Kurdistan Region
Salahaddin University-Erbil
College of Engineering
Chemical-Petrochemical Engineering Department

Study the effect of welding time on mechanical property of stainless steel

A Project Submitted to the Chemical-PetrochemicalEngineering Department
University of Salahaddin-Erbil
in the Partial Fulfillment of the Requirement for the Degree of Bachelor of Science
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Abstract

Shielded Metal Arc Welding is one of the most economical and intermediate productive methods in joining metals for welding steel, stainless steel, mild steel, iron, and aluminum. It is widely used in industrial applications.

This study aims to determine the effect welding time on the mechanical properties of Shielded Metal Arc Welding on AISI 304. Subsequently, mechanical tests including tensile, and impact testing assessments are performed to evaluate the resultant properties. Including the study of applications, advantages, and challenges. Material characterizations were conducted on a (2) mm thick plates and (20*40) cm area of type-304 austenite stainless steel were weld using Shielded Metal Arc Welding at variation of time used are 40 seconds, 60 seconds, and 80 seconds, while the current constant used is 95 Ampere. This study also focuses on the challenges faced during Shielded Metal Arc Welding.

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Supervisor’s Certificate

I certify that the engineering project titled **"Study the effect of welding time on mechanical property of stainless steel”** was done under my supervision at the Chemical-PetrochemicalEngineering Department, College of Engineering - Salahaddin University–Erbil. In the partial fulfillment of the requirement for the degree of Bachelor of Science in Chemical-PetrochemicalEngineering.

Supervisor

Signature:

Name:

Date: /   /

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Nomenclature

You may wish to include a nomenclature if you have many mathematical symbols. Remember that your reader may not be an expert in the field of your project. In any case, symbols should be defined on first appearing in text.

Chapter One

Introduction

Welding is the fusion of two parts into one. This fusion can be accomplished in a number of different ways. In every case, however, a chemical bond is achieved at the interface between the two, previously separate, components. The materials that can be welded are therefore limited to those that can be processed to allow a change in chemistry or structure. This typically limits welding processes to metals and thermoplastic polymers. Metal welding has existed for millennia as a forging process and is well established. Plastic welding is a much more recent development, but equally important in the modern world. (Marcus et al.)

Welding has several types which are shown in Table 1.1 Types of Welding.

Types Of Welding	
Arc Welding	is the fusion of two pieces of metal by an electric arc between the pieces being joined – the work pieces – and an electrode that is guided along the joint between the pieces.
Gas Welding	oxy-fuel welding, is one of the oldest forms of heat-based welding that uses oxygen and fuel gases to join metal surfaces. This welding method typically uses acetylene or gasoline as its fuel gas.
Resistance Welding	Resistance or pressure welding uses the application of pressure and current between two metal surfaces to create fusion.
Laser Welding	laser beam as a concentrated heat source to melt metals and create welds. LBW's high power density results in small heat-affected zones.
Electron Beam Welding	is a fusion welding process where electrons generated by an electron gun are accelerated to high speeds.

1.1 Arc welding

Arc welding is a family of welding processes that produce coalescence of materials using the heat of an electric arc to melt the metal(s) and form the weld. The arc can be made with either non consumable or consumable electrodes. Arc processes are further defined by the shielding mechanism, which protects the weld pool from atmosphere that can react with molten metals and impair properties. Oxygen and nitrogen can produce oxides and other compounds in the weld that may reduce strength and toughness and may introduce defects such as porosity or slag inclusion to name a few. Arc shielding can be from an inert gas, active gas, and fluxes that decompose in the arc to provide shielding via a gas blanket and/or slag and may control welding process behavior.(Marcus et al.)

1.1.1 Shielded Metal Arc Welding

Also known as manual metal arc welding (MMAW/MMA), uses a consumable flux-coated metal electrode to join metals. As we strike the electrode with the base metal, it creates an arc that melts down the materials in the weld pool. The flux releases a shielding gas to protect the weld metal from contamination. Slag deposits are removed after the cooling process using common shop tools such as a wire brush.(Farnsworth, 2021)

1.1.2 Gas metal Arc Welding (GMAW)

Also known as MIG/MAG welding (metal inert gas/metal active gas), uses a continuous wire electrode fed through a welding gun. As the electric arc melts the electrode wire it is then fused along with the base metals in the weld pool.(Farnsworth, 2021)

1.1.3 Tungsten Inert Gas (TIG) welding:

Is a welding process, in which heat is generated by an electric arc struck between a tungsten non-consumable electrode and the work piece. The weld pool is shielded by an inert gas (Argon, helium, Nitrogen) protecting the molten metal from atmospheric contamination.

