ADDIS ABABA UNIVERSITY

ADDIS ABEBA INSTITUTE OF TECHNOLOGY

SCHOOL OF MECHANICAL AND INDUSTRIAL ENGINEERING

Optimization of process parameters of friction welding of brass – steel metals

A Master Thesis Submitted to Graduate School of Addis Ababa University in Partial Fulfilment of the Requirements for the Award of Degree of Masters of Science (M.Sc.) In Mechanical Engineering (Manufacturing Engineering)

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Submitted in accordance with the requirements for the degree of

Master of Science (M.Sc.)

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DECLARATION

I hereby declare that this thesis entitled ‘‘**Optimization of process parameters of friction welding of brass –steel**’’ is my original work and that is has not been submitted incomplete or part, for any other degree or professional qualification.

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First, I would like to express my heart full thanks to my almighty God and his mother for allowing me to begin and to complete this thesis.

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ABSTRACT

Brass metal has a high strength, strong corrosion resistance, and high electrical and thermal conductivity, making it popular engineering materials in industry and electromechanical works for building water supply systems. They have a good appearance and are easily formed, but fusion welding of brass with other brass and with metals like black steel is a challenging process. The zinc evaporation during the welding process is the primary issue with these alloys in fusion welding. After the welding process, the metal is permeable after welding. Furthermore, because evaporation reduces the amount of zinc in the alloy, the material made of brass lacks its typical chemical and physical characteristics. These issues are not being sufficiently resolved when it comes to fusion welding brass metals; Investigators were instructed to use novel techniques. These issues appear to be resolved by friction welding, one of the more recent techniques created. These researches describes optimization of process parameters and give result of rotational speed, friction time and material size of Taguchi design experimental investigation by using direct drive friction welding (DDFW) methods for welding of brass with black steel rod on set up of Lathe machine with the help GRA.

Finally on this research the optimization process parameter of 1200rpm rotational speed, 30sec of friction time and 15 mm diameter material size with quenching cooling system was attained. In addition of state optimizations from a Taguchi experimental process result it shows as cooling system and material size was more influenced as best performance whereas rotational speed is next to cooling system and material size influenced welding performance but from Taguchi experimental welding time is less effect or almost no effect in welding performance.

Key Words: Steel, Brass, dissimilar metal, joint properties and Friction Welding, Direct Drive Friction Welding.

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LIST OF ABBREVIATIONS AND ACRONYMS

FSW	Friction stirs welding
FRW	Friction welding
FCU	Fan-coil units
LCS	Low Carbon Steel
TMAZ	Thermos-Mechanically
IMCs	Intermetallic compounds
ST	Stir zone
HAZ	Heat-Affected Zone
NDT	Non-Destructive test
FP	Friction Pressure
λ	Rotation Speed
FT	Friction Time
UP	Upset Pressure
UT	Upset Time
BOL	Burn-Off Length
PM	Parent Materials
CNC	Computer Numerical Control
SEM	Scan Electro Machine
TWI	Welding Institute
EDS	Energy Dispersive Spectrometer
OD	Outer Diameter
WT	Wall Thickness
UTS	Ultimate Tensile Strength

TS	Tensile Strength
HVAC	Heating ventilation and air conditions
YS	Yield Strength
IMCs	Intermetallic Compounds
Dia.	Diameter
SN	Sample Number
RPM	Revolution per Time
Sec.	Second
TMC	Traffic Management Centre
MM	Millimetre
EBCS	Ethiopian building code standards
DDFW	Direct drive friction welding
DNC	Direct numerical control
LHI	Low Heat Input
AHU	Air Handling Unit
RT	Roof Top Package
FV	Float valve
PPR	Polypropylene
CT	Compression Test
TT	Tensile Test
HT	Hardness Test
S/N	Signal to noise ration
GRA	Gray relation analysis

CHAPTER ONE

1. INTRODUCTION

1.1 BACKGROUND

Water supply for air handling units (AHU), roof top packagers (RTP), fan-coil units (FCU), and chillier is a common feature of central air conditioning systems. and other addition system like water treatment, central boiler system use water as source of backbone for the system which get from main tanker or from their own tanker system, especially in tall buildings to attain the thermal comfort zone and indoor air quality, In order to supply water for a chillier pipe line, the electric water valve on-off control and the three-way valve bypass ratio of the FCU must be correctly fixed with chilled water pipe lines and used return hot water from return chilled water to hot water tank by controlling of floating valve [1][2].

To connect floating valve brass rod with black steel nut immersed in float valve which means float ball and rod by using threaded connection like chilled water pipe lines use different fitting as seen in figure 1.1 and figure 1.2,those fitting body material done from brass. Because of its acoustic qualities, corrosion resistance, and malleability, brass is frequently used for pipes, screws, fittings, and many other applications. As brass's zinc content rises, brass can also become more prone to dezincification., to joint different chilled water pipe lines use welding mechanism to get the required pressure and to avoid leakage in all pipe lines and also similar scenario avoid leakage for connection float valve rod and float nut in water tank to supply water for different system use welding mechanism to get also the required pressure and protect connection of floating valve rod and immersed steel nut of float and whereas to connect gate valve with black steel pipe use threaded black steel nipples and socket which is a source of leakage for system, this leakage happened pipe line, in addition of this leakage problem of water tank float valve rod and float nut very critical and also even if nearly to close the system because of connection of threaded and Teflon tape life time [3] [4].

Dissimilar metal meets at the treads in later stages creating a micro fine leak and lose connection this point is most of the time damaged has already occurs in water supply system like for supply of water for FCU in this case installed in permanently closed ceiling area leakage happen a lot of damaged occurred and also especially leakage in water tank affected flow rate problem because droplet of leakage in water tanker so the required flow does not supply for the demand and the valve get stuck ,leading to an overflowing tank and subsequent water damage. To avoid this leakage permanently in water supply for the equipment of air condition like FCU, AHU,RTP and treatments water one method is required, this paper is study welding of brass rod with black steel to avoid leakage, So the goal of this paper is to provide experimental in welding between brass rod with black steel FV in addition to get implication for welding piping and valves in dissimilar material [5][10].

Leakage connections in pipes with fittings and in FV may occur for a few different reasons. On the one hand, these may be related to the geometric parameters of the pipe part, such as wall thickness and length, etc.; on the other hand, they could be related to the screw threaded components, such as taper, threaded pitch, and chamfer, etc. In addition, various factors such as temperature stress, moisture, environmental pressure, and structural materials can cause leaks; the type of material used is particularly important in this regard[7].

This study examines the viability of employing welding to check threaded pipe connectors for loosening; welding is the joining of two different or similar materials constructed in tandem because of the production of heat Due to the strength loss in the fusion zone caused by the evaporation of zinc it is extremely difficult to fuse brass to black steel using fusion welding as well as the stark differences in the physical attributes of heat between brass and black steel, including conductivity, heat expansion coefficient, and melting point. Recently, solid-state welding has been attempted as a solution to this difficult problem. Conventional welding processes typically require heat generation to melt and fuse materials by external sources such as gas, electricity, or chemicals. Because the procedure minimizes the welding errors caused by conventional welding procedures and does not require total melting of the metal surfaces at the junction, friction stir welding (FSW), recently discovered solid-state welding technique, was initially commercialized in the UK by TWI in 1991. And also other dissimilar metal welding process is direct drive friction welding (DDFW) using friction welding methods especially to keeping a constant speed of rotation is one way of option to welding. So In this research to attempts Performance evaluation and mechanical properties by direct drive frictional welding brass rod FV with black steel nut of float FV in water supply system to develop on the setup on lathe machine [6].

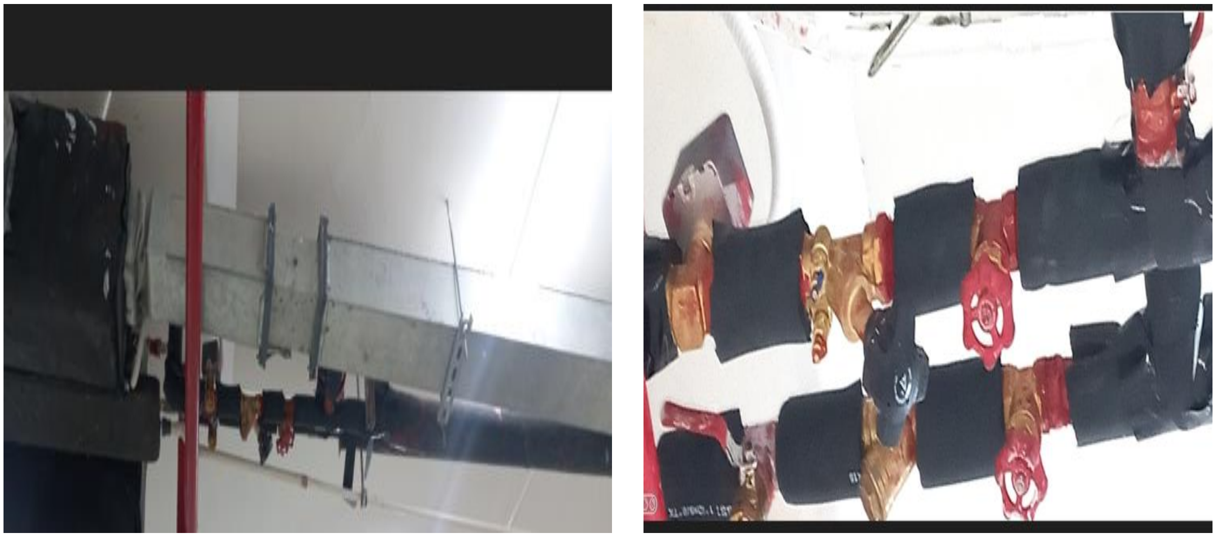


Figure 1.1 connection of valve with pipe (photo taken from traffic management centre (TMC) project).

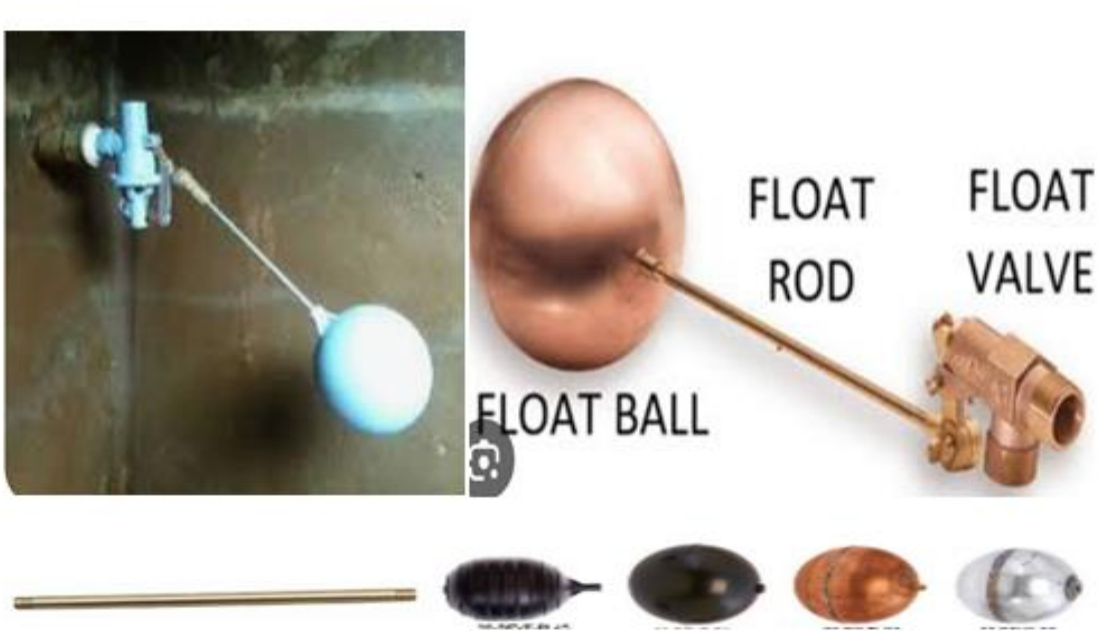


Figure 1.2 connections of float valve with part name [Source: https://support .boshart.com]

1.2 STATEMENT OF THE PROBLEM

Through the world wide welding dissimilar metals like brass and black steel (a type of carbon steel) presents several challenges due to differences in their physical, chemical, and mechanical properties. Because brass has a lower melting point (~900-940°C) compared to black steel (~1425-1540°C). This can lead to brass melting or vaporizing before the steel reaches its welding temperature. Again because of thermal expansion coefficients of brass and steel difference during heated time they expand at different rates, which can cause stress and distortion at the weld joint during the heating and cooling cycles.

- ❖ Highly loss of strength generated because of water pressure fluctuation.
- ❖ Traded joint mechanism is a subject to leakage due to vibration load.[3]
- ❖ Corrosion of steal nut inside float valve [4].

For that matter in order to weld low carbon steel with brass round metal this research used a specialized welding techniques of friction welding on setup of lathe machine to successfully join these dissimilar metals. Clearly state the joint problem in due to the use of poor welding technic and significant of use of optimized process parameters of friction welding in improving the joint performance.

1.3 RESEARCH QUESTION

- ❖ Is that possible to weld black steel rod with brass rod throw friction welding on the set up of Lathe machine?
- ❖ Which welding process parameter is influencing the joint performance?
- ❖ Shall friction welding of brass float valve rod with black steel nut found inside float pipes can be achieve Nominal working pressure load than threaded joint for application of water tanker?
- ❖ What are the optimum process parameters of friction for better weld performance?

So that this research give ways on welding of dissimilar material brass rod with steel nut of FV to avoid corrosion by removing previously most of the time application steel rod weld with steel nut in water tank FV and substitute this by brass for avoid corrosion, Additionally this proposal will conduct further research on identifying the optimum process parameters during welding processes.

1.4 OBJECTIVE OF STUDY

1.4.1 GENERAL OBJECTIVE

The primary goal of this study is to optimize friction welding parameters of brass –black steel for better weld joint performance for water supply system on air conditioning system.

1.4.2 SPECIFIC OBJECTIVE

- To create a friction welding setup for a lathe machine.
- Weld low carbon steel rod with brass rod by direct drive friction welding on set up of lathe machine.
- Identify the optimum process parameter during welding of brass and steel using Taguchi method
- Apply the compression, hardness, tensile tests and also corrosion test to the sample of welded line and come up with the better categories.

1.5 SCOPE OF THE STUDY

The scope of this study is to provide better knowledge and understanding of the mechanism for differently sized brass valve and black steel pipe joints using friction welding on the set up lathe machine, which are capable of being installed in air condition pipe line systems.

The influence of process factors on the characteristics brass rod FV and steel nut FV friction welding is expected to be addressed, considering significant process parameters

1.6 MOTIVATION STATEMENT

Motivation statement of this project is to save unnecessary damaged due to leakage, some of problem is:-

- In treatment system the treated water affected by FV rod because pipe line is anti-corrosion like PPR but float valve rod is steel which is source of corrosion and affected treated water.

- Over flow of water due to damage of FV in tanker so with control water flow several time and wastage of eater
- Many indoor lighting fixtures are not designed to prevent water. Due to water leakage pipe lines electrical wires affected because of develop dangerous moulds and experience corrosion. These tolls on the electrical wiring can lead to electrical shorts and further more fires happened over time if they are used during or after a leak.
- Rework ceiling materials due to damage of water leakage with in short period of time
- Any material affected by water other than lighting and ceiling which installed below chilled water pipe lines damaged by water leakage

1.7 SIGNIFICANT OF STUDY

The results of this proposal will be useful in figuring out how to improve the frictional welding joints' black steel nut FV and brass rod FV.

Effective of dissimilar material by frictional welding will be achieve time, easy working methodology and high durability of performance system by avoiding leakage and also protect water from corrosions effected.

1.8 ORGANIZATION OF THE THESIS

This thesis, which is divided into five chapters, focuses on Optimization of friction welding of brass – black steel

The following is the format of the thesis:

Chapter 1 discusses the float valve's introduction, the problem statement, the thesis's objectives, its scope, its constraints, and its methods.

Chapter 2 is totally focused on previous works, the first section briefs join process type of welding and mechanism of friction, the second section review process parameterises that affected friction welding

Chapter 3 shows the methodology of thesis followed during the research work gives a thorough explanation of the materials utilized in the investigation. This chapter also presents the testing procedures and Taguchi methodologies.

Chapter 4 shows the results of experimental research on the friction welding process parameter. It also includes descriptions of how Minitab software's process optimization results have affected the outcomes of experiments.

Chapter 5 provides a conclusion and recommendations for further investigation.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 JOINING PROCESS

One type of attachment method that creates a fixed link between the many elements that need to be joined is joining; Joining processes are the actions of attaching one structural part or component to another in order to generate an assembly. According to the American Welding Society, the joining process is divided into three main classes (AWS) which is welding, adhesive bonding, and mechanical fastening, not majorly but also the joining processes involves brazing and soldering process generally classification of joining process as shown in detail in figure 2.2 All the processes are not the same, though, and there are a few variations based on the temperature and joining circumstances. Here in figure 2.1 shown pipes joining with different joint methods as shown with different option as per classification of joint process [11].

Figure2.1 Different joint methods [Source: Roman Milert/Dreamstime.com]

Joining process is a very old process, this process done to the past 2000 years with different classification. The most effective kind of joints among all these joining procedures is welded joints, which are made in the Gorgonian 1800. They are highly flexible and strong despite their uneven shapes.

In order to help connect that solidifies and creates a perfect union, additional filler material or welding electrode is added in the molten pool while the welding materials are melting down at the joint. Both dissimilar and similar materials can be bonded with ease during this technique. Unlike conventional mechanical fastening, which involves the diffusion of materials during component fusion, the weld structure is created through this process. Numerous advancements have been made in welding, such as the use of electricity to generate high temperatures; Literature has a variety of welding process kinds. which seen detail in 2.1.1 sub title [6][11]

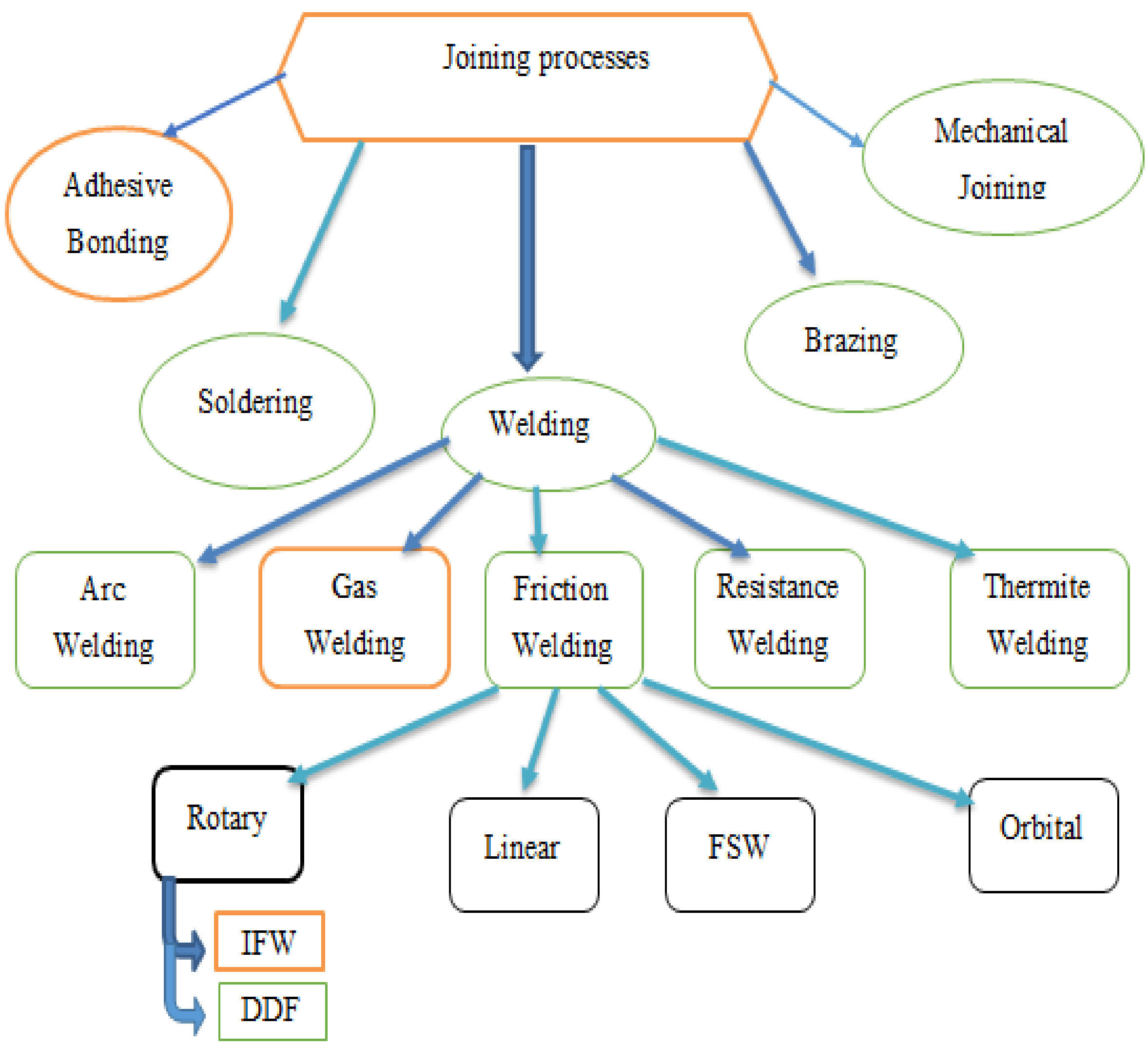


Figure 2.2 classification of joining process [6]

2.1.1 TYPES OF WELDING

Welding has been more and more prevalent in recent years, there are various welding techniques available and each has benefits and drawbacks of its own. In general Gas welding, arc welding, resistance welding, exothermic welding, and solid-state welding are the many types of welding procedures.

Acetylene is the most important gas fuel used in gas welding, which produces heat or aflame by the combustion of fuel gas, a mixture of oxygen, Arc welding generates heat using an electrical arc, and while this method has several advantages such as deep penetration, flawless weld finishing, and improved cost control, its drawbacks include expensive equipment costs associated with complex processes and flux contamination. Resistance welding is another type of non-fusion welding procedure that involves heating metal by electrically resisting sections against a current source. The disadvantage of resistance welding is that it can only be used on specific types of material; it cannot be used to all types of material. The other name of thermite Welding is thermo-chemical welding also some time which is known as exothermic welding because of do not need any current source where the chemical exothermic reaction between the two part produces heat, those process is also used for dissimilar material joining but Because of the nature of the explosive process which is primarily utilized under specific circumstances [6].

Solid-state welding differs from traditional welding techniques in that it uses pressure to join materials together while they are in close contact with one another and requires a temperature below the melting point of the materials to be melted. Traditional welding required heat generated to melt and fuse material by extra means, such as electricity, gas, and chemicals. This indicates that all metal adhesion is achieved without melting through the diffusion of interfacial atoms, and stronger, more consistent joints are produced as a result of the extremely tiny surface area being influenced by the lower temperature [6][11].

The primary issue with these alloys is the evaporation of zinc during the welding process, which presents challenges when welding traditional materials like brass and steel together. The primary issue with joining materials is that the weld metal becomes porous after welding, therefore, because zinc has poor strength capabilities, fusion welding a liquid melt of zinc and its oxides on the surface of brass results in a decrease in the strength of the welded joint or its absence altogether [12].

Thus, in order to prevent this issue, research has identified solid state welding as a solution. Of those solid state welding techniques, friction stir welding and friction welding have gained popularity recently as the most promising methods for joining high temperature variations and reducing heat-affected zones.

2.1.2 FRICTION STIR WELDING

In the solid state welding technique known as friction welding, heat is produced by rubbing the surfaces of the work pieces together due to relative motion and material plastic deformation. [8]. The Welding Institute created friction stir welding (FSW) in the early 1990s as a way to fuse low melting temperature materials, like hard-to-fusion weld Al alloys. Many people believe that one of the most important welding innovations of the past 30 years is this relatively recent joining technique [9].

Friction welding can be used to successfully weld Al-steel dis-similarly because solid state welding can solve dissimilar welding issues. Because friction welding is the most practical method for welding steel cylindrical rods, friction welding is typically used [14].

The Welding Institute (TWI) developed FSW, a variation on friction welding, in 1991. The non-consumable tool is applied to the surfaces of the work components that need to be connected during the FSW process. Heat is produced by the rubbing motion of the tool surfaces against the work piece, which softens the material beneath the tool shoulder. The softened material is then moved from the tool's front to its trail by the transverse movement of the tool, which comes next. The recrystallized weld zone and the bond between the two work pieces are obtained when the material cools to room temperature. In order to achieve full penetration equal to or greater than pin length, two process parameters axial pressure and tool tilt angle are utilized to help forge the material downward in the direction of the tool axis. Using a non-consumable spinning tool, friction stir welding (FSW) is a well-known solid-state joining process that joins two facing work pieces together without melting the work piece material [14].

These days, the FSW process is becoming more and more widespread. It may be used to weld both similar and dissimilar metals [20]. A non-consumable welding tool is forcefully inserted into the joint line of plates to be welded at a specific rotation speed during the FSW process. The tool moves the whole length of the joint, generating enough heat through friction to cause the material to flex plastically [15]. The heat-affected zone (HAZ), thermo mechanically affected zone (TMAZ), and nugget zone also known as the stir zone (ST) make up the weld zone in the FSW. The materials in the HAZ do not plastically distort, but the welding heat influences this area and results in some microstructural changes. The heat produced during the FSW impacts the material and causes partial deformation in the second zone, or TMAZ. Lastly, during the welding, the material suffers significant deformation in the SZ near the pin site. [15].

Considered the most important advancement in metal joining in a decade is friction stir welding. Friction Stir Welding is a green technology since it uses no cover gas or flux and is therefore energy-efficient, versatile, and environmentally benign. Since filler metal is not used in the joining process, any aluminium alloy can be connected without worrying about composition compatibility, a problem with fusion welding. In FSW, the characteristics of the joints are better than those of the parent metal because there is no usage of cover gas, flux, or filler metal. Friction stir welding can be used on a variety of joints, including fillet, T, lap, and butt joints as well as pipes with varying thicknesses and profiles. The FSW technique was originally created for Al alloys, but it also has a lot of potential for welding lead, some steels, stainless steels, magnesium, copper, and titanium alloy matrix composites, as well as a variety of other material combinations, especially those with similar behaviours and close melting temperatures, like hot workability [15].

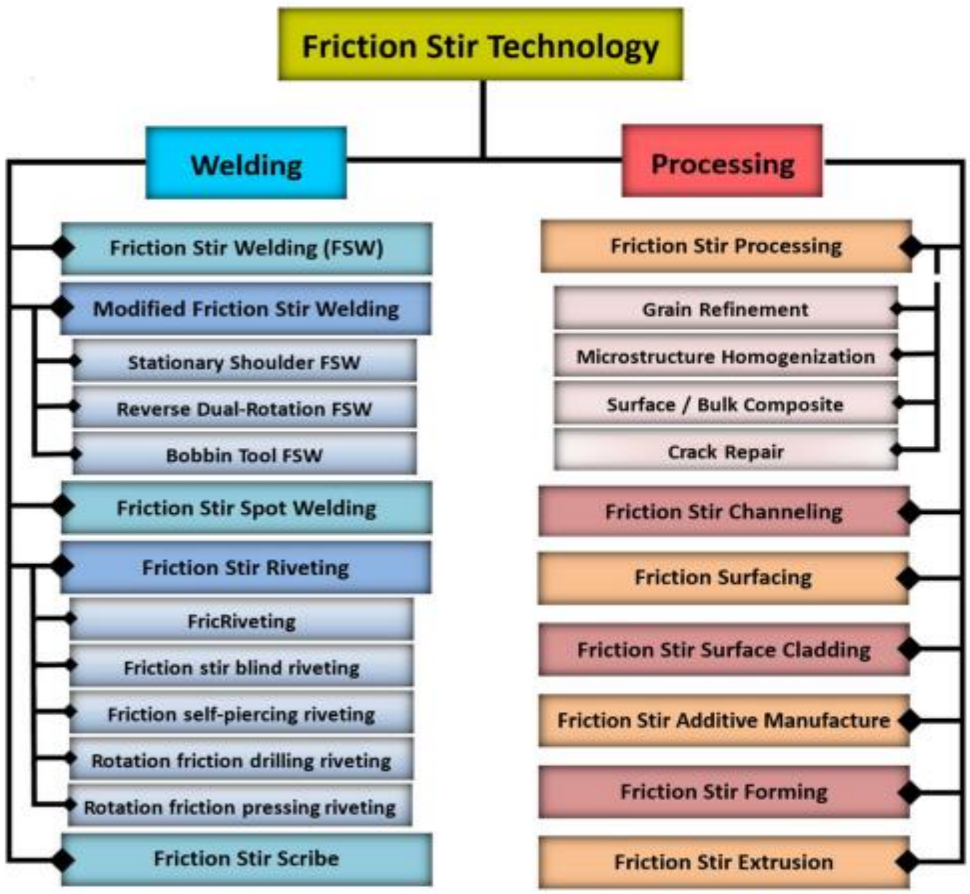


Figure 2.3 Classification of technologies based on friction stir [35].

2.1.3 FRCTION WEILDING

Friction welding is also one a solid state joining technique in which an upsetting force is used to heat the two work parts to a plastic state, dislodging the materials to form the weld. When two metallic work parts are in touch and under a compressive force, heat is produced by their relative motion [6].

Additionally, can be as concise as detailed because friction-based welding techniques produce strong joints with surprisingly little energy consumption and no environmental impact, they are regarded as extremely well-organized solid-state metal joining processes. The idea behind these procedures is to fuse materials together by taking advantage of the higher temperatures created by mechanical friction at contacting surfaces. In order to illustrate the differences between friction stir welding (FSW) and friction welding (FRW), a number of distinct friction-based welding techniques are categorized and their processes are explained.

Both friction welding and friction stir welding are unique welding processes that are best suited for different purposes. Friction stir welding was created in 1991 by The Welding Institute (TWI) in the United Kingdom, while friction welding was created in the 1940s by Friction Welding Ltd. The best method for connecting various metals is friction welding.

Furthermore, Friction Stir Welding can be used to fuse dense aluminum alloys together. On the other hand, Friction Stir Welding (FSW) produces finer microstructural grain structures and has greater welding speeds since it uses a non-consumable spinning tool to fuse material at the junction. In the welding business, both approaches are becoming more and more well-known for their distinctive procedures and excellent welds. Friction welding offers significantly lower operating temperatures as a key benefit. There are no flaws associated with melting or solidification, such as oxide coatings, gas porosity, or hot cracking during solidification, because no melting occurred. Additionally, unlike fusion welding processes, the overall heat input is significantly lower, resulting in a smaller heat affected zone, less distortion, and less intermetallic formation in dissimilar metal joints. The weld strength in like-material welds is also frequently stronger than the base material. Contact between the specimens in FRW causes friction, is usually quicker and less expensive than FSW, and is better suited for high-volume production.

The basic concept of FSW is simple. A non-consumable rotating tool with a specially designed pin and shoulder is inserted into the abutting edges of sheets or plates to be joined till the shoulder contact the top surface of workpice and traversed along the line of joint to produce the weld. The tool serves primary functions heating of work piece, deform the material, movement of deform material to produce the joint. The heating is accomplished by friction between the rotating tool and the work piece and plastic deformation of work piece. The localized heating softens the material around the pin and combination of tool rotation and translation leads to movement of material from the front of the pin to the back of the pin. As a result of this process a joint is produced in ,solid state a variety of frictional welding techniques are available, including direct drive, inertia, linear, and rotary friction welding [34]

As suggested by the name, linear friction welding involves a linear relative effort between the two components across the interface. Since the components must always be kept under pressure, the speeds in this linear friction welding are substantially lower.

