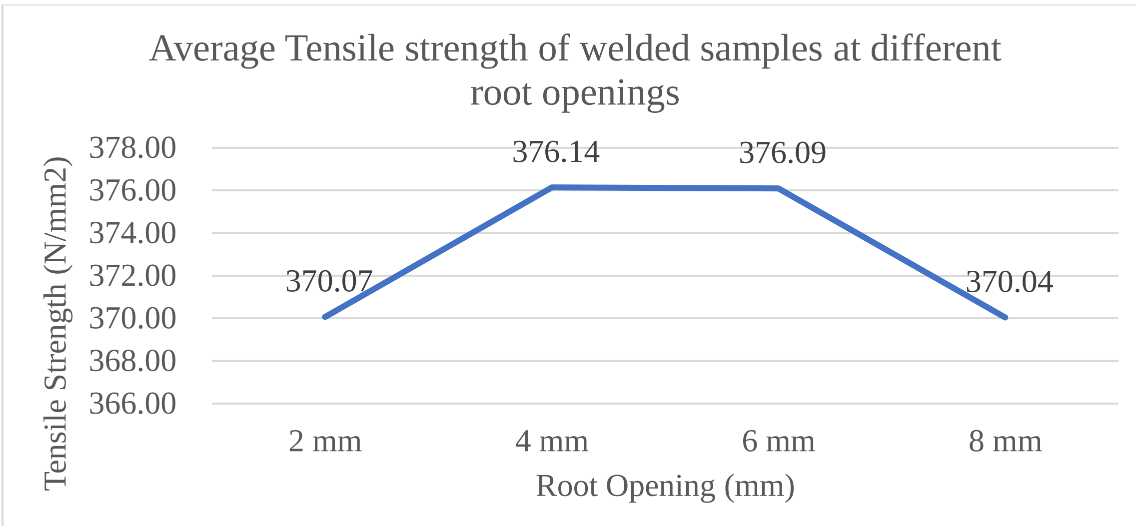

Figure 4.13: Tensile strength of welded samples at different root openings

Table 4.11: Tensile Strength (UTS) of different welded samples obtained from UTM

SN	Sample	Thickness (mm)	Width (mm)	Area (mm^2)	Ultimate load(kN)	Ultimate Tensile Strength(N/mm^2)
1	A1	7.07	38.33	270.99	101.50	374.55
2	A2	7.33	38.41	281.55	102.93	365.58
3	B1	6.82	37.99	259.09	97.12	374.85
4	B2	7.28	38.16	277.80	104.85	377.43
5	C1	6.83	38.09	260.15	96.14	369.56
6	C2	7.67	38.01	291.54	111.55	382.62
7	D1	7.35	38.01	279.37	101.97	365.00
8	D2	6.78	38.19	258.93	97.12	375.08

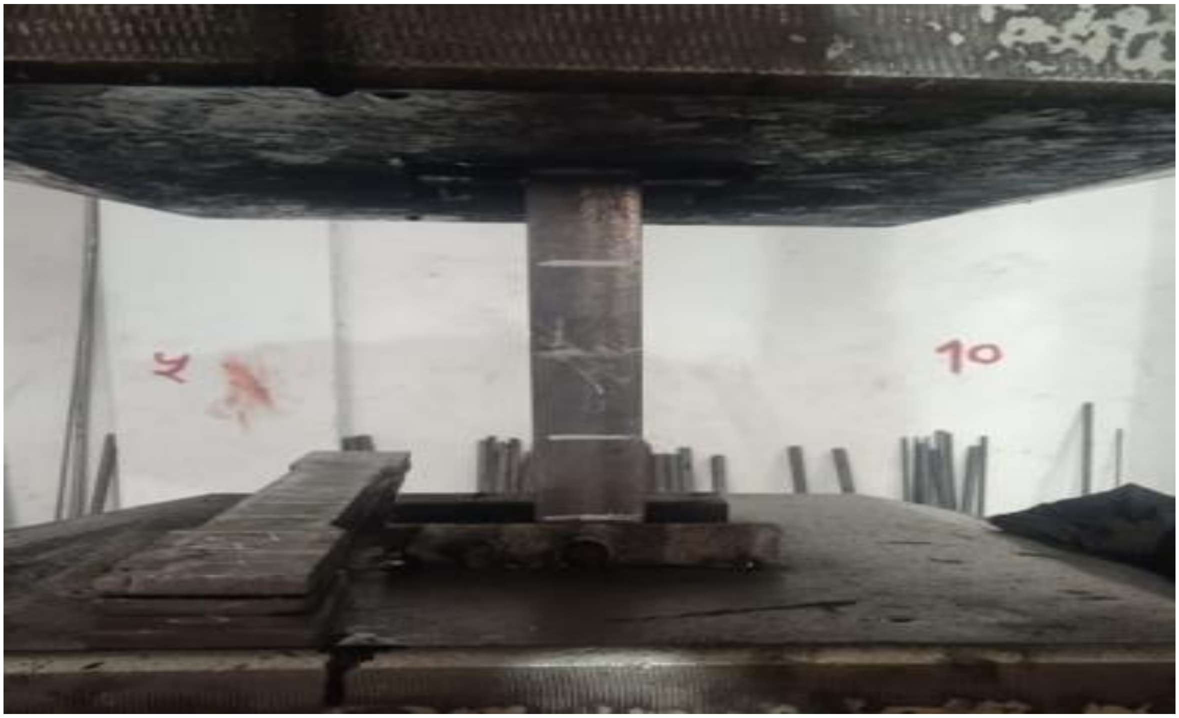

Figure 4.14: Tensile test in UTM

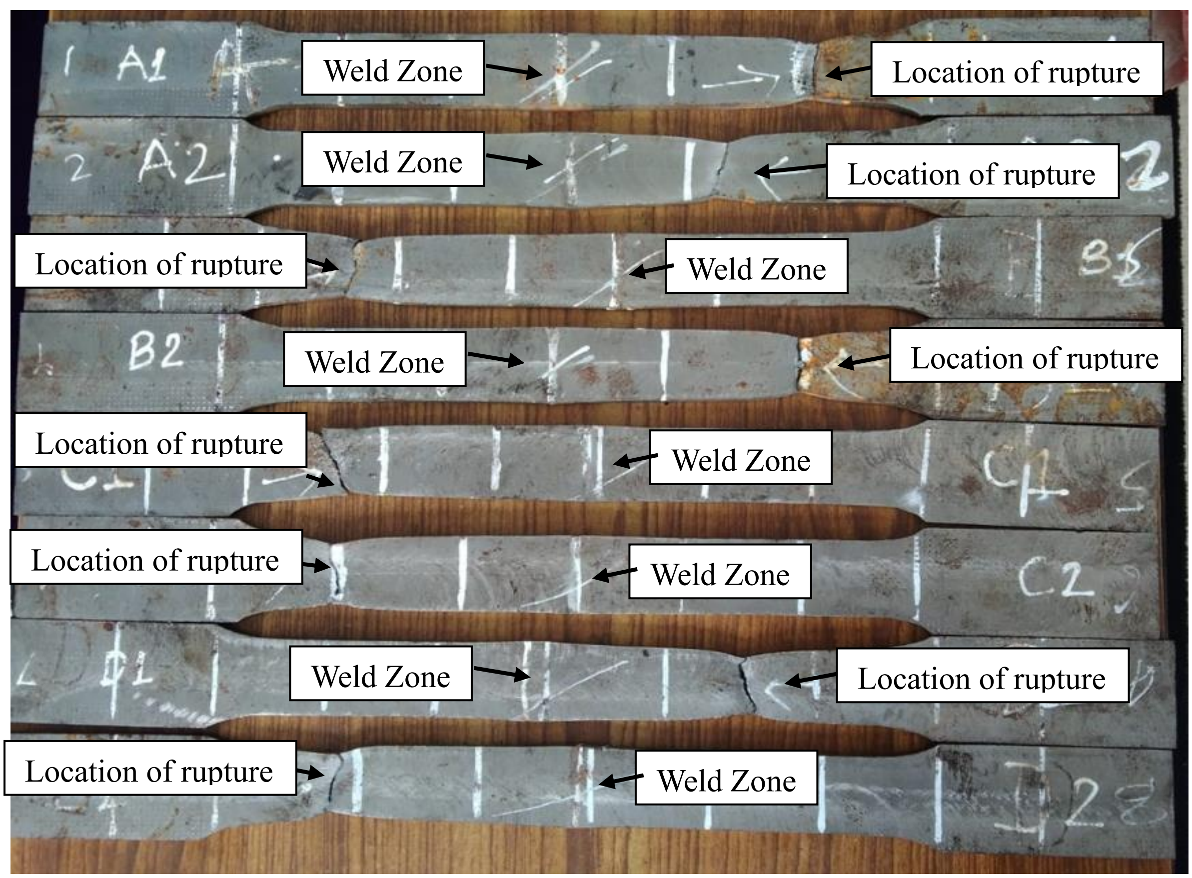

Figure 4.15: Samples after tensile test with location of rupture

CHAPTER FIVE: CONCLUSION AND RECOMMEDATION

The study calculated the welding speed while performing welding at different root opening of 2 mm ,4 mm, 6 mm and 8 mm. The welding speed decreased while welding from 2 mm to 8 mm. The welding speed decreased from 81.31 mm/min to 76.23 mm/min, 66.58 mm/min and 55.54 mm/min when welding performed at root opening of 2 mm, 4 mm, 6 mm and 8 mm respectively. As the root opening increases, the time required to fuse the welding electrode to base metal increases causing the linear welding speed to decrease.