(Farnsworth, 2021)

1.1.4 Flux-Cored Arc Welding (FCAW)

Is an automatic or semiautomatic process that uses a welding electrode that contains a flux core that acts as a shielding agent. Additional protection from contaminants is called dual-shielded FCAW, wherein a shielding gas is used along with the flux-cored electrode.(Farnsworth, 2021)

1.1.5 Plasma Arc Welding

works in a similar concept to TIG welding, but the torch is designed in a manner that the inert gas exits the nozzle at a higher velocity in a narrow and constricted path.(Farnsworth, 2021)

1.2 Stainless Steel

Stainless steel refers to the family of iron-based alloys having appreciable concentrations of nickel and chromium alloying elements. The term stainless derives from the corrosion resistance afforded by the protective surface oxide layer attributable to these alloying elements.

Specific stainless steels are useful for biomedical applications due to their desirable shaping, joining, and mechanical properties, acceptable corrosion resistance, durability, and manufacturing economics.

It contains at least 10.5% chromium and usually nickel, as well as 0.2 to 2.11% carbon. Stainless steel's resistance to corrosion results from the chromium, which forms a passive film that can protect the material and self-heal in the presence of oxygen.(Andersen, 2020)

1.2.1 Stainless Steel 304

AISI 304 stainless steel is the most widely used stainless steel, containing 18-20% Cr and 8-10.5% Ni, and also known as 18-8 stainless steel.

SS 304 is non-magnetic under annealing conditions, but after cold working (such as stamping, stretching, bending, rolling), part of the austenite structure may be converted into martensite and therefore weakly magnetic. Type 304 has good resistance to atmospheric corrosion and oxidation. The high nickel-chromium alloy content gives it excellent corrosion resistance and is widely used in the food industry as a standard food grade stainless steel. (Andersen, 2020)

1.3 Background and Historical Development

The history of welding stainless steel can be traced back to the early 20th century when the material was first developed. One of the earliest methods used for welding stainless steel was gas welding, which involved using a flame to heat the metal and then joining the pieces together. However, this method was not very effective for welding stainless steel due to its high melting point and the need for precise control of the heat input.

In the 1930s, the invention of electric arc welding revolutionized the welding industry and made it possible to weld stainless steel more effectively. This method involved using an electric arc to melt the metal and join the pieces together, providing a more controlled and precise heat input compared to gas welding. Electric arc welding quickly became the preferred method for welding stainless steel and paved the way for further advancements in the field.

In the 1950s, the development of inert gas welding techniques such as TIG (Tungsten Inert Gas) welding and MIG (Metal Inert Gas) welding further improved the quality of stainless-steel welds. These methods used a shielding gas, such as argon or helium, to protect the weld from contamination and oxidation, resulting in stronger and more durable welds. TIG welding, in particular, became widely used for welding stainless steel due to its high precision and ability to produce clean and high-quality welds.

In more recent years, advancements in welding technology, such as the use of laser welding and robotic welding systems, have further improved the efficiency and accuracy of welding stainless steel. Laser welding, for example, uses a high-powered laser beam to melt and join the metal, providing a fast and precise welding process with minimal heat input. Robotic welding systems, on the other hand, use computer-controlled robots to perform the welding operations, resulting in consistent and high-quality welds.(Lippold and Kotecki, 2005)

1.3.1 Applications of stainless steel 304 in chemical industry

Stainless steel 304 is one of the most commonly used stainless steels in the chemical industry due to its excellent corrosion resistance, high temperature strength, and ease of fabrication.One of the key advantages of stainless steel 304 in chemical industries is its resistance to corrosion. This material contains a high percentage of chromium, which forms a protective layer on the surface when exposed to oxygen, preventing rust and corrosion. Stainless steel 304 is also known for its high temperature strength, making it suitable for use in high-temperature applications such as reactors, heat exchangers, and furnaces. Another benefit of using stainless steel 304 in chemical industries is its ease of fabrication. This material can be easily shaped, welded, and formed into complex shapes.

1. **Chemical processing equipment**

Some examples of their applications are: storage tanks, pressure vessels, pipes, heat exchangers (both tube and plate), agitators and mixers in chemical reactors and mixing vessels, as well as valves, distillation equipment, filters, stream and gasoil strippers, cyclones, trays, vacuum tower feed.

2. **Power Generation**

For example, steam turbines, gas turbines, exhaust systems, flue gas desulfurization (FGD) systems, Boiler tubes and heat exchangers.(Di Schino, 2020)

3. **Pharmaceutical**

The main reason of using stainless steel 304 is that it is less reactive to pharma products and does not absorb pharma products in any form.

such as tanks, vessels, reactors, mixers, pumps, piping systems, Storage and Transport.(Winters and Nutt, 2003)

4. **Food industry**

For example, evaporator tubes, tanks holding dairy, food mixers, ovens, pipes, vessels, and pumps.(Di Schino, 2020)

1.4 Aims and Objectives

The primary aim of this academic project is to investigate the effects of various times on the quality and performance of components produced throughshielded metal arc welding using stainless steel (304).