Among all other types of friction welding, rotary friction welding—also referred to as spin welding—is a method in which one component is rotated against the other stationary component in order to produce the necessary heat for the operation [45].

In DDFW, the joining process is accomplished by continually applying compressive force to the rotating work piece that is powered by an electric motor. This procedure is also referred to as continuous drive since the chuck is continuously driven by the drive motor while it is heating up. After that, the proper forge pressure is used to accomplish the weld. The stationary metal component is then brought into contact with the revolving one; the major goal of this welding joining is to maintain a consistent speed of rotation. DDFW is used in a variety of industries, including pipelines, pressure tanks, axles, drive shafts, and engine valves. This is because the constant speed rotation of these components is crucial to the research being done [27].

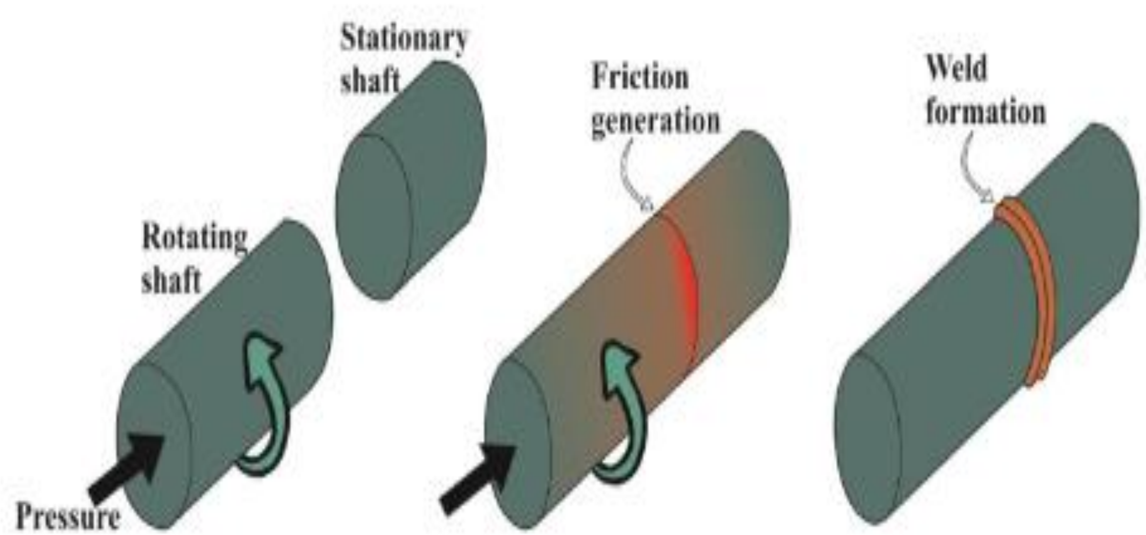


Figure 2.4 direct drive friction welding (DDFW) [6]

2.2 MECHANISM OF FRICTION WELDING

The welding cycle can be split into two stages: the rubbing or friction stage and the upsetting or forging stage. Although the specifics of the bonding process are unknown, these are the general guidelines. In the first step, the heat generated during welding is developed, and in the second stage, the weld is cemented and cooled.

Friction welding, which is well known among solid state joining methods, can be applied to join dissimilar materials. However, since it's joining mechanism has not been fully clarified, to determine the friction welding conditions for material combinations are essential. In particular, the joining mechanism between dissimilar materials differs from that of similar materials because mechanical properties such as the tensile strength and thermal properties such as the thermal conductivity are different in their combinations. To theoretically determine the friction welding conditions, it is necessary to clarify the joining phenomena and the joint mechanical properties for various combinations of materials.

A continuous (direct) drive friction welding machine, which had an electromagnetic clutch to prevent braking deformation during the rotation stop, was used for the joining. During the friction welding operations, the friction welding condition was set to the required combinations friction speed of and friction pressure to observe the joining phenomena.

One method of solid-state welding is friction welding. The heat produced by friction between rubbing surfaces is what causes the coalescence because it elevates the temperature at the interface to a point where high pressure forces the two surfaces to meld together. When it comes to joining techniques that are easily automated and result in joints with uniform mechanical qualities, friction welding is the favoured method during the fabrication process. Friction welding's sub-melting temperatures and quick weld periods enable the joining of a wide variety of work metal combinations. This procedure does not call for the use of shielding gas, flux, or filler metal. In the instance of a metal matrix composite (MMC) with short fibres or oxide particles as the strengthening phase, friction welding was successfully used [23]

2.3 FRICTION STAGE

The joining process takes place in phases when the work parts are identical. Rubbing occurs between the faying surfaces when the pieces come into contact, and strong adhesion occurs at different constant spots. There is a lot of pressure in the unit. The adhesion sometimes outperforms the metal on either side. Shearing occurs during the process, and the metal is moved from one surface to the next. The torque and the interfacial temperature rise as the rubbing continues. The shards that are transferred grow in size until they form a single, continuous sheet of metal that has been plasticized. This is when a liquid film forms, if it does. As the metal is heated and driven away from the interface during this time, the torque peaks and falls to a minimum value that stays relatively constant, and the axial shortening proceeds [33].

Iron is a rare ferrous metal, while aluminum is a non-ferrous metal and stainless steel is primarily composed of nickel and chromium. Because the two separate metals have different chemical compositions, it is challenging to weld them together using conventional welding processes. Research on the weld feasibility test revealed that it is feasible to use rotary friction welding (RFW) to weld aluminum with stainless steel in a confined heat-affected zone, without any faults or scars. Due to the soft nature of aluminum, stainless steel, a hard metal, has seeped into the soft substance. The metals SA213 (tube) and SA387 (tube plate) by friction welded process as per the L9 orthogonal array and found that the welded joints had no defects. Microstructure and mechanical properties were studied. The authors experimented with two modes; one was with holes and another one was without holes on the circumference of the tubes. The results showed that the projection of the tube during the welding was the most influencing factor and identified the fine grains near the weld interface. The joint without holes on the circumference showed higher Hardness and strength compared to that of joints with holes and also aluminium alloy by rotary FW and studied the effect of the speed of weld specimen rotation. The results found an increase in the friction heat at the centre of the joint while the rotational speed increased. The equated grain structure was formed in the joint. Phases like TiAl and Ti3Al were found at the interface. It was stated that a speed of 100 rpm was needed to attain improved strength and impact toughness [24].

2.4 FORGING STAGE

Friction welding, which is well known among solid state joining methods, can be applied to join dissimilar materials. However, since it’s joining mechanism has not been fully clarified, to determine the friction welding conditions for material combinations are essential. In particular, the joining mechanism between dissimilar materials differs from that of similar materials because mechanical properties such as the tensile strength and thermal properties such as the thermal conductivity are different in their combinations. To theoretically determine the friction welding conditions, it is necessary to clarify the joining phenomena and the joint mechanical properties for various combinations of materials.

The friction welding machine utilized for the joining was a continuous (direct) drive unit equipped with an electromagnetic clutch to prevent braking deformation during the rotation halt. The necessary combinations of friction speed and friction pressure were set during the friction welding procedures in order to witness the joining phenomenon. One such observation was friction touring with friction pressure. [46]

Applying forging pressure at the end of the heating process causes the work piece to become axially shorter. The effect of this disturbance has been observed to be the flash. When compared, the speed, pressure, and axial shortening/upset mechanism of the later phases of the friction welding procedures involving direct drive and inertia are quite similar. As the speed decreases, a second torque peak emerges as a result of the interface bonding and cooling below its maximum temperature. The torque then decreases when the rotating speed hits zero.

With different metals, the bonding process is more intricate. The bonding process may be influenced by a variety of elements, such as mutual solubility, surface energy, crystal structure, physical and mechanical characteristics, and IMCs. A very small area near the interface is probably going to see some alloying due to mechanical mixing and diffusion. The overall joint qualities could be significantly impacted by the characteristics of this layer. Bonding can also be facilitated by mechanical mixing and interlocking. It is very difficult to anticipate the weld ability of different metals due to their complexity.

A set of tests created specifically for that purpose should be used to determine whether a given combination is suitable for each application [33].

2.5 PROCESS PARAMETER

Important welding parameters in the FW process include burn-off length (BOL), edge preparation/modification, parent material position (PM) on both the rotating and nonrotating sides, friction time (FT), friction pressure (FP), upset pressure (UP), and upset time (UT) [31]. To construct the junction in the base metal, three crucial elements must be considered: time, pressure, and speed, either separately or in combination. Few flaws are created by the melting and solidification of the metal during solid state welding because the metal does not reach its melting temperature. Since melting does not occur during solid state welding, the metals being welded maintain their original characteristics. [33].

The present manifestation, sequence, and value of these process parameters—which include oscillation frequency, oscillation amplitude, friction pressure, oscillation direction, forging pressure, friction time, forging time, welding time, axial shortening—can have a significant impact on the process as well as the final welding properties, according to Wenya Li in the review article on the use of various process parameters to control when welding with linear friction welding. Forging pressure, friction pressure, and oscillation direction are the three most important factors that affected the rate of heat generation among them. Whereas welding time, axial shortening and axial shortening rate depends which list in the above in experimental procedure that much not need to now axial shortening but in industrial it is very critical to now for production [27]

Process parameter is challenge for mechanical test because when see Maximizing the UTS, YS, and % E of FS welded joints of AA 6061-T6 as well as determining the ideal process parameters were two of the investigation's main goals. The UTS, YS, and TE in the FSW process were modelled and analysed using response surface methods. Up to a maximum value, the UTS and YS of the FS welded joints increased as the tool's rotating speed, welding speed, and tool axial force increased. After that, they dropped. Joint TE grew as rotating speed and axial force increased, but steadily dropped as welding speed increased [28].

2.5.1 ROTATIONAL SPEED

Conditions related to heat input are directly impacted by rotational speed. Rotation speed increases heat input, which in turn controls the behaviour of the material softening at the work pieces' facing surfaces. In the case of FRW, adequate rotation speed is necessary to create a sound weld free of defects. Given its direct correlation with heat input conditions, rotation speed has a considerable effect on weld characteristics for dissimilar FRW. Temperature and deformation of bulk materials at mating surfaces are influenced by variations in rotation speed. As a result, different welds produced at various rotational speeds provide varied microstructural characteristics and material mixing behaviours [31].

For both active damping of the first drive-train mode and power control, the rotational speed is recorded.

Process parameters of LFW there are a large number of process parameters to control when welding with LFW, whose presence, sequence and value can have a significant impact on the process as well as on the finished joint properties. These are: (1) oscillation frequency, (2) oscillation amplitude, (3) friction pressure, (4) oscillation direction, (5) forging

Pressure, (6) friction time, (7) forging time, (8) welding time, (9) axial shortening (or burn-off or upset) and (10)axial shortening rate. Among them the first three parameters are the most important factors which influence the heat generation rate. The last three parameters in the list above are dependent on the first seven. Industry uses axial shortening as a marker for a successful joint and production of a part to specific dimensions [45].

Using a rotary encoder on the generator shaft to detect rotational speed is standard procedure. This is a digital device with a rotating portion and a stationary part. The spinning component, which is positioned on the generator shaft and has a normal speed range of 750 to 1500 rpm, is outfitted with several equidistant markers. Shaft's rotational speed The shaft's rotational speed was determined both experimentally and numerically using the model. We looked into the shaft's rotation up to 40°. The ten chambers of the hydraulic motor are represented by the ten similar patterns that were found. The rotational speed measured in the laboratory was, on average, somewhat lower than the rotational speed obtained numerically. The areas around the peaks and valleys showed the biggest variation in the results. There was little variation in the "peak to peak" or "valley to valley" patterns. There was a slight variation in several patterns. Turbulences in the hydraulic motor's channels and chambers as well as less-than-ideal manufacturing techniques may be the causes of that [25].

2.5.2 FRICTION PRESSURE

While the chosen pressure should be repeatable for each particular activity, the effective pressure ranges for heating and forging are likewise wide. The axial shortening, necessary driving power, and temperature gradient in the weld zone are all regulated by pressure. The metals being bonded and the geometry of the junction determine the specific pressure. As in the case of tube to plate welds, pressure can be employed to make up for heat loss to a big mass. To prevent oxidation, the heating pressure needs to be strong enough to maintain close contact between the faying surfaces. Low pressure restricts heating with little to no axial shortening for a given spindle speed. Rapid axial shortening and local heating to a high temperature are caused by high pressure. The rate of axial shortening for mild steel is roughly proportional to the heating pressure. It also demonstrates that axial shortening is larger at low speed than at high speed for a given pressure during the heating phase. Applying more forging power towards the conclusion of the heating process improves the joint quality of several metals, including steel. [33].

2.5.3 HEATING TIME

The amount of time needed to heat something is decided upon during setup or by past experience. Overheating consumes materials and reduces production. Inadequate time can lead to unbounded regions at the interface, entrapped oxides, and uneven heating. Friction welding in a bar stock is characterized by uneven heating. The surface velocity may be insufficient to produce sufficient frictional heating close to the centre of a revolving bar. Therefore, to guarantee a strong bond overall, thermal diffusion from the outer part of the faying surface must occur. There are two ways to manage the heating time. The first is with a suitable timing device that stops rotation at the end of a pre-set time. With the use of a sequence timer, the heating time can be combined with the preheating and forging functions. The second technique is to halt rotation when reaching a specific axial shortening [33].

2.6 PROPERTIES OF FW OF DISSIMILAR METALS

The ability to weld a wide variety of incompatible metal combinations is the most significant aspect of FW. It is not hyperbole to state that the FW process is superior to all other welding procedures in terms of this attribute. Additionally, the joining process is highly reproducible, mechanized, and uses processing procedures that combine three factors cost-effectiveness, speed, and strength that have been proven to be essential to the manufacturing of commodities in recent years. Even in cases where the combination of materials to be welded has significant differences in mechanical and metallurgical properties, such as melting points (between tungsten and copper), low melting point metallic materials (between copper and aluminium), and material strengths (between stainless steel and pure aluminium), friction welding can still produce a good joint efficiency. Additionally, this joining method has many benefits, including the fact that it doesn't require any prior welding knowledge, produces less heat than other welding methods, and doesn't release any harmful gases like carbon dioxide into the atmosphere. Surprisingly, though, few designers are aware of this procedure, and some engineers even seem to view it as an odd processing technique [32].

2.7 FRICTION WELDING OF STEEL ALLOYS WITH OTHER METALS

Friction welding is a solid state joining technique that uses the heat created by carefully rubbing two faying surfaces together to create coalescence. The material enters the softened stage due to the heat generated, at which point the plasticized material starts to form layers that interfere with one another and produce a high-quality weld. Numerous scholars have examined the impact of FW parameters on steel quality [31].

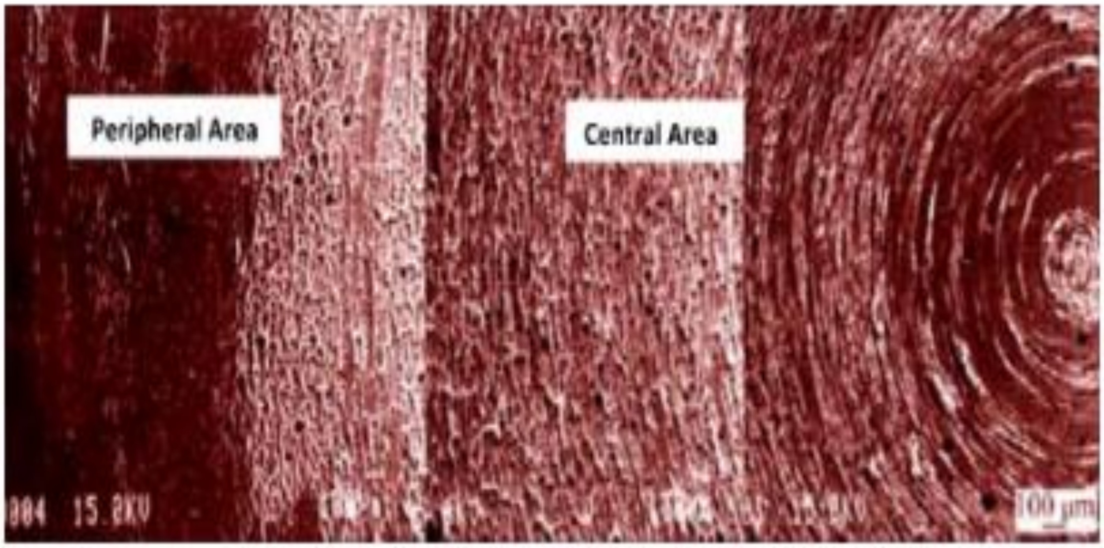


Figure 2.5 SEM image of the fracture surface on the nodular cast iron side [33].

Localized mechanical property fluctuations and microstructure control are important considerations when analyzing friction stir welding. Even in cases where a sound weld can be created, the full transformation of microstructure and the ensuing loss of mechanical properties associated with fusion welding pose a major concern. Friction stir welding has the ability to prevent major changes in mechanical characteristics and microstructure because it is a solid-state technique.This work aimed to assess the microstructural modifications brought upon by friction stir welding 7075 Al [10].

The interesting thing about friction stir welding is that the grain size within the weld zone is not incredibly small in the friction stir weld development that is illustrated and compared. As a result, basic concepts involving grain boundary sliding to account for the superplastic deformation associated with the friction stir weld appear insufficient. However, during recrystallization, there may be a significant increase in grain size. Grain boundary sliding is simply one cause of plastic strain incompatibility; slip and cross-slip also play a role. In order to meet the requirements of surface traction continuity and displacement at these interphase boundaries during the deformation, intergranular accommodation slip must also occur when second-phase particles arise, as in this experimental study.

The development of friction stir welds appears to be dominated by slip deformation, and recrystallization is dynamic and continuous, evolving where sub-grain boundaries occur and cause a constant rise in disorientation. Thus, the introduction of ac-commendation dislocations within sub grains and their absorption into the boundaries through "annealing,"

Which is aided by friction-induced heating in the weld zone, characterize the process. An understanding of the dynamic continuous recrystallization mechanism under superplastic deformation is given [11].

There are many studies, this shown the grave detrimental impact of corrosion on steel performance. The mechanical behaviour of steel has been improved by friction stir processing, which modifies its surface. Nevertheless, the impact of corrosion and its pace of deterioration are crucial considerations when using steel in corrosive settings.

Examined the low carbon steel's corrosion behaviour in two different environments—air and water—following the completion of FSP. Fine-grained marten site and ferrite were produced in the treated zone as a result of the phase transition and dynamic recrystallization seen during FSP. When FSPed underwater more homogeneous dispersion of fine marten site lath developed. At room temperature, PDP and EIS testing were carried out in a 3.5 weight per cent NaCl solution. The underwater electrochemical corrosion resistance of FSPed steel specimens was superior because of the dense and consistent passive film [56].

2.8 FRICTION WELDING OF BRASS ALLOY WITH OTHER METALS

Jian luo et, al perform a study of a radial friction welding interface between high carbon steel and brass. The CT-130 unique inertia friction welding equipment is utilized to complete the dissimilar welding of H90 brass and D60 steel, which has a large diameter of 156 mm. To analyse the interfacial properties of the H90/D60 welding junction, SEM and EDS techniques are used. The findings demonstrate that a smooth line forms in the centre of the welding interface, a nice welding seam is generated, and some furrow-shaped holes arise at the end of the welding joint. [30].

Y. Gao et,al also analyse the microstructures and mechanical characteristics of friction stir-welded dissimilar lap joints made of steel and brass at different welding speeds through experimentation. Friction stir welding was used to create dissimilar lap joints between ordinary carbon steel (S25C) and commercial brass (Cu-40Zn). During the friction stir welding operations, the relationship between welding speed and heat input was examined. Investigations were conducted into the impact of welding speed on the mechanical characteristics and microstructures of brass/S25C dissimilar junctions. [26].

2.9 RELATED RESEARCH

Different author can conduct certain research in joining two dissimilar metals using certain techniques as shown below:-

Gomathisankar et al, Conduct an experimental friction stir welding process for AA6061-T6. Values for hardness and tensile strength are gathered for several welding parameter combinations under varied welding situations. The following results were then reached: - The Taguchi-based COPRAS decision model is a highly helpful tool for solving the multi-objective function that predicts the tensile strength and hardness of AA6061-T6 during friction stir welding. Welding speed (50.63%) is the most important parameter, according to the ANOVA results, followed by tool rotational speed (19.17%), dwell duration (21.98%), and tilt angle (8.20%). Additionally, the author's results show that the ideal friction stir welding parameters are 1112, which stands for tool tilt angle at 1 (degree), dwell duration at 1.5 (min), welding speed at 20 (mm/min), and tool rotational speed at 450 (r.p.m.). The outcome showed that increasing tensile strength and hardness required a high feed rate. Comparatively speaking, the tool's tilt angle, dwell time, and rotation speed have relatively little of an impact on its mechanical qualities [18].

Mao Yuqin et, al in this work, five distinct pin-tip profiles were created for AA7075-T6 alloy plates with a thickness of 20 mm via friction stir welding. There was a description of how the pin-tip profile affected the temperature distribution. The fracture surface analysis demonstrated that the joints were impacted by the different pin profiles used in the tool [19].

Shojaeefard et al Using Taguchi's method, the tool's rotation speed, feed rate, and shoulder diameter were optimized for tensile strength, hardness, and grain size. The ideal parameters were a feed rate of 6.5 mm/min, a tilt angle of 1.5 degrees, and a rotational speed of 1120 tools. Due to the development of small recrystallized grains, the welded nugget region (ST) had the maximum hardness value [16].

Boldsaikhan et al presented a novel method for the non-destructive identification of wormhole faults in the FSW. They gave an example of a method that offered real-time feedback on the quality of the weld. The suggested real-time evaluation algorithm for FSW appears to be a promising solution for creating an intelligent feedback control system for FSW, based on all of the results. Additional research is suggested in this publication to examine the effects of additional parameters on the feedback forces [17].

Baratzadeh et al The micro structure and mechanical characteristics of lap joints created by friction stir welding (FSW) between 3.5 mm thick sheets of the automotive aluminium alloys AA6082-T6 and AA6063-T6 are the subject of a study. Their research determined the optimal process variables for improved weld quality while employing different aluminium alloys. Ultimately, it was found that the interface between the top and bottom sheets was where the greatest portion of the stress distribution based 237 the Von Mises contour map occurred. Overall, this 238 study helped to find different process parameters for improved weld quality and optimized 239 friction stir lap welds of dissimilar aluminium alloys [15].

Msomi et al. examined the joint quality of aluminium alloys 5083-H111 and 1050-H14 that were welded together using friction stir welding. The mechanical characteristics and micro structure of the welded joint were examined and contrasted with those of the base materials. There was discussion of the relationship between the welded joint's micro structure and mechanical behaviour. The findings showed that the welded joint's tensile strength was more than that of AA-1050-H14 and less than that of AA-5083-H111.When compared to AA-5083-H111, the friction stir region's micro-hardness fell within the same range and exceeded that of AA-1050-H14 [21].

Regression analysis, analysis of variance, and the Taguchi approach were recently used by Nakowong and Sillapasa et al. to optimize the process parameters for the FSW. Their main areas of interest were microstructure, hardness, and tensile strength; the semi-solid metal alloy 5083 aluminium was the subject of the study. The goal of this manuscript is to optimize the parameters of the welding process for a commercial aluminium alloy using friction stir welding (FSW).

The literature evaluation stated above demonstrates how crucial this kind of research is for industrial decision-making and major structural design. To the best of the authors' knowledge, there are studies that optimize the process parameters of FSW on aluminium alloy 5451, which is commonly used in many industrial applications, including marine applications due to its excellent weld ability and corrosion resistance, but few studies look into the process parameters of some materials in the joint process. [22].

2.10 SUMMARY OF MOSTLY RELATED RESEARCH

Table2.1.Summary of most related research paper.

Title of paper	Author	Methodology used	Gaps to solve	Finding and solution
Microstructures and mechanical properties of friction stir welded Brass/steel dissimilar lap joints at various welding speeds [29].	Y. Gaoa K. Nakataa K. Nagatsukaa	During the friction stir welding operations, the relationship between welding speed and heat input was examined; Additionally, the impact of welding speed on mechanical characteristics and microstructures was examined.	This research focuses solely on the mechanical and micro-structural characteristics of lap joints that are welded.	For sound dissimilar lap joints made of steel and brass, the range of welding settings is relatively limited. Regarding the fluctuation in welding speed:- There are variations in the tensile shear fracture, Vickers hardness at the agitated zone, and grain size. .
Optimizing tool diameter for friction stir welded brass/steel lap joint [26].	Y. Shibatac Nagatsukaa M. Amano	Commercially available brass plate are welded with plain carbon steel S25C	Determining the optimum diameter of tool material	The increase in probe diameter significantly reduced the tensile shear fracture load of the lap joints, although the increase in shoulder diameter somewhat increased it.

The Specifics of Producing Steel to Brass Bimetal Using Explosion Welding [28].	O.L. Pervukhina, I.V. Denisov	Energy-condensed systems based on industrial explosives of a mixture of ammonium porous nitrate with diesel fuel in a ratio of 96:4 by weight. Experiment was conducted. Material used was low alloy steel with L63 brass, then after joins Ultrasonic test was used for result indication.	Because of welding dissimilar metals was a main gap due to evaporation of zinc and copper	The metallographic studies of bimetal showed that when the distance from the beginning of the process increased, the number of cast inclusions in the bond increased. In the zone adjacent to the discontinuity flaws, the cast inclusions formed by a continuous strip with a large number of pores was observed.
Effect of friction welding condition on joining phenomena and joint strength of friction welded joint between brass and low carbon steel [8]	M. Kimura , K. Kasuya, M. Kusaka, K.Kaizu1 and A. Fuji	During Experimental conduct A continuous (direct) drive friction welding machine was used for the joining. During friction welding operations, the friction speed and pressure were set to the following combinations: 27.5/Second (1650 rev per min) and 30 MPa, and 27.5 per second and 90 MPa.	Determining the effect FW on the strength and surface of brass with steel metal, Only literature review was conducted no compression test and also no use of Taguchi method	Brass moved to the LCS side of the weld interface's half-radius area. Next, with increased friction duration, the transferred brass stretched towards nearly the entire weld contact. Prior to the first peak, the centreline temperature at the LCS side's weld interface was higher than the half-radius and peripheral temperatures.

2.11 RESEARCH GAP

From certain research paper, article and journals reviewed above the following gaps are identified:-

- So many researches in the literature can conduct a dissimilar welding on friction welding in aluminium and its alloy and also copper and its alloys very limited researchers are conduct a friction welding especially brass metals weld with other material.

- There is also a wide gap of researchers visited on which performance parameters of friction welding which can affect the strength and surface of welded products. Because some of journals concludes as rotating speed and the other as feed rate can play a great role on strength and surface of welded parts.

- This research is focused on experimental with has done task and also no need of tools for friction welding the material by itself function as a tool for weld of Brass and carbon steel dissimilar material , carbon steel material using act like a work pieces itself as welding mechanisms to join the material.

CHAPTER THREE

3. EXPERIMENTS METHODS AND MATERIALS

3.1 RESEARCH METHODOLOGY

This chapter section is offered under different list of subdivisions such as the experiment's parent materials, the experimental setup, the experimental techniques, the process parameters, and the testing procedures. Before see the subdivisions parts in detail first see the detail research process flow chart for current investigation in figure 3.1

3.1 METHODS

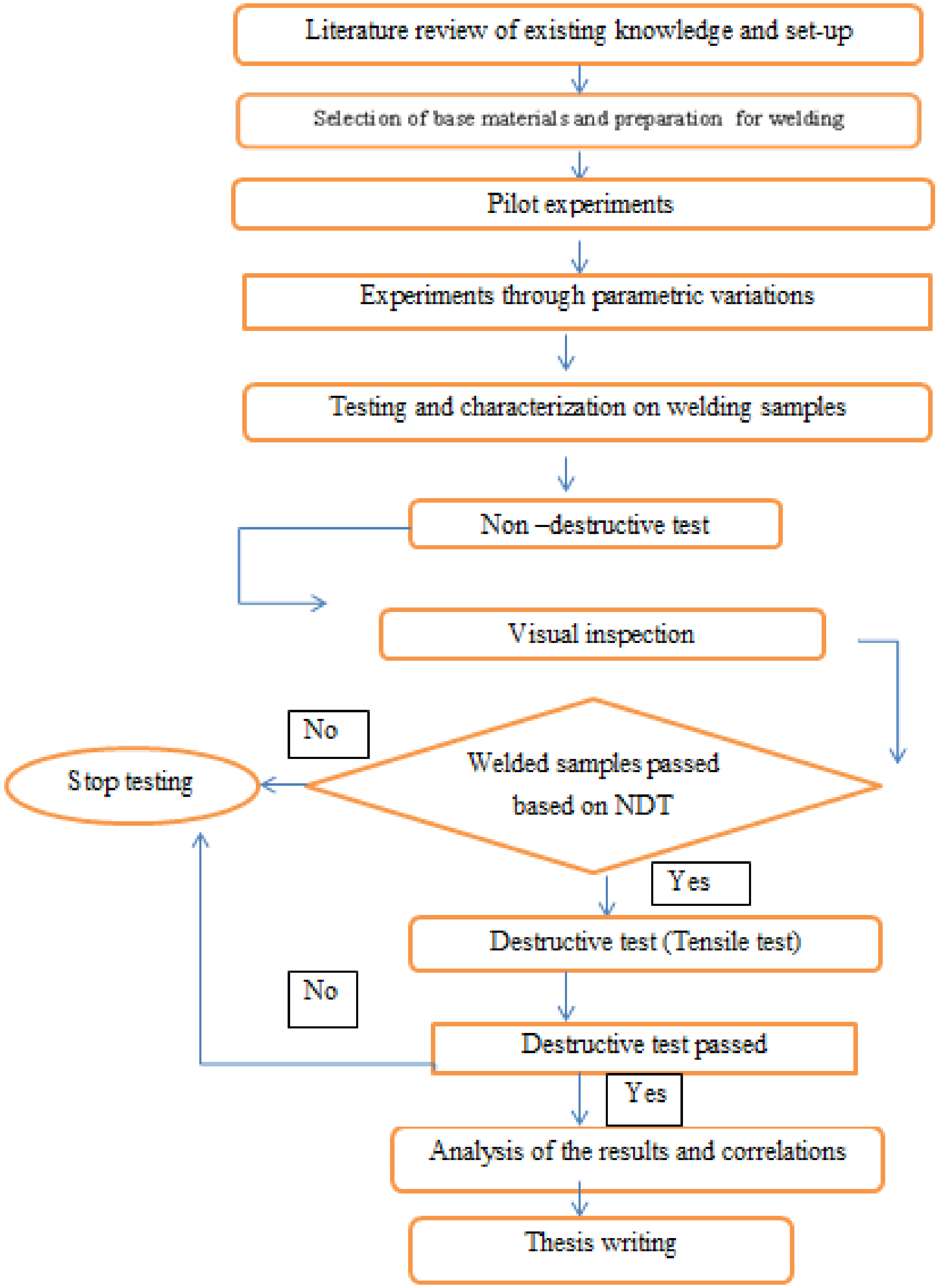


Figure 3.1 Research methodology flow chart

3.2 PARENT MATERIALS AND EXPERIMENTAL SET-UP

The experimental procedures involve frictional welding of various sizes on a brass and steel joint arrangement using a lathe machine.

The experimental joint materials have an outer diameter of 12 mm and an outer diameter of 15 mm (OD) [37].