The hardness of each zone, weld metal, heat affected zone and parent metal increased while performing welding at 2 mm, 4 mm, 6 mm and 8 mm root opening. The hardness in weld metal increased from 125.6 HV to 127.3 HV, 136.8 HV and 139.2 HV when performing welding at root opening of 2 mm, 4 mm, 6 mm and 8 mm respectively. Similarly, the hardness in heat affected zone increased from 104.3 HV to 106.8 HV, 107.7 HV and 108.6 HV when performing welding at root opening of 2 mm, 4 mm, 6 mm and 8 mm respectively. Similarly, in the same sample the hardness was higher in weld metal followed by heat affected zone and unaffected parent metal. With the increase in root opening of weld joints, the grain size is decreased caused by thermal fluctuation by reheating on sidewall during weaving procedure which hence increases the hardness.

The root penetration was optimum at 4 mm compared to 2 mm, 6 mm and 8 mm. There was complete root penetration of 10 mm while welding at root opening of 4 mm. Minimum root penetration of 8.8 was seen in root opening of 2 mm, 8.1 mm in root opening of 6 mm and 6.9 mm in root opening of 8 mm. The root penetration decreased with an increase of root opening. With the increase in root opening, heat input has to be increased. As, the experiment is carried in constant current and voltage, the heat input required for 6 mm and 8 mm root opening is less causing less root penetration in welds. Similarly, in SMAW welding, it also becomes difficult for welders to maintain proper arc length causing defects in root penetration while performing welding by weaving technique. Hence, the root opening of 4 mm must be maintained in order to receive proper root penetration from technical acceptability point of view. As the 4 mm root opening falls under the tolerance of root opening as suggested by American Welding Society, its financial impact is not present.

During the tensile test, the rupture location was found in parent metal of all the samples. No rupture was found in weld zone. Hence, there is no effect in minimum required tensile strength of welded zone when welding is performed by E7018 welding electrode in E250 grade materials by weaving technique varying the root opening from 2 mm to 8 mm. The tensile strength of weld part is strong enough to join E250 plates at root opening from 2 mm to 8 mm.

The tensile strength of sample with root opening of 2 mm was 370.07 N/mm^2. Similarly, the tensile strength was 376.14 N/mm^2, 376.09 N/mm^2 and 370.04 N/mm^2 of the sample with root opening 4 mm, 6 mm and 8 mm respectively. Hence, from this experiment it is concluded that there is no effect in minimum required tensile strength of welded joints being performed by E7018 electrodes in E250 plates at different root opening from 2 mm to 8 mm by weaving technique but proper care must be taken of hardness. The hardness increases with increase in root opening while performing welding by weaving technique. Though the root opening is a non-essential variable for qualification of WPS, it is always recommended to optimize the welding parameters like welding current, welding voltage and welding speed so that the hardness may not exceed the referenced value and hence maintain the good engineering practice.

It is further recommended to extend this research incorporating the following suggestions:

- Microstructure analysis of weld zone, heat affected zone and parent metal
- Experimenting the hardness and tensile strength properties at samples of thickness more than 38 mm.
- Use of higher-grade materials like E350, E450 and others.
- Welding to be performed at lower ambient temperature (below 5 °C)
- Study effect of preheating and post heating in weld zone for hardness

REFERENCES

Abdulkareem Aloraier, A. A. (2021). TBW technique by varying polarities in SMAW as an alternative to PWHT.

Abdullah Modh Tahir, N. A. (2018). Investigation on Mechanical Properties of Welded Material under different types of Welding Filler (Shielded Metal Arc Welding). *AIP Conference Proceedings 1958.*

Alam Vasko, J. S. (2019). Accuracy of Portable Hardness Testers.

American Society of Civil Engineers. (2012). *Steel Penstocks.*

American Welding Society. (1991). *Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding.*

American Welding Society. (2000). *Structural Welding Code-Steel.*

American Welding Society. (2007). *Standard Methods for Mechanical Testing of Welds.*

ASTM International. (2019). *Standard Test Method for Leeb Hardness Testing of Steel Products.*

ASTM. (n.d.). *Standard Test Methods for Tension Testing of Metallic Materials.*

Azwinur, S. A. (2022). The effect of electrode type on the tensile strength characteristics of welded joints between S.240 Tp.304 stainless steel and SA.36 carbon steel alloys through SMAW welding process. *International Journal of Integrated Engineerng* .

Baghel, P. K. (2022). Effect of SMAW process parameters on similar and dissimilar metal welds: An overview.

Barry G. Bubar, P. (2011). *Pipeline Planning and Construction Field Manual.*

Bijaya Kumar Khamari, S. S. (2019). Effects of welding parameters on mechanical and microstructural properties of GMAW and SMAW mild steel joints.

Bureau of Indian Standards. (2011). *IS 2062 (2011):Hot Rolled Medium and High Tensile Structural Steel-Specification.* New Delhi.

Deepak Pathak, R. P. (2020). Experimental investigation of effects of welding current and electrode angle on tensile strength of shihelded metal arc welded low carbon steel plates. *Materials Today:Proceedings*.

Deepak Pathak, R. P. (2020). To study the influence of process parameters on weld bead geometry in shielded metal arc welding. *Mateials Today:Proceedings*.

G Magudeeswaran, V. B. (2008). Effect of Welding Processes and Consumables on Tensile and Impact Properties of High Strength Quenched and Tempered Steel Joints. *Journal of Iron and Steel Research*.

I. Sattari-Far, M. F. (2009). Effect of the weld groove shape and pass number on residual stresses in butt-welded pipes. *International Journal of Pressure Vessels and Piping*.

J.R. Deepak, V. B. (2021). Non-destructive tesing (NDT) techniques for low carbon steel welded joints: A review and experimental study. *Material Today: Proceedings*.

Jin-Hyeong Park, S.-H. K.-S.-H.-W. (2020). Effect of process parameters on root pass welding and analysis of microstructure in V-groove pulsed gas metal arc welding for mild steel. *The International Journal of Advanced Manufacturing Technology*.

K V Gogolinskii, V. A. (2019). Mechanical properties measurements with portable hardness testers : advantages, limitations, prospects.

K.R. Jagtap, M. R. (2017). Effect of Welding Parameters on Tensile & Yield Strength of IS 2062 grade steel Using Design of Experiment Approach.

LS. Sisira K. Weerasekaralage, S. P. (2019). Optimization of Shielded Metal Arc Welding (SMAW) process for mild steel.

Mohd-Lair, N. A. (2021). SMAW:The effects of currents and welding rod diameters on welded joint ultimate tensile strength using the full factorial DOE. *Journal of Physics:Conference Series*.

Mohsen Amraei, A. A. (2019). Effects of heat input on the mechanical properties of butt-welded high and ultra-high strength steels. *Engineering Structures*.

Mst Nazma Sultana, M. F. (2014). Analysis of Mechanical Properties of Mild Steel Applying Various Heat Treatment. *International Conference on Mechanical, Industrial and Energy Engineering*.

Parmar, R. (2005). *Welding Engineering and Technology.* New Delhi: Khanna Publishers.

Philippa Moore, G. B. (2015). *The welding Engineers Guide to Fracture and Fatigue.*

Prasanta Majumder, A. S. (2020). Effect of preheating techniques on bead geometry and microhardness of weldment developed through the submerged arc welding process. *Materials Today: Proceedings*.