The specific objective is as follow:

1.4.1 Optimize Process Times

- Evaluate the effects of different process times, on the quality and characteristics of the deposited stainless steel (304).

By achieving these aims and objectives, this academic project aims to enhance the understanding of shielded metal arc welding with stainless steel (304), optimize the process times, and contribute to the advancement and broader applications of additive manufacturing technologies.

Chapter Two

Methodology

2.1 Sheilded Metal Arc Welding Process

Before welding, it is always recommended to check the condition of your equipment. It is crucial for both safety and welding quality to have a well-functioning power source, clamps, cables and electrode holder.

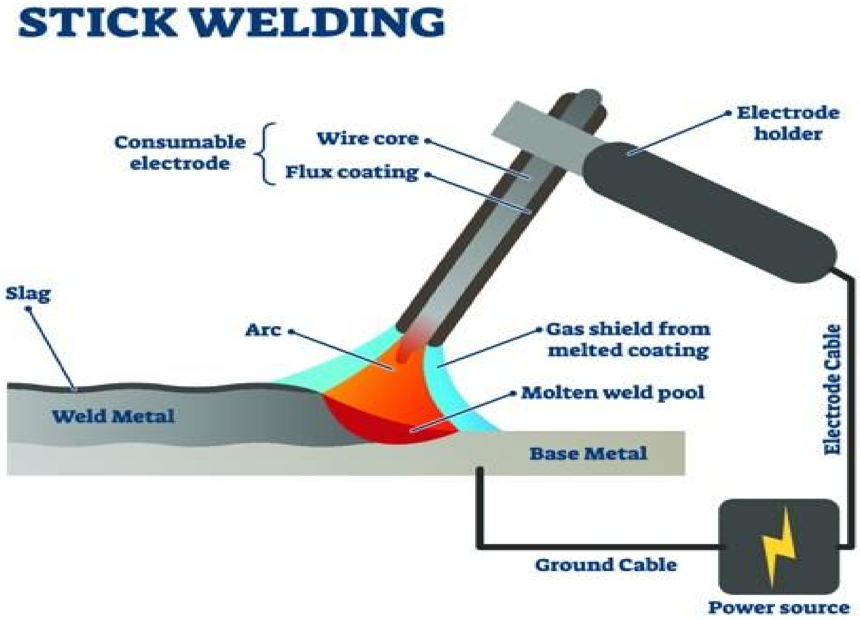


Figure 2.1 Shielded Metal Arc Welding Process.

2.1.1 Equipment

SMAW requires a relatively simple setup, including:

- **Power Source**

  Stick welding can be used in both alternating current (AC) and direct current (DC) power sources. The power source, whether DC negative, DC positive, or AC, should be set depending on the type of electrode.

  The welding machine requires a constant current, which is determined by the electrode size. The voltage will depend on the arc length and rod composition and can be regulated by moving the electrode closer or farther from the workpiece.(Bridigum, 2008)

- **Electrodes**

  Electrode type is one of the determining factors in ensuring weld quality. Its chemical composition can influence the arc stability, deposition rate, depth of penetration and other factors. The electrodes come at a fixed length of 14″ (35cm) or 18″ (45cm) and the welder has to manually change them.(Bridigum, 2008)

- **Electrode holder**

  The electrode holder, also known as an electrode clamp or stinger, is a crucial component in shielded metal arc welding (SMAW).

  It is the tool that holds and provides electrical contact to the welding electrode during the welding process.(Bridigum, 2008)

- **Ground clamp**

is needed to prevent electrical shock. It needs to be connected to the workpiece or fixture. The ground clamp must be capable of carrying the electric current without overheating to avoid hazards.(Bridigum, 2008)

- **Welding cables**

They must have a sufficient cross-sectional area and length to carry out the welding current with minimal voltage drop. There are two welding cables in a stick welding machine, one for the electrode holder, and the other for the ground clamp.(Bridigum, 2008)

2.1.2 Type of Materials

- **Steel**

Steel is a versatile and widely used metal alloy composed primarily of iron and carbon, with the addition of other elements in varying proportions. The carbon content in steel typically ranges from 0.2% to 2.1% by weight. (Farnsworth, 2021)