Figure 3.2 Brass rod with dia 12mm and 15 mm

Figure 3.3 low Carbon steel rod with dia 12mm and 15 mm

In this research brass material thickness used the same as most of different worker installed in the previous time apply for water tanker float valve for high reservoir tanker , in the water pipe line system float valve does not contact with water but indirectly influence by the vibration load which happened in container and also fluctuate of pressure in pipe line, when pump start and close unexpected load create challenged for threaded brass rod connected with carbon steel nut materials, when connection of nut and float rod problem happened in fluctuation of pressure through life time stage ,can have a miner option to managed ones again only by rework two dissimilar threaded. If similar problem happened for float steel nut and brass rod threaded connection it is difficult to use threaded for the third time by different factor, and also when brass rod is replace with carbon steel rod steel will be corrosion and it is difficult for use different purpose because corrosions damaged water tank water quality unless otherwise if not maintain corrosion [36].

Generally tables 3.1 and table 3.2 is mechanical properties of brass and low carbon steel shown whereas the chemical composition value shown in table 3.3 and table 3.4 below provide for brass and steel respectively the experimentally tested values for chemical compositions of the parent materials

Table3. 1 Mechanical properties of brass [8].

Parent material	**YS (MPa)**	**TS(MPa)**	**% Elongation**
Brass	247 MPa	391 MPa	46%

Table 3.2 Mechanical properties of steel [8]

Parent material	**YS (MPa)**	**TS(MPa)**	**% Elongation**
black steel	284 MPa	451 MPa	36%

Table 3.3 Chemical composition of brass

Parent material	**Cu**	**Zn**	**Al**	**Si**	**Pb**
BRASS (wt%)	59.39%	33.69%	1.36%	2.56%	2.10%

Table 3.4 Chemical composition of Steel

Parent material	**Fe**	**Zn**	**Cu**	**Si**	**Al**	**S**
Low Black steel (wt%)	94.61%	0.12%	0.57%	1.46%	0.94%	0.18%

All above chemical compositions value which is taken sample test result from Quality and standards Authority seen in appendix parts by using Setting up Your Niton XL5 Analyzer machine from Thermo Fisher Scientific chemical composition reading Manufacture Company.

During this research friction welding operates under rubbing action of direct drive friction through weld faying surface between two work pieces which means brass gate valve and schedule 40 black steel pipes. Additionally, it has three distinct versions that regulate the relative mobility of the work components. These three distinct variations are linear, orbital, and rotary. Ultimately, the setup of lathe machine setups, as depicted in figure 3.4 below, will be the subject of this study procedure [39][41].

Figure 3.4 C620 lathe machine (Photo taken from AAiT mechanical work shop)

The research experimental material will be done by a machine as per detail specification as shown in table 6.

Table 3.5 Lathe machine specifications

Machine	Lathe
Model	C620
Overall length	5 feet
Swing over gap	32 inch
Swing over bed	21 inch
Table width	11 inch
Spindle bore	1/34 inch
4 jaw chuck	20 inch
Motor	15.5 KW
Specification	400x1000 (mm)
Certification	Serial no 630690
Max Speed	1200 rpm

This machine which seen in figure 11 manufacture 1963 not much sophisticated but can access the machine by use work pieces as tool and further any important methods to weld, when it is slightly old system which means can use for friction weld based on the capacity of this thesis required. With this technique, heat is produced by specimens rotating and shifting from one material to another under drive stresses. This heat is necessary to create a bond between the brass rod and carbon black steel and eliminates needless material waste from the welding joint permanently [40].

The work piece or specimens will be welded using the low heat input friction welding method (LHI method), which is applied in this research, while the joining mechanism of the brass rod and carbon black steel is by means of a continuous or direct drive friction welding machine on setup of a lathe machine.

LHI method have more advantage from other method ones is by using this method can avoid deformed weld joint during breaking time the other is less axial shortening in addition of this LHI method apply for this research can get remove unnecessary heat input and less flush comparing of other [47]

The welding geometry of the brass rod and carbon black steel based on figure 12 and figure 13 respectively as shown below.

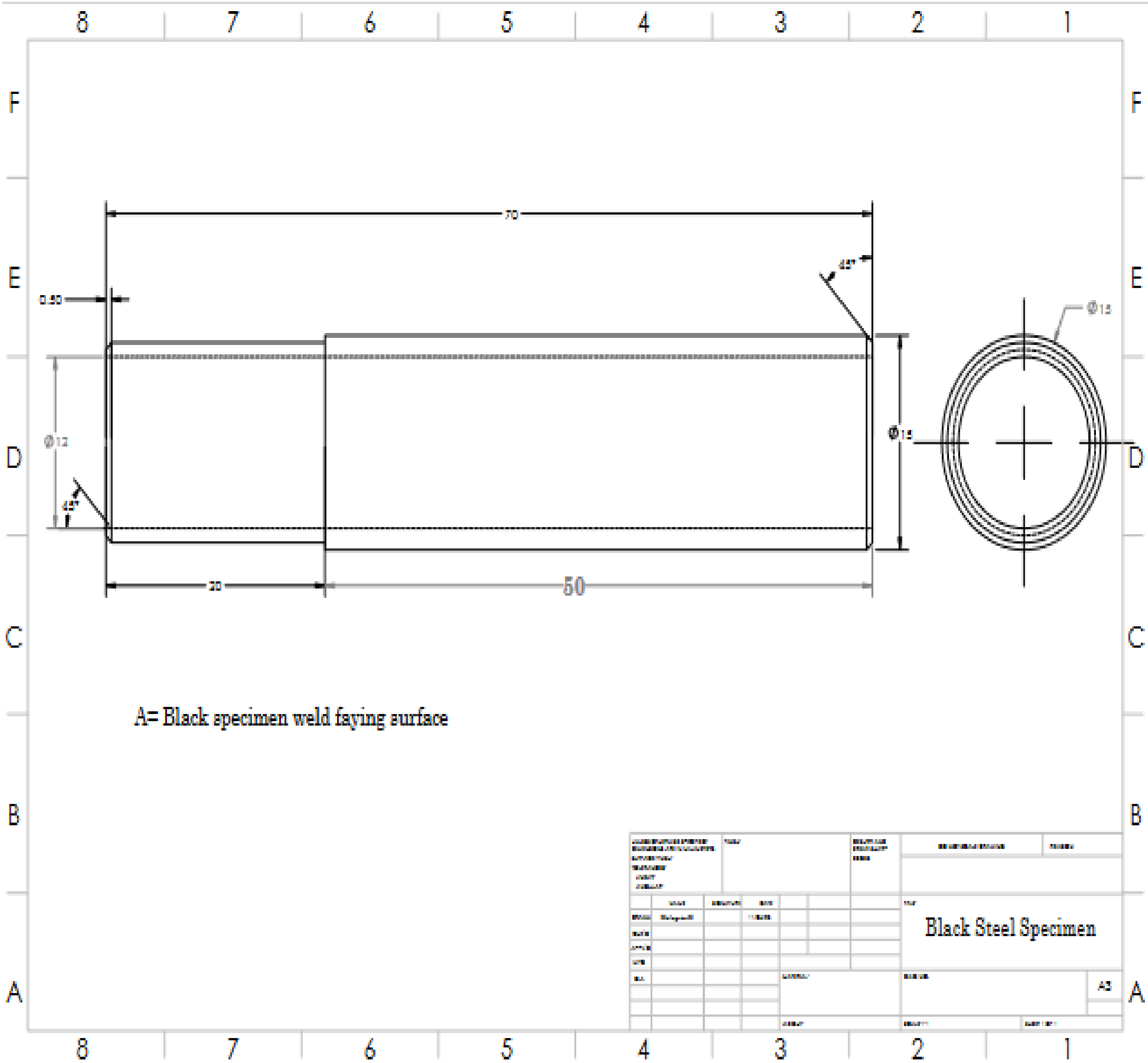


Figure 3.5 Dimensions of friction welding steel rod (mm) [8]

The above figure 3.5 and below figure 3.6 shows the detail dimensions of brass rod and low carbon steel specimens done in solid work for detail dimensions ready experiment procedure as per standards, which is can using for a machine of continuous direct friction welding method in the lathe machine's by arranged setup for dissimilar friction welding was made ready for various tests.

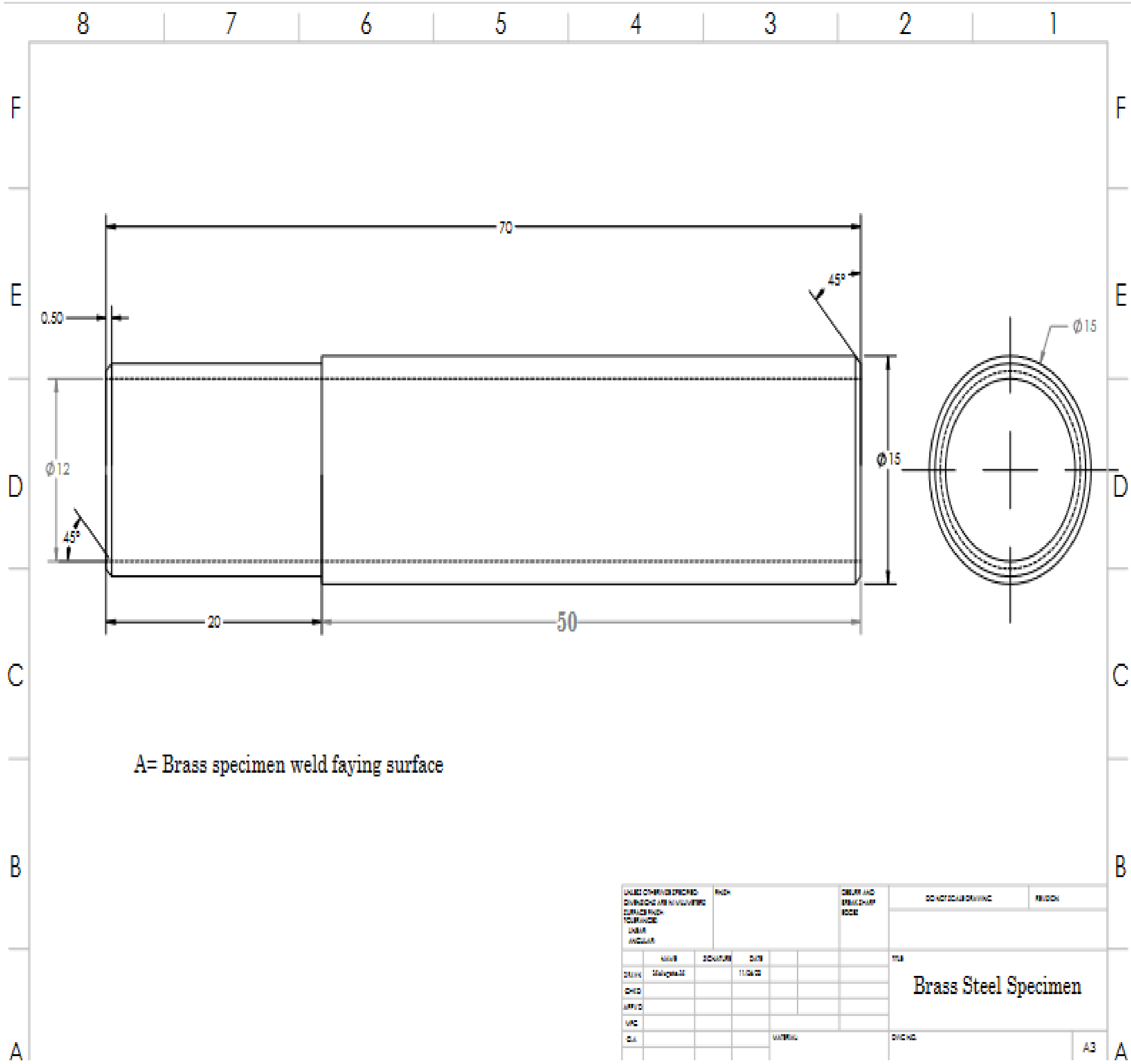


Figure 3.6 Dimensions of friction welding brass rod (mm) [8]

3.3 TESTING METHODS

To verify the quality of the weld connection, welding of different materials is subjected to both destructive and non-destructive tests. Tensile and hardness tests are conducted when examining the mechanical properties of dissimilar material junctions in a destructive manner. On the other hand, non-destructive testing involves the following tests: visual examination, which is covered in this research's subtitle 3.3.1, and mechanical testing hardness test, compression test and tensile test and finally corrosion test which is covered in detail in sections 3.3.2 through 3.3.5.

3.3.1 VISUAL INSPECTION

To performed visual inspection before welding check for surface cleanliness any contamination like oil, grease, or rust can lead to poor weld quality so in this thesis to identify visual inspection those step is performed. Visual inspection of welded connections will be performed by examining external surfaces immediately following the welding process, during which visually inspected by normal eye and test manually by hand. And also examine the heat-affected zone for signs of excessive heat input, such as discoloration or distortion. Different materials may react differently to heat, so it’s important to ensure that neither material has been adversely affected. Following finalized of non-destructive tests the next procedure is to destructive tests to test destructive tests different test applied in this thesis from those the first one is hardness test, next is compression test, then tensile testing and finally corrosion test done in this thesis no need pressure test because of different issue the main purpose is leakage improved or leakage test is not address in this thesis because the research is focus on rod (solid) material which is focused the effect of lose connection of steel nut and brass rod indirectly affect the pipe line system so no water flow in steel nut and brass rod connection (damaged of float valve doesn’t manage water flow in water tank) [44].

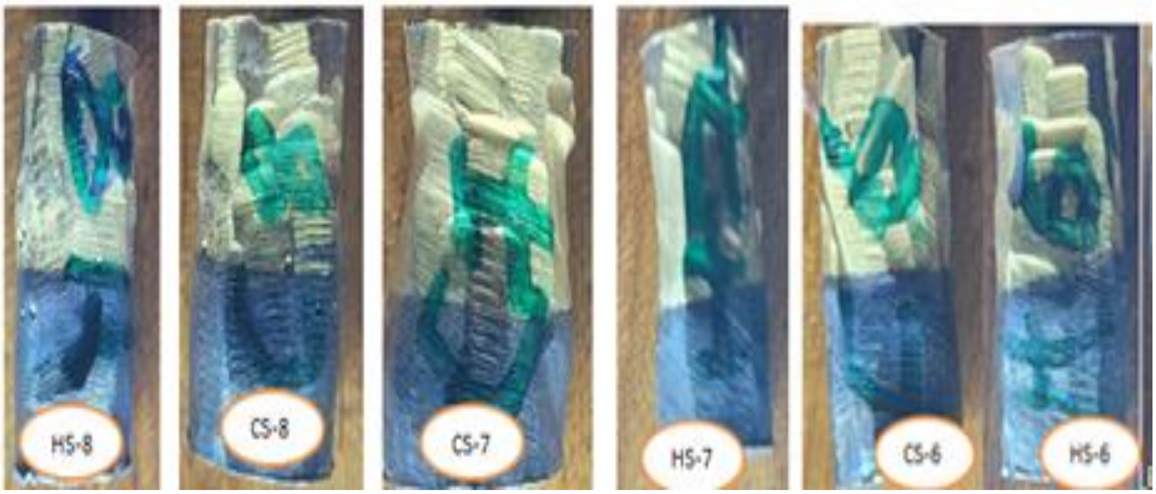
3.3.2 HARDNESS TEST

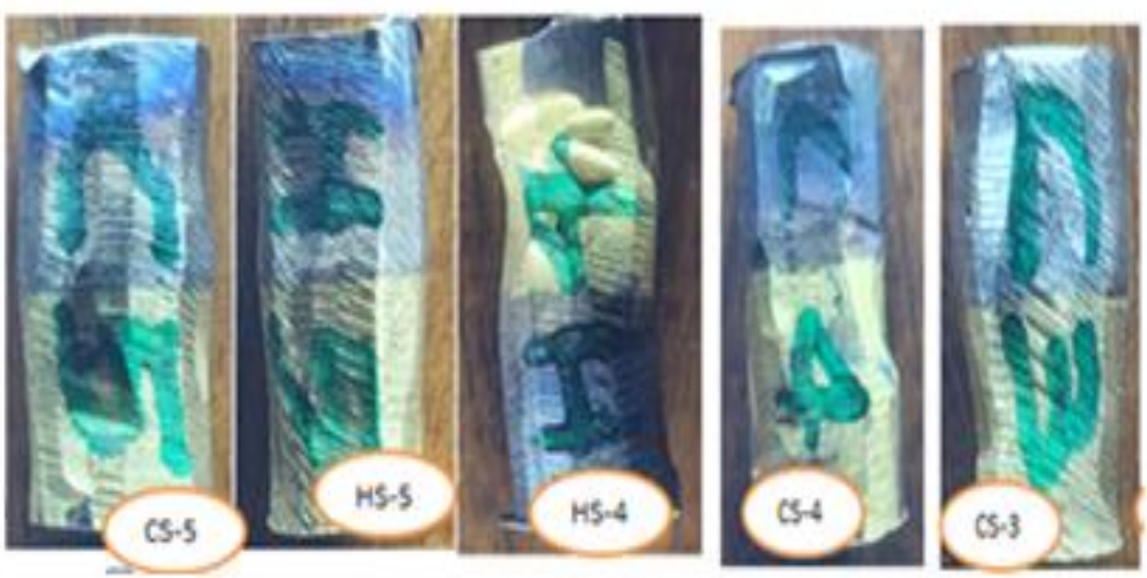
Utilizing cross-sections perpendicular to the welding line, hardness tests were performed on the work piece in three horizontal profiles: one at the Centre of the welding section and two at 2 mm intervals from the borders of one side, which represents the top side, and the other side, which represents the bottom side. The examination was carried out using 100 kg and the Rockwell hardness test, which is based on the ASTM E18 standard test. The distance between the indentations was 1/16 inch [42]52].

The first test in this research is hardness test which is done after weld of round steel and brass by direct friction welding machine on set up of lathe machine based on standards, hardness test specimens and compression test specimens done with in similar item by following of ASTM E18 standards.

3.3.3 COMPRESSION TEST

As per standards of ASTM International and ISO (International Organization for Standardization) the compression test specimens dimension ASTM E9 which is suggests for test at room temperature for metallic material it provides guidelines for arrange with length to diameter ration of 2:1 so with this reference the specimen size is for diameter 12 mm is 24 mm length and 15 mm diameter of second type of specimen is 30 mm length.





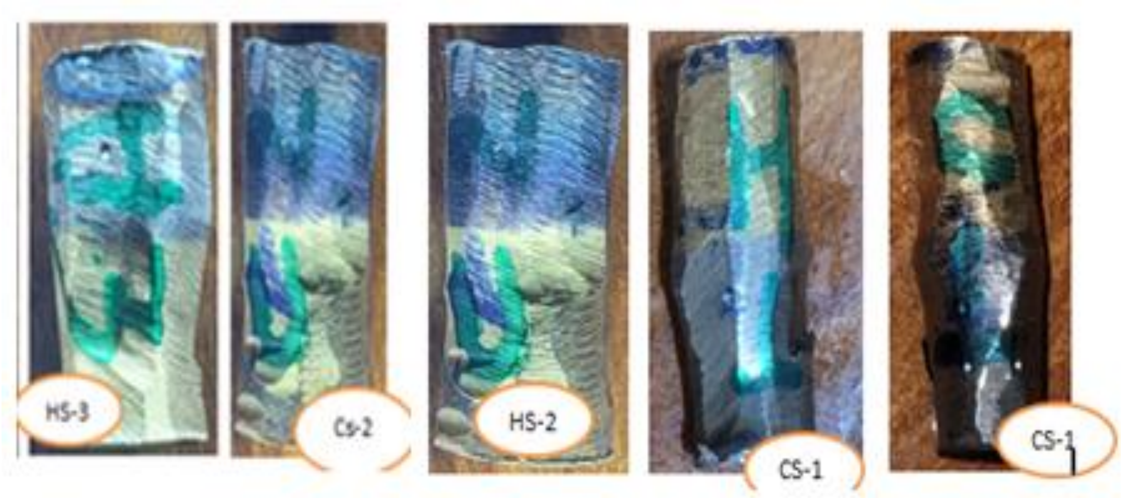


Figure3.7 Compression and hardness specimens sample

Hardness test done by united test Rockwell hardness below machine test as see in figure3.8 for two type of diameter which is diameter 12 mm and diameter 15 mm and two type of material which is brass and steel.

Figure3.8 United test Rockwell hardness test machine

3.3.4 TENSILE TEST

To determine the joints' capability, a continuous direct friction welding joint with the sample configured as shown in Figure 3.10 underwent a tensile test on specimens of black steel and brass welding material. The Friction sample tensile test specimens the welding joints have dimensions of 9 mm and 12 mm in centre and 125 mm in total length. The thickness varies according to the pipe diameter, which is 12 mm or 15 mm, which is the same as the original welded junction. To ensure the test specimen's axial loading, the two pieces which stand in for the adhesively joined black steel and brass on the welded specimens will be exhibited as shown in figure 3.10. To create a tensile test specimen, the investigative machining method is used. Based on the ASTM E8-08 standard for tension testing, the type universal testing machine model HTM1000 testing machine, as shown in figure 3.9, was used to study tensile strength [48][47].

Figure 3.9 Universal test machine

After reading of hardness test for the variety of specimen can progress lab test with similar sample of specimens ready for the reading of compression test for similar diameter and variety of specimens.

Next to reading measure of hardness and compression test the final test is tensile test with new specimen according to ASTM E8 standards specimens dimension is ready as shown in figure 3.11. The specimen material also done by direct driven friction welding machine on set up of lathe machine [47].

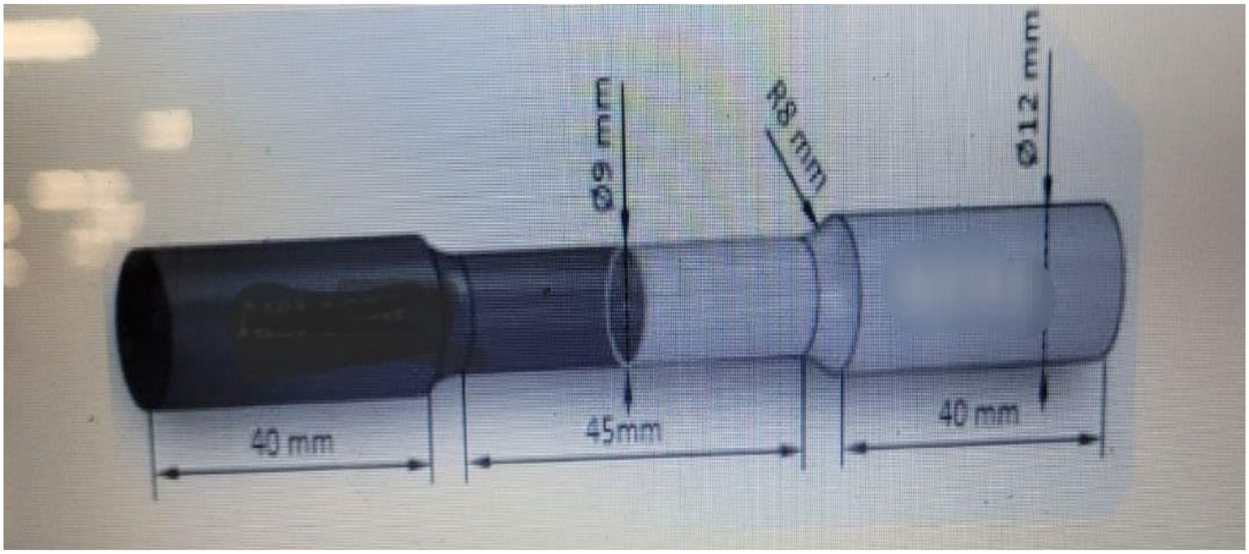


Figure 3.10Tensile specimen preparations as per standards [50]

After the tensile properties of the welds were assessed according to standard ASME as per figure 3.10 these tensile samples specimens material detail dimensions were sectioned and ready with the help of cutting machine from the welding work pieces material as shown in figer 3.11 and 3.12 below

Figure3.11 Welded part before extraction of tensile specimen

Figure 3.12 Extracted tensile specimens

3.3.5 COROSSION TEST

After non distractive test done followed by mechanical test done in this thesis like hardness test , Compression test, Tensile test done final in this thesis the corrosion test has be done for dissimilar brass and low carbon steel metal by Electro chemical corrosion testing

The specimens were subjected to 30 minutes of immersion in a 3.5% NaCl bath in order to conduct corrosion testing. The test specimens measured 14 mm in length and 15 mm in diameter. For one 14 mm in length and 12 mm in diameter for the other specimens as shown in corrosion specimens sample figure and to clean the specimen's surface the metal surface was treated by degreasing in absolute ethanol and the sample were put in as per standards of ASTM G44 in room temperature before they use in the corrosion studies

The list of reagents used in this corrosion study include Ethanol for state above, Sodium chloride (NaCL3.5%) is used to generate a highly corrosive environment in test system, distilled water because ions are not found in distilled water so it is free of oxygen no any rusting minerals create element are required, electrode which used in Electro chemical corrosion testing was graphite.

Apparatus used in this research include 200 ml graduated measuring cylinder, Electronic weighing balance, Spatula, stop watch and any other relevant apparatus used for this test.

Figure 3.13 Electro chemical corrosion testing set up (A) and Sample prepared for corrosion test (B)

The source of electric is DC power supply which is a device that creates and supplies direct current from AC power supply out with low volt procedure integrated with chemical is NaCI of 3.5 % and the rest is distilled water to create corrosion.

The corrosion rate was calculated using the conversion formula (3.1)

Corrosion rate (mm/y) =

$$87.6W//DAT \qquad (3.1)$$

Where

W is the weight loss in milligrams of specimen (mg),

D is the density of the specimen (g/cm3)

A is area of sample in cm2

T is time of exposure of the metal sample in hours

Weight loss was calculated by comparing the sample's weight before and after it was fully submerged in the prescribed solution in an open glass beaker for a suitable amount of time.

The weight loss calculated (g) is

$$W1- W2$$

Where

W1 is the weight of the sample before immersion in test sample and

W2 is the weight of the sample after immersion in test sample

Density of the specimens were determined from weight and volume measurements

Density is

$$M/V$$

Whereas

M is weight of sample

V is volume sample

The sample's weight can be obtained directly using an electronic weighing balance, but the volume can be obtained indirectly by applying the Archimedes principle, which states that the volume of a solid immersed in water equals the volume of the solid itself. The sample volumes were computed as follows: V2-V1 is the sample volume. Area specimens with an exposed is 1cm2 for diameter of 15 mm and time for 30 min are consider for corrosion rate calculation [53].

3.4 EXPERIMENTAL PROCEDURE

The experiment procedure to weld specimens on lathe machine lay out as follow brass will be hold by vice of lathe machine which shown in figure 18 which is lathe machine vice Photo taken from AAU AAiT and fix on lathe worktable because brass will be easily evaporated than steel, so in a case welding process zinc and copper will be evaporation due to soft material because of this to reduce flash formation brass will be fixed specimen material position.

Whereas carbon steel rod as compare to brass rod interims of porous happened after welding schedule steel rod is great than brass so for this research black steel rod will be as used tool for continuous drive friction welding process on the set up of lathe machine to weld this dissimilar material of black steel and brass [43][31].

The other part of dissimilar material which means carbon steel is inserted in holder based on equivalent size with the help of adjusting size holder which shown in figure 3.14 and the joining black steel rod and specimen clamp fit with lathe machine in spindle.

Figure 3.14 Lathe machine specimen clamp (A) and lathe machine vice (B) (Photo taken from from AAU AAiT mechanical work shop)

In order to explore dissimilar welding for its range of material sizes and process parameters, several sets of research tests will be conducted. Every series of experiments is carried out in order to analyse the effects of particular process parameters on the characteristics of different sized rod joints. This dissimilar welding experiment will do by using lathe machine setup as per shown in figure 3.15 with high rotational speed machine [43].

Figure 3.15 Welding experimental process records on lathe machine

3.5 EXPERIMENTAL PROCEDURE DETAIL

When welding experimental procedure done pass different obstacle phase the one which challenge process parameter is welding with normal scenario is very extremely difficult so to solve this process apply varies methodology

When welding brass steel the dissimilar material in lathe machine identify the materials which fix on rotation part and other material fix in stationary parts so based on selection brass rod material is fix on stationary parts where as black steel rod material fix in on the rotational of lathe machine

After fix the material on machine the next step is based on the specified experimental parameters start friction weld machine but within this scenario when apply similar pressure with different rotational speed with fluctuate time the welding process do not weld, the problem of this when friction start between the material the brass material immediately molten before heat of steel which is very challenged so based on this problem take different measure.

The first problem solving mechanism is heating of steel so to give heat to steel before heating of brass, which is give a good indication but when temperature of steel increase and to connect with brass it is also difficult because within contact time which is before steel contact of brass the temperature of steel rapidly decease and the results is not satisfied.

So to weld this dissimilar material last option is reduce the contact time of heated steel with brass rod so fix one material besides of brass to create heat for steel by this scenario can weld the dissimilar material but it is not strong connection with miner vibration the material disconnect so to solve this one problem one last option is required.

The last option is by heating of steel material as the previous steps and reach of average from 600 to 800 degree centigrade shift the steel material with rapid flow to brass as informed before between this time the steel is decrease so when steel contact to brass immediately the steel material does not contact brass instead of brass steel contact jacket of brass which cover 0.8 mm sheet metal to maintain the decrease temperature of steel to the required with this immediately the brass and the steel achieve the required temperature for welding.

Finally after processing of this procedure for welding of dissimilar material on set up of lathe machine the material is welded [38]

3.6 TAGUCHI METHOD

The Taguchi approach applies control elements and experimental design .Uncontrollable elements or noisy components that are continuously taken into account as variations. These variables' influence cannot be eliminated. As a result, the primary goal of the Taguchi approach is to minimize product variation; to do this, the effects of every combination of certain process factors are examined while the remaining process parameters remain unchanged. During these research certain process parameters are considered through varying there capabilities. From those mainly friction time, rotational speed, cooling system and the material size are the one which illustrated detail [54].

The aforementioned variations in the size of the brass and black steel rod welding samples were used to determine the proper process parameter selection, which was based on the process's evolution and its unique outcome for each friction welding variant. Heat generation plays a crucial part in friction welding, as the process is controlled by localized deformation of the material. If additional sample is needed for the experiment, it will be conducted as needed to draw conclusions. The research will optimize the rotational speed were designed in the range of rpm, corresponding to the border linear velocity range from 0.66m/s to 2.73m/s. the completion of the study project based on the necessary [48][49].

Process parameters were built up using direct drive friction welding on a lathe machine using the rubbing technique on a faying surface.

3.6.1 Taguchi orthogonal array

On these research four factors, with mixed level, one factor having four levels and another three factor having two levels. L-8 (4^1, 2^3) Orthogonal arrays (OAs) were used in welding of steel and brass as shown on Table 3.6.

Table 3.6 List of varied factor used and their level

Factor		Range	Level			
			1	2	3	4
A	Rotational speed	610-1200	610	765	955	1200
B	Material size	12-15	12	15	-	-
C	Welding time	30-50	30	50	-	-
D	Cooling system	Yes –No	Yes	No	-	-

Therefore, the welding performed on eight runs with different model and the total iteration of 8 welding with 8 trial sequence was conducted. Table 3.7 displays the number of trials based on the amount of the specified criteria.