Ranjan, R. (2014). Parametric OPtimization of Shielded Metal Arc Welding Processes by Using Factorial Design Approach.

Rathi, A. K. (2020). To study the effect of submerged arc welding parameters on bead geometry and hardness for mild steel (IS-2062A) using fractional factorial design. *Materials Today:Proceedings*.

Rudra Pratap Singh, S. K. (2020). Effect of current and chemical composition on the hardness of weld in shielded metal arc welding. *Materials Today: Proceedings*.

Santosh. S, J. S. (2018). Experimentation and Comparitive Study of E6013 and E7018 Weldments Using Shielded Metal Arc Welding.

Seyedtabaii, S. (2012). Performance Evaluation of Neural Network Based Pulse-Echo Weld Defect Classifiers.

Syukran, A. M. (2022). Hardness Analysis of Weld Metal Electrode Low Hydrogen Potassium E7016 and E7018.

Talabi, S. O. (2014). Effect of welding variables on mechanical properties of low carbon steel welded joint. *Advances in Production Engineering & Management*.

The American Society of Mechanical Engineers. (2017). *VIII Rules for Construction of Pressure Vessels.*

The American Society of Mechanical Engineers. (2019). *ASME Boiler & Pressure Vessel Code Section V Nondestructuve Examination.*

The American Society of Mechanical Engineers. (2019). *Qualification Standard for Welding, Brazing and Fusing Procedures;Welders;Brazers;and Welding, Brazing, and Fusing Operators.*

Wilhelmsen Ships Service. (n.d.). *The Welding Handbook.* Norway.

Y, M. S. (2015). Investigation on effect of welding current on welding speed and hardness of HAZ and weld metal of mild steel. *IJRET:International Journal of Research in Engineering and Technology*.

APPENDIX 1: WELDER CERTIFICATE

NDT CORROSION CONTROL SERVICES CO.
P.O. Box No: 322, Dammam - 31411. KSA

WELDER PERFORMANCE QUALIFICATION TEST RECORD

Cert. No.: *43586*

Company: *M/S. SAMSUNG SAUDI ARABIA CO. LTD*

Welder's Name *DINA NATH CHAUDHARY* Symbol / Id. No. *SSA-038* Date: *22-APR-2015*

Test Description

Identification of WPS followed *SSA-P1-GTSM-002S, REV. 4* ☒ Test coupon ☐ Production weld

Specification of base metal(s) *API5L Gr. B* Thickness *18.26 MM*

Testing Conditions and Qualifications Limits

Welding Variables (QW-350)	**Actual values**	**Range Qualified**
Welding process(es)	GTAW / SMAW	GTAW / SMAW
Type (ie; manual, semi-auto) used	MANUAL	MANUAL
Backing (metal, weld metal, double-welded, etc.)	GTAW WITHOUT BACKING, SMAW WITH WELD BACKING	GTAW WITH / WITHOUT BACKING, SMAW WITH BACKING
☐ Plate ☒ Pipe (enter diameter if pipe or tube)	6" Ø	2-7/8" OD TO UNLIMITED
Base metal P- or S-Number to P- or S-number	P1 TO P1	P1 THRU P15F, P34 & P41 THRU P49
Filler metal or electrodes specification(s) (SFA) (info. only)	SFA 5.18 / SFA 5.1	--
Filler metal or electrode classification(s) (info. only)	ER70S-3 / E7018	--
Filler metal F-number(s)	F6 / F4	ALL F6 / F4 & BELOW WITH BACKING
Consumable insert (GTAW or PAW)	--	--
Filler type (solid / metal or flux cored / powder) (GTAW or PAW)	SOLID	SOLID
Deposit thickness for each process		
Process 1: GTAW 3 layers minimum ☐ Yes ☐ No	4.0 MM	8.0 MM MAX.
Process 2: SMAW 3 layers minimum ☒ Yes ☐ No	14.26 MM	MAX. TO BE WELDED
Position qualified (2G, 6G, 3F, etc.)	6G	GROOVE(PLATE & PIPE)-ALL FILLET (PLATE & PIPE)-ALL
Vertical progression (uphill or downhill)	UPHILL	UPHILL
Type of fuel gas (OFW)	--	--
Inert gas backing (GTAW, PAW, GMAW)	WITHOUT BACKING	WITH / WITHOUT BACKING
Transfer mode (spray/globular/ or pulse to short circuit-GMAW)	--	--
GTAW current type/polarity (AC, DCEP, DCEN)	DCEN	DCEN

RESULTS

Visual examination of Completed Weld (QW-302.4) *ACCEPTABLE*

☐ Bend Test; ☐ Transverse root and face [QW-462.3(a); ☐ Longitudinal root and face [QW-462.3(b); ☐ Side (QW-462.2);
☐ Pipe bend specimen, corrosion-resistant overlay [QW-462.5(c)]; ☐ Plate bend specimen, corrosion-resistant overlay [QW-462.5(d)];
☐ Macro test for fusion [QW-462.5(b)]; ☐ Macro test for fusion [QW-462.5(e)];

Type	Result	Type	Result	Type	Result
--	--	--	--	--	--
--	--	--	--	--	--

Alternative radiographic examination result (QW-191) *ACCEPTABLE* Report No. *RT/15/5541*

Fillet weld – fracture test (QW-180) -- Length and percent of defects --

Macro examination (QW-184) -- Fillet size (in.) -- X -- Concavity/ convexity (in.) --

Other tests --

Film or specimens evaluated by *R. KUMAR* Company *NDT CCS CO.*

Mechanical tests conducted by -- Laboratory test no. --

Welding supervised by *P. PRABHAKAR* Test Date: *18-APR-2015*

We certify that the statements in this record are correct and that the test coupons were prepared, welded, and tested in accordance with the requirements of ASME Sec. IX 2013.

Organization *NDT CORROSION CONTROL SERVICES CO.*

By *P. BASKAR, Operations Manager*

Council for Technical Education and Vocational Training

National Skill Testing Board

Madhyapur Thimi, Sanothimi, Bhaktapur, Nepal

Citizenship No: 1545

NATIONAL SKILL CERTIFICATE

राष्ट्रिय सीप प्रमाण-पत्र

S.No.: 468720/446015
Regd.No.: 631899/079
Skill No.: 26807/079-080

प्राविधिक शिक्षा तथा व्यावसायिक तालीम परिषद्, राष्ट्रिय सीप परीक्षण समितिद्वारा निर्धारित राष्ट्रिय व्यावसायिक सीप प्रमाणिका मुताबिक मिति २०७९ माघ मा पिस प्राबिधिक तालिम केन्द्र प्रा. लि. बाट ग्वार्को, ललितपुर केन्द्रमा संचालित वेल्डर व्यवसायको तह २ (दुई) को सीप परीक्षण परीक्षामा सम्मिलित भएका श्री बाल कृष्ण चौधरी का छोरा दाङ्ग जिल्ला निवासी वि.स. २०३७/०८/१९ मा जन्मेका श्री दिनानाथ चौधरी ले निर्धारित सीप तथा ज्ञानको स्तर प्रदर्शन गरी उत्तीर्ण हुनु भएकोले यो प्रमाण-पत्र प्रदान गरिएको छ ।

This is to certify that **Mr. Dinanath Chaudhary** *born on* **A.D 1980/12/04** *son of* **Mr. Bal Krishna Chaudhary** *and a resident of* **Dang district** *has attended Skill Test on* **Welder, Level Two** *Occupation conducted on* **Jan, 2023** *by* **Peace Prabhidhik Talim Kendra Pvt. Ltd.** *at* **Gwarko, Lalitpur** in accordance with the requirements of the National Occupational Skill Standards prescribed by the COUNCIL FOR TECHNICAL EDUCATION AND VOCATIONAL TRAINING, NATIONAL SKILL TESTING BOARD, NEPAL. He demonstrated the required standard of proficiency and has successfully passed to acquire this certificate.