- **Stainless Steel**

is a versatile and highly durable material that is commonly used in a wide range of applications. It is known for its strength, resistance to corrosion, and aesthetic appeal, making it a popular choice for both industrial and domestic purposes.(Farnsworth, 2021)

- **Mild Steel**

Mild steel is a type of carbon steel with a low amount of carbon; thus, the terms low-carbon steel and mild steel are generally used interchangeably. Carbon steels are metals that contain a small percentage of carbon (max 2.1%) which enhances the properties of pure iron.(Chawla, 2012)

- **Iron**

Iron is the fourth most abundant element and second most abundant metal in the Earth’s crust (after aluminum). It is one of the seven metals known in antiquity (along with gold, silver, copper, mercury, tin and lead).(Chawla, 2012)

- **Aluminum**

Like stainless steel, aluminum is great at resisting corrosion. And aluminum offers another pretty terrific characteristic: It’s lightweight. Compared to steel and stainless steel, aluminum is a real featherweight. Pure aluminum is a popular choice for welders, but aluminum alloys are also frequently used. Copper, manganese, and zinc are just a few of the metals that are often alloyed with aluminum to produce enhanced characteristics in the finished product.(Farnsworth, 2021)

2.1.3 Procedure

1)The welder first cleans and prepares the surfaces to be welded, removing any dirt, rust, or other contaminants.

2)The welder then selects the appropriate electrode type and size based on the metal being welded, the desired weld thickness, and the welding position.

3)The electrode is clamped into the electrode holder, and the ground clamp is attached to the workpiece.

4)The welder strikes the arc by briefly touching the tip of the electrode to the workpiece and then lifting it slightly to create a gap. This gap is critical for maintaining a stable arc.

5)As the welder moves the electrode along the joint to be welded, the intense heat from the arc melts the base metal and the end of the electrode. The molten flux coating on the electrode decomposes and releases gases that shield the molten metal from contamination from the atmosphere. The molten metal from the electrode and the base metal fuse together to form the weld.

6)The welder maintains a consistent travel speed and torch angle to ensure proper weld penetration and bead profile.

7)As the weld is completed, the welder allows the electrode to cool slightly and then chips off the slag (the solidified flux) with a chipping hammer.(Weman, 2011)

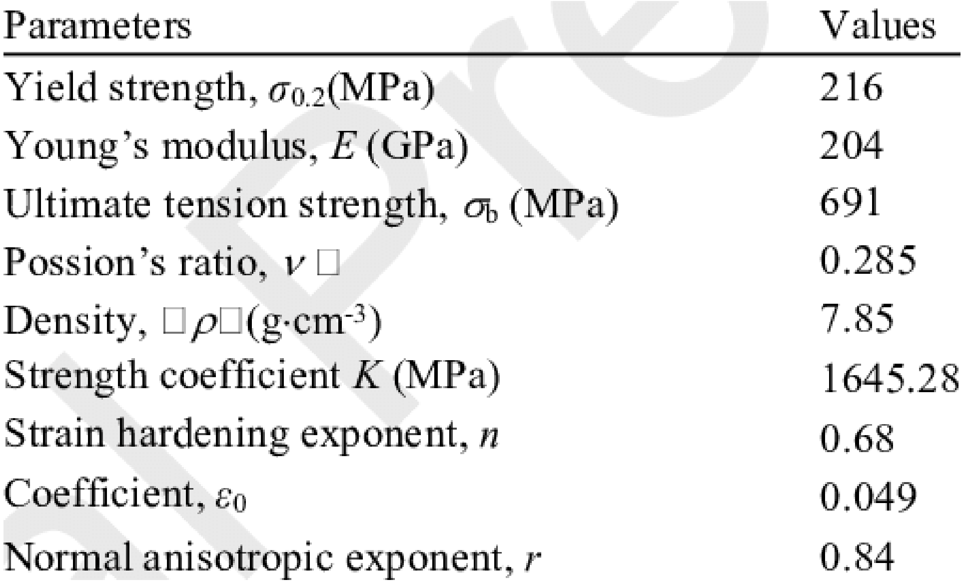
2.2 Stainless Steel (304) Properties

Stainless steel 304 plate was used as the base metal in the experiment, and has both chemical composition and mechanical properties, As shown in the tables.

Table 2.1 Chemical composition of AISI SS 304

Element	Weight percentage
Carbon	0.08 max
Manganese	2.00 max
Phosphorus	0.045 max
Sulphur	0.030 max
Silicon	0.75 max
Chromium	18.00-20.00
Nickel	8.00-12.00
Nitrogen	0.10 max
Iron	67-71

Table 2.2 Mechanical properties of AISI SS 304.(Liu et al., 2020)



Parameters	Values
Yield strength, $\sigma_{0.2}$(MPa)	216
Young's modulus, E (GPa)	204
Ultimate tension strength, σ_b (MPa)	691
Possion's ratio, ν □	0.285
Density, □ρ□(g·cm^{-3})	7.85
Strength coefficient K (MPa)	1645.28
Strain hardening exponent, n	0.68
Coefficient, ε_0	0.049
Normal anisotropic exponent, r	0.84

2.3 E6013 Properties

E6013 is a designation for a specific type of welding electrode.