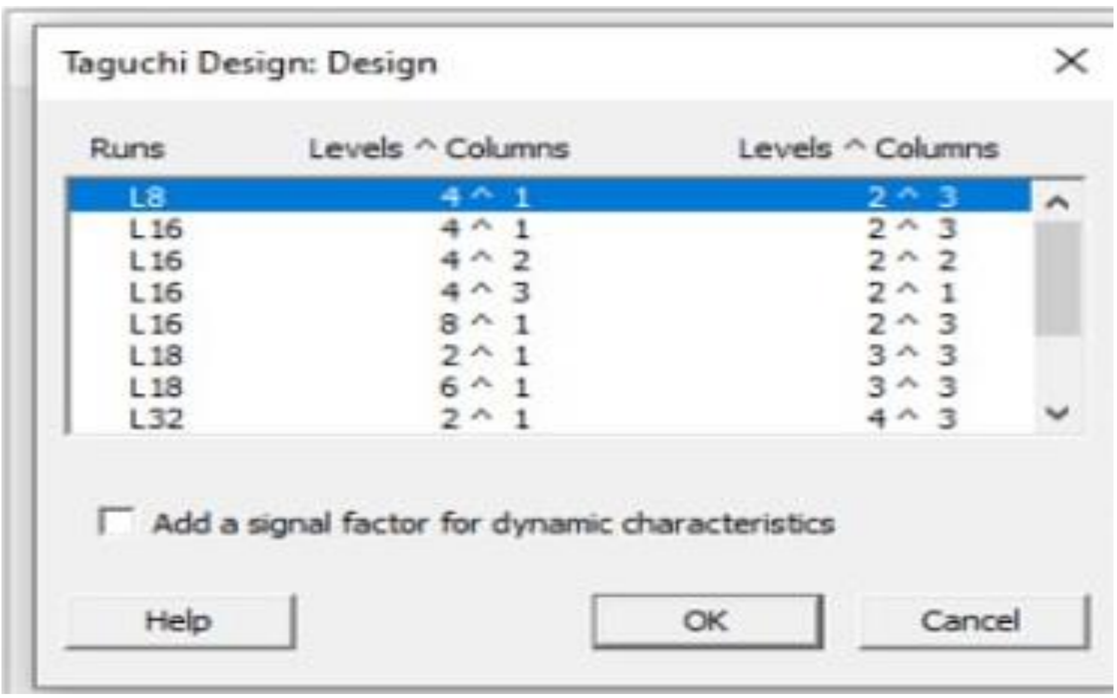


Figure 3.16 Welding experimental process records on lathe machine

Table 3.7 L-8 (4^1, 2^3) Orthogonal arrays [53]

Trial Order	Factor				Recorded Result			
	A	B	C	D	Tensile test	hardness test	Compression test	Corrosion test
1	1	1	1	1	-	-	-	-
2	1	2	2	2	-	-	-	-
3	2	1	1	2	-	-	-	-
4	2	2	2	1	-	-	-	-
5	1	1	2	1	-	-	-	-
6	1	2	1	2	-	-	-	-
7	2	1	2	2	-	-	-	-
8	2	2	1	1	-	-	-	-

When: -

A: - Rotational Speed

B: - Material Size

C: - Welding time

D: - Cooling System

The sequence that was designed with four factors versus four different levels applied to Minitab statistical software as calculation helps seen on Table 3.8

Table3.8:- Designed Taguchi Orthogonal Array

Trial order	**Factor**			
	A	B	C	D
1	1	1	1	1
2	1	2	2	2
3	2	1	1	2
4	2	2	2	1
5	3	1	2	1
6	3	2	1	2
7	4	1	2	2
8	4	2	1	1

.

Table 3.9 designed Taguchi for optimum process parameter OAs

Trial order	**Factor**			
	A (rpm)	B (mm)	C (sec)	D
1	610	12	30	Yes
2	610	15	50	No
3	765	12	30	No
4	765	15	50	Yes
5	955	12	50	Yes
6	955	15	30	No
7	1200	12	50	No
8	1200	15	30	Yes

.

Depending on designed Taguchi array eight different welding processes were conducted and their result of tensile strength, hardness and compression results were recorded separately and can refer Tguchiu design steps and references attached in appendix. After design taguchi array, selection of optimum process parameter conducted with a Grey analysis method using Minitab software.

3.7 GRAY RELATIONAL ANALYSIS (GRA)

When it comes to solving optimization issues in the realm of production engineering, the Taguchi approach is widely used. The technique makes use of the signal-to-noise ratio (S/N ratio), which serves the objective function to be optimized or maximized within the experimental, and an orthogonal array design, which is a well-balanced experimental design with a restricted number of experimental runs. Nevertheless, multi-objective optimization problems are outside the scope of the conventional Taguchi approach. The Taguchi method and Grey relational analysis have a broad range of applications in manufacturing processes to address this. Multi-response optimization problems can be simultaneously solved with this method. Grey relational analysis is becoming a very effective approach for analyzing processes that have several performance criteria. Grey relational analysis (GRA) makes use of a particular notion of data [51].

CHAPTER FOUR

4. RESULT AND DISCUSSION

4.1 RESULT

4.1.1 Mechanical property result

The discussion and results sections are given with several subsections and sections that take into account diverse materials of hardness test, compression test and tensile tests

4.1.1.1 Hardness test result

For Hardness test result, there were eight specimens of brass and steel welded material which is done on weld area by Rockwell scale B, indenter 1/16" and ball P major is 100kg from one specimens taken three reading.

TABLE 4.1 Rockwell hardness result of brass-steel weld (A) and Maximum and minimum hardness test specimen's value (B) (HRB)

HARDNESS SAMPLE S/N	**TEST1**	**TEST2**	**TEST3**	**AVERAGE TEST (HRB)**
HARDNESS TEST 1	57.2	60.7	34.4	50.76
HARDNESS TEST 2	54.2	46.8	44.5	48.5
HARDNESS TEST 3	85.6	61.3	73.8	73.6
HARDNESS TEST 4	83.4	54.8	69.3	69.2
HARDNESS TEST 5	35.9	33.6	43.9	37.8
HARDNESS TEST 6	75.6	69.4	68.5	71.2
HARDNESS TEST 7	52.2	76.6	53.3	60.7
HARDNESS TEST 8	84.2	94	76.9	85

Table A

HARDNESS SAMPLE S/N	maximum (HRB)	minimum (HRB)	range (HRB)	AVERAGE TEST (HRB)
HARDNESS TEST 1	60.7	34.4	26.3	50.76
HARDNESS TEST 2	54.2	44.5	9.7	48.5
HARDNESS TEST 3	85.6	61.3	24.3	73.6
HARDNESS TEST 4	83.4	54.8	28.6	69.2
HARDNESS TEST 5	43.9	33.6	10.3	37.8
HARDNESS TEST 6	75.6	68.5	7.1	71.2
HARDNESS TEST 7	76.6	52.2	24.4	60.7
HARDNESS TEST 8	94	76.9	17.1	85

Table B

The hardness of weld dissimilar material of brass and steel was done according to standard of ASTM E18 at room temperature 20^0c in a place of FDRE Technical and vocational training institute material testing laboratory shop.

Hardness of brass is 55-70HRB whereas steel is 55 up to 80 HRB, the maximum reading of hardness in test 8 is 85HRB this value record with different issue one is cooling system which means quenching ,the other is preheating the steel component can help reduce thermal stresses and improve the weld quality. However, be cautious not to overheat the brass.in this scenario hardness is increase from normal circumstances

4.1.1.2 Compression test result

Compression test results are read as hardness in eight specimens by MODEL HTM1000 of echo LAB Universal Testing Machine in Addis Ababa University AAiT mechanical work shop, speed of Pos 4.00 mm/min. The result load in kN is listed in table 4.2. The compression test measures when the load applied on one surface while the other surface is fully supported.

TABLE 4.2 UTM compression test result of brass-steel weld (KN)

Compression test Sample S/N	Compression test (KN)	Diameter Size (mm)
Compression test 1	38.124	12
Compression test 2	63.837	15
Compression test 3	57.94	12
Compression test 4	74.344	15
Compression test 5	65.471	12
Compression test 6	80.092	15
Compression test 7	67.611	12
Compression test 8	83.828	15

Figure 4.1 of this thesis illustrates the stresses vs. elongation curve results under compression loading using the ASTM E9standard.

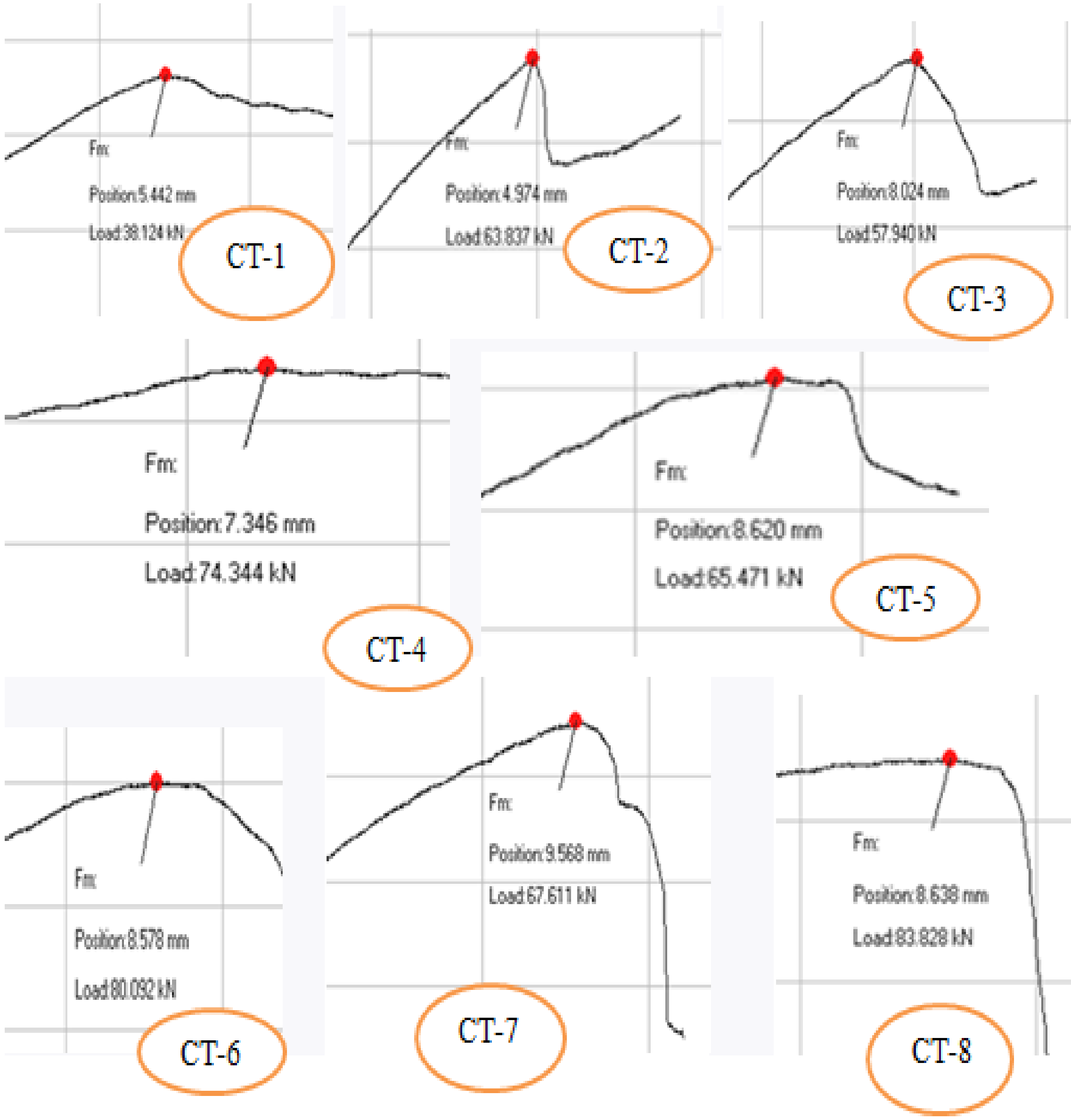


Figure 4.1 Eight specimen's compression test ultimate testing machine load result

4.1.1.3 Tensile test result

The welded samples' tensile testing results are displayed in figure 4.2 as stresses vs. elongation curve results. The values represent each of the eight specimens that were seen in the case of the reading that was obtained.

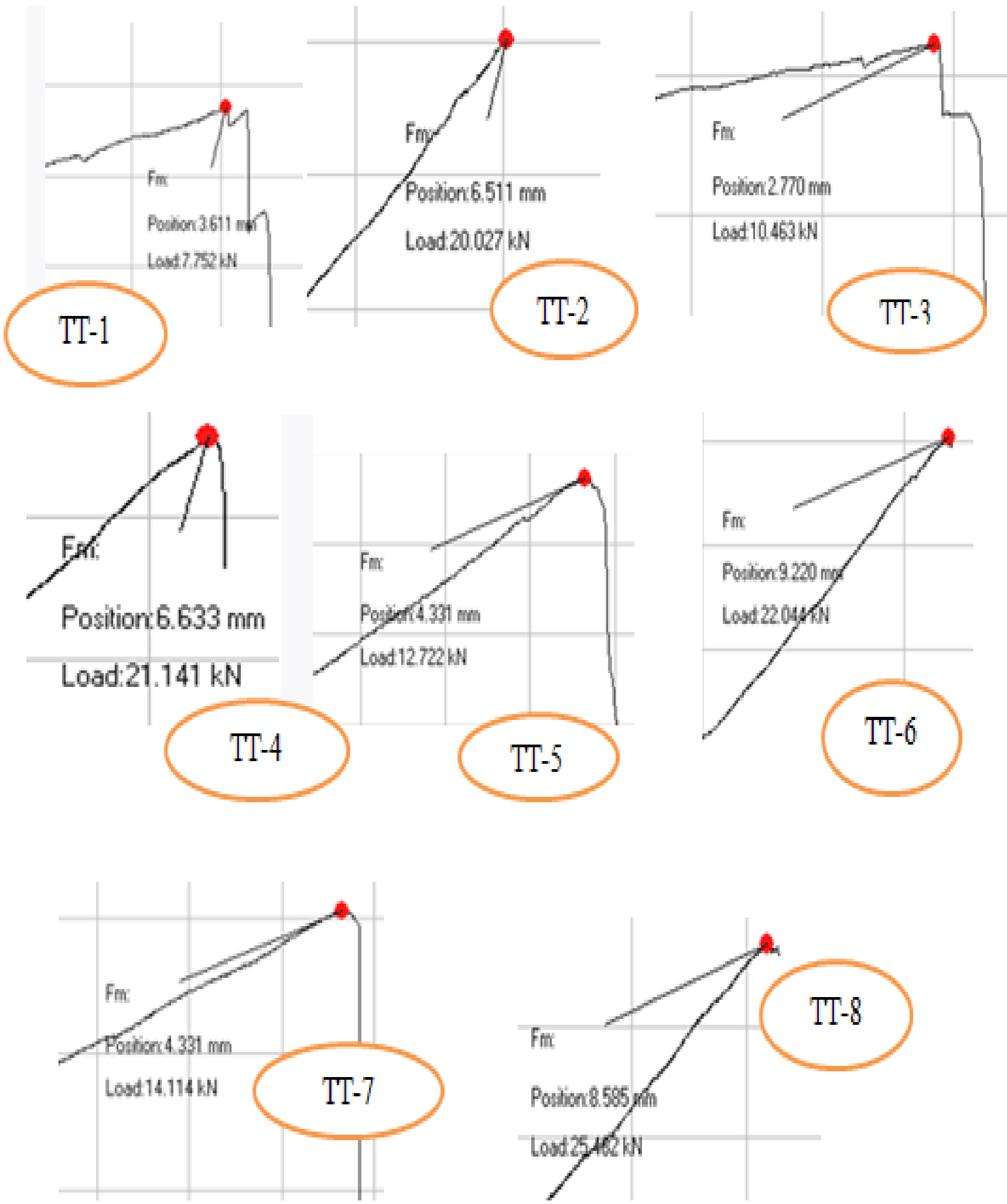


Figure 4.2 Eight specimens Tensile test ultimate testing machine load result

The tensile strength evaluation load force reading with different type of diameter of welding of brass- steel taken by the same testing machine of MODEL HTM1000 of echo LAB Universal

Testing Machine in Addis Ababa University AAiT mechanical work shop which is used for compression test reading as per standards of ASTM E8.

TABLE 4.3 UTM tensile test result of brass-steel weld (KN)

Tensile test sample S/N	Tensile test (KN)	Size (mm)
Tensile test 1	7.752	12
Tensile test 2	20.027	15
Tensile test 3	10.463	12
Tensile test 4	21.141	15
Tensile test 5	12.722	12
Tensile test 6	22.044	15
Tensile test 7	14.114	12
Tensile test 8	25.482	15

4.2 Discussion

4.2.1 Hardness test

The peak values of hardness at the maximum and minimum values for all hardness test specimens from table 4.1 based on average values of Hardness specimens, the maximum or higher hardness value 94 (HRB) and the minimum or lower hardness value 32.3 (HRB), the output force is 100kg as the Rockwell hardness test indenter scale for brass and steel type material.

The appendix portion of this thesis contains the hardness findings values for each of the eight specimens that are visible under reading.

When reading of hardness in steel part weld area it look like the hardness properties increasing when come to brass side alit bit low but in weld area reduce hardness properties compare as steel and brass area.

4.2.2 Compression test

As result when evaluated compression test when the size increases slightly increase in some area but generally when quenching cooling system is very important to increase ultimate compression values, the maximum compression stress is 598.12 MPa sample no CT-7and the minimum compression stress is 337.26 from reading which seen in detail in table 4.4.

Compression test value is increase with increasing of rotational speed and rotational time ,the time is for test 7 is recorded is the maximum of this thesis data which is 50 sec so, Rotation at high speeds and increasing time can generate heat due to friction and air resistance. Thermal expansion can introduce additional stress or exacerbate existing stresses because of this compression is high value record.

TABLE 4.4 UTM compression test result of brass-steel weld (MPa)

Compression test Sample S/N	Compre test (N)	Compression test (KN)	Size (mm)	Area(mm2)	Area(m2)	Ultimate compression stress	Ultimate compression (MPa)
Compression test 1	38124	38.124	12	113.04	0.00011304	337261146.5	337.26
Compression test 2	63837	63.837	15	176.625	0.000176625	361426751.6	361.43
Compression test 3	57940	57.94	12	113.04	0.00011304	512561925	512.56
Compression test 4	74344	74.344	15	176.625	0.000176625	420914366.6	420.91
Compression test 5	65471	65.471	12	113.04	0.00011304	579184359.5	579.18
Compression test 6	80092	80.092	15	176.625	0.000176625	453457891	453.46
Compression test 7	67611	67.611	12	113.04	0.00011304	598115711.3	598.12
Compression test 8	83828	83.828	15	176.625	0.000176625	474610049.5	474.61

4.2.3 Tensile test

The UTS (σ), strain (ε), elongation, and Young's modulus are the tensile parameters that are assessed based on the tensile test. This indicates that until the ultimate tensile of the welding of brass-steel material is reached, the tensile strength of the brass-steel weld material is increasing correspondingly to load value and elongation position.

As it seen in table by using Tensile strength is force over area and tensile strength of MPa reading in table the speed of machine which means RPM increase also tensile strength similarly increase and in addition of this when increase diameter and Tensile strength increases in tandem with friction time and vice versa. Generally from experimental lab test result diameter of brass –steel weld, friction time and also revolution of per minute (RPM) direct proportional to tensile strength in this thesis report scenario.

Quenching is a critical process for increasing the tensile strength of metals, especially steels. By carefully controlling the heating, quenching, and tempering processes, can tailor the mechanical properties of metals to meet specific performance requirements.so test 8 is used cooling system after welding. High rotational speeds often generate heat due to friction and air resistance. Elevated temperatures can decrease the tensile strength of materials, particularly metals, by reducing their yield strength and making them more ductile. This test time duration is 30 sec which is smaller than other test duration so when decreasing time the elevated temperature also decrease because of this can achieve high tensile strength

TABLE 4.5 UTM tensile test result of brass-steel weld (MPa)

Tensile test sample S/N	Tensile test (N)	Tensile test (KN)	Size (mm)	Area(mm2)	Area(m2)	Ultimate tensile stress	Ultimate tensile (MPa)
Tensile test 1	7752	7.752	12	113.04	0.00011304	68577494.69	68.58
Tensile test 2	20027	20.027	15	176.625	0.000176625	113387119.6	113.39
Tensile test 3	10463	10.463	12	113.04	0.00011304	92560155.7	92.56
Tensile test 4	21141	21.141	15	176.625	0.000176625	119694267.5	119.69
Tensile test 5	12722	12.722	12	113.04	0.00011304	112544232.1	112.54
Tensile test 6	22044	22.044	15	176.625	0.000176625	124806794.1	124.81
Tensile test 7	14114	14.114	12	113.04	0.00011304	124858457.2	124.86
Tensile test 8	25482	25.482	15	176.625	0.000176625	144271762.2	144.27

4.2.4 Corrosion test

The corrosion test result is as per equation 3.1 calculated and corrosion rate based on the weight loss is seen in table 4.6

Table 4.6 Corrosion test specimen's value in mm per year

CORROSION SAMPLE	Intial weight gram	After test weight gram	weight loss	volume cm3	D =M1/V (g/cm3)	87.6 W	DAT	CR=87.6W/ DAT is (mm/y)
CORROSION TEST 1	8.6162	8.6122	0.004	2	4.3081	0.3504	2.1541	0.16267
CORROSION TEST 2	14.7214	14.7128	0.0086	2.5	5.8886	0.7534	2.9443	0.255872
CORROSION TEST 3	12.839	12.8348	0.0042	2	6.4195	0.3679	3.2098	0.114626
CORROSION TEST 4	18.4739	18.4601	0.0138	2.5	7.3896	1.2089	3.6948	0.327186
CORROSION TEST 5	13.1632	13.1248	0.0384	2	6.5816	3.3638	3.2908	1.022195
CORROSION TEST 6	20.7338	20.6903	0.0435	3	6.9113	3.8106	3.4556	1.102721
CORROSION TEST 7	15.1051	15.1009	0.0042	2.5	6.0420	0.3679	3.0210	0.121787
CORROSION TEST 8	23.635	23.6187	0.0163	3.5	6.7529	1.4279	3.3764	0.422897

The corrosion sample test result is below 1.1027mm per year and sample of specimens reading is attached in appendix. Corrosion of copper was found to be 4.3, 10.8, and 6.4 mm/y in atmosphere, underground and splash zone, respectively. The corresponding corrosion of brass was **2.5, 29.3, and 19.9 mm/y** so from review corrosion rate is safe [55]

4.3 PROCESS PARAMETER OPTIMIZATION RESULT

4.3.1 Taguchi method analysis results

When weld was performed on lathe machine according to L8 orthogonal array (ORs) of Taguchi approach welding result of mean tensile strength in MPA

Table 4.7: L8 orthogonal arrays weld process arrangement L8 orthogonal array input/process parameters and output properties.

	A	B	C	D	Recorded Value			
Trial No	Rotational speed	Material size	Welding time	Cooling system	Ultimate tensile stress (MPa)	Hardness test (HRB)	Compression test (MPa)	Corrosion test (mm/y)
1	610	12	30	Yes	68.58	50.76	337.26	0.1627
2	610	15	50	No	113.39	48.5	361.43	0.2559
3	765	12	30	No	92.56	73.6	512.56	0.1146
4	765	15	50	Yes	119.69	69.2	420.91	0.3272
5	955	12	50	Yes	112.54	37.8	579.18	1.0222
6	955	15	30	No	124.81	71.2	453.46	1.1027
7	1200	12	50	No	124.86	60.7	598.12	0.1218
8	1200	15	30	Yes	144.27	85	474.61	0.4229

When: -

A: - Rotational Speed

B: - Material Size

C: - Welding time

D: - Cooling System

4.3.1.1 Signal-to-noise [S/N] ratio and normalization result

Value resulting from the welding process was thought to be the primary characteristic in this thesis investigation. The mean and the signal-to-noise ratio for each control factor were computed in order to evaluate the influence of factors on the response. The MINITAB®21.2 program was utilized to calculate the influence of process parameters. The S/N ratio is determined by the heuristic "greater is better." the S/N ratio response table and normalization table displayed in Tables 4.8.

Table 4.8:- Response table for higher rate S/N ratios and normalization for welding at different input parameter levels

S/N Ratio				**Normalization**			
Ultimate tensile stress (MPa)	Hardness test (HRB)	Compression test (MPa)	Corrosion test (mm/y)	Ultimate tensile stress (MPa)	Hardness test (HRB)	Compression test (MPa)	Corrosion test (mm/y)
36.724	34.110	50.559	15.774	1.000	0.636	1.000	0.155
41.091	33.715	51.160	11.840	0.952	0.874	0.269	0.000
39.328	37.338	54.195	18.814	0.597	0.178	0.269	0.000
41.561	36.802	52.484	9.704	0.962	0.954	0.945	0.516
41.026	31.550	55.256	-0.191	0.334	1.000	0.056	0.967
41.925	37.050	53.131	-0.849	0.971	0.960	0.957	-0.045
41.928	35.664	55.536	18.288	0.194	0.416	0.000	0.027
43.184	38.588	53.527	7.475	1.000	1.000	0.964	0.397

4.3.1.2 Delta Oj, Grey relational Coefficient and grade

There are several uses for grey relation analysis in the examination of difficult issues. The basis of the grey connection analysis approach is the similarity or dissimilarity between different process variables. Additionally, the approach offers data for forecasting and making decisions. The process can also be used when making decisions based on multiple factors. This is displayed in Table 4.9 below. Grey relational coefficient and grade result

Table 4.9 Grey relational coefficient and grade result

Delta-Oj				**Grey relational coefficient**					
Ultimate tensile stress (MPa)	Hardness test (HRB)	Compression test (MPa)	Corrosion test (mm/y)	Ultimate tensile stress (MPa)	Hardness test (HRB)	Compression test (MPa)	Corrosion test (mm/y)	**Grade**	**Rank**
0.000	0.364	0.000	0.845	1.000	0.531	1.000	0.406	0.734	3
0.048	0.126	0.731	1.000	0.893	0.765	0.406	0.365	0.607	6
0.403	0.822	0.731	1.000	0.500	0.333	0.406	0.365	0.401	7
0.038	0.046	0.055	0.484	0.915	0.899	0.901	0.552	0.817	2
0.666	0.000	0.944	0.033	0.377	1.000	0.346	1.000	0.681	4
0.029	0.040	0.043	1.045	0.933	0.413	0.920	0.355	0.655	5
0.806	0.584	1.000	0.973	0.333	0.413	0.333	0.372	0.363	8
0.000	0.000	0.036	0.603	1.000	1.000	0.933	0.494	0.857	1

From GREY Relational analysis result on Table 4.9, it shows as weld parameter at trial model number eight selected as higher process parameter of weld result. However, in order to now the optimum parameter combination we are going to Minitab software. For every control factor, the mean and the signal-to-noise ratio are computed in order to evaluate the impact of the factors on the response. The deciding criterion that determines the S/N ratio is "higher is better." The S/N ratio and mean response table is given at Tables 4.10 and 4.11.

Table 4.10:- Response Table for Higher Value Signal to Noise Ratios for Welding at Different Input Parameter Levels.

Larger is better

Level	Rotational Speed	Material Size	Welding time	Cooling System
1	-3.511	-5.691	-3.910	-2.280
2	-4.846	-2.777	-4.558	-6.188
3	-3.506			
4	-5.071			
Delta	1.565	2.914	0.648	3.908
Rank	3	2	4	1

Table4.11:- Response Table for Greater Value Means for Welding at Different Input Parameter Levels.

Level	Rotational Speed	Material Size	Welding time	Cooling System
1	0.6705	0.5448	0.6618	0.7723
2	0.6090	0.7340	0.6170	0.5065
3	0.6680			
4	0.6100			
Delta	0.0615	0.1892	0.0448	0.2658
Rank	3	2	4	1

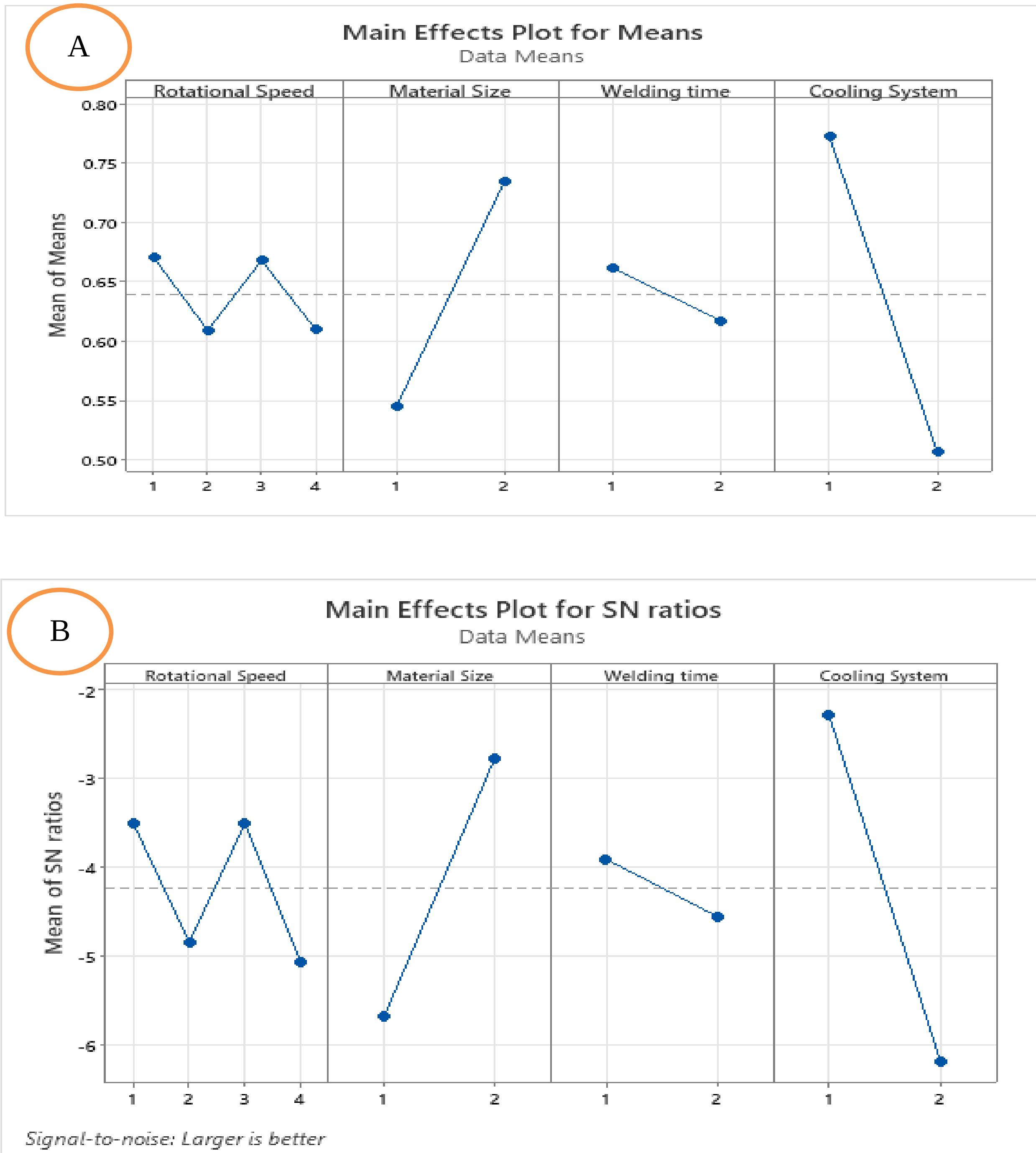


Figure 4.3:- : Main effect plots for S/N ratios (B) and mean values (A)

The figures 4.3(A) and 4.3(B) shows the primary main effect charts for welding's means and S/N ratio, respectively. Based on the presented tables and data, it can be inferred that the welding process's cooling system is the most significant factor, while the material size next to cooling system significant factor, rotational speed have a relatively minor impact on the welding duration and the last factor welding time had a small effect or no effect to the signal – to –noise ratio.

CHAPTER FIVE

5. CONCLUSION AND RECOMMEENDATION

5.1 CONCLUSION

To optimization of process parameters of friction welding of brass steel metals welding of brass steel metals setup is required so this set setup is successfully develop on C620 lathe machine as shown on figure 3.14 and with this set up welding of low carbon steel and brass metals with material size of diameter 12 mm and 15 mm done perfectly.