Co-ordinator Technical Sub-Committee	**Member Secretary** NSTB	Jeeb Narayan Kafle **Chairman** NSTB

Date of issue : 2 4 MAR 2023

BUTWAL TECHNICAL INSTITUTE

BUTWAL, NEPAL

Two Year Training Certificate

S. No. : 32/057 Period: 055/057

This is to certify that Mr./ ~~Ms.~~ Dina Nath Chaudhary son/ ~~daughter~~ of Mr. Bal Krishna Chaudhary inhabitant of Bela V.D.C. Ward No-2, Dang district, has successfully completed the Two Year Training Course in Welding trade. During the period, he/ ~~she~~ has obtained the following marks:

FINAL TEST :

Trade	Drawing	Total	Theory	Practical
75.0	63.0	138.0	69.0	49.0

TEST RESULT :

Details	Marks	Theory	Practical
Average from 4 Semesters	10%	7.3	6.8
Final Test	90%	69.0	49.0
Total	100%	76.3	55.8

General Manager

Nepal Hydro and Electric (Pvt) Ltd.

Sponsoring Organization

Director

Butwal Technical Institute

Date : 06.10.057 (19 Jan, 2001)

APPENDIX 2: WELDING ROD MANUFACTURER TEST CERTIFICATE

TEST CERTIFICATE

D & H SECHERON ELECTRODES PVT. LTD.

Serial No :2023/U3/E2392/EX Brand Name & Size(mm):SUPRATHERME 2.50 X 350 MM

Date of issue :18-04-2023 Batch No:D0358222392 Date of Mfg:27-03-2023

PO No. & Date :

TDC No. & Date :

Chemical Composition of all Weld Metal wt. (%):

C	0.049	Nb	0.005
Mn	1.180		
Si	0.598		
S	0.010		
P	0.029		
Cr	0.014		
Ni	0.008		
Mo	0.002		
V	0.009		
Cu	0.008		

Mechanical Properties of All Weld Metal:	
Test Condition	As Welded
Y.S. 0.2% offset (MPa)	488.000
U.T.S. (MPa)	590.000
Elongation (%)	28.000
CVN Impact Energy (Joules Test Temp. at °C)	-30
CVN Impact (Joules)	54,56,58,60,62
Hardness	160-170 BHN
Radiography	Satisfactory
Hydrogen (ml/100 gms of Weld Metal)	3.26
Fillet Weld Test	Satisfactory
Lot Classification	"C5" as per AWS/SFA-5.01
Level of Testing Schedule	"J" as per AWS/SFA-5.01
Moisture content in coating %	0.26
Special Requirements :	Mn+Cr+Ni+Mo+V : <1.75%

1922 - CPR - 1471

Test Conducted as per :	**AWS/SFA-5.1 : E7018**
As per EN 10204 Type : 3.1	**EN ISO 2560-A E 42 3 B 3 2**

We certify that supply made against this TC conforms to all the requirements of ASME section-II, Part-C Edition 2021 in all respects. This clause is applicable for products identified to AWS code only.

Issued To:	Checked By:	
KEYPU INTERNATIONAL PVT. LTD.		Signature valid Digitally signed by RAVINDRA KUMBHARE Date: 2023.04.18 15:55:03 +05:30 Reason: Digital Sign Location: MANAGER - QA & QC **Authorised Signatory(QA/QC)**

Head office: 44-46 Industrial Estate, Kila Maidan, Post Bag No 3, Indore - 452006 (M.P.) INDIA,
Tel:+91-731 4229240/41, Fax:+917314229260, Email:qc@dnhsecheron.net, tsd@dnhsecheron.net

This is the system generated test certificate signature not required.

QC-21/Rev.No.08/Dated:Aug-2021

APPENDIX 3: REPORTS OF ULTRASONIC TEST FOR ROOT PENETRATION

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KATHMANDU, NEPAL

ACM REGISTERED ISO 9001:2015 | UKAS MANAGEMENT SYSTEMS 245

ULTRASONIC EXAMINATION REPORT

REPORT NO	GIC/SAMPLE(A)/UT/-A1	**DATE OF TEST**	13/06/2023			
EQPT. MAKE/MODE	MODSONIC/EINSTEIN II TFT	**EQUIPMENT SR. NO**	E-4492-1215			
IDENTIFICATION	SAMPLE A (ROOT GAP 2mm)	**PROBE DESCRIPTION**	0 Deg.	45 Deg	60 Deg.	70 Deg.
LOCATION	GIC OFFICE	**PROBE SR. NO**		-	6976	7483
STAGE OF TEST	HALF SKIP & FULL SKIP	**TEST RANGE in mm**		-	50	75
DRAWING NO.		**PROBE SIZE in mm**		-	8*9	8*9
SKIP DISTANCE		**FREQUENCY in MHz**		-	2	2
MATERIAL SPEC.	IS 2062-250	**REF. GAIN in dB**		-	57.5	57
SIZE	300x300 mm THK 10 mm	**SCANNING GAIN in dB**		-	+14dB	+14dB
METHOD	PULSE ECHO CONTACT,ASCAN-MANUAL	**REF. REFLECTOR**		DIA 2.5 SDH		
SURFACE CONDITION	AS GRIND AS CLEANED	**PROCEDURE REF.**	GIC/NDT/UT/01, REV.00			
COUPLANT	GREASE & MOBIL	**CODE REFERENCE**	ASME Sec. V, Article 4			
SCANNIGN SURFACE	FACE SIDE	**ACCEPTANCE REF.**	ASME Sec. VIII, Div. 1, Appendix 12			

S.N.	ITEM NO./NAME	JOINT NO.	WELD LENGTH	TEST LENGTH	LOCATION OF INDICATION	INDICATION LENGTH	INDICATION DEPTH	ECHO HEIGHT WITH REF. to DAC	OBSERVATION	REMARKS
1	SAMPLE	A	300	300	@ 0-90		10	-	-	Single Bevel
					90 - 110		9	+0dB	LP	
					110 - 170		10	-		
					170 - 280		8.8	-2 dB	LF	
					280 - 300		10		-	

Note : All dimension are in mm, Welding check for root penetration and fusion.

NAME MANOJ DEVKOTA **SIGN:** **DATE: 14/06/2023** **ASNT Level II**	**NAME: BINOD DEVKOTA** **SIGN:** **DATE: 14/06/2023** **ASNT Level II, CSWIP 3.1**
CHECKED BY	**VERIFIED BY**

GLOBAL INSPECTION CONSULTANCY PVT. LTD. NEPAL GIC Estd. 2067 A team of inspection Specialists and Associated Services

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ULTRASONIC EXAMINATION REPORT

REPORT NO	GIC/SAMPLE(B)/UT/-B1	**DATE OF TEST**	13/06/2023			
EQPT. MAKE/MODEL	MODSONIC/EINSTEIN II TFT	**EQUIPMENT SR. NO**	E-4492-1215			
IDENTIFICATION	SAMPLE B (ROOT GAP 4mm)	**PROBE DESCRIPTION**	0 Deg.	45 Deg	60 Deg.	70 Deg.
LOCATION	GIC OFFICE	**PROBE SR. NO**		-	6976	7483
STAGE OF TEST		**TEST RANGE in mm**		-	50	75
DRAWING NO.		**PROBE SIZE in mm**		-	8*9	8*9
SKIP DISTANCE	HALF SKIP & FULL SKIP	**FREQUENCY in MHz**		-	2	2
MATERIAL SPEC.	IS 2062-E250	**REF. GAIN in dB**		-	57.5	57
SIZE	300x300 mm THK 10 mm	**SCANNING GAIN in dB**		-	+14dB	+14dB
METHOD	PULSE ECHO CONTACT,ASCAN-MANUAL	**REF. REFLECTOR**		DIA 2.5 SDH		
SURFACE CONDITION	AS GRIND AS CLEANED	**PROCEDURE REF.**	GIC/NDT/UT/01, REV.00			
COUPLANT	GREASE & MOBIL	**CODE REFERENCE**	ASME Sec. V, Article 4			
SCANNIGN SURFACE	FACE SIDE	**ACCEPTANCE REF.**	ASME Sec. VIII, Div. 1, Appendix 12			

S.N.	ITEM NO./NAME	JOINT NO.	WELD LENGTH	TEST LENGTH	LOCATION OF INDICATION	INDICATION LENGTH	INDICATION DEPTH	ECHO HEIGHT WITH REF. to DAC	OBSERVATION	REMARKS
1	SAMPLE	B	300	300	0-300		10		Root pass completed	Single Bevel

Note : All dimension are in mm

NAME MANOJ DEVKOTA **SIGN:** **DATE: 14/06/2023** **ASNT Level II**	**NAME: BINOD DEVKOTA** **SIGN:** **DATE: 14/06/2023** **ASNT Level II, CSWIP 3.1**
CHECKED BY	**VERIFIED BY**

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ULTRASONIC EXAMINATION REPORT