Specifically, E6013 is a mild steel electrode that is commonly used for welding thin materials, maintenance and repair welding, and general-purpose welding applications. It has a rutile coating, which provides good arc stability and produces a smooth and clean weld bead.

E6013 electrodes are known for their ease of use, good slag removal, and versatility.(Ovat et al., 2012)

Table 2.3 Chemical Compositionof Weld Metal,wt %

	C	MN	SI	S	P
Typical	0.09	0.4	0.25	0.02	0.02
Specification	0.12 max	0.65 max	0.45 max	0.03 max	0.03 max

Table 2.4 Mechanical Properties of All Weld Metal.

	Condition	UTS, MPa	YSat 0.2% offset, MPa	EL%	CVN Impact at 0°C, J
Typical	As Welded	500	415	26	54
Specification		460-550	360-480	22-30	47-70

Chapter Three

Example of Analysis and Design

3.1 Sample Preparation

First, we welded stainless steel 304 by Shielded Metal Arc Welding and used E6013 to dimension (40*20*0.2) cm at variation of time used are 40 seconds, 60 seconds, and 80 seconds, while the current constant used is 95 Ampere. Then, we cut the samples by cutting machine and used fabrication machine (Tournage) by ASTM E8 for tensile testing and ASTM E23 for impact testing. Finally, we prepared the samples for impact and tensile testing.

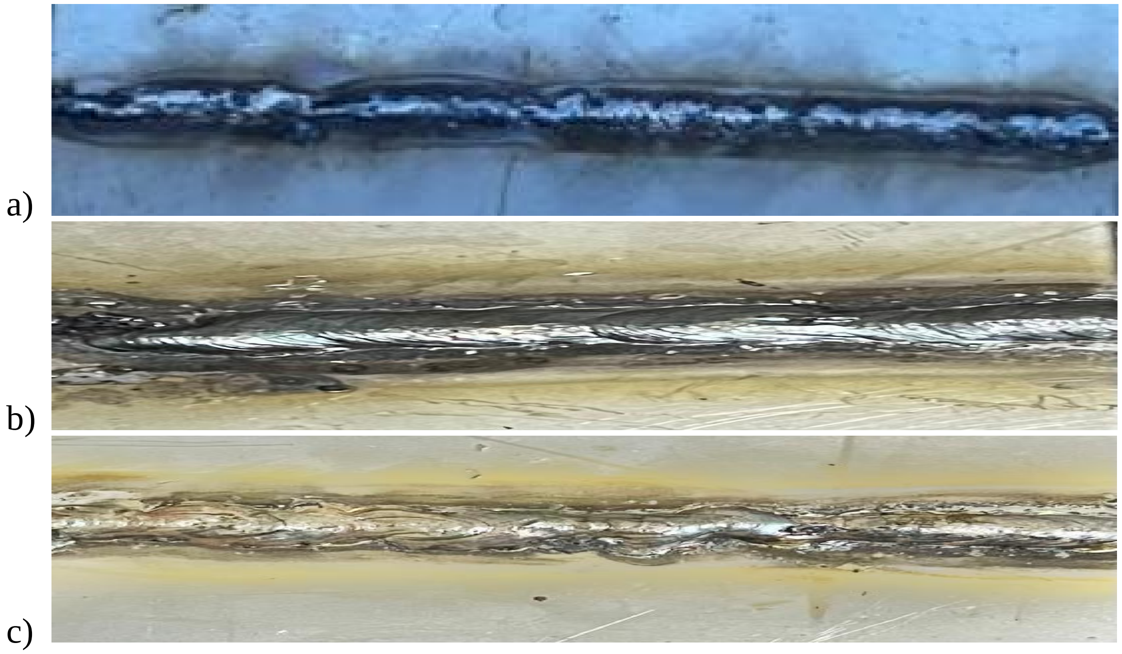


Figure 3.1 Welding experiment. (a) 40 s; (b) 60 s; (c) 80 s.