The research presents Optimization of process parameters of friction welding of brass –steel metal by welding of brass and steel was performed, The main objective of this thesis optimum process parameter selected through grey analysis based on experimental investigation

It has been demonstrated that Taguchi-based GRA is a successful optimization technique for welding dissimilar metals, such as brass and steel. The following is a summary of the total results.

- From a result welding of brass and black steel is can be conclude and can have the following mechanical properties
    - Hardness test maximum 85 HRB
    - Compressive strength of maximum 598.12 MPa
    - Tensile strength of maximum 144.27 MPa
    - Corrosion resistance rate is minimum 0.1146 mm per year,
- Corrosion test result of welded of brass and low carbon steel in mm per year is safe corrosion rate of all sample is below 1.1027 mm per year.
- From Taguchi’s method and Gray relation analysis the optimum process parameters which is rotational speed is 1200rpm, diameter is 15 mm and friction time is 30 sec with quenching mechanism apply.
- Cooling time is more influenced for best performance welding of dissimilar material brass and steel, whereas Material size and rotational speed relatively influenced performance besides of this frictional time to take welding of black steel rod and brass rod is a small effect or no effect for welding performance.

The findings indicate that different applications can be made of friction welding of brass and steel with optimized parameters. When this research is finished, it will be applied to heating, ventilation, air conditioning, water supply, and specifically for water tanker management. Friction-based welding procedure exposes major applications in the pipe line, aerospace, automotive, marine, and nuclear industries.

5.2 RECOMMENDATIONS FOR FUTURE RESEARCH

Even if the welding of brass and steel rod was successful, there are still a number of areas that may use better. First, an experimental technique is formed using pipe or tubular material, meaning that varying thicknesses can be maintained while still increasing the strength of the welding junction.

Future work recommendation is

- When welding dissimilar material by optimizing the parameters using changes in the beginning pressure, forge pressure, amplitude, and frequency.
- Welding dissimilar material brass with low carbon steel with hole or pipe material with various parameters.
- Welding of optimization process parameters of friction welding brass with high carbon steel metals.

REFERENCES

[1] Ho-Chiao Chuanga, Jung-Hung Chia and Kuei-Yuan ChangM Study on a fan coil unit and chiller by an intelligent control method with a stepless variable speed driving technology, pp. 137-146,vol 134, January 2018.

[2] Zhao Tianyi a, Zhang Jili a and Sun Dexing Experimental study on a duty ratio fuzzy control method for fan-coil units, pp. 527-534,vol 46, January 2011.

[3] Karan Sotoodeh ,and Baker Hughes Hovik Dissimilar welding between piping and valves in the offshore oil and gasIndustry , Volume 35, issue no 1,May 2021.

[4] Alexandre Romaine, Martial Crozet, Nicolas Mary and Bernard Normand, Importance of the surface and environmental conditions on the corrosion behaviour of brass, steel and brass coated steel wires and brass coated steel cords, pp. 108966,vol 177, December 2020.

[5] PK Chauhan and K Nanduri, Is Small Bore Tubing Systems an Achilles' Heel of Asset Integrity? An In-Depth Analysis Through Case Studies, pp. 4596, Vol 001, July 2019.

[6] Dipen Kumar Rajak, Durgesh D. Pagar, Pradeep L. Menezes and Arameh Eyvazian ,Friction-based welding processes friction welding and friction stir welding , pp. 2613-2637, Vol 34, No24, June 2020.

[7] Yabin Liang,Qian Feng,Dongsheng Liand Sijia Cai, Loosening Monitoring of a Threaded Pipe Connection Using the Electro-Mechanical Impedance Technique—Experimental and Numerical Studies , pp. 3699,vol 18, No11, October 2018.

[8] M. Kimura, K. Kasuya , M. Kusaka , K. Kaizu1 and A. Fuji , Effect of friction welding condition on joining phenomena and joint strength of friction welded joint between brass and low carbon steel, pp. 704-712,vol 14, No5, December 2009.

[9] G. Çam , G. İpekoğlu , T. Küçükömeroğlu and S.M. Aktarer c, Applicability of Friction Stir Welding to steels , pp. 65-85,vol 80, No 25, February 2017.

[10] Taha AL-Washali , Meidy Mahardani , Saroj Sharma , Francisco Arregui and Maria Kennedy, Impact of float-valves on water meter performance under intermittent and continuous supply conditions,Volume 163,April 2020.

[11] Ashok K Srivastava and Ashutosh Sharm, Advances in Joining and Welding Technologies for Automotive and Electronic Applications, Volume 5, No 1, pages 7-13, August 2017

[12] O.L. Pervukhina and I.V. Denisov, The Specifics of Producing Steel to Brass Bimetal Using Explosion Welding,pp.44-46,No3,December 2017.

[13] T. Van Engelen, S. Kanev Optimising Design and Construction for Safe and Reliable peration Woodhead Publishing Series in Energy, pages 247-273, March 2011.

[14] Kush P. Mehta, A review on friction-based joining of dissimilar aluminum–steel joints, PP 78-98, Vol. 34, No. 1, Jan, 2019.

[15] Farzad Baratzadeh , Enkhsaikhan Boldsaikhan , Rajeev Nair , Dwight Burford and Hamid Lankarani, Investigation of Mechanical Properties of AA6082-T6/AA6063-T6 Friction Stir Lap Welds,vol 1,April 2020.

[16] Mohammad Hasan Shojaeefard , Amir Najibi, Mahdi Anbarloei and Mohsen Yeganeh,Experimental and numerical crashworthiness investigation of combined circular and square sections, pp. 999-1006,vol 28, No3, March 2014.

[17] Enkhsaikhan Boldsaikhan, Edward M. Corwin, Antonette M. Logar and William J. Arbegast, The use of neural network and discrete Fourier transform for real-time evaluation of friction stir welding,pp4839-4846,Vol 11,No8,December 2011.

[18] Gomathisankar M, Gangatharan M and Pitchipoo P, A Novel Optimization of Friction Stir Welding Process Parameters on Aluminum Alloy 6061-T6, pp14397-14404,Vol 5,No6,June 2018.

[19] Mao Yuqing , Ke Liming,Liu Fencheng, Chen Yuhua & Xing Li, Effect of tool pin-tip profiles on material flow and mechanical properties of friction stir welding thick AA7075-T6 alloy joints, pp. 949-960,Vol88, May 2016.

[20] Abhishek Chauhan and Sanjeev Kumar, Impact strength of joints of aluminum matrix composite formed using friction stir welding technique, pp. 234-236, Vol38, No 1, February 2021.

[21] Velaphi Msomi , Nontle Mbana and Sipokazi Mabuwa, Microstructural analysis of the friction stir welded 1050-H14 and 5083-H111 aluminium alloys, pp. 189-192, Vol26, No2, June 2020.

[22] Konkrai Nakowong and Kittima Sillapasa, Optimized Parameter for Butt Joint in Friction Stir Welding of Semi-Solid Aluminum Alloy 5083 Using Taguchi Technique, pp.88, Vol5, No3, June 2020.

[23] Ahmet Hascalik and Nuri Orhan, Effect of particle size on the friction welding of Al2O3 reinforced 6160 Al alloy composite and SAE 1020 steel, Volume 28, Issue no.1, pages 313-317 May 2007.

[24] Sahin M., Joining of Aluminium and Copper Materials with Friction Welding, The International Journal of Advanced Manufacturing Technology, Volume 49, Issue no.1, pages 527-534, May 2010.

[25] Mohamadreza Nourani, Abbas S. Milani and Spiro Yannacopoulos, Taguchi Optimization of Process Parameters in Friction Stir Welding of 6061 Aluminum Alloy: A Review and Case Study, pp. 144-155,vol 3, No2, February 2011.

[26] Y. Gao, K. Nakataa , K. Nagatsukaa , Y. Shibatac and M. Amano, Optimizing tool diameter for friction stir welded brass/steel lap joint, pp.313-321, Vol229, March 2016.

[27] Wenya Li, Achilles Vairis , Michael Preuss and Tiejun Ma, Linear and rotary friction welding review, Volume 61, No2, pages 71-100, February 2016.

[28] G. Elatharasana and V.S. Senthil Kumar, An experimental analysis and optimization of process parameter on friction stir welding of AA 6061-T6 aluminum alloy using RSM, pp. 1227-1234,vol 69, No5, December 2013.

[29] Y. Gao , K. Nakata , K. Nagatsuka , T. Matsuyama, Y. Shibata and M. Amano,Microstructures and mechanical properties of friction stir welded Brass/steel dissimilar lap joints at various welding speeds, pp.1018-1025, Vol90, January 2016.

[30] Jian Luoa, Junfeng Xiang, Dejia Liu, Fei Li and Keliang Xue,Radial friction welding interface between brass and high carbon steel, pp.385- 392, Vo2127, No2, February2012.

[31] Vyas Hardik Dineshbhai, Investigation on Friction Welding of Pipes for Dissimilar Metals, Vol 42, issue No96,October2022.

[32] Wei Guo, Guoqiang You, Guangyu Yuan and Xiuli Zhang, Microstructure and mechanical properties of dissimilar inertia friction welding of 7A04 aluminum alloy to AZ31 magnesium alloy,pp.549-557,Vol 5,No11,November 2016.

[33] M. B. Uday, M. N. Ahmad Fauzi, H. Zuhailawati and A. B. Ismail, Review Advances In Friction Welding Process,pp.534-558,Vol 15,No7,Augest 2010.

[34] Prashant Prakash , Sanjay Kumar Jha and , Shree Prakash Lal, A Study Of Process Parameters Of Friction Stir Welded Aa 6061 Aluminum Alloy,pp.2304-2309, Vol. 2, issue No 6, June 2013

[35] G.K. Padhy, C.S. Wu and S. Gao, Friction stir based welding and processing technologies - processes, parameters, microstructures and applications: A review,pp1-34,Vol 34,No1,January2018.

[36] G. R. Spalding, Effect Of Solutions Of Filter Alum On Brass Pipe And Fittings, Vol.3, No.1, PP.107-110, May 2014

[37] A.S. Pugachuk, O.A. Vorozheeva , and A.V. Chernyshev, Calculation procedure for minimum thicknesses of ball valve bodies,Vol.2412, No.1, PP.301-355, December 2021.

[38] LI Bao-mian, XU Guang-ming and CUI Jian-zhong, Inversion Solidification Cladding of H90-Steel,pp51-56,Vol 15,No4,July2008.

[39] Efe Işık and Çiçek Özes, Determination of the Mechanical Properties of Friction Welded Tube Yoke and Tube Joint ,pp51-56,Vol 15,No4,July2008.

[40] American Welding Society, "Recommended practices for friction welding," ANSI/AWS C6.1-89, American Welding Society,Miami, Fla, USA, 1989.

[41] Onur ŞEN and Mert Can KAHYALAR, Investigation of the Effect of Reduced Shank Thickness of Friction Welded Yoke Shaft on Strength, Vol.4, No.1, PP.49-58, April 2023.

[42] Mariane Chludzinski , Rafael Eugenio dos Santos , Daniela Ramminger Pissanti,Filipe Cantelli Kroeff , Fabiano Mattei , Giovani Dalpiaz and Marcelo Torres Piza Paes, Fullscale friction welding system for pipeline steels,Vol.8, No.2, PP.1773-1780, April 2019.

[43] Cemal Meran, The joint properties of brass plates by friction stir welding Vol.27, No.9, PP.719-726, December 2006.

[44] Demiss Alemu,Werede Melaku and Addis Tesfaye ,Ethiopian Building Code Standards On Mechanical Ventilation And Air Conditioning In Building,Vol.11, December 2014.

[45] G. Liu, L.E. Murr, C-S. Niou, J.C. McClure, and F.R. Vega, Microstructural Aspects Of The Friction-Stir Welding Of 6061-T6 Aluminum, pp. 355-365,vol 37, No3, February 1997.

[46] M. Kimura , Y. Saitoh , M. Kusaka , K. Kaizu and A. Fuji ,Effect of friction pressure on joining phenomena of friction welds between pure titanium and pure copper, Volume 16, No 5, pages 392-398, July 2011.

[47] ASTM International. Standard Test Methods for Tension Testing of Metallic Materials E 8M-04. In Annual Book of ASTM Standard; ASTM International: West Conshohocken, PA, USA, 1996; Volume 03.01, pp. 1–24.

[48] Sabbah Ataya , Mohamed M. Z. Ahmed , Mohamed M. El-Sayed Seleman , Khalil Hajlaoui ,Fahamsyah H. Latief , Ahmed M. Soliman , Yousef G. Y. Elshaghoul and Mohamed I. A. Habba, Effective Range of Friction Stir Spot Welding Parameters for High Load-Carrying Capacity of Dissimilar Steel A283M-C/Brass CuZn40 Joints, Volume 15, Issue no.4, pages 1394 February 2022.

[49] Wenya Li, Achilles Vairis , Michael Preuss and Tiejun Ma, Linear and rotary friction welding review, Volume 61, No2, pages 71-100, February 2016.

[50] Mehmet Şükrü Adin1, Bahattin İşcan and Şehmus, Optimization of Welding Parameters of AISI 431 and AISI 1020 Joints Joined by Friction Welding Using Taguchi Method , Volume 9, Issue no.1, pages 453-470 May 2022.

[51] P. B. Surapong Bangphan, J, "A Grey Relational Analysis Method For Multi-Attribute Decision Making In Turning Machine (Metal Cutting)," Volume 55, Issue no.5, pages 58-76 May 2022.

[52] C.G. Rhodes, M.W. Mahoney, W.H. Bingel, R.A. Spurling and C.6. Bampton, Ieffects Of Friction Stir Welding On Microstructure Of 7075 Aluminum, pp. 69-75,vol 36, No1, July 1996.

[53] Moera Gutu Jira &Mekonnen Girma Dimbushe, Synthesis and Experimental Investigation of Copper Matrix HybridComposite Reinforced with Sic/Gr/Cr and Optimization of Extrusion Parameter for Further Property Enhancement, 2023.

[54] Tamari,and S., Ploquet, J, Determination of leakage inside buildings with a roof tank.
Urban Water , Volume 9, Issue no.5, pages 287-303 May 2012.

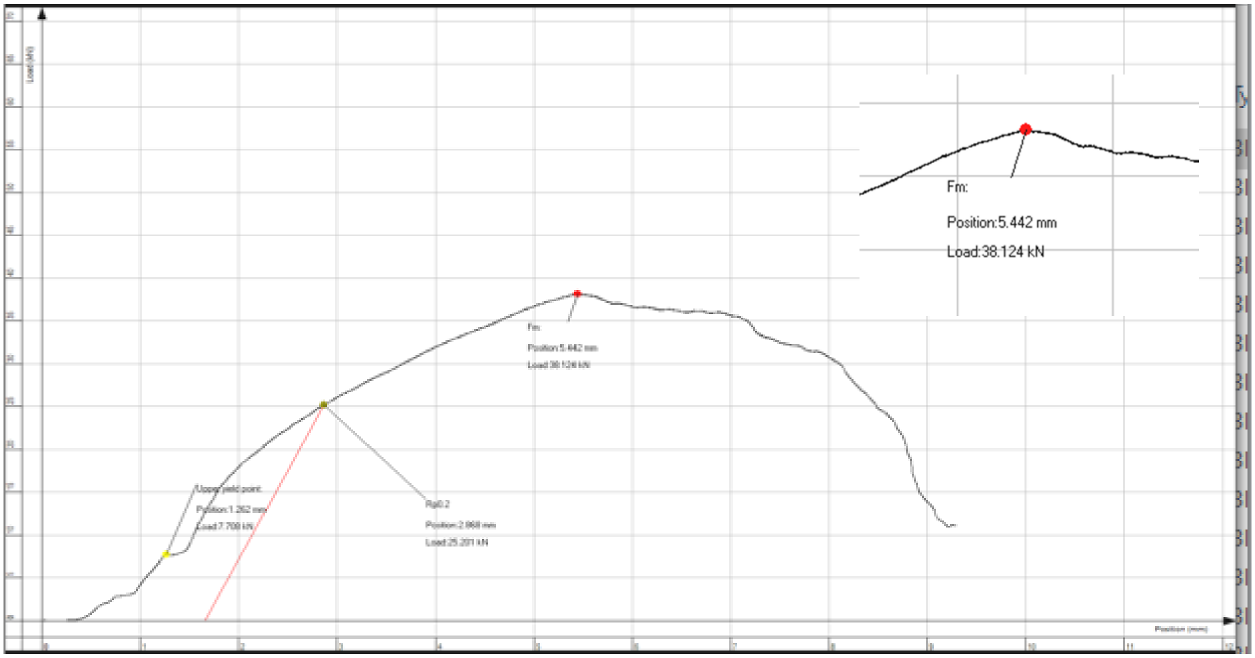
[55] H. Saricimen, A. Quddus, A. Ahmad, A. Aksakal, T. A. Siddique and A. Ul-Hamid,
Performance of Cu and Cu-Zn alloy in the Arabian Gulfenvironment, Volume 9, Issue no.5,
pages 287-303 May 2010.

[56] Neçar Merah , Mohammed Abdul Azeem , Hafiz M. Abubaker , Fadi Al-Badour , Jafar Albinmousa and Ahmad A. Sorour , Friction Stir Processing Influence on Microstructure,Mechanical, and Corrosion Behavior of Steels, Vol.14, No.17, PP. 5023, September 2021.

APPENDIX

Compression Test Result

Sample CT-01



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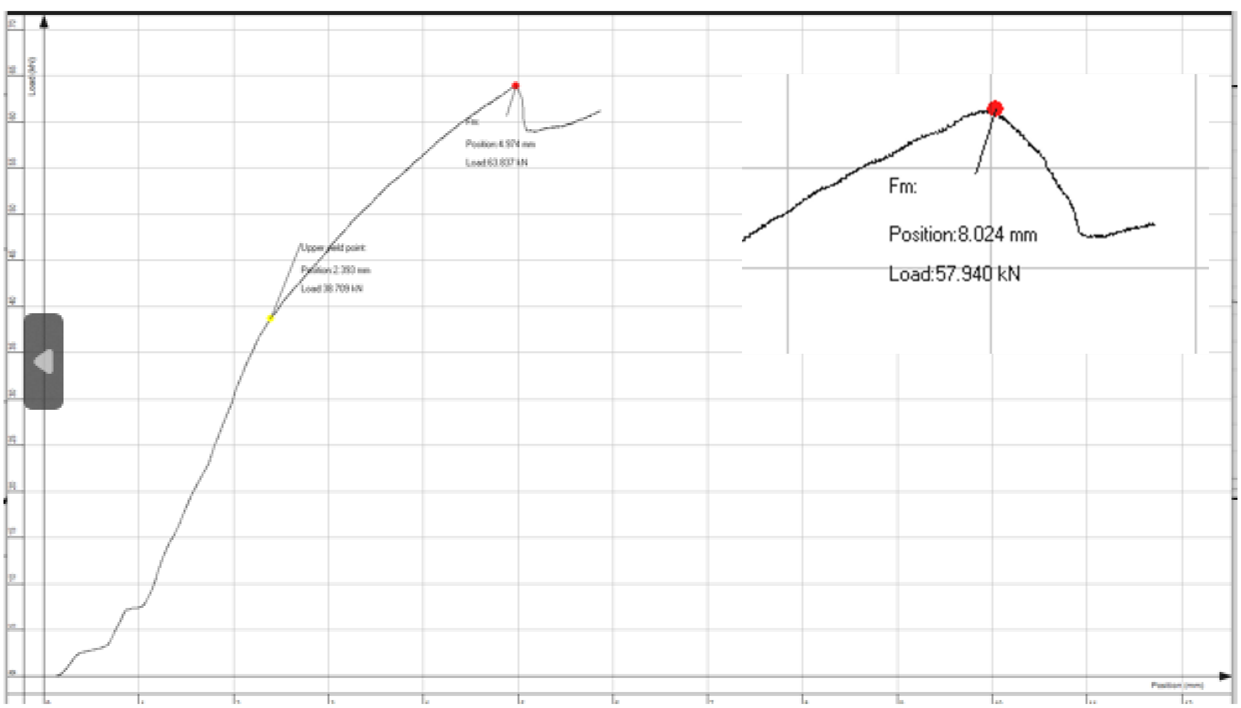

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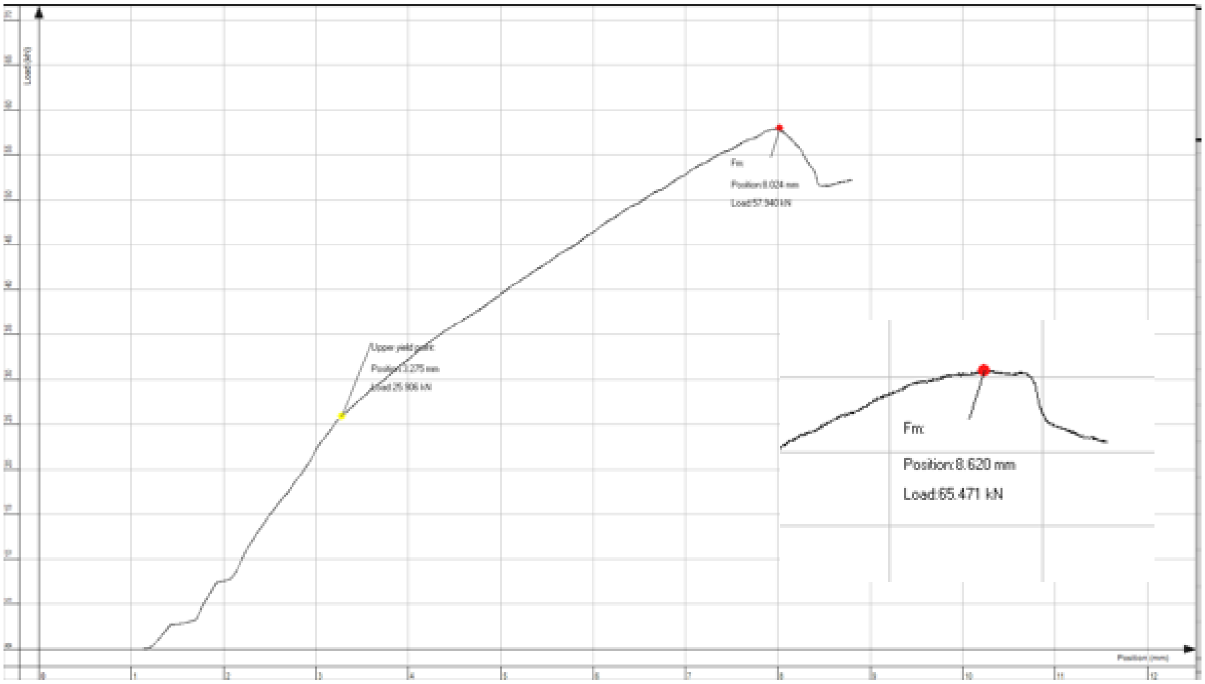

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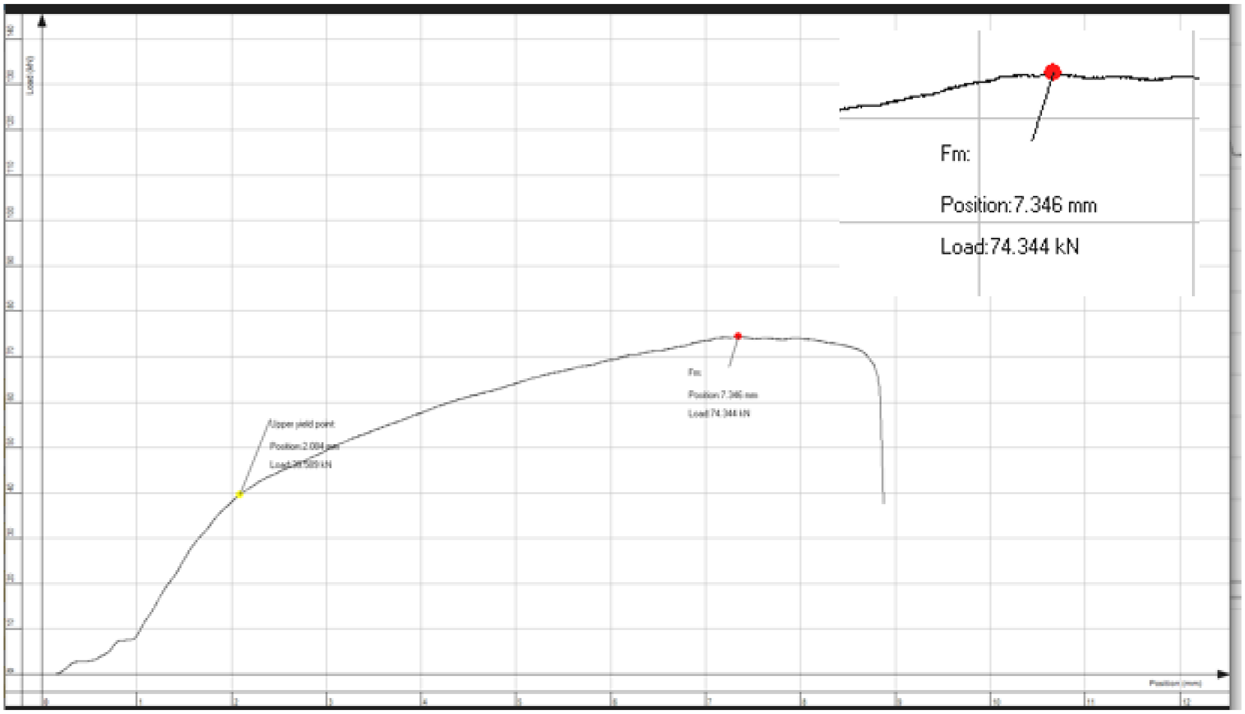

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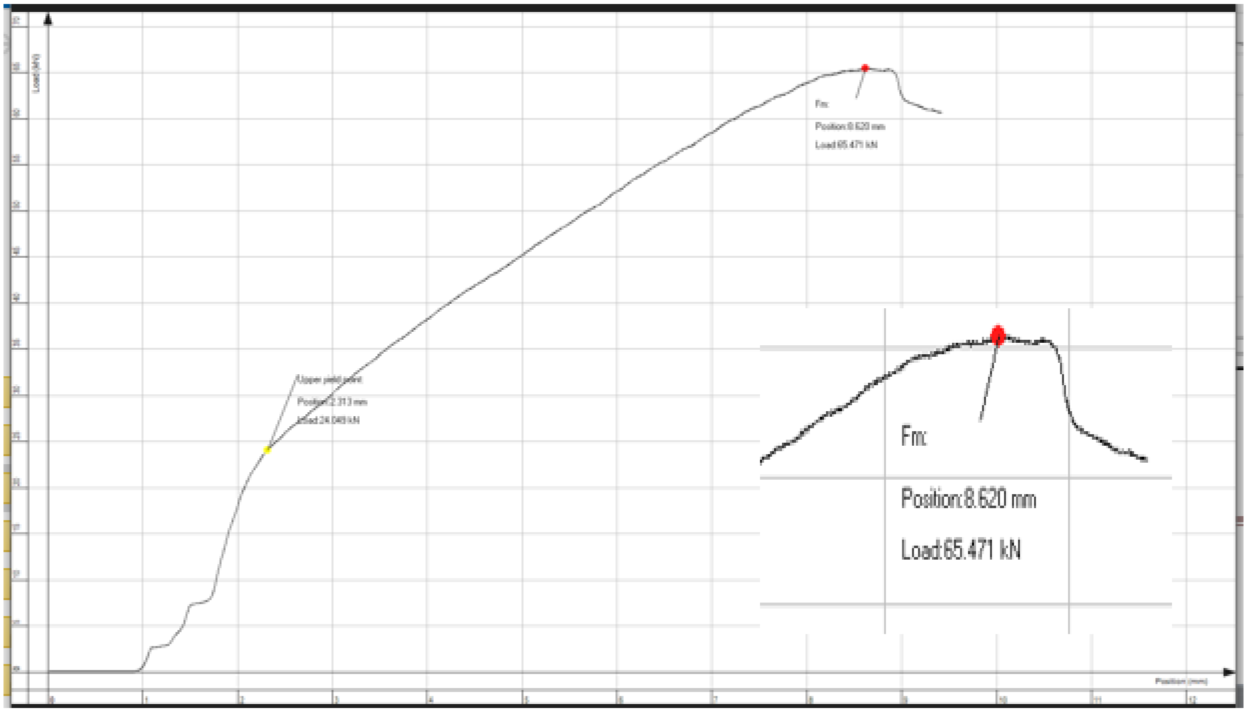

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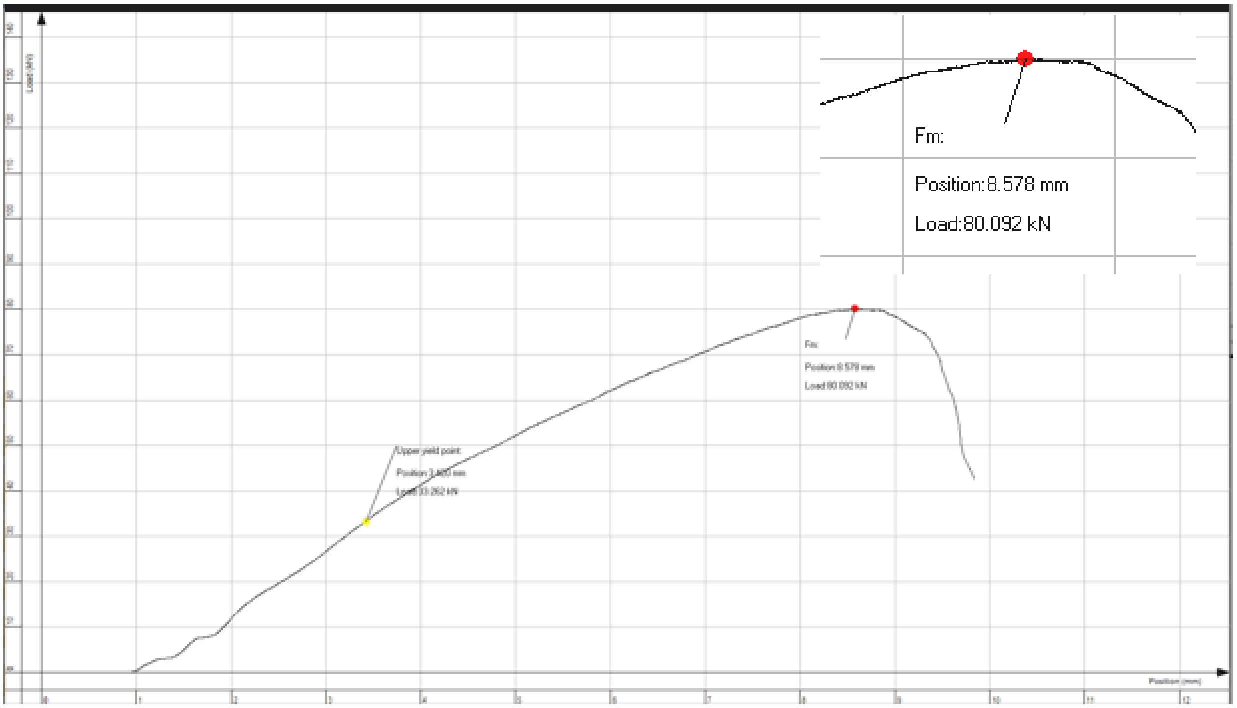