REPORT NO	GIC/SAMPLE(C)/UT/-C1	**DATE OF TEST**	24/06/2023			
EQPT. MAKE/MODEL	MODSONIC/EINSTEIN II TFT	**EQUIPMENT SR. NO**	E-4492-1215			
IDENTIFICATION	SAMPLE C (ROOT GAP 6mm)	**PROBE DESCRIPTION**	0 Deg.	45 Deg	60 Deg.	70 Deg.
LOCATION	GIC OFFICE	**PROBE SR. NO**		-	6976	7483
STAGE OF TEST		**TEST RANGE in mm**		-	50	75
DRAWING NO.		**PROBE SIZE in mm**		-	8*9	8*9
SKIP DISTANCE	HALF SKIP & FULL SKIP	**FREQUENCY in MHz**		-	2	2
MATERIAL SPEC.	IS 2062-E250	**REF. GAIN in dB**		-	57.5	57
SIZE	300x300 mm THK 10 mm	**SCANNING GAIN in dB**		-	+14dB	+14dB
METHOD	PULSE ECHO CONTACT,ASCAN-MANUAL	**REF. REFLECTOR**		DIA 2.5 SDH		
SURFACE CONDITION	AS GRIND AS CLEANED	**PROCEDURE REF.**	GIC/NDT/UT/01, REV.00			
COUPLANT	GREASE & MOBIL	**CODE REFERENCE**	ASME Sec. V, Article 4			
SCANNIGN SURFACE	FACE SIDE	**ACCEPTANCE REF.**	ASME Sec. VIII, Div. 1, Appendix 12			

S.N.	ITEM NO./NAME	JOINT NO.	WELD LENGTH	TEST LENGTH	LOCATION OF INDICATION	INDICATION LENGTH	INDICATION DEPTH	ECHO HEIGHT WITH REF. to DAC	OBSERVATION	REMARKS
1	SAMPLE	C	300	300	0-10	-	10	-6 dB		Single Bevel
					10-25	10	8.5	-6 dB	LF / LP at root	
					25-55	10	10	0 dB		
					55-65	20	8.1	-6 dB	LF / LP at root	
					65-75	-	10	-	-	
					75-110	-	8.4	-4 dB	LF/ Slag at root	
					110-135	15	8.6		LF / LP at root	
					135-175		10			
					175-200	20	8.6	-6 dB	LF / LP at root	
					200-225	25	9.4	0 dB	LF / LP at root	
					225-300	35	9.4	0 dB	LF / LP at root	

Note : All dimension are in mm

NAME MANOJ DEVKOTA	**NAME: BINOD DEVKOTA**
SIGN:	**SIGN:**
DATE: 24/06/2023	**DATE: 24/06/2023**
ASNT Level II	**ASNT Level II, CSWIP 3.1**
CHECKED BY	**VERIFIED BY**

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ULTRASONIC EXAMINATION REPORT

REPORT NO	GIC/SAMPLE(D)/UT/-D1	**DATE OF TEST**	24/06/2023				
EQPT. MAKE/MODEL	MODSONIC/EINSTEIN II TFT	**EQUIPMENT SR. NO**	E-4492-1215				
IDENTIFICATION	SAMPLE D (ROOT GAP 8 mm)	**PROBE DESCRIPTION**	0 Deg.	45 Deg	60 Deg.	70 Deg.	
LOCATION	GIC OFFICE	**PROBE SR. NO**		-	6976	7483	
STAGE OF TEST		**TEST RANGE in mm**		-	50	75	
DRAWING NO.		**PROBE SIZE in mm**		-	8*9	8*9	
SKIP DISTANCE	HALF SKIP & FULL SKIP	**FREQUENCY in MHz**		-	2	2	
MATERIAL SPEC.	IS 2062-E250	**REF. GAIN in dB**		-	57.5	57	
SIZE	300x300 mm THK 10 mm	**SCANNING GAIN in dB**		-	+14dB	+14dB	
METHOD	PULSE ECHO CONTACT,ASCAN-MANUAL	**REF. REFLECTOR**		DIA 2.5 SDH			
SURFACE CONDITION	AS GRIND AS CLEANED	**PROCEDURE REF.**	GIC/NDT/UT/01, REV.00				
COUPLANT	GREASE & MOBIL	**CODE REFERENCE**	ASME Sec. V, Article 4				
SCANNIGN SURFACE	FACE SIDE	**ACCEPTANCE REF.**	ASME Sec. VIII, Div. 1, Appendix 12				

S.N.	ITEM NO./NAME	JOINT NO.	WELD LENGTH	TEST LENGTH	LOCATION OF INDICATION	INDICATION LENGTH	INDICATION DEPTH	ECHO HEIGHT WITH REF. to DAC	OBSERVATION	REMARKS
1	SAMPLE	D	300	300	0-12		10			Single Bevel
					12-25	10	6.9	-2dB	LP at root	
					25-60		10		-	
					60-75	15	8.1	-6 dB	LF / LP at root	
					75-125	15	9.4	-6 dB	LF at root	
					125-175	50	8.8	-6 dB	LF at root	
					175-225	50	9	0 dB	LP at root	
					225-250	25	9.8	-2 dB	LF at root	
					250-300	50	9.7	-6 dB	LF/LP at root	

Note : All dimension are in mm

NAME MANOJ DEVKOTA	**NAME: BINOD DEVKOTA**
SIGN:	**SIGN:**
DATE: 24/06/2023	**DATE: 24/06/2023**
ASNT Level II	**ASNT Level II, CSWIP 3.1**
CHECKED BY	**VERIFIED BY**

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APPENDIX 4: REPORTS OF ULTRASONIC TEST FOR WELD AT BEVEL SIDE

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ULTRASONIC EXAMINATION REPORT

REPORT NO	GIC/SAMPLE(A)/UT/-A2	**DATE OF TEST**	13/06/2023				
EQPT. MAKE/MODE	MODSONIC/EINSTEIN II TFT	**EQUIPMENT SR. NO**	E-4492-1215				
IDENTIFICATION	SAMPLE A (ROOT GAP 2mm)	**PROBE DESCRIPTION**		0 Deg.	45 Deg	60 Deg.	70 Deg.
LOCATION	GIC OFFICE	**PROBE SR. NO**			-	6976	7483
STAGE OF TEST	HALF SKIP & FULL SKIP	**TEST RANGE in mm**			-	50	75
DRAWING NO.		**PROBE SIZE in mm**			-	8*9	8*9
SKIP DISTANCE		**FREQUENCY in MHz**			-	2	2
MATERIAL SPEC.	IS 2062-250	**REF. GAIN in dB**			-	57.5	57
SIZE	300x300 mm THK 10 mm	**SCANNING GAIN in dB**			-	+14dB	+14dB
METHOD	PULSE ECHO CONTACT,ASCAN-MANUAL	**REF. REFLECTOR**	DIA 2.5 SDH				
SURFACE CONDITION	AS GRIND AS CLEANED	**PROCEDURE REF.**	GIC/NDT/UT/01, REV.00				
COUPLANT	GREASE & MOBIL	**CODE REFERENCE**	ASME Sec. V, Article 4				
SCANNIGN SURFACE	FACE SIDE	**ACCEPTANCE REF.**	ASME Sec. VIII, Div. 1, Appendix 12				

S.N.	ITEM NO./NAME	JOINT NO.	WELD LENGTH	TEST LENGTH	LOCATION OF INDICATION	INDICATION LENGTH	INDICATION ON DEPTH	ECHO HEIGHT WITH REF. to DAC	OBSERVATION	REMARKS
1	SAMPLE	A	300	300	During Inspection No Recordable Indication Was Observed					Single Bevel

Note : All dimension are in mm

NAME MANOJ DEVKOTA **SIGN:** **DATE: 14/06/2023** **ASNT Level II**	**NAME: BINOD DEVKOTA** **SIGN:** **DATE: 14/06/2023** **ASNT Level II, CSWIP 3.1**
CHECKED BY	**VERIFIED BY**

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ULTRASONIC EXAMINATION REPORT

REPORT NO	GIC/SAMPLE(B)/UT/-B2	**DATE OF TEST**	13/06/2023
EQPT. MAKE/MODE	MODSONIC/EINSTEIN II TFT	**EQUIPMENT SR. NO**	E-4492-1215