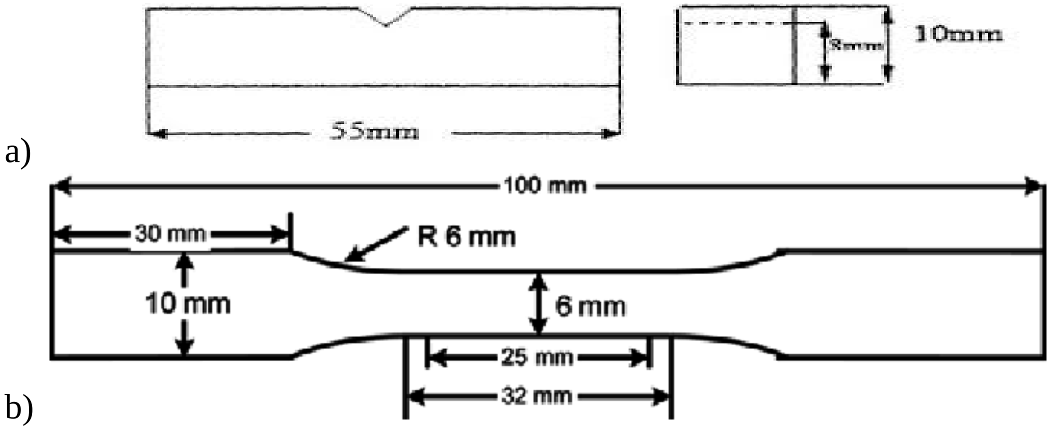


Figure 3.2 ASTMs. a) ASTM E23; b) ASTM E8

3.2 Impact Testing

Impact testing is the most important testing processes used for finding the joining strength of the welded material. Toughness is a measure of the amount of energy a material can absorb before fracturing. It becomes of engineering importance when the ability of a material to withstand an impact load without fracturing is considered. Impact test conditions were chosen to represent those most severe relative to the potential for fracture, namely, (1) deformation at a relatively low temperature, (2) a high strain rate (i.e., rate of deformation), and (3) a triaxial stress state (which may be introduced by the presence of a notch).The Charpy Impact Test is one of the most common methods for determining the toughness or impact strength of a material, particularly metals and alloys. It evaluates the amount of energy absorbed by a material when subjected to a sudden impact. The test is named after its inventor, Georges Charpy, a French engineer.

Figure 3.3. Impact testing samples. a) 40s; b) 60s; c) 80s.

Figure 3.4 Experiment result of Impact testing. a) 40s; b) 60s; c) 80s.

3.3 Tensile Testing

Tensile testing, also known as tension testing, is a fundamental test in materials science and engineering. It involves subjecting a standardized specimen of a material to a controlled pulling force (tension) until it fractures. By measuring the applied force and the resulting deformation (strain) throughout the test, engineers can gain valuable insights into the material's mechanical properties. Now the profile is used for welding the plate type specimen. So, the selection of standard tensile testing specimen is plate type. The applied tensile load and extension are recorded during the test for the calculation of stress and strain values. The tensile test is known as a basic and universal engineering test to achieve material parameters such as ultimate strength, yield strength, % elongation, % area of reduction and Young's modulus.

Figure 3.5 Tensile testing samples. a) 40s; b)60s; c)80s.

Figure 3.6 Experiment result of Tensile testing. a) 40s; b) 60s.

3.4 Calculation

The calculation is contained both strength testing (Impact and Tensile) testing.

3.4.1 Impact Testing Calculation

U= Charpy impact energy (J)

w= width (mm)

t= thickness (mm)

Impact strength= $\frac{\mathrm{U}}{\mathrm{t*w}}$ $\left(\frac{\mathrm{J}}{\mathrm{mm}^2}\right)$

Table 3.1. Experimental Charpy impact energy.

Sample (sec)	Charpy impact energy (J)
40	2.2
60	8
80	2.4

Impact strength= $\frac{\mathrm{U}}{\mathrm{t}*\mathrm{w}}$

impact strength(40s)=$\frac{2.2}{2*8}$

impact strength(40s)= 0.1375 $\frac{\mathrm{J}}{\mathrm{mm}^2}$

impact strength(60s)= $\frac{8}{2*8}$

impact strength(60s)= 0.5 $\frac{\mathrm{J}}{\mathrm{mm}^2}$

impact strength(80s)= $\frac{2.4}{2*8}$

impact strength(80s)= 0.15 $\frac{\mathrm{J}}{\mathrm{mm}^2}$

3.4.2 Tensile Testing Calculation

Table 3.2. (40s) Experiment of tensile testing.