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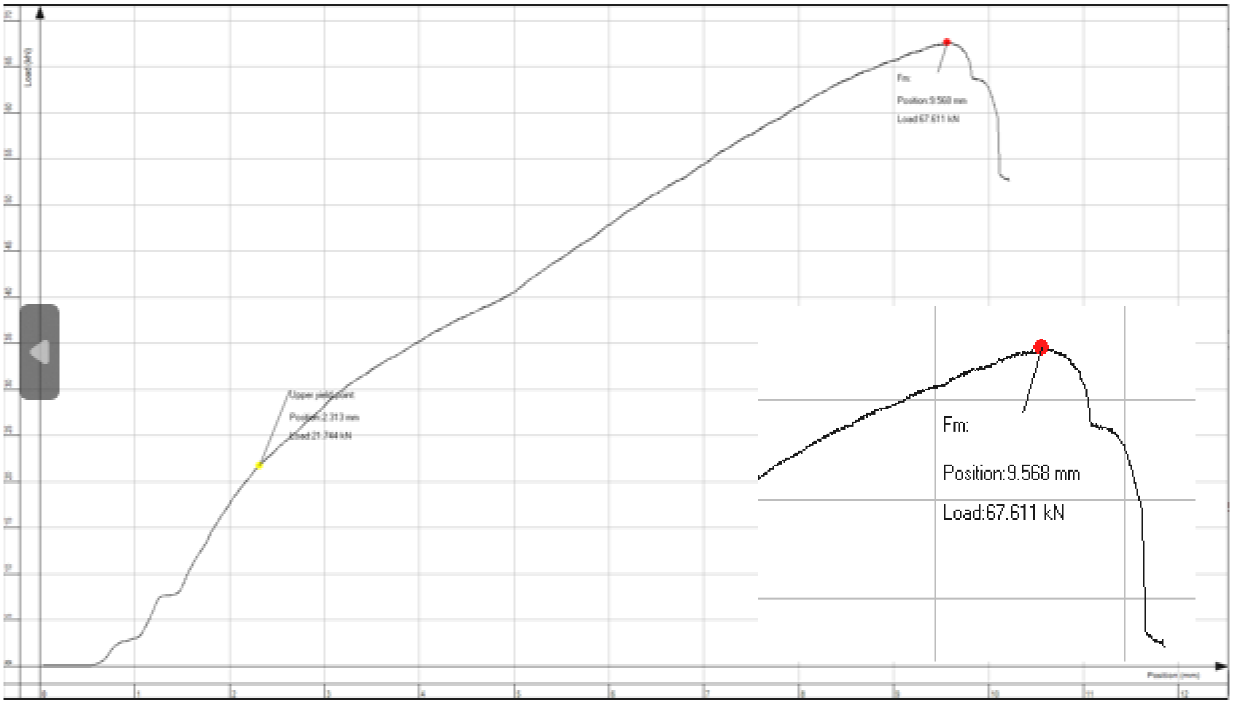

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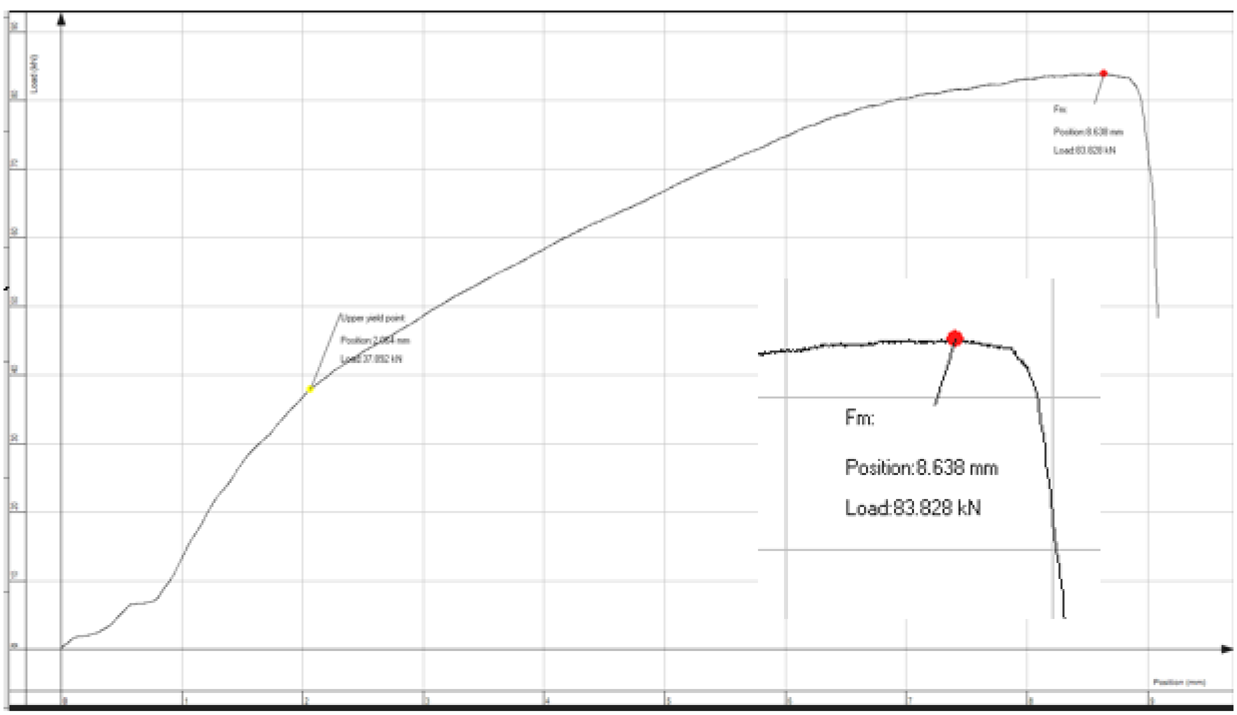
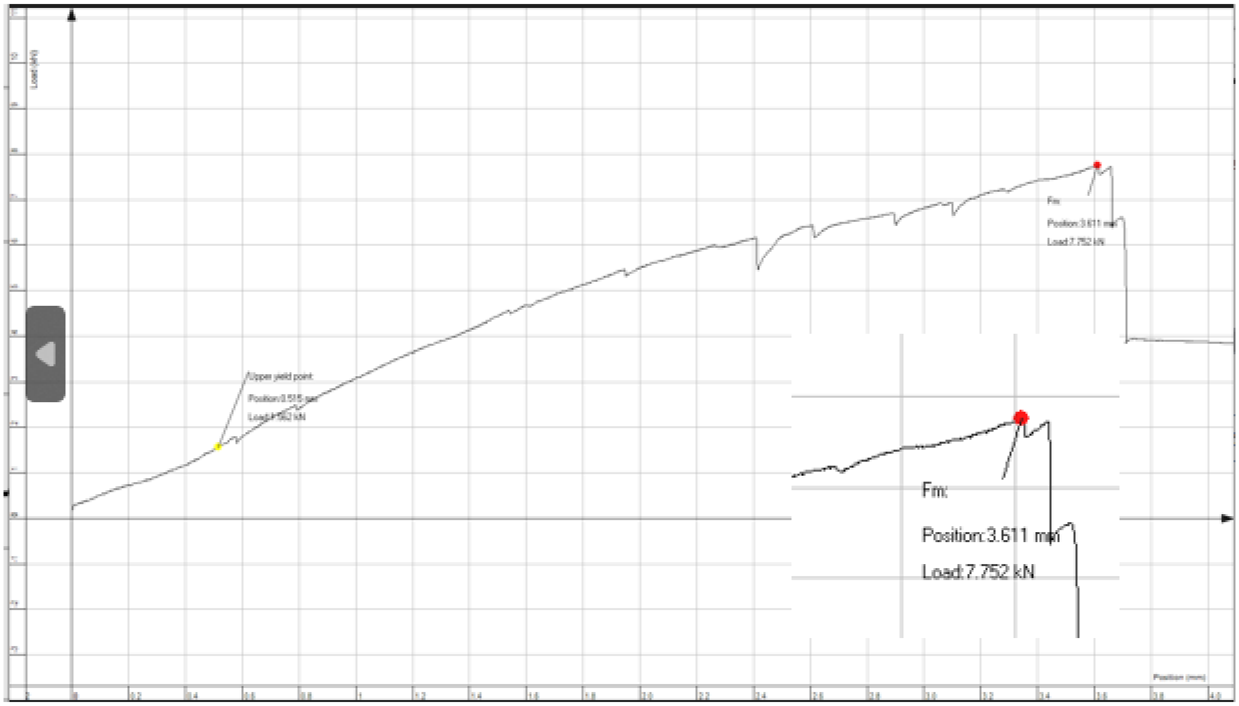
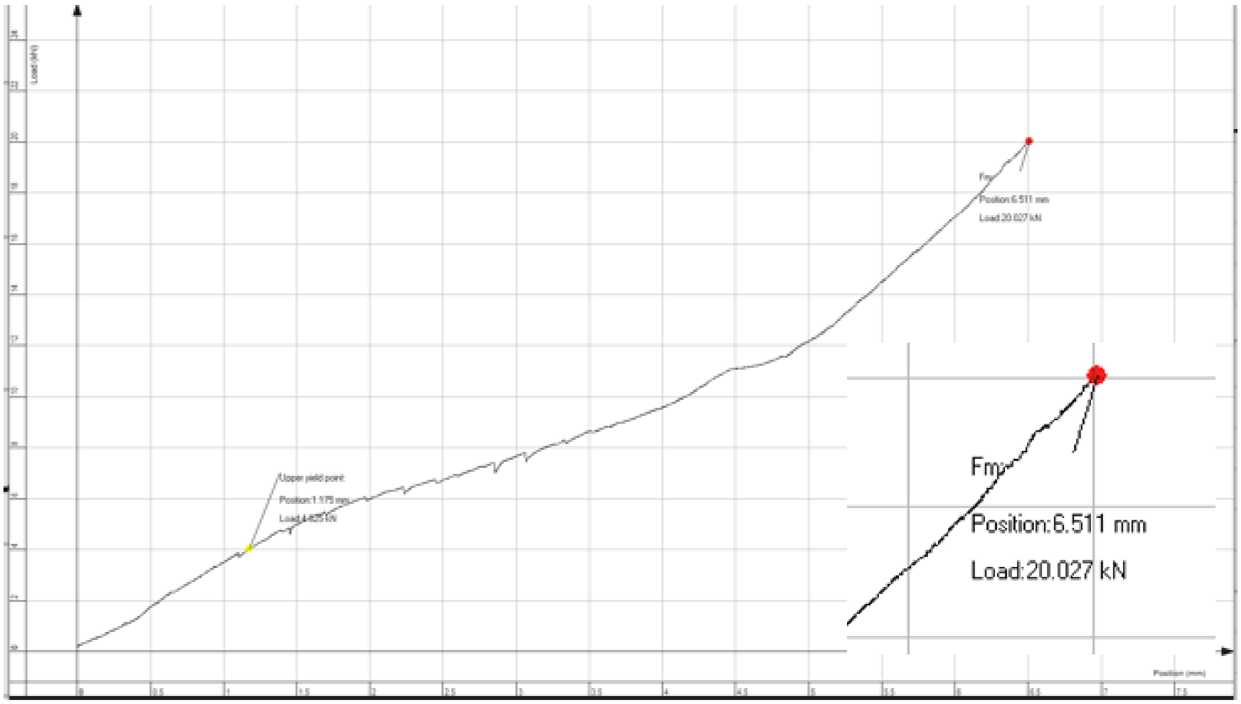


TENSILE TEST RESULT

Sample TT-01



Sample TT-02



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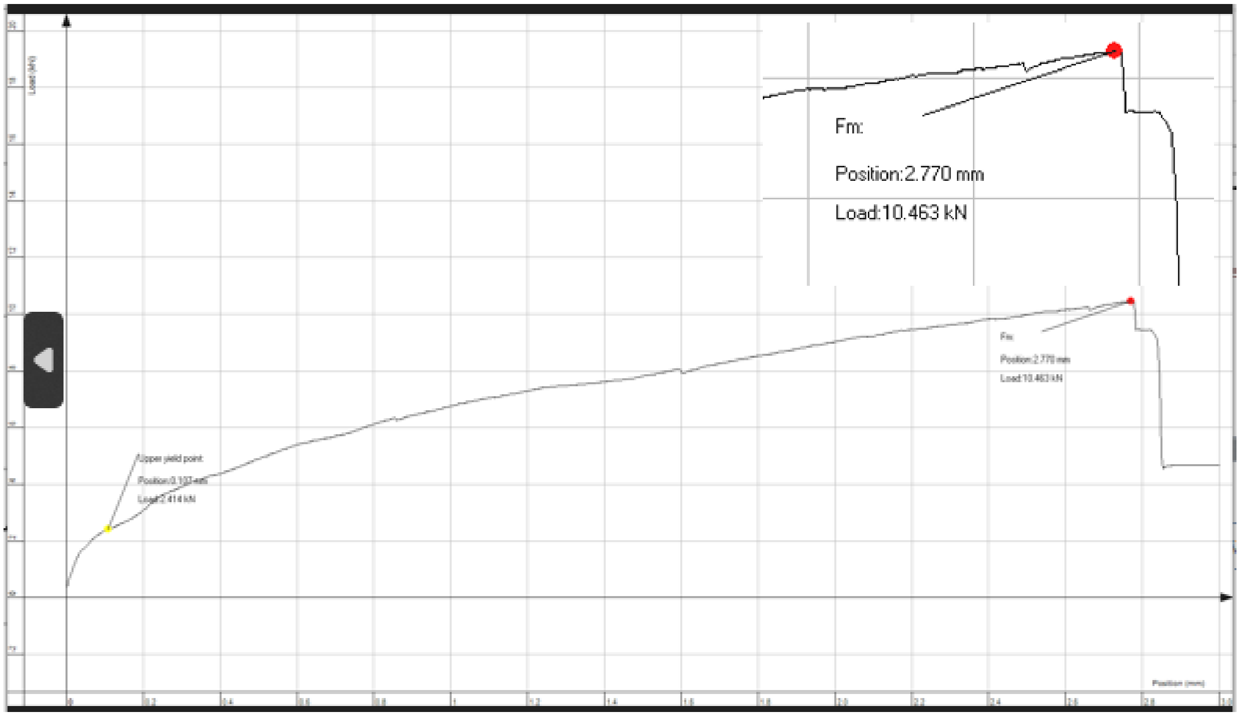

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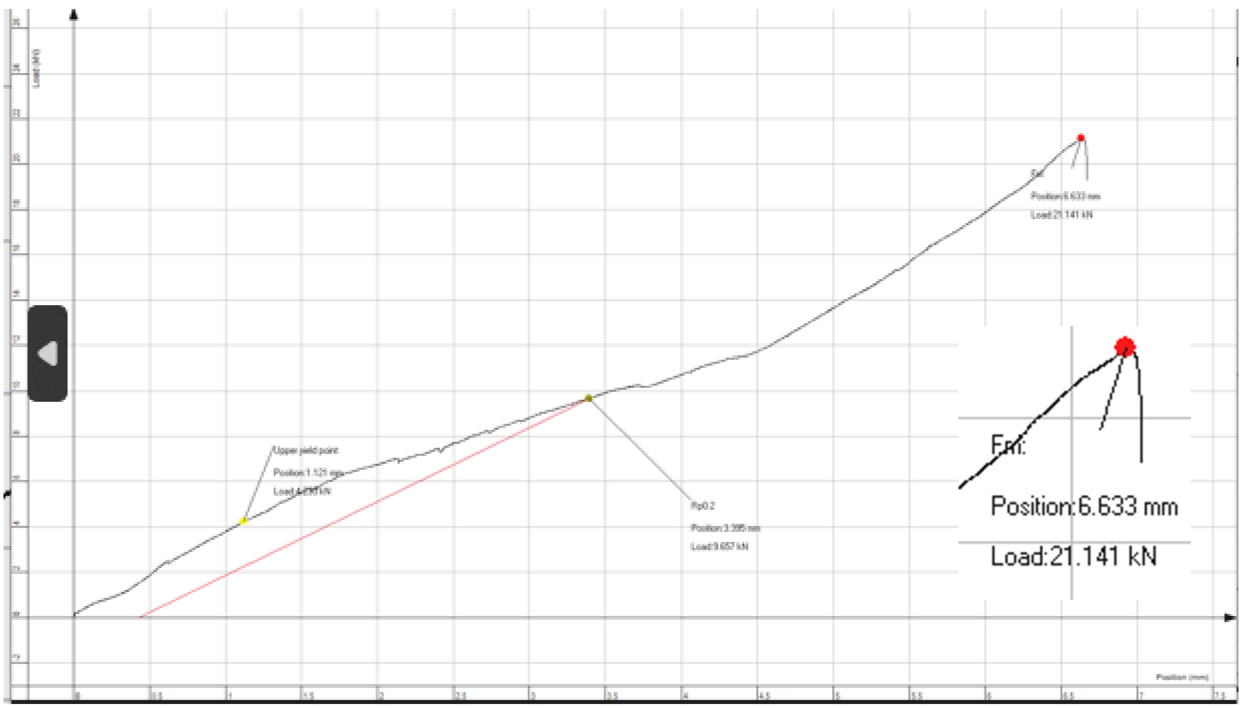

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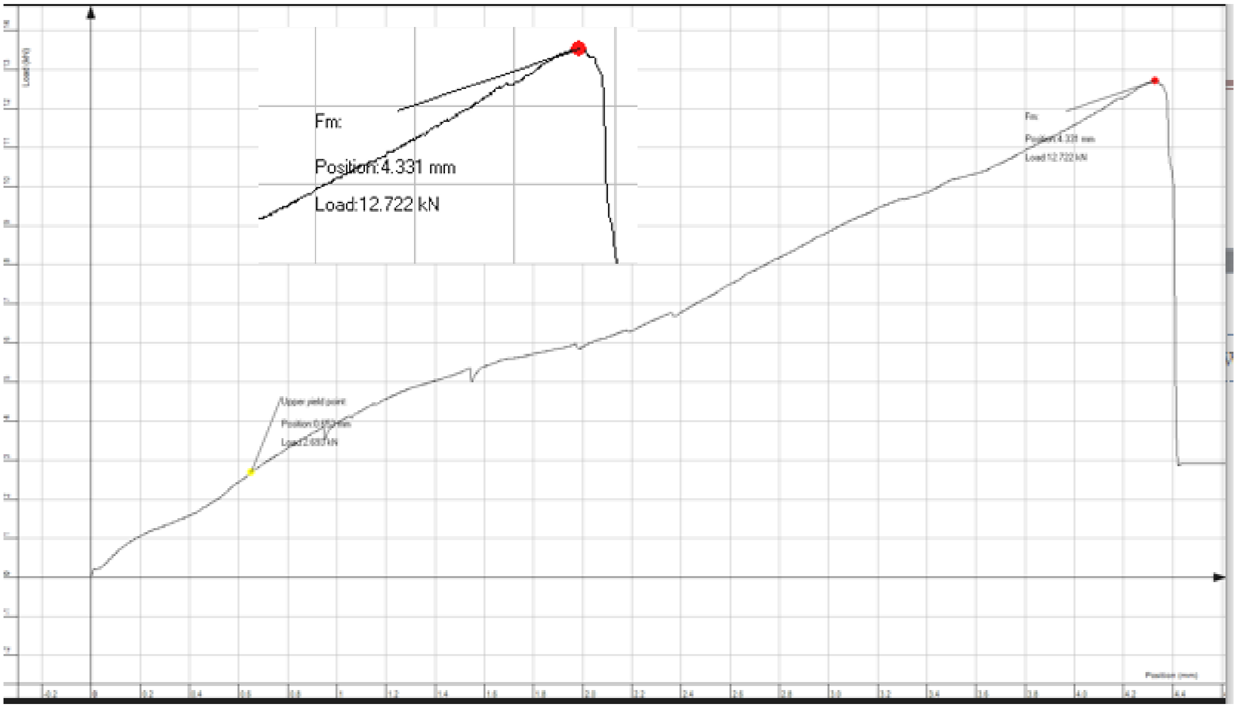

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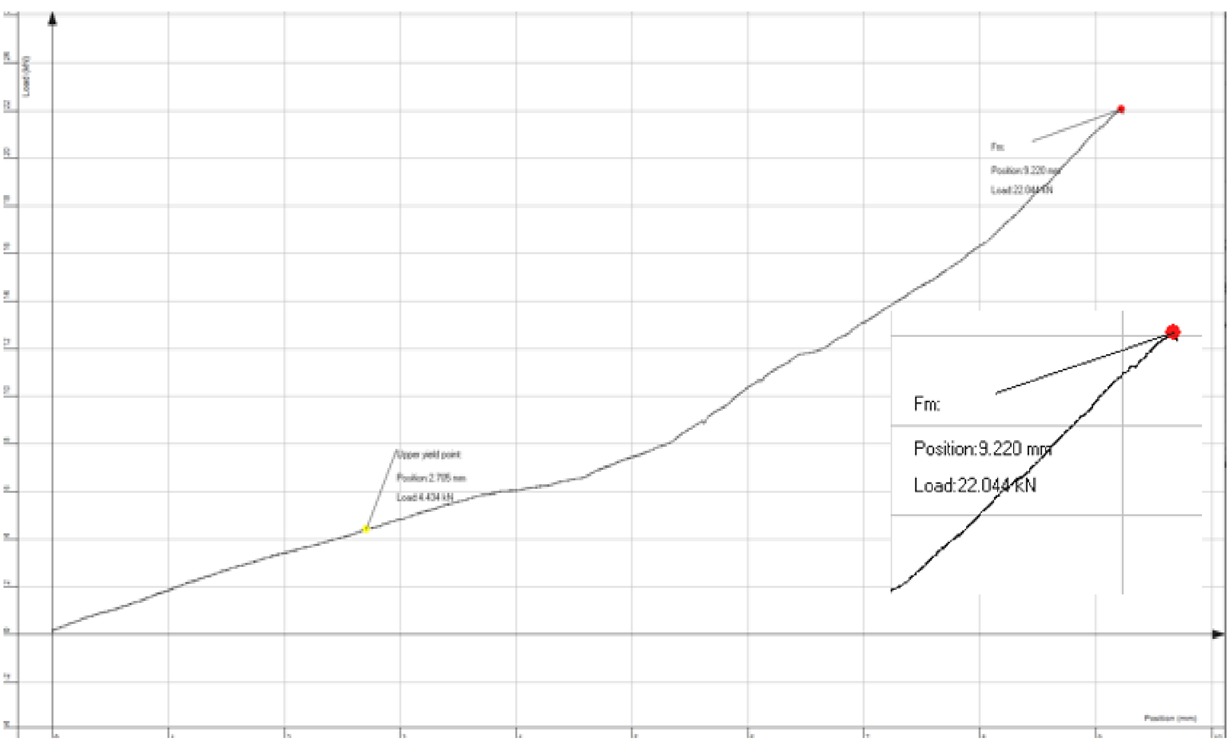

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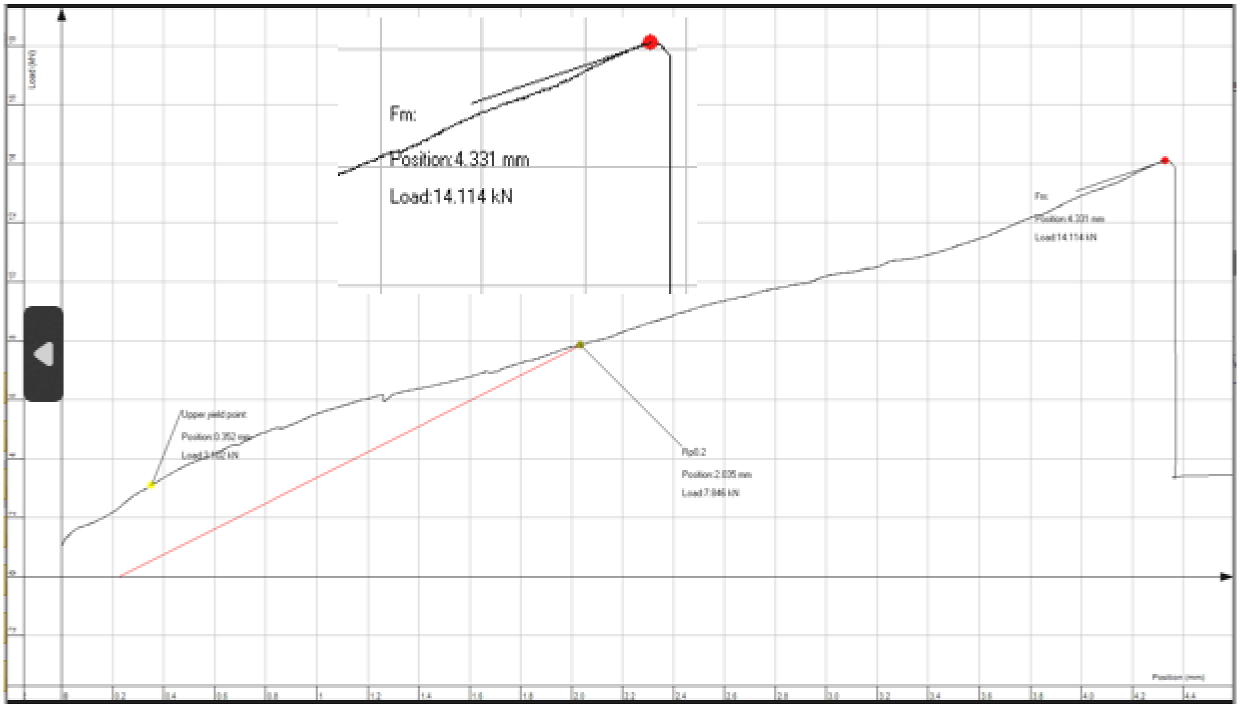

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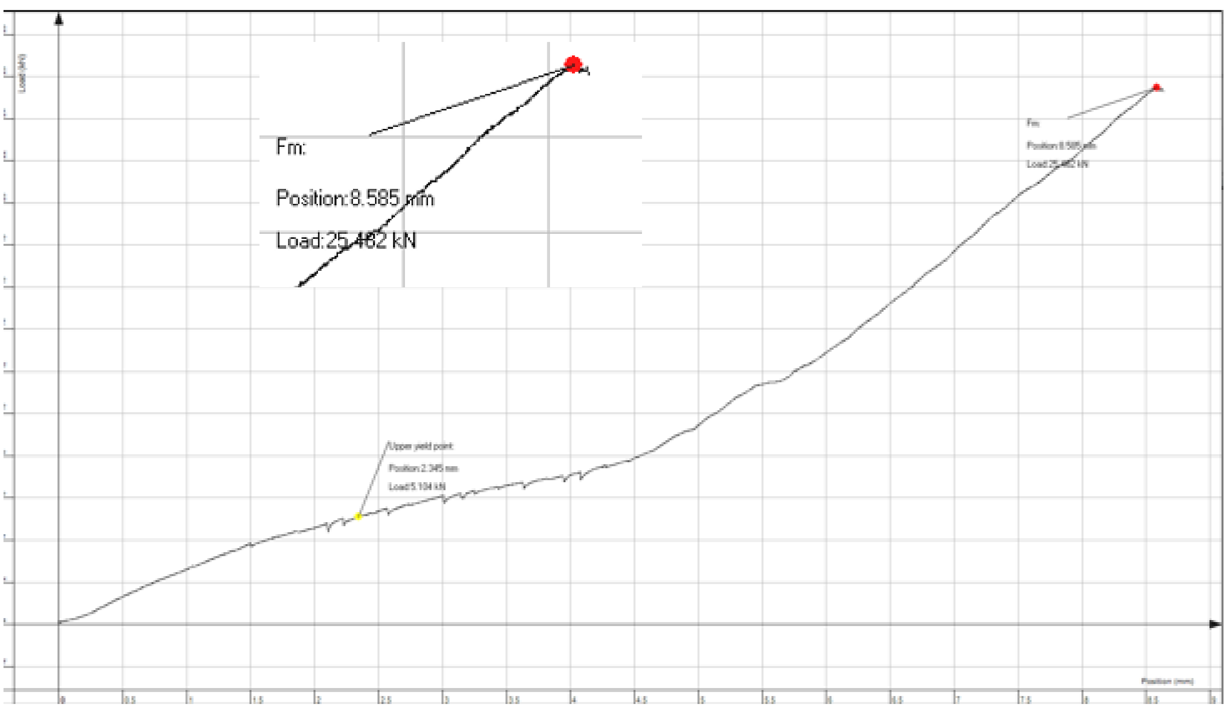


Hardness Test Result

Sample HT-01

Sample HT-02

Sample HT-03

Sample HT-04


Sample HT-05

Sample HT-06


Sample HT-07

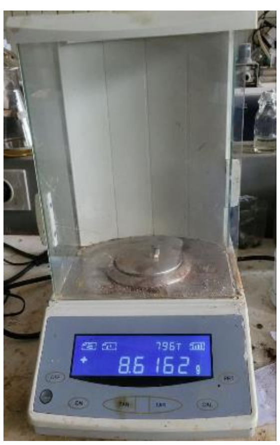
Sample HT-08

BRASS MATERIALOF WELDING

STEEL MATERIALOF WELDING

Sample corrosion test initial mass (CTM1) and Sample mass 2 after corrosion test (CTM2)