IDENTIFICATION	SAMPLE B (ROOT GAP 4mm)	**PROBE DESCRIPTION**	0 Deg.	45 Deg	60 Deg.	70 Deg.
LOCATION	GIC OFFICE	**PROBE SR. NO**		-	6976	7483
STAGE OF TEST		**TEST RANGE in mm**		-	50	75
DRAWING NO.		**PROBE SIZE in mm**		-	8*9	8*9
SKIP DISTANCE	HALF SKIP & FULL SKIP	**FREQUENCY in MHz**		-	2	2
MATERIAL SPEC.	IS 2062-E250	**REF. GAIN in dB**		-	57.5	57
SIZE	300x300 mm THK 10 mm	**SCANNING GAIN in dB**		-	+14dB	+14dB
METHOD	PULSE ECHO CONTACT,ASCAN-MANUAL	**REF. REFLECTOR**		DIA 2.5 SDH		
SURFACE CONDITION	AS GRIND AS CLEANED	**PROCEDURE REF.**	GIC/NDT/UT/01, REV.00			
COUPLANT	GREASE & MOBIL	**CODE REFERENCE**	ASME Sec. V, Article 4			
SCANNIGN SURFACE	FACE SIDE	**ACCEPTANCE REF.**	ASME Sec. VIII, Div. 1, Appendix 12			

S.N.	ITEM NO./NAME	JOINT NO.	WELD LENGTH	TEST LENGTH	LOCATION OF INDICATION	INDICATION LENGTH	INDICATION DEPTH	ECHO HEIGHT WITH REF. to DAC	OBSERVATION	REMARKS
1	SAMPLE	B	300	300	DURING INSPECTION NO RECORDABLE INDICATION WAS OBSERVED					Single Bevel

Note : All dimension are in mm

NAME MANOJ DEVKOTA	**NAME: BINOD DEVKOTA**
SIGN:	**SIGN:** GLOBAL INSPECTION CONSULTANCY PVT. LTD. NEPAL GIC Estd. 2062 A Team of Inspection Specialists and Associated Services
DATE: 14/06/2023	**DATE: 14/06/2023**
ASNT Level II	**ASNT Level II, CSWIP 3.1**
CHECKED BY	**VERIFIED BY**

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ULTRASONIC EXAMINATION REPORT

REPORT NO	GIC/SAMPLE(C)/UT/-C2	DATE OF TEST	24/06/2023				
EQPT. MAKE/MODEL	MODSONIC/EINSTEIN II TFT	EQUIPMENT SR. NO	E-4492-1215				
IDENTIFICATION	SAMPLE C (ROOT GAP 6mm)	PROBE DESCRIPTION		0 Deg.	45 Deg	60 Deg.	70 Deg.
LOCATION	GIC OFFICE	PROBE SR. NO			-	6976	7483
STAGE OF TEST		TEST RANGE in mm			-	50	75
DRAWING NO.		PROBE SIZE in mm			-	8*9	8*9
SKIP DISTANCE	HALF SKIP & FULL SKIP	FREQUENCY in MHz			-	2	2
MATERIAL SPEC.	IS 2062-E250	REF. GAIN in dB			-	57.5	57
SIZE	300x300 mm THK 10 mm	SCANNING GAIN in dB			-	+14dB	+14dB
METHOD	PULSE ECHO CONTACT,ASCAN-MANUAL	REF. REFLECTOR		DIA 2.5 SDH			
SURFACE CONDITION	AS GRIND AS CLEANED	PROCEDURE REF.	GIC/NDT/UT/01, REV.00				
COUPLANT	GREASE & MOBIL	CODE REFERENCE	ASME Sec. V, Article 4				
SCANNIGN SURFACE	FACE SIDE	ACCEPTANCE REF.	ASME Sec. VIII, Div. 1, Appendix 12				

S.N.	ITEM NO./NAME	JOINT NO.	WELD LENGTH	TEST LENGTH	LOCATION OF INDICATION	INDICATION LENGTH	INDICATION DEPTH	ECHO HEIGHT WITH REF. to DAC	OBSERVATION	REMARKS
1	SAMPLE	C	300	300	90 - 125	35	5.2	-6 dB	LF / Slag	Single Bevel
					125 - 155	20	4.3 - 5.1	-6 dB	Slag	
					@200	10	4	0 dB	LF / Slag	
					@240	15	4.4	-6 dB	LF / Slag	
					@260	20	5.5	-2 dB	Slag	

Note : All dimension are in mm

NAME MANOJ DEVKOTA	NAME: BINOD DEVKOTA
SIGN:	SIGN:
DATE: 24/06/2023	DATE: 24/06/2023
ASNT Level II	ASNT Level II, CSWIP 3.1
CHECKED BY	VERIFIED BY

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ULTRASONIC EXAMINATION REPORT

REPORT NO	GIC/SAMPLE(D)/UT/-D2	**DATE OF TEST**	24/06/2023			
EQPT. MAKE/MODEL	MODSONIC/EINSTEIN II TFT	**EQUIPMENT SR. NO**	E-4492-1215			
IDENTIFICATION	SAMPLE D (ROOT GAP 8mm)	**PROBE DESCRIPTION**	0 Deg.	45 Deg	60 Deg.	70 Deg.
LOCATION	GIC OFFICE	**PROBE SR. NO**		-	6976	7483
STAGE OF TEST		**TEST RANGE in mm**		-	50	75
DRAWING NO.		**PROBE SIZE in mm**		-	8*9	8*9
SKIP DISTANCE	HALF SKIP & FULL SKIP	**FREQUENCY in MHz**		-	2	2
MATERIAL SPEC.	IS 2062-E250	**REF. GAIN in dB**		-	57.5	57
SIZE	300x300 mm THK 10 mm	**SCANNING GAIN in dB**		-	+14dB	+14dB
METHOD	PULSE ECHO CONTACT,ASCAN-MANUAL	**REF. REFLECTOR**		DIA 2.5 SDH		
SURFACE CONDITION	AS GRIND AS CLEANED	**PROCEDURE REF.**	GIC/NDT/UT/01, REV.00			
COUPLANT	GREASE & MOBIL	**CODE REFERENCE**	ASME Sec. V, Article 4			
SCANNIGN SURFACE	FACE SIDE	**ACCEPTANCE REF.**	ASME Sec. VIII, Div. 1, Appendix 12			

S.N.	ITEM NO./NAME	JOINT NO.	WELD LENGTH	TEST LENGTH	LOCATION OF INDICATION	INDICATION LENGTH	INDICATION DEPTH	ECHO HEIGHT WITH REF. to DAC	OBSERVATION	REMARKS
1	SAMPLE	C	300	300	@50	10	7.1	-6 dB	LF / Slag	Single Bevel
					@75	7	7	-6 dB	Slag	
					@125	15	6.9	0 dB	LF / Slag	
					@150	20	6.8	-6 dB	LF / Slag	
					@200	12	8.6	-2 dB	Slag	
						-	-	-	-	

Note : All dimension are in mm

NAME MANOJ DEVKOTA	**NAME: BINOD DEVKOTA**
SIGN:	**SIGN:**
DATE: 24/06/2023	**DATE: 24/06/2023**
ASNT Level II	**ASNT Level II, CSWIP 3.1**
CHECKED BY	**VERIFIED BY**

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APPENDIX 5: REPORTS OF ULTRASONIC TEST FOR WELD AT BOTH SIDES

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ULTRASONIC EXAMINATION REPORT

REPORT NO	GIC/SAMPLE(A)/UT/-A3	**DATE OF TEST**	26/06/2023			
EQPT. MAKE/MODEL	MODSONIC/EINSTEIN II TFT	**EQUIPMENT SR. NO**	E-4492-1215			
IDENTIFICATION	SAMPLE A (ROOT GAP 2mm)	**PROBE DESCRIPTION**	0 Deg.	45 Deg	60 Deg.	70 Deg.
LOCATION	GIC OFFICE	**PROBE SR. NO**		-	6976	7483
STAGE OF TEST	HALF SKIP & FULL SKIP	**TEST RANGE in mm**		-	50	75
DRAWING NO.		**PROBE SIZE in mm**		-	8*9	8*9
SKIP DISTANCE		**FREQUENCY in MHz**		-	2	2
MATERIAL SPEC.	IS 2062-250	**REF. GAIN in dB**		-	57.5	57
SIZE	300x300 mm THK 10 mm	**SCANNING GAIN in dB**		-	+14dB	+14dB
METHOD	PULSE ECHO CONTACT,ASCAN-MANUAL	**REF. REFLECTOR**		DIA 2.5 SDH		
SURFACE CONDITION	AS GRIND AS CLEANED	**PROCEDURE REF.**	GIC/NDT/UT/01, REV.00			
COUPLANT	GREASE & MOBIL	**CODE REFERENCE**	ASME Sec. V, Article 4			
SCANNIGN SURFACE	FACE SIDE	**ACCEPTANCE REF.**	ASME Sec. VIII, Div. 1, Appendix 12			