No.	p(KN)	ΔL	σ	ε
0	0	0	0	0
1	2.1	0.08	0.0109375	0.0025
2	2.4	0.15	0.0125	0.0046875
3	2.6	0.2	0.013541667	0.00625
4	2.8	0.28	0.014583333	0.00875
5	2.9	0.36	0.015104167	0.01125
6	3.1	0.5	0.016145833	0.015625
7	3.2	0.7	0.016666667	0.021875
8	3.2	0.77	0.016666667	0.0240625
9	3.3	0.88	0.0171875	0.0275
10	3.4	0.95	0.017708333	0.0296875
11	3.4	0.97	0.017708333	0.0303125
12	3.5	1.06	0.018229167	0.033125
13	3.5	1.09	0.018229167	0.0340625
14	3.2	1.13	0.016666667	0.0353125
15	3.1	1.14	0.016145833	0.035625
16	2.9	1.15	0.015104167	0.0359375

Table 3.3. (60s) Experiment of tensile testing.

No	p(KN)	ΔL	σ	ε
0	0	0	0	0
1	3.3	0.39	0.0171875	0.0121875
2	3.9	0.69	0.0203125	0.0215625
3	4.4	0.78	0.022916667	0.024375
4	4.8	0.92	0.025	0.02875
5	5	1.06	0.026041667	0.033125
6	5.2	1.34	0.027083333	0.041875
7	5.3	1.42	0.027604167	0.044375
8	5.6	1.61	0.029166667	0.0503125
9	5.8	1.74	0.030208333	0.054375
10	6.1	2.02	0.031770833	0.063125
11	5.9	2.06	0.030729167	0.064375
12	5.7	2.11	0.0296875	0.0659375
13	5.5	2.2	0.028645833	0.06875
14	5.3	2.24	0.027604167	0.07
15	5.1	2.25	0.0265625	0.0703125

Figure 3.7. p&ΔL of (40s) Experiment.

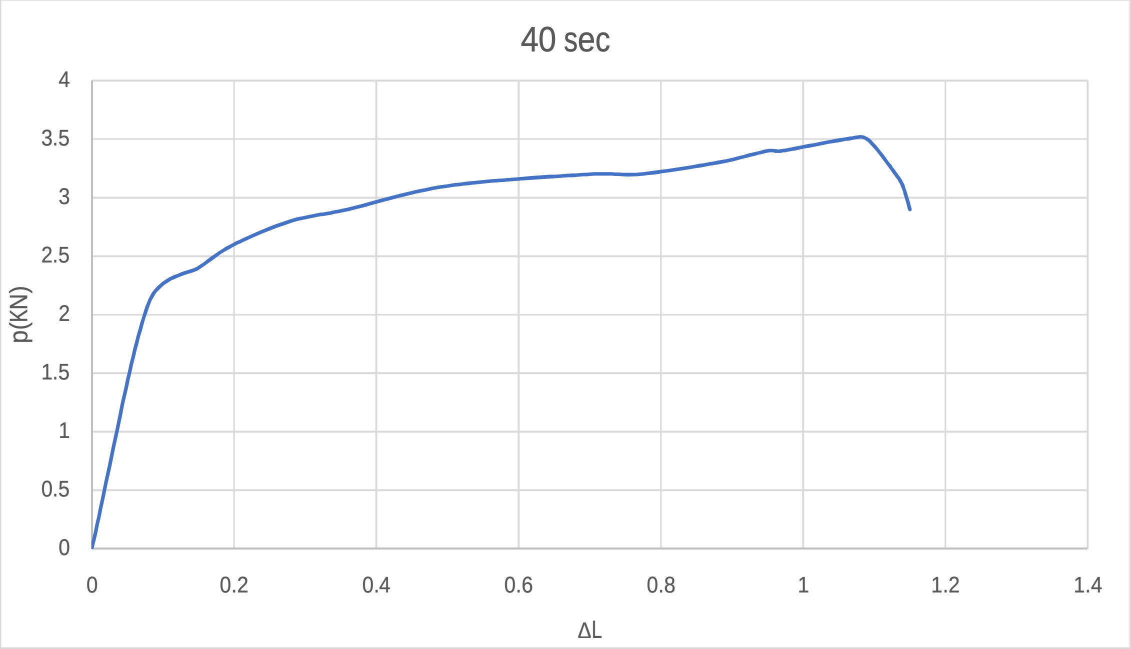


Figure 3.8. p&ΔL of (60s) Experiment.