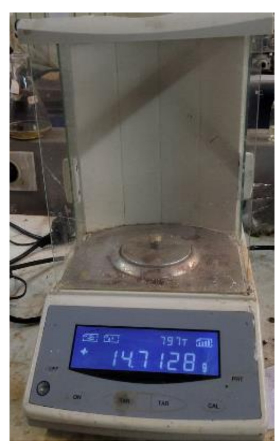
CTM1-1



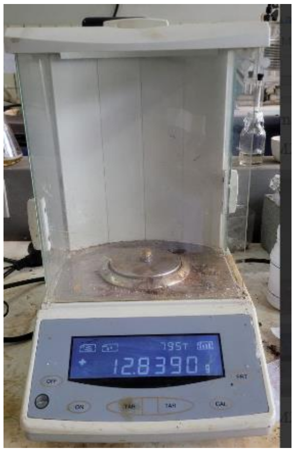
CTM1-2

CTM2-1

CTM2-2

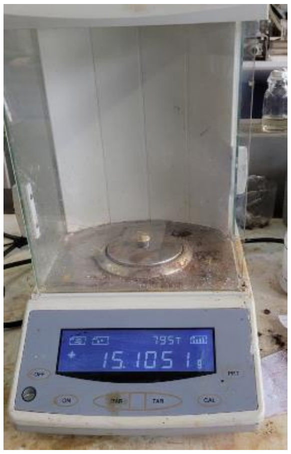


CTM3-1 CTM3-2 CTM4-1 CTM4-2



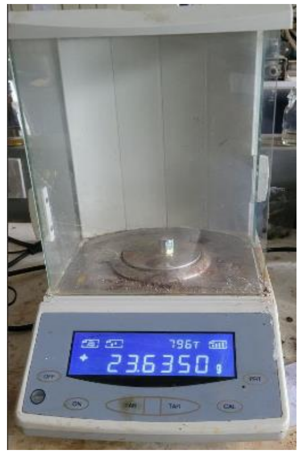
CTM5-1 CTM5-2 CTM6-1 CTM6-2

CTM7-1

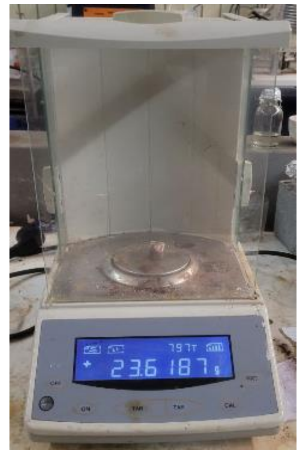


CTM7-2

CTM8-1



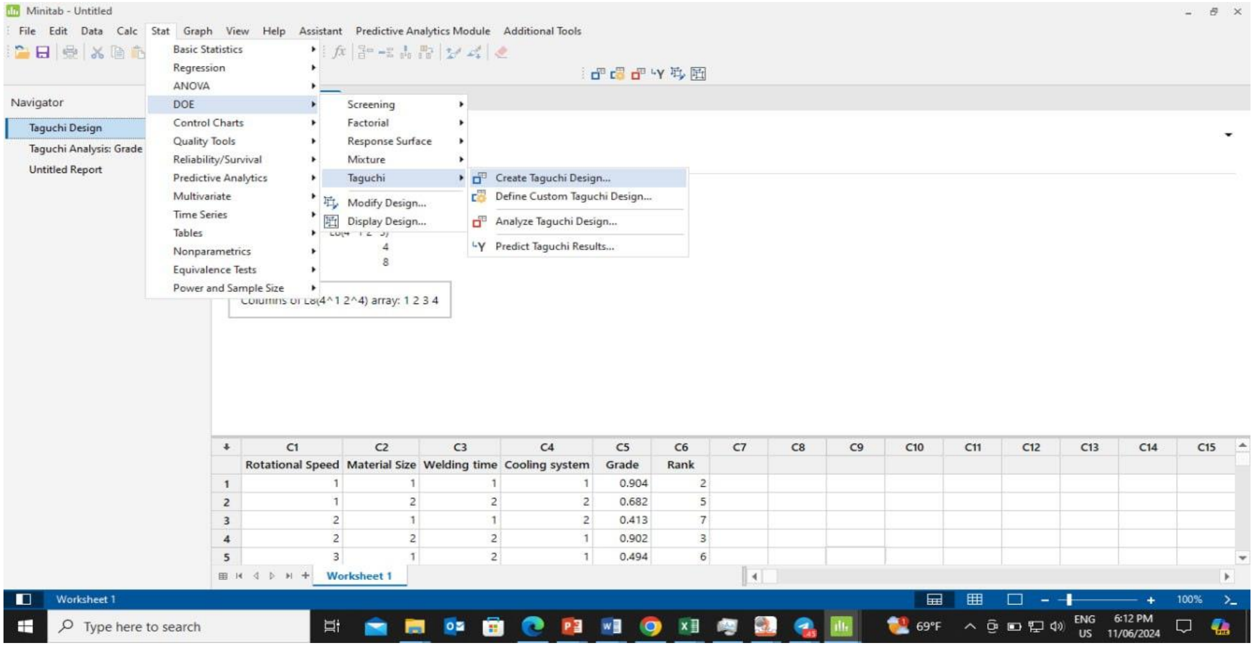
CTM8-2

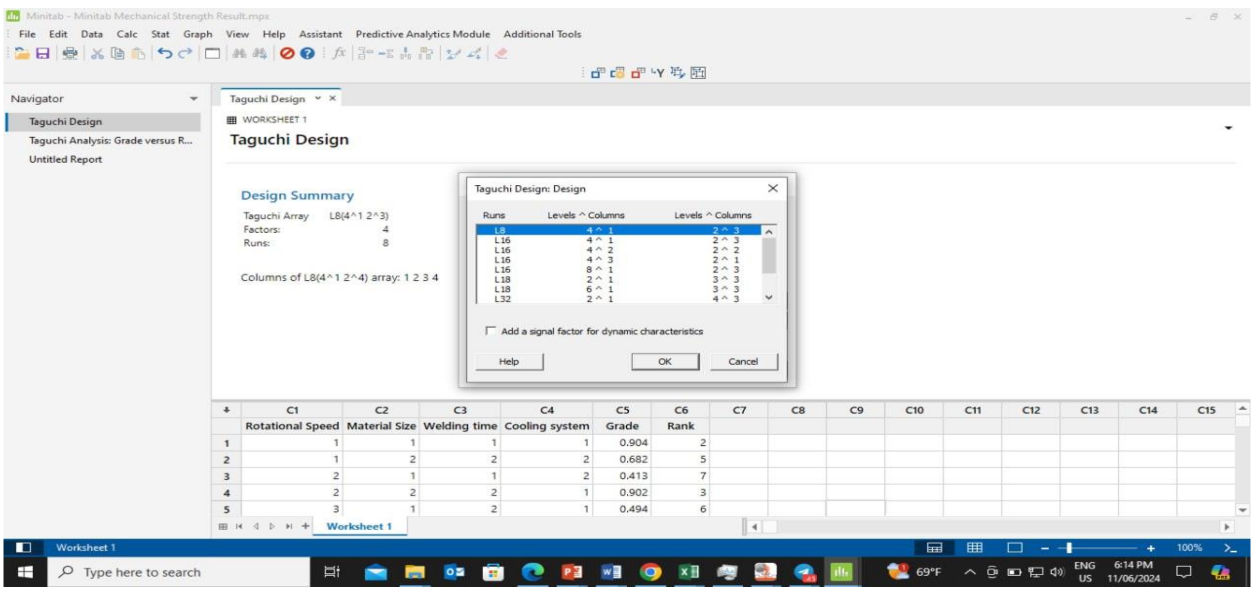


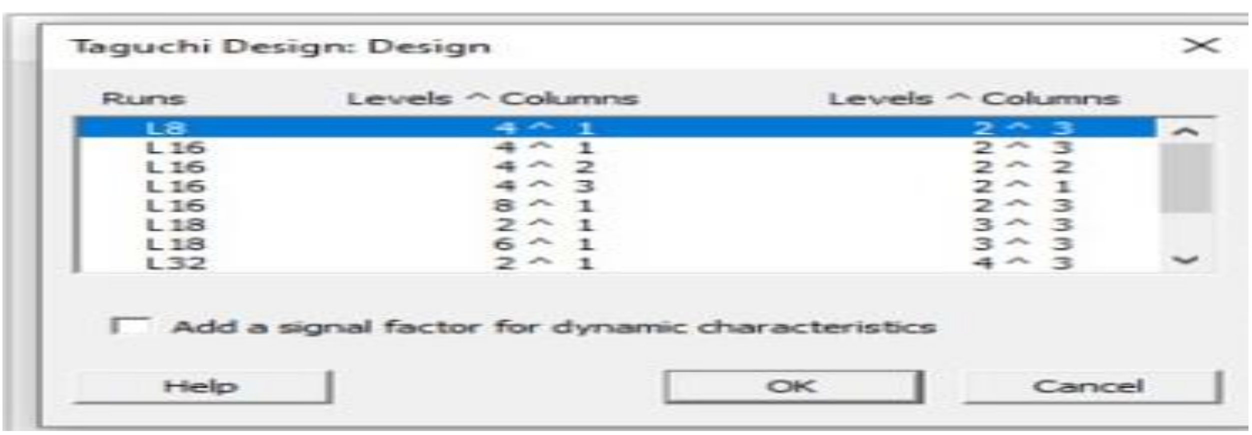
Spacimens of corrision test after test

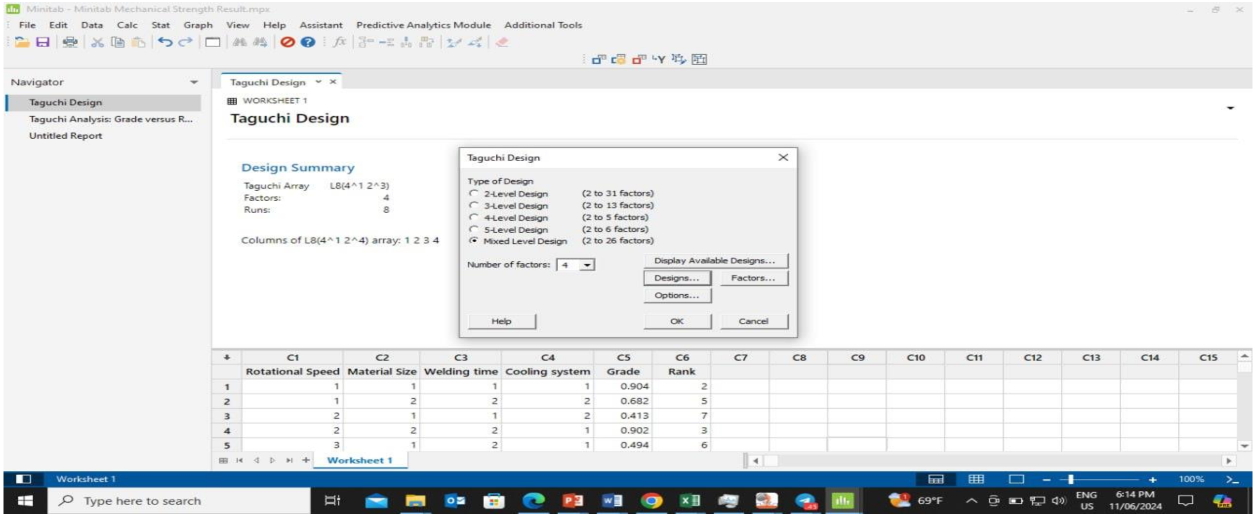
Sodium chloride and cable connecter of DC with graphite in chemical

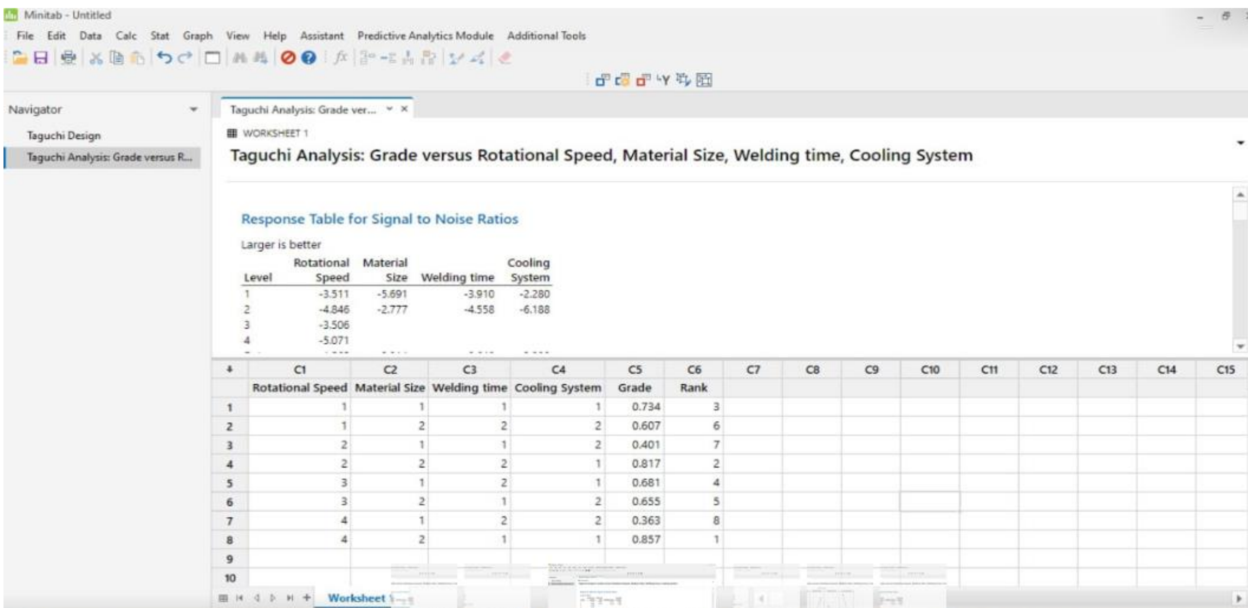
Taguchi design by Min tab soft ware

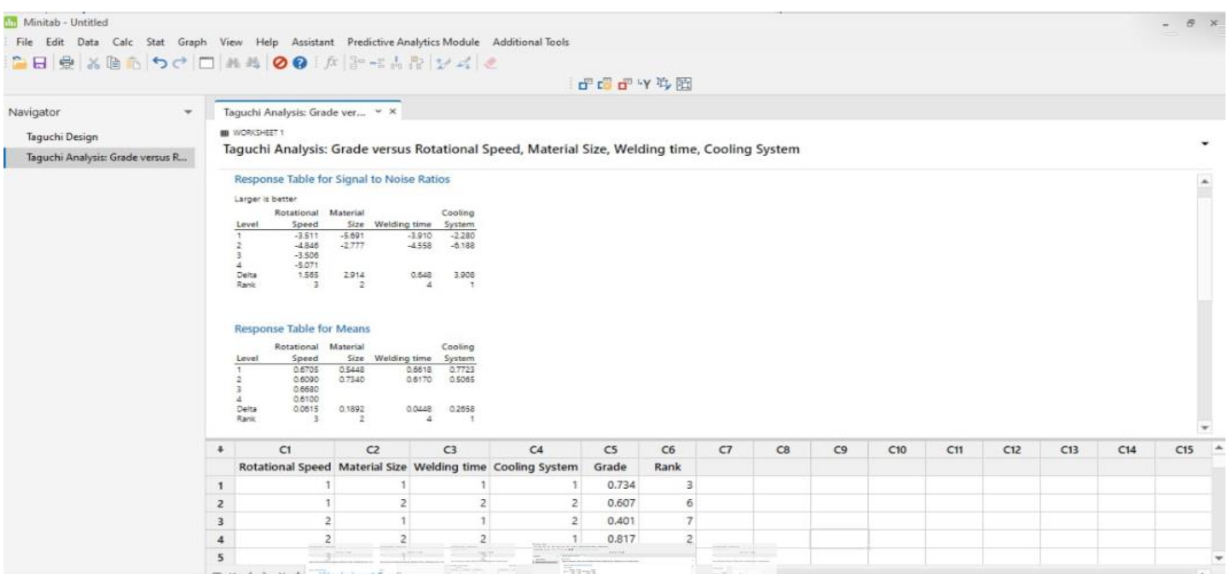


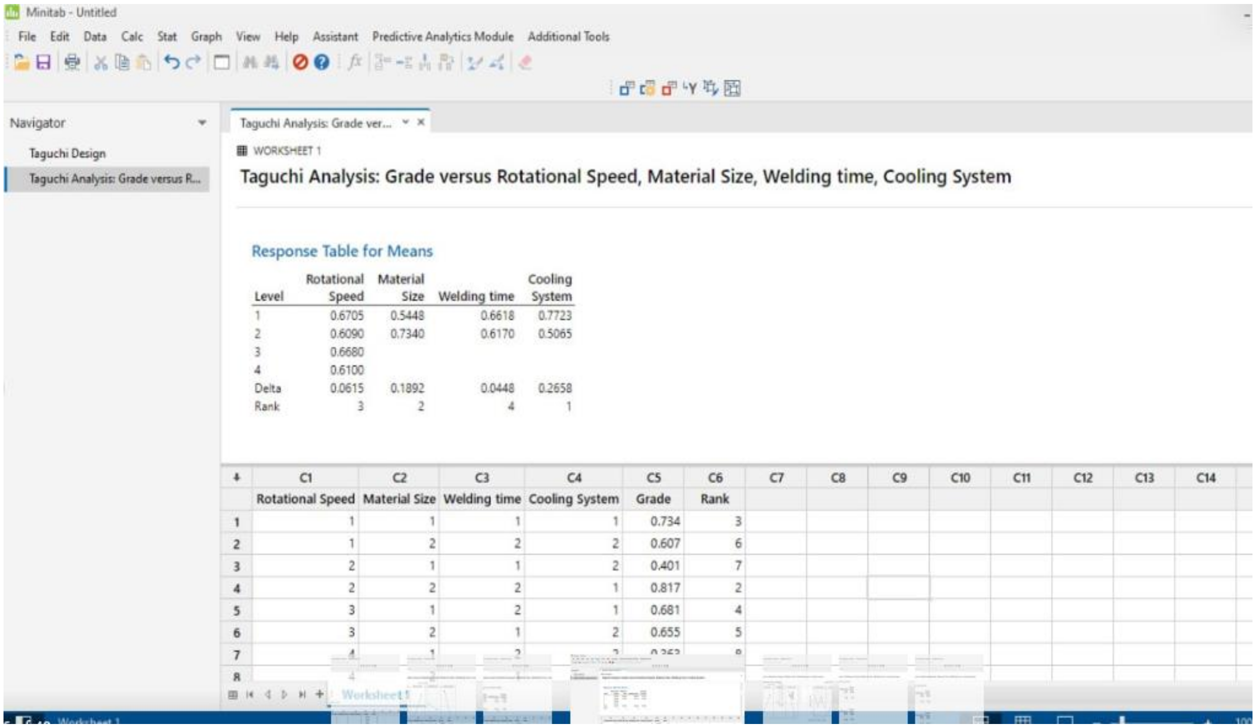


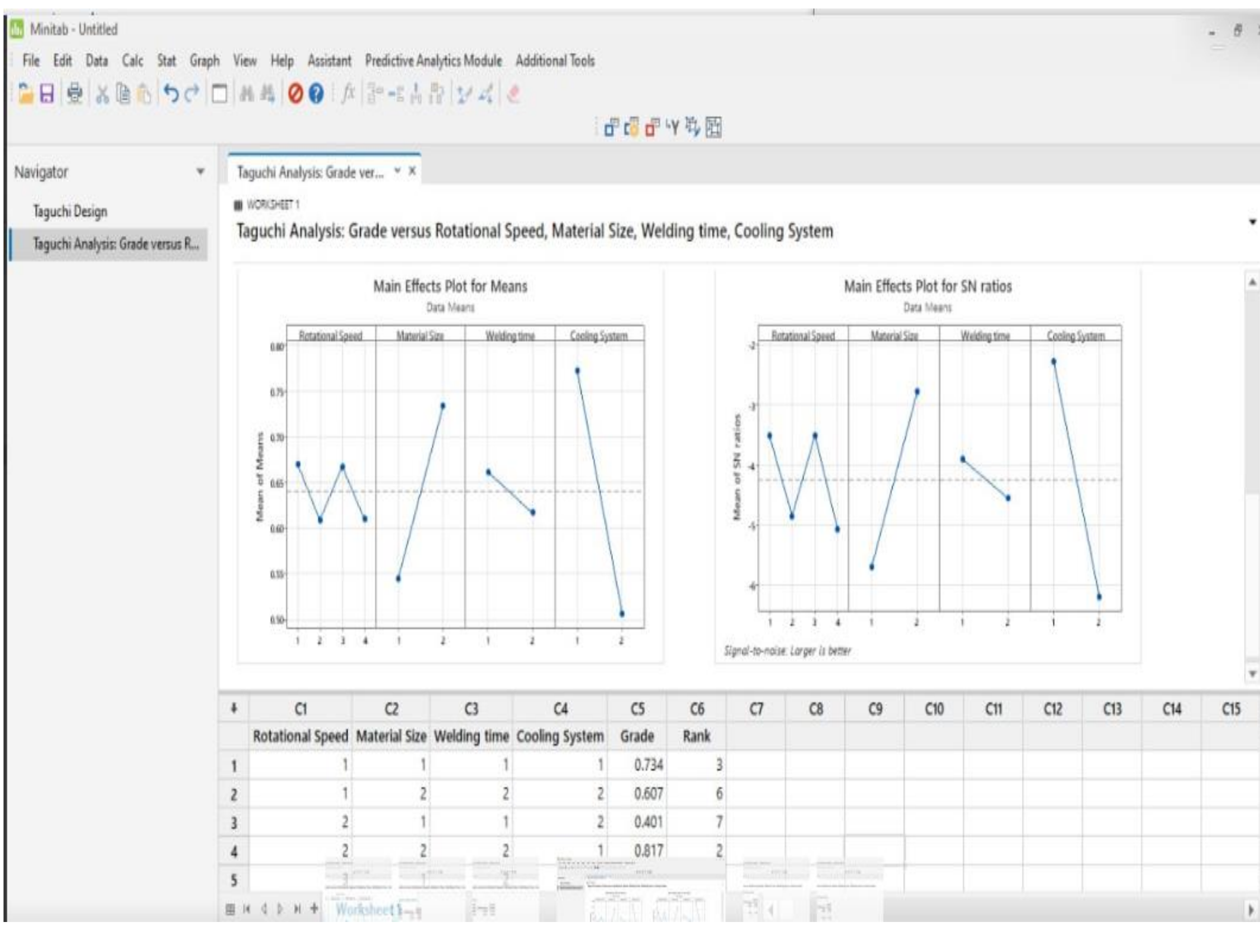



Taguchi Design
WORKSHEET 1
Taguchi Design
Design Summary
Taguchi Array L8(4^1 2^3)
Factors: 4
Runs: 8
Columns of L8(4^1 2^4) array: 1 2 3 4
Type of Design
2-Level Design (2 to 31 factors)
3-Level Design (2 to 13 factors)
4-Level Design (2 to 5 factors)
5-Level Design (2 to 6 factors)
Mixed Level Design (2 to 26 factors)
Number of factors: 4
Display Available Designs...
Designs...
Factors...
Options...
Help
OK
Cancel
Rotational Speed
Material Size
Welding time
Cooling system
Grade
Rank
Worksheet 1

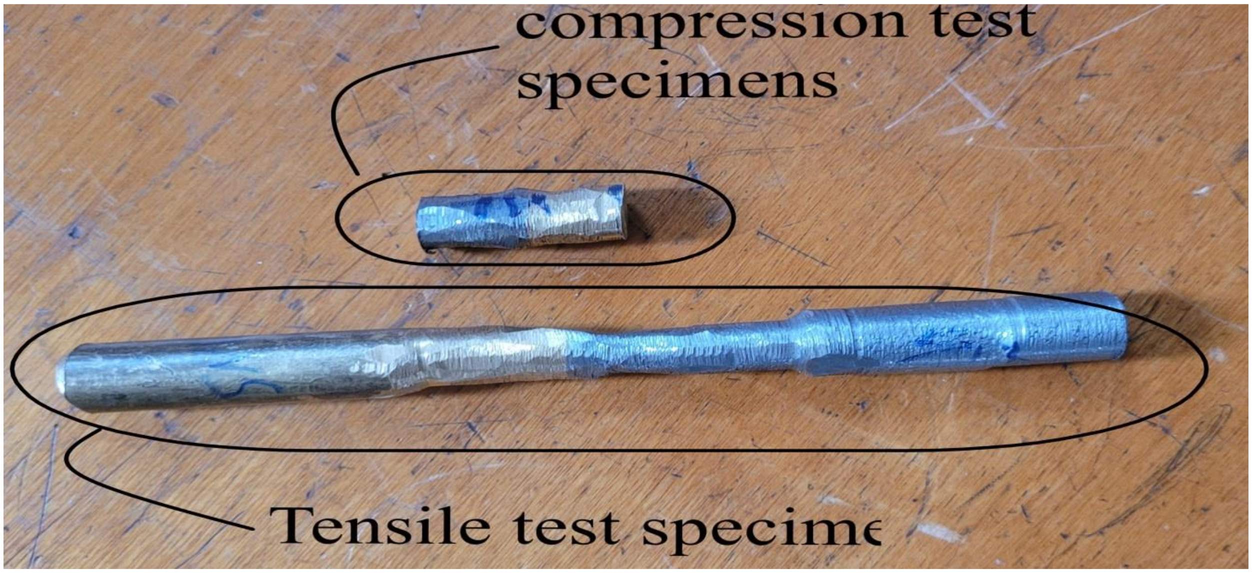

Taguchi Analysis: Grade versus Rotational Speed, Material Size, Welding time, Cooling System
Response Table for Signal to Noise Ratios
Larger is better
Rotational Speed
Material Size
Welding time
Cooling System
Grade
Rank
Worksheet 1


Taguchi Analysis: Grade versus Rotational Speed, Material Size, Welding time, Cooling System
Response Table for Signal to Noise Ratios
Larger is better
Response Table for Means
Rotational Speed
Material Size
Welding time
Cooling System
Grade
Rank


Minitab - Untitled
File Edit Data Calc Stat Graph View Help Assistant Predictive Analytics Module Additional Tools
Navigator
Taguchi Design
Taguchi Analysis: Grade versus R...
Taguchi Analysis: Grade ver...
WORKSHEET 1
Taguchi Analysis: Grade versus Rotational Speed, Material Size, Welding time, Cooling System
Response Table for Means
Level Rotational Speed Material Size Welding time Cooling System
1 0.6705 0.5448 0.6618 0.7723
2 0.6090 0.7340 0.6170 0.5065
3 0.6680
4 0.6100
Delta 0.0615 0.1892 0.0448 0.2658
Rank 3 2 4 1
C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12 C13 C14
Rotational Speed Material Size Welding time Cooling System Grade Rank
1 1 1 1 1 0.734 3
2 1 2 2 2 0.607 6
3 2 1 1 2 0.401 7
4 2 2 2 1 0.817 2
5 3 1 2 1 0.681 4
6 3 2 1 2 0.655 5
Worksheet 1


Minitab - Untitled
File Edit Data Calc Stat Graph View Help Assistant Predictive Analytics Module Additional Tools
Navigator
Taguchi Design
Taguchi Analysis: Grade versus R...
Taguchi Analysis: Grade ver...
WORKSHEET 1
Taguchi Analysis: Grade versus Rotational Speed, Material Size, Welding time, Cooling System
Main Effects Plot for Means
Data Means
Rotational Speed
Material Size
Welding time
Cooling System
Mean of Means
Main Effects Plot for SN ratios
Data Means
Mean of SN ratios
Signal-to-noise: Larger is better
C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12 C13 C14 C15
Rotational Speed Material Size Welding time Cooling System Grade Rank
1 1 1 1 1 0.734 3
2 1 2 2 2 0.607 6
3 2 1 1 2 0.401 7
4 2 2 2 1 0.817 2
Worksheet 1

Mechanical test sample



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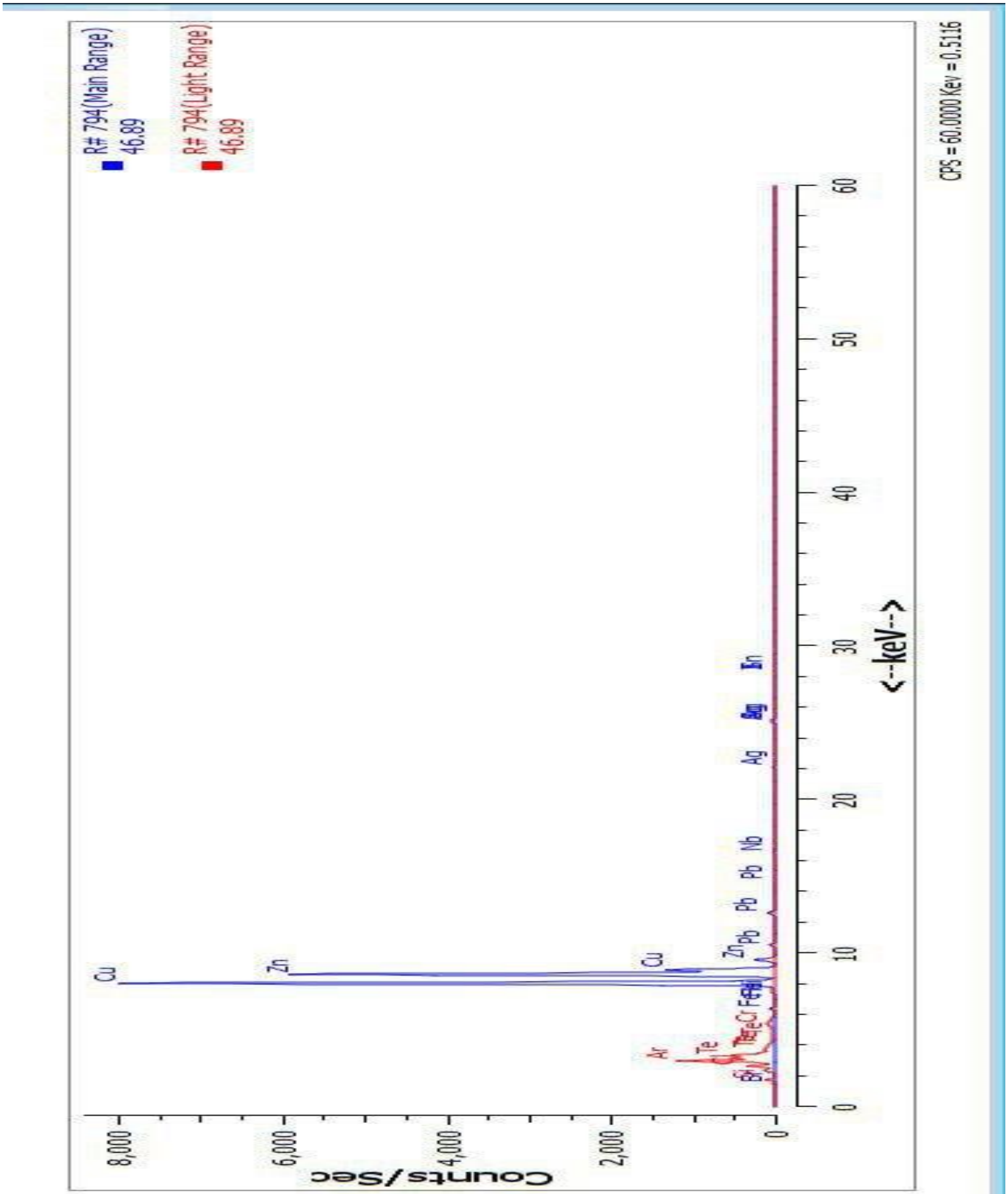
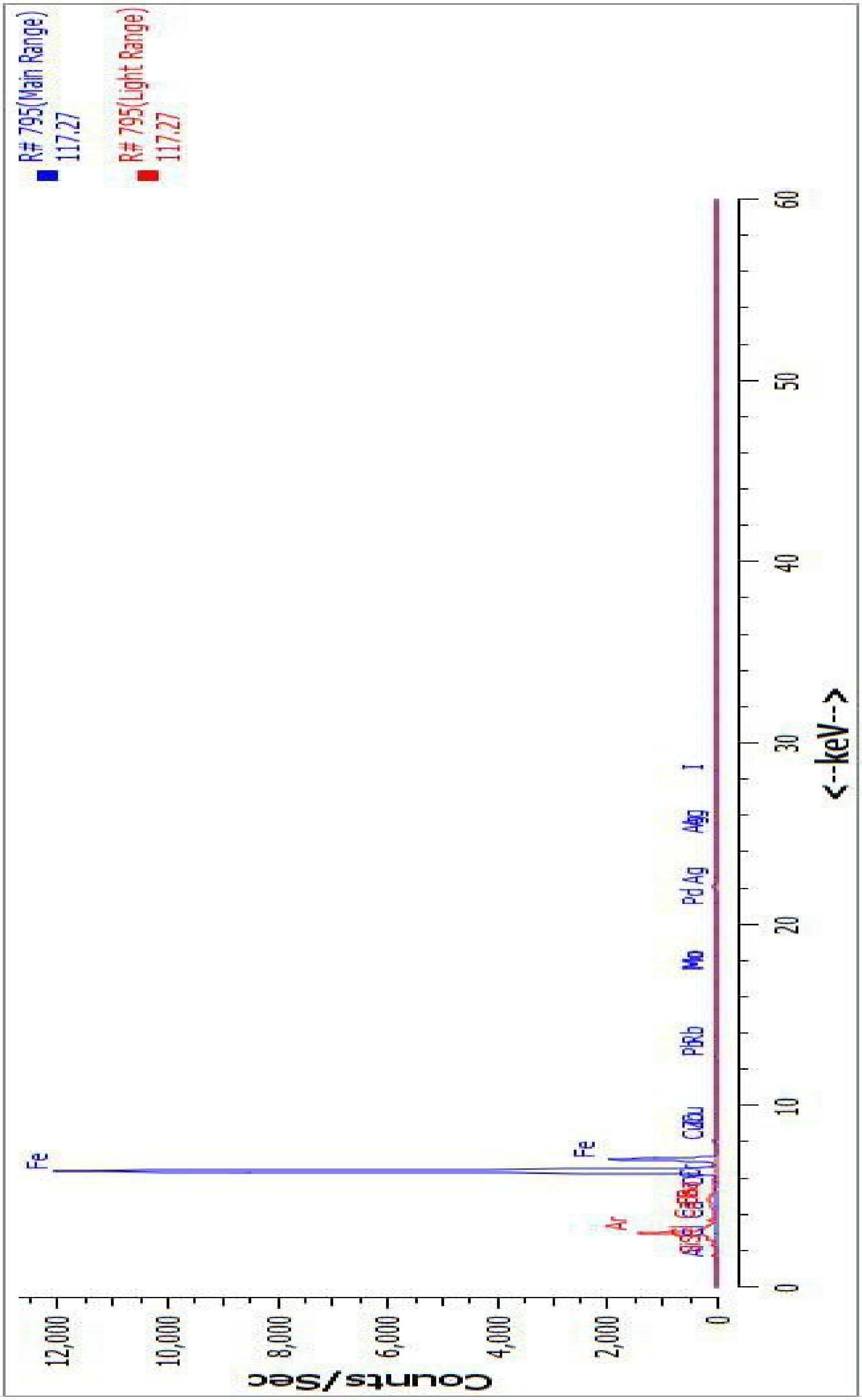
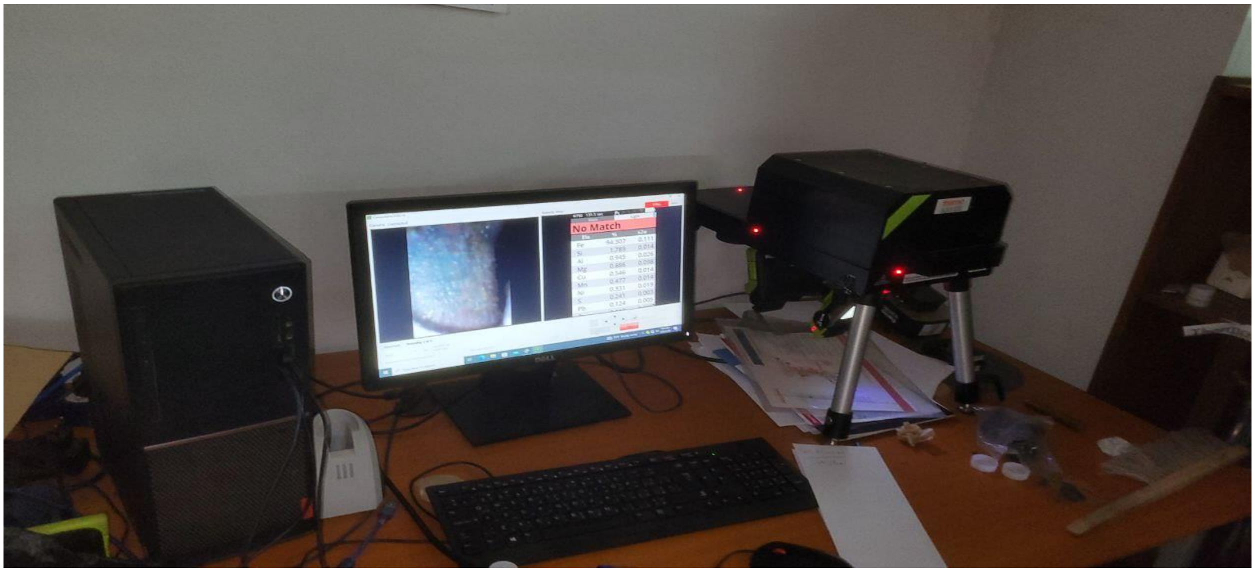
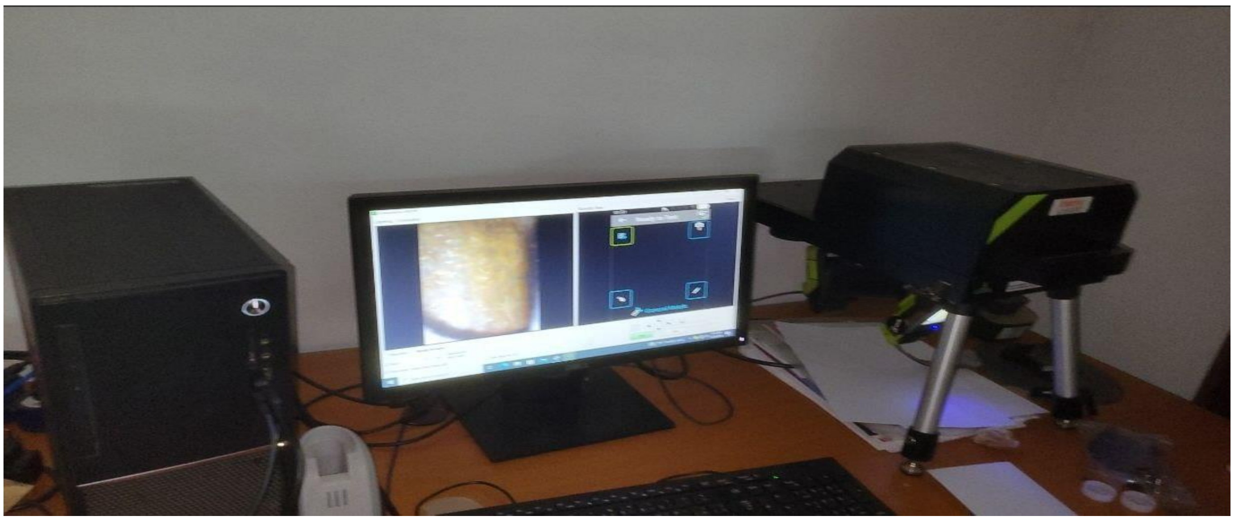
Chemical composition graph for brass and low carbon steel