S.N.	ITEM NO./NAME	JOINT NO.	WELD LENGTH	TEST LENGTH	LOCATION OF INDICATION	INDICATION LENGTH	INDICATION ON DEPTH	ECHO HEIGHT WITH REF. to DAC	OBSERVATION	REMARKS
1	SAMPLE	A	300	300	After Root Repair & Retest, No Recordable Indication Was Observed					Double Bevel

Note : All dimension are in mm

NAME: MANOJ DEVKOTA	**NAME: BINOD DEVKOTA**
SIGN:	**SIGN:**
DATE: 14/06/2023	**DATE: 14/06/2023**
ASNT Level II	**ASNT Level II, CSWIP 3.1**
CHECKED BY	**VERIFIED BY**

GLOBAL INSPECTION CONSULTANCY PVT. LTD. NEPAL GIC Estd. 2067 A team of Inspection Specialist and Associated Services

GIC/NDT/UT/01

दर्ता नं. ७३६५८/०६६/०६७

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UKAS MANAGEMENT SYSTEMS 245

KATHMANDU, NEPAL

ULTRASONIC EXAMINATION REPORT

REPORT NO	GIC/SAMPLE(B)/UT/-B3	**DATE OF TEST**	26/06/2023				
EQPT. MAKE/MODE	MODSONIC/EINSTEIN II TFT	**EQUIPMENT SR. NO**	E-4492-1215				
IDENTIFICATION	SAMPLE B (ROOT GAP 4mm)	**PROBE DESCRIPTION**		0 Deg.	45 Deg	60 Deg.	70 Deg.
LOCATION	GIC OFFICE	**PROBE SR. NO**			-	6976	7483
STAGE OF TEST		**TEST RANGE in mm**			-	50	75
DRAWING NO.		**PROBE SIZE in mm**			-	8*9	8*9
SKIP DISTANCE	HALF SKIP & FULL SKIP	**FREQUENCY in MHz**			-	2	2
MATERIAL SPEC.	IS 2062-E250	**REF. GAIN in dB**			-	57.5	57
SIZE	300x300 mm THK 10 mm	**SCANNING GAIN in dB**			-	+14dB	+14dB
METHOD	PULSE ECHO CONTACT,ASCAN-MANUAL	**REF. REFLECTOR**	DIA 2.5 SDH				
SURFACE CONDITION	AS GRIND AS CLEANED	**PROCEDURE REF.**	GIC/NDT/UT/01, REV.00				
COUPLANT	GREASE & MOBIL	**CODE REFERENCE**	ASME Sec. V, Article 4				
SCANNIGN SURFACE	FACE SIDE	**ACCEPTANCE REF.**	ASME Sec. VIII, Div. 1, Appendix 12				

S.N.	ITEM NO./NAME	JOINT NO.	WELD LENGTH	TEST LENGTH	LOCATION OF INDICATION	INDICATION LENGTH	INDICATION DEPTH	ECHO HEIGHT WITH REF. to DAC	OBSERVATION	REMARKS
1	SAMPLE	B	300	300	DURING INSPECTION NO RECORDABLE INDICATION WAS OBSERVED					Double Bevel

Note : All dimension are in mm

NAME MANOJ DEVKOTA	**NAME: BINOD DEVKOTA**
SIGN:	**SIGN:**
DATE: 14/06/2023	**DATE: 14/06/2023**
ASNT Level II	**ASNT Level II, CSWIP 3.1**
CHECKED BY	**VERIFIED BY**

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ACM REGISTERED ISO 9001:2015

UKAS MANAGEMENT SYSTEMS 245

KATHMANDU, NEPAL

ULTRASONIC EXAMINATION REPORT

REPORT NO	GIC/SAMPLE(C)/UT/-C3
EQPT. MAKE/MODEL	MODSONIC/EINSTEIN II TFT
IDENTIFICATION	SAMPLE C (ROOT GAP 6mm)
LOCATION	GIC OFFICE
STAGE OF TEST	
DRAWING NO.	
SKIP DISTANCE	HALF SKIP & FULL SKIP
MATERIAL SPEC.	IS 2062-E250
SIZE	300x300 mm THK 10 mm
METHOD	PULSE ECHO CONTACT,ASCAN-MANUAL
SURFACE CONDITION	AS GRIND AS CLEANED
COUPLANT	GREASE & MOBIL
SCANNIGN SURFACE	FACE SIDE

DATE OF TEST	26/06/2023
EQUIPMENT SR. NO	E-4492-1215

PROBE DESCRIPTION	0 Deg.	45 Deg	60 Deg.	70 Deg.
PROBE SR. NO		-	6976	7483
TEST RANGE in mm		-	50	75
PROBE SIZE in mm		-	8*9	8*9
FREQUENCY in MHz		-	2	2
REF. GAIN in dB		-	57.5	57
SCANNING GAIN in dB		-	+14dB	+14dB
REF. REFLECTOR		DIA 2.5 SDH		

PROCEDURE REF.	GIC/NDT/UT/01, REV.00
CODE REFERENCE	ASME Sec. V, Article 4
ACCEPTANCE REF.	ASME Sec. VIII, Div. 1, Appendix 12

S.N.	ITEM NO./NAME	JOINT NO.	WELD LENGTH	TEST LENGTH	LOCATION OF INDICATION	INDICATION LENGTH	INDICATION DEPTH	ECHO HEIGHT WITH REF. to DAC	OBSERVATION	REMARKS
1	SAMPLE	C	300	300	After Repair and Retest No Recordable Indication Was Observed					Double Bevel

Note : All dimension are in mm

NAME MANOJ DEVKOTA	**NAME: BINOD DEVKOTA**
SIGN:	**SIGN:**
DATE: 26/06/2023	**DATE: 26/06/2023**
ASNT Level II	**ASNT Level II, CSWIP 3.1**
CHECKED BY	**VERIFIED BY**

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KATHMANDU, NEPAL

ULTRASONIC EXAMINATION REPORT

REPORT NO	GIC/SAMPLE(D)/UT/-D3	**DATE OF TEST**	26/06/2023			
EQPT. MAKE/MODEL	MODSONIC/EINSTEIN II TFT	**EQUIPMENT SR. NO**	E-4492-1215			
IDENTIFICATION	SAMPLE D (ROOT GAP 8 mm)	**PROBE DESCRIPTION**	0 Deg.	45 Deg	60 Deg.	70 Deg.
LOCATION	GIC OFFICE	**PROBE SR. NO**		-	6976	7483
STAGE OF TEST		**TEST RANGE in mm**		-	50	75
DRAWING NO.		**PROBE SIZE in mm**		-	8*9	8*9
SKIP DISTANCE	HALF SKIP & FULL SKIP	**FREQUENCY in MHz**		-	2	2
MATERIAL SPEC.	IS 2062-E250	**REF. GAIN in dB**		-	57.5	57
SIZE	300x300 mm THK 10 mm	**SCANNING GAIN in dB**		-	+14dB	+14dB
METHOD	PULSE ECHO CONTACT,ASCAN-MANUAL	**REF. REFLECTOR**	DIA 2.5 SDH			
SURFACE CONDITION	AS GRIND AS CLEANED	**PROCEDURE REF.**	GIC/NDT/UT/01, REV.00			
COUPLANT	GREASE & MOBIL	**CODE REFERENCE**	ASME Sec. V, Article 4			
SCANNIGN SURFACE	FACE SIDE	**ACCEPTANCE REF.**	ASME Sec. VIII, Div. 1, Appendix 12			

S.N.	ITEM NO./NAME	JOINT NO.	WELD LENGTH	TEST LENGTH	LOCATION OF INDICATION	INDICATION LENGTH	INDICATION DEPTH	ECHO HEIGHT WITH REF. to DAC	OBSERVATION	REMARKS
1	SAMPLE	D	300	300	After Repair and Retest, No Recordable Indication Was Observed					Double Bevel

Note : All dimension are in mm

NAME MANOJ DEVKOTA	**NAME: BINOD DEVKOTA**
SIGN:	**SIGN:**
DATE: 26/06/2023	**DATE: 26/06/2023**
ASNT Level II	**ASNT Level II, CSWIP 3.1**
CHECKED BY	**VERIFIED BY**

GLOBAL INSPECTION CONSULTANCY PVT. LTD. NEPAL GIC Estd. 2067 A team of Inspection Specialist and Associated Services

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APPENDIX 6: CALIBRATION CERTIFICATE OF UT MACHINE

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GLOBAL INSPECTION CONSULTANCY PVT. LTD.