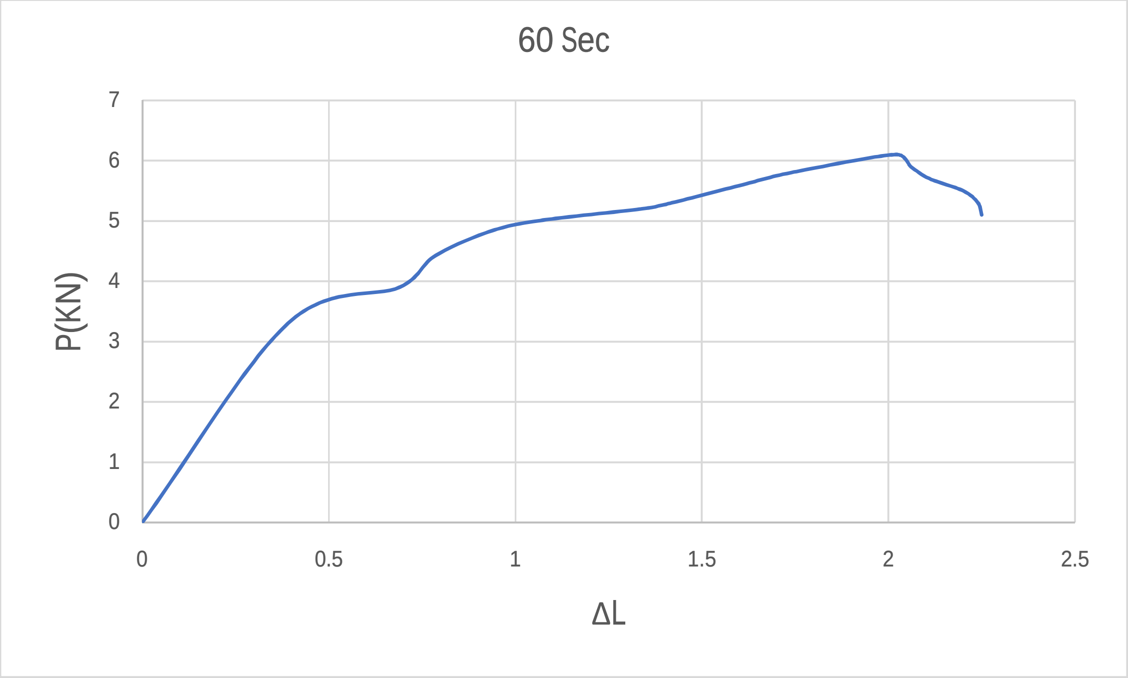


Figure 3.9. σ&ε of (40s) experiment.

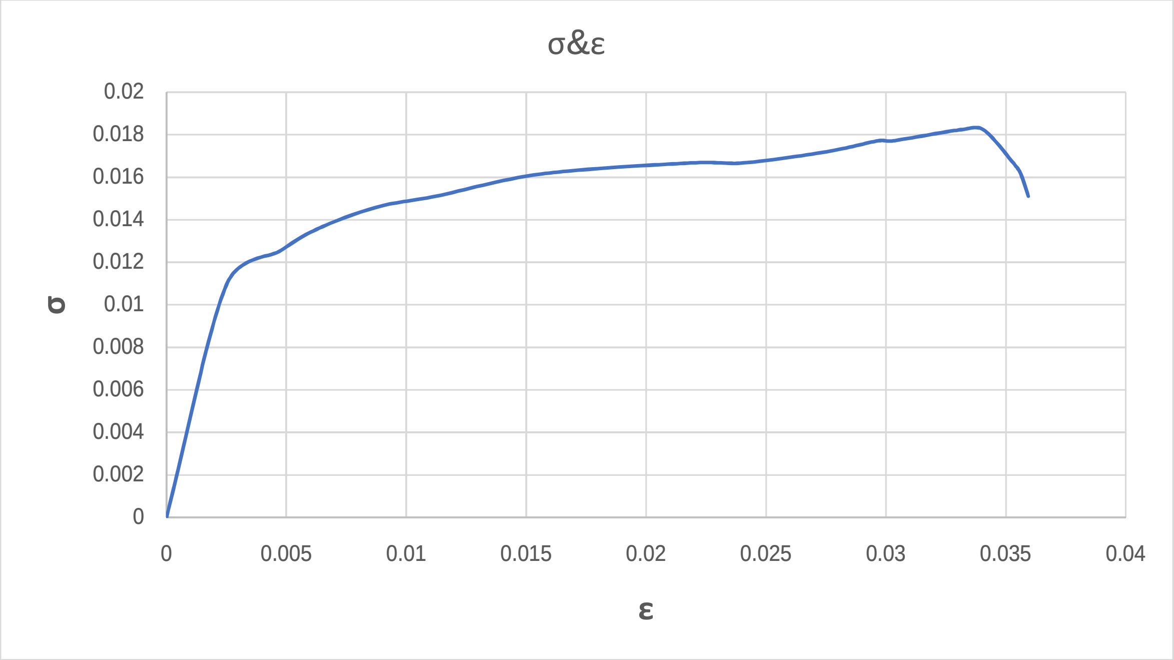