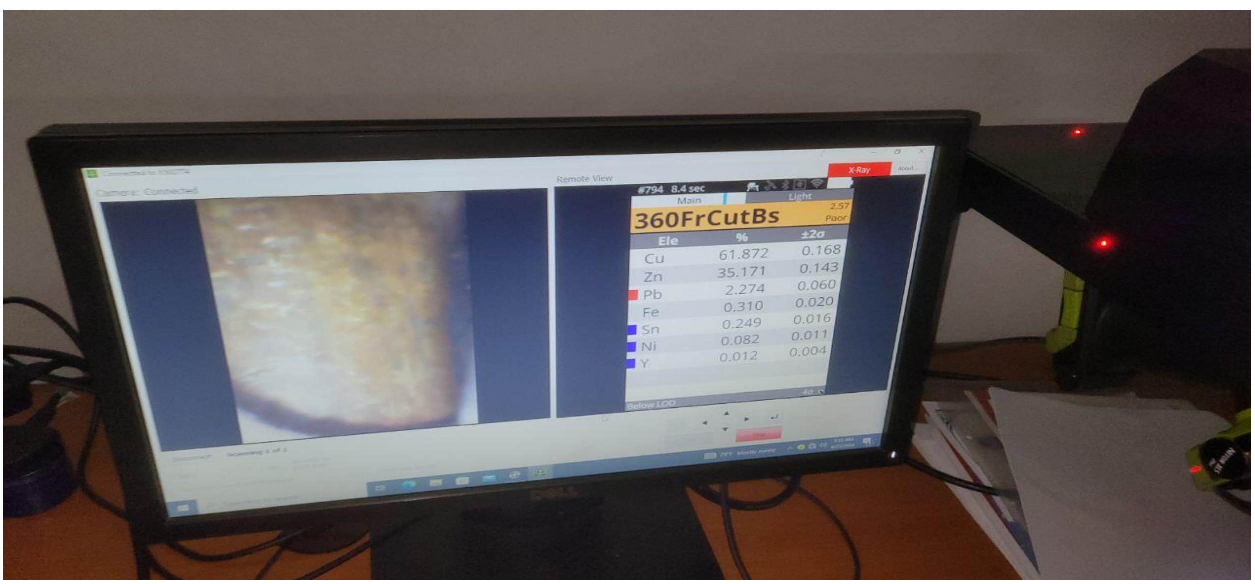


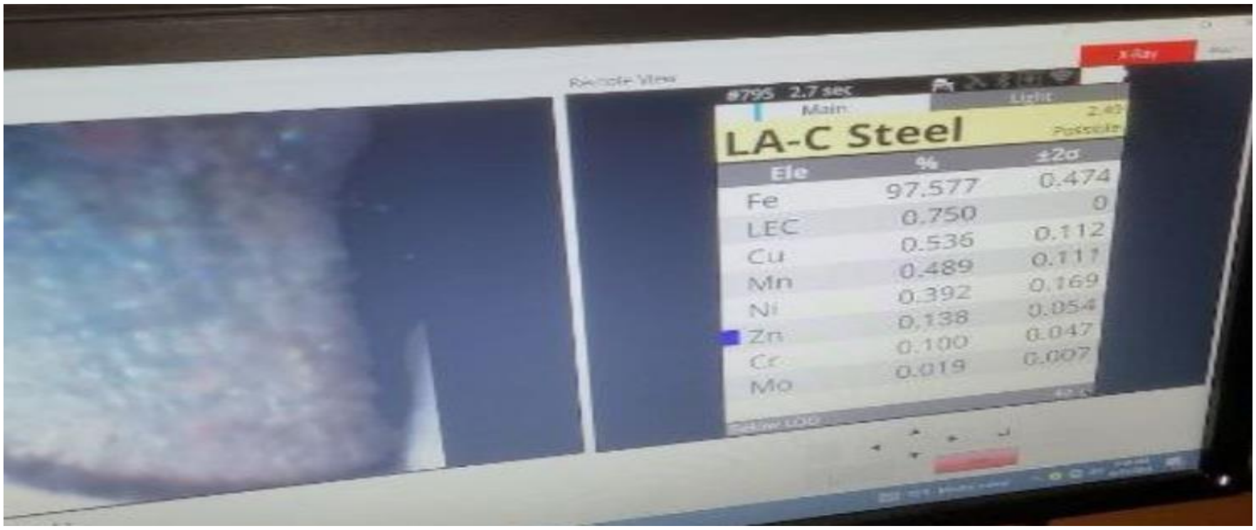

R# 795(Main Range)
117.27
R# 795(Light Range)
117.27
CPS = 60.0000 Kev = 0.0000
Counts/Sec
<--keV-->
Fe
Fe
Ar
Pd Ag
I

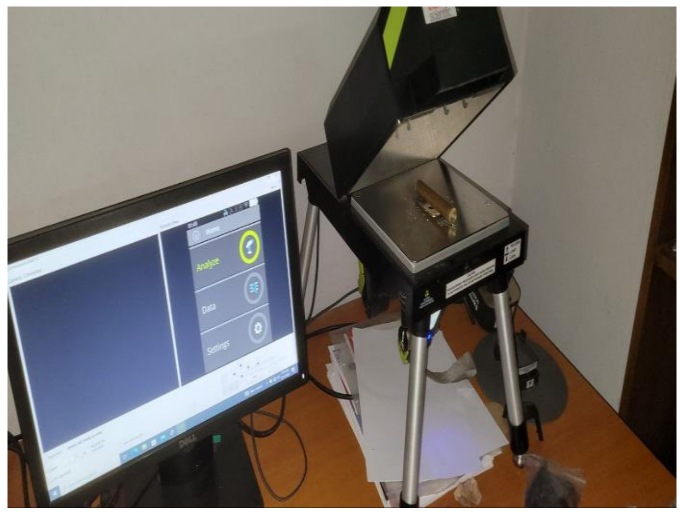
Chemical composition machine reading brass and steel

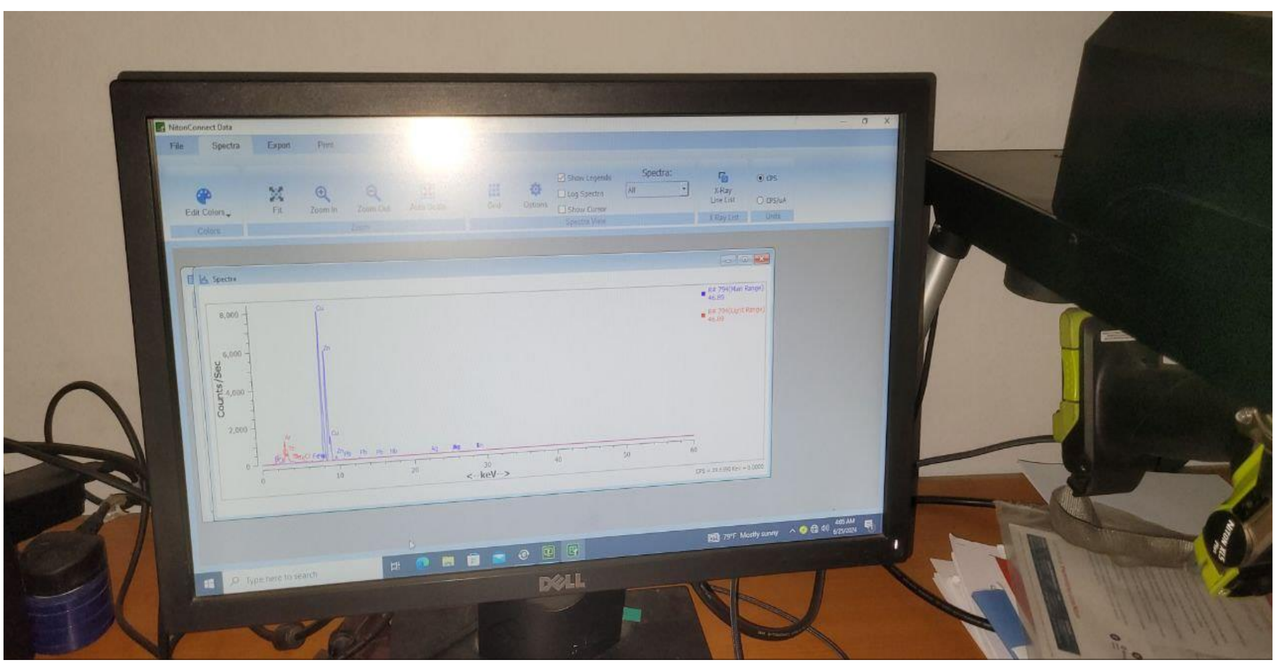







#795 2.7 sec
Main
LA-C Steel
Ele % ±2σ
Fe 97.577 0.474
LEC 0.750 0
Cu 0.536 0.112
Mn 0.489 0.111
Ni 0.392 0.169
Zn 0.138 0.054
Cr 0.100 0.047
Mo 0.019 0.007





Total chemical composition Wt. % result of 794 item no brass and 795 item no steel reading no of manufacturing industry development institute chemical and construction inputs industry research and development.

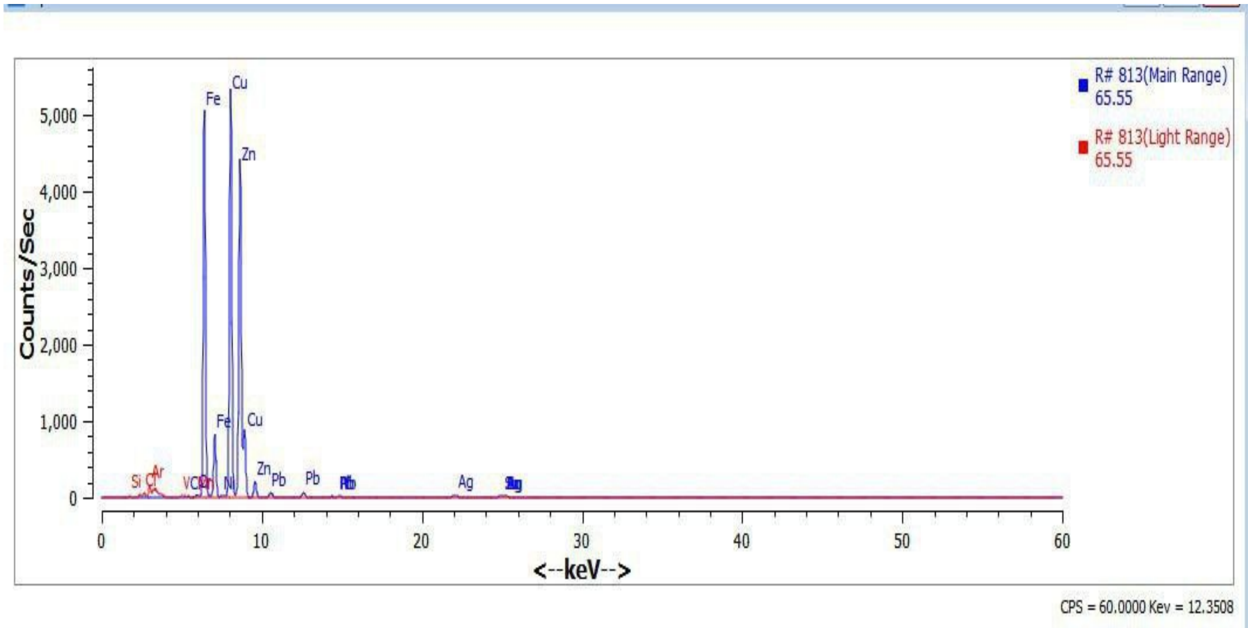
Reading	Reading	Duration	Main	Low	High	Light	Time	User	Sigma Va	Units	Batch	Heat	Lot	Note	Sample	Mode	Match 1	Match Nu	Match 2	Match Nu	Ag	Ag 2-Sigm	Al	Al 2-Sigm	Au
794	General	184.59	46.89			119.42	Wed Jun	User	2	%						General	No Matc	6.01	No Matc	6.74	0.0144	0.0038	1.3564	0.0299	<LOD
795	General	180.44	117.27			38.12	Wed Jun	User	2	%						General	No Matc	6.86	No Matc	6.94	<LOD	0.0045	0.9439	0.022	<LOD

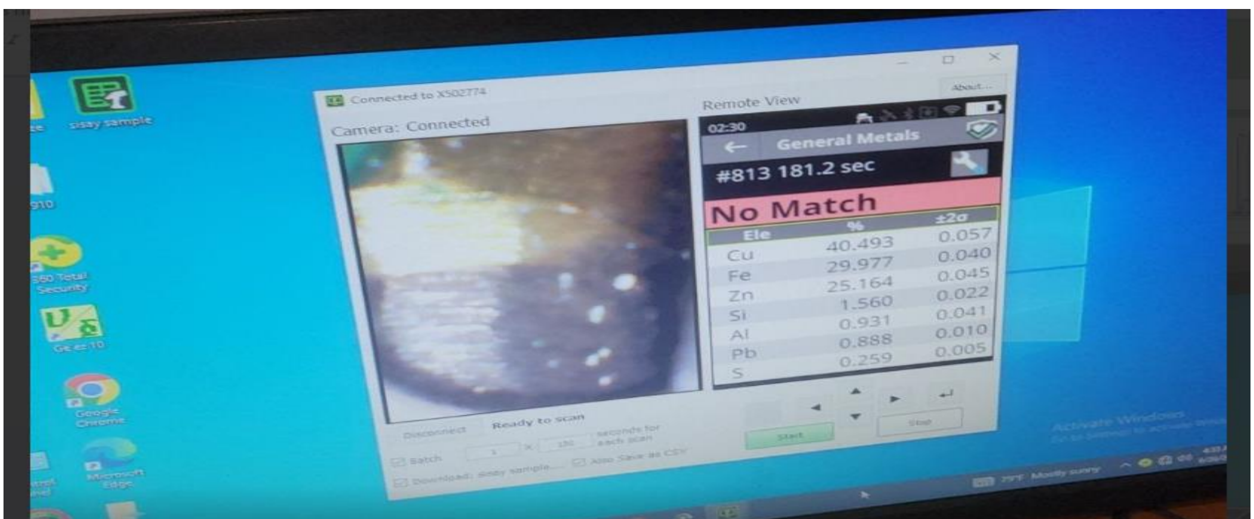
Au 2-Sign	Bi	Bi 2-Sigm	Cd	Cd 2-Sign	Co	Co 2-Sign	Cr	Cr 2-Sigm	Cu	Cu 2-Sign	Fe	Fe 2-Sign	Hf	Hf 2-Sign	Mg	Mg 2-Sig	Mn	Mn 2-Sig	Mo	Mo 2-Sig	Nb	Nb 2-Sign	Ni	Ni 2-Sign	P
0	0.0305	0.0051	0.0091	0.0035	<LOD	0.017	0.0065	0.0061	59.387	0.0553	0.2995	0.0073	<LOD	0	<LOD	0	0.0067	0.0049	<LOD	0.0022	<LOD	0.0018	0.077	0.0042	0.1322
0	<LOD	0.0065	<LOD	0.0043	<LOD	0.0591	0.1144	0.0049	0.5724	0.0111	94.6098	0.0938	<LOD	0	0.878	0.0841	0.4834	0.0109	0.0137	0.0006	0.0008	0.0005	0.3288	0.0152	0.0664

BA	BB	BC	BD	BE	BF	BG	BH	BI	BJ	BK	BL	BM	BN	BO	BP	BQ	BR	BS	BT	BU	BV
P 2-Sigma	Pb	Pb 2-Sign	Pd	Pd 2-Sign	Re	Re 2-Sign	Ru	Ru 2-Sign	S	S 2-Sigma	Sb	Sb 2-Sign	Se	Se 2-Sign	Si	Si 2-Sigm	Sn	Sn 2-Sign	Ta	Ta 2-Sign	Te
0.0028	2.1046	0.021	<LOD	0.0073	<LOD	0	0.0017	0.0009	<LOD	0.0075	0.0094	0.0042	<LOD	0.0041	2.5639	0.0178	0.2335	0.0055	<LOD	0	<LOD
0.0018	0.128	0.0037	<LOD	0.0047	<LOD	0	<LOD	0.0009	0.2414	0.0022	<LOD	0.0053	<LOD	0.0011	1.4643	0.0117	0.0334	0.0024	<LOD	0	<LOD

BW	BX	BY	BZ	CA	CB	CC	CD	CE	CF	CG	CH	CI
Te 2-Sign	Ti	Ti 2-Sigm	V	V 2-Sigma	W	W 2-Sigm	Y	Y 2-Sigma	Zn	Zn 2-Sign	Zr	Zr 2-Sigma
0.0121	0.0315	0.0183	<LOD	0.0532	0.0284	0.0196	0.0129	0.0092	33.6878	0.0485	0.0071	0.0012
0	<LOD	0.0458	<LOD	0.0266	<LOD	0.0133	<LOD	0.0005	0.1211	0.0049	0.0004	0.0003

Welded of brass and steel chemical compositions metal material at Welded area





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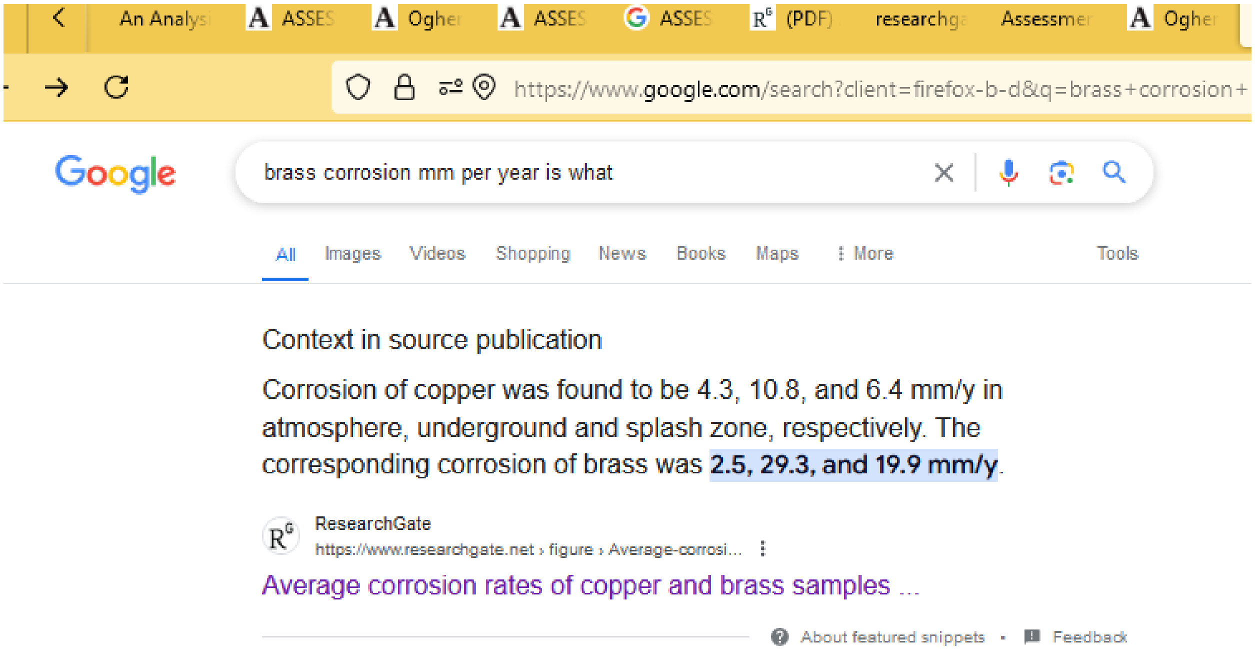
An Analysi
ASSES
Ogher
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ASSES
(PDF)
researchga
Assessmen
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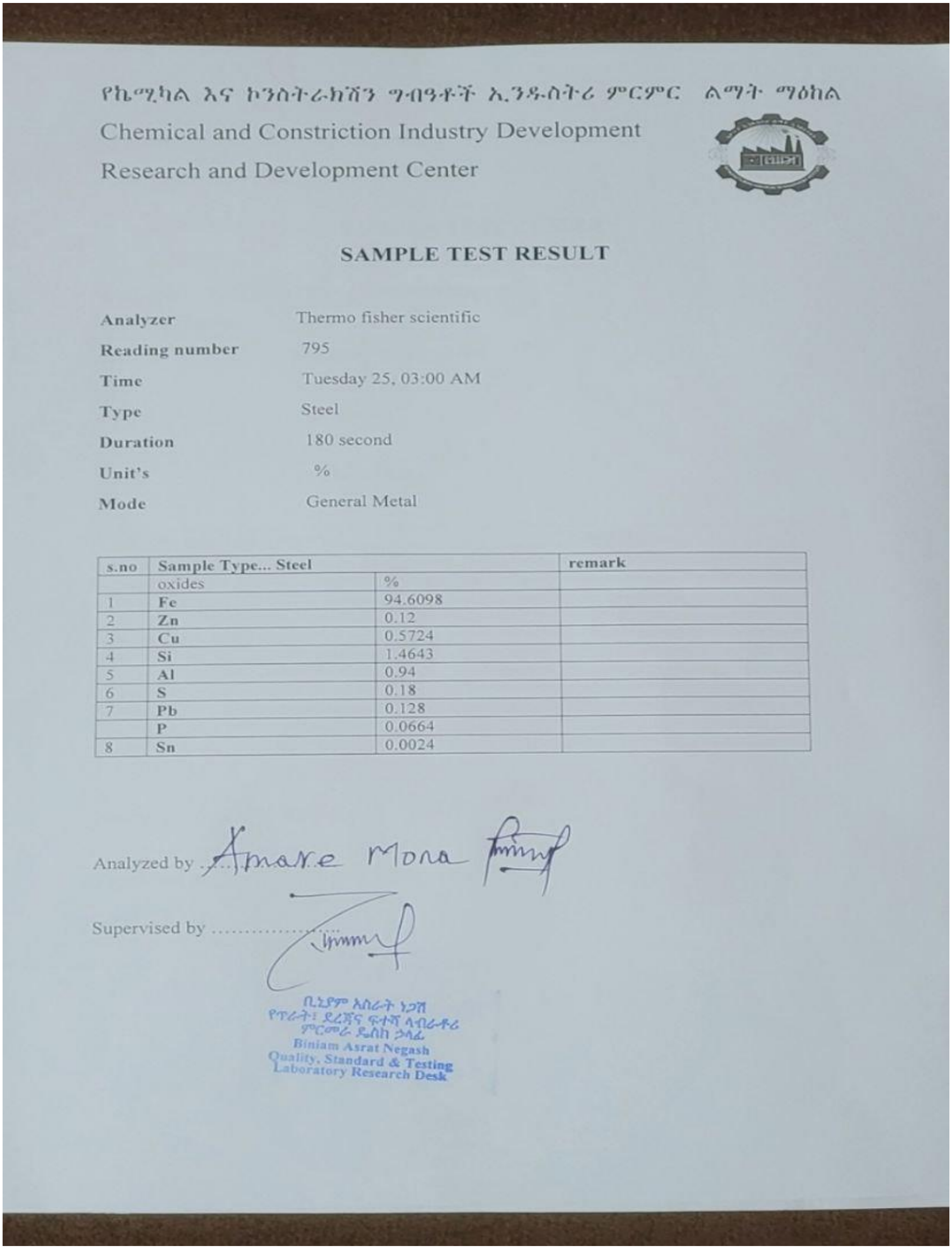
https://www.google.com/search?client=firefox-b-d&q=brass+corrosion+
Google
brass corrosion mm per year is what
All
Images
Videos
Shopping
News
Books
Maps
More
Tools
Context in source publication
Corrosion of copper was found to be 4.3, 10.8, and 6.4 mm/y in atmosphere, underground and splash zone, respectively. The corresponding corrosion of brass was 2.5, 29.3, and 19.9 mm/y.
ResearchGate
https://www.researchgate.net › figure › Average-corrosi...
Average corrosion rates of copper and brass samples ...
About featured snippets
Feedback

CHEMICA COMPOSTION BRASS AND STEEL LETTER



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Chemical and Constriction Industry Development

Research and Development Center

SAMPLE TEST RESULT

Analyzer	Thermo fisher scientific
Reading number	795
Time	Tuesday 25, 03:00 AM
Type	Steel
Duration	180 second
Unit's	%
Mode	General Metal

s.no	Sample Type... Steel		remark
	oxides	%	
1	Fe	94.6098	
2	Zn	0.12	
3	Cu	0.5724	
4	Si	1.4643	
5	Al	0.94	
6	S	0.18	
7	Pb	0.128	
	P	0.0664	
8	Sn	0.0024	

Analyzed by ... Amare Mona

Supervised by ....

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የጥራት፣ ደረጃና ፍተሻ ላብራቶሪ
ምርምር ዴስክ ኃላፊ
Biniam Asrat Negash
Quality, Standard & Testing
Laboratory Research Desk

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Chemical and Constriction Industry Development

Research and Development Center

Sample test result

Analyzer	Thermo fisher scientific
Reading number	794
Time	Tuesday 25, 02:30 AM
Type	Brass
Duration	180 second
Unit's	%
Mode	General Metal

s.no	Sample Type... Brass		remark
	Element	%	
1	Cu	59.39	
2	Zn	33.69	
3	Al	1.36	
4	Si	2.56	
5	Pb	2.1	
6	Sn	0.2335	
7	P	0.1322	
8	Ni	0.077	
9	Mn	0.0067	

Analyzed by ....Amare Mona

Supervised by ....

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የጥራት፣ ደረጃና ፍተሻ ላብራቶሪ
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Quality, Standard & Testing
Laboratory Research Desk

BRASS- STEEL WELDING AREA CHEMICAL COMPOSITION

የኬሚካል እና ኮንስትራክሽን ግብዓቶች ኢንዱስትሪ ምርምር ልማት ማዕከል

Chemical and Constriction Industry Development

Research and Development Center

SAMPLE TEST RESULT

Analyzer	Thermo fisher scientific
Reading number	813
Time	Thursday 27, 03:00 AM
Type	Not specified
Duration	180 second
Unit's	%
Mode	General Metal

S.no	Sample Type... Mixed		Remark
	oxides	%	
1	Cu	40.49	
2	Fe	29.977	
3	Zn	25.164	
4	Al	0.931	
5	Pb	0.88	
6	S	0.25	
7	P	0.0664	
8	Sn	0.0024	

Analyzed by .... Amare Mona

Supervised by ....

ቢኒያም አስራት ነጋሽ
የጥራት፣ ደረጃና ፍተሻ ላብራቶሪ
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Biniam Asrat Negash
Quality, Standard & Testing
Laboratory Research Desk