(A team of Welding Inspection Specialist in the Field of Non destructive Testing of Hydropower & Structural Sector)

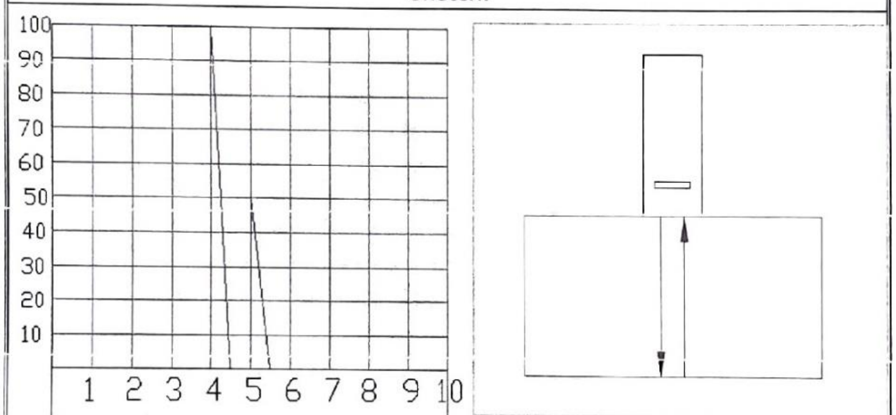
ACM REGISTERED ISO 9001:2015 | UKAS MANAGEMENT SYSTEMS 246

(AN ISO 9001:2015 CERTIFIED COMPANY)

SCREEN HEIGHT LINEARITY

Instrument Model	Einstein II TFT	Sr. No.: 2590-0610	Manufacturer : Modsonic
Applicable Code	ASME SEC. V, Article 4, Mandatory Appendix - I		Calibration Date : 22-05-2023
Acceptance Limit	Indication Shall be in 2:1 within 5% of FSH		Next Calibration Date: 21-08-2023

Sketch:



Height of Indication	1st indication	2nd Indication	Remarks
Height of Indication at start	100%	50%	
Height of Indication after decrease 2 dB from previous height	79%	41%	
Height of Indication after decrease 2 dB from previous height	62%	31%	
Height of Indication after decrease 2 dB from previous height	49%	25%	
Height of Indication after decrease 2 dB from previous height	38%	19%	
Height of Indication after decrease 2 dB from previous height	29%	14%	
Height of Indication after decrease 2 dB from previous height	23%	11%	
Height of Indication after decrease 2 dB from previous height	19%	9%	

	Tested By	Approved By	
Name	Prakash Dhital	Name: Binod Devkota	
Sign	[signature]	Sign: [signature]	
Level	ASNT Level II (UT,RT,MT,PT)	ASNT Level II (UT,RT,MT,PT) & CSWIP 3.1	
Date	23/05/023	23/05/023	
	Inspector	GIC Approved	Client / Consultant

दर्ता नं. ०३६५८/०६६/०६७

ग्लोबल इन्सपेक्सन कन्सल्टेन्सि प्रा.लि.

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UKAS MANAGEMENT SYSTEMS 246

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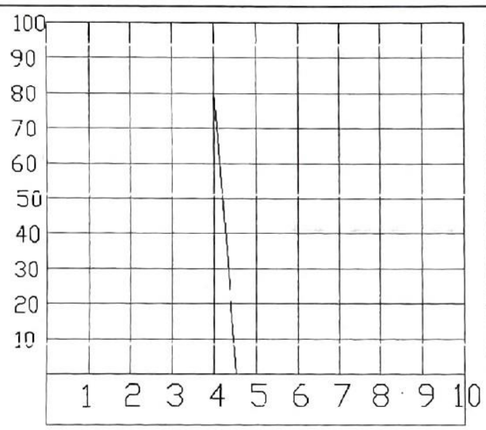
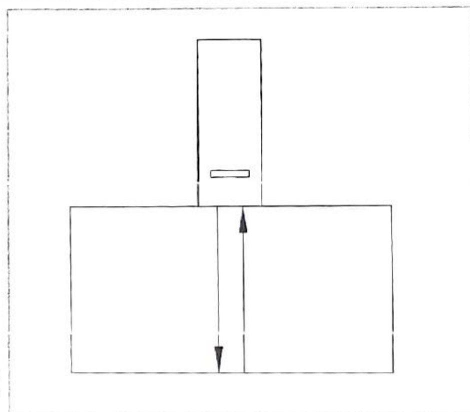
AMPLITUDE CONTROL LINEARITY

Instrument Model	Einstein II (TFT)	Sr. no.: E 2590-0610	
Manufacturer	Modsonic		Calibration Date: 22/05/2023
Applicable Code	ASME SEC. V, Article 4, Mandatory Appendix - II		Next Calibration Date: 21/08/2023

Sketch:





Indication Set at % of Full Screen	dB Control Change	Accepted Limit % Of Full Screen	Obtained Indication % Of Full Screen
80%	- 6 dB	32 to 48 %	39%
80%	- 12 dB	16 to 24 %	18%
40%	+ 6 dB	64 to 96 %	85%
20%	+ 12 dB	64 to 96 %	90%

	Tested By	Approved By	Approved by
Name	Prakash Dhital	Name: Binod Devkota	
Sign		Sign:	
Level	ASNT Level II (UT,RT,MT,PT)	ASNT Level II (UT,RT,MT,PT) / CSWIP 3.1	
Date	23/05/023	Date: 23/05/023	
	INSPECTOR	GIC APPROVED	CLIENT / CONSULTANT

APPENDIX 7: TENSILE TEST REPORT

TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
PULCHOWK CAMPUS
DEPARTMENT OF CIVIL ENGINEERING
CENTRAL MATERIAL TESTING LABORATORY
TEST STATEMENT

Tensile Strength of Flat Plate

Project : MSc Thesis | Report No: 8003CMTL312

Client : NA | Date : 24/03/2080

Contractor : NA | Machine: UTM

Contact No: NA

Placement: NA

Sample Type: Mild Steel Plate (Butt Welding-E250)

S.No.	Thickness (mm)	Width (mm)	Area (mm^2)	Ultimate Load (kN)	Yield Strength (N/mm^2)	Ultimate Strength (N/mm^2)	Elongation %	Remarks
1	7.07	38.33	270.99	101.50	285.98	374.53	29.02	A1
2	7.33	38.41	281.55	102.93	264.81	365.60	25.26	A2
3	6.82	37.99	259.09	97.12	268.83	374.84	31.11	B1
4	7.28	38.16	277.80	104.85	278.97	377.41	30.53	B2
5	6.83	38.09	260.15	96.14	273.39	369.54	31.11	C1
6	7.67	38.01	291.54	111.55	289.38	382.62	26.32	C2
7	7.35	38.01	279.37	101.97	266.87	365.01	26.32	D1
8	6.78	38.19	258.93	97.12	276.57	375.08	26.67	D2

Note: Material Supplied by Researcher

Ananda Niketan, Pulchowk, Lalitpur, Nepal, Tel. 5548835, Email: cmtl@ioe.edu.np, www.pcampus.edu.np/

APPENDIX 8: ORIGINALITY REPORT

WS_ effects of opening on welding speed hardness root penetration and tensile testing strength using e7018 welding electrode by waving method

ORIGINALITY REPORT

12%
SIMILARITY INDEX

PRIMARY SOURCES

1	www.scribd.com Internet	102 words — 1%
2	www.science.gov Internet	92 words — 1%
3	Baloyi, Pardon. "Reinforcement of Mild Steel AISI 1008 -MIG Welds Using Titanium Powder", University of Johannesburg (South Africa), 2023 ProQuest	74 words — 1%
4	businessdocbox.com Internet	73 words — 1%
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6	Welding Handbook, 1987. Crossref	71 words — 1%
7	Abima, Cynthia Samuel. "Experimental and Numerical Study of Welded Components for Enhanced Structural Integrity", University of Johannesburg (South Africa), 2023 ProQuest	51 words — < 1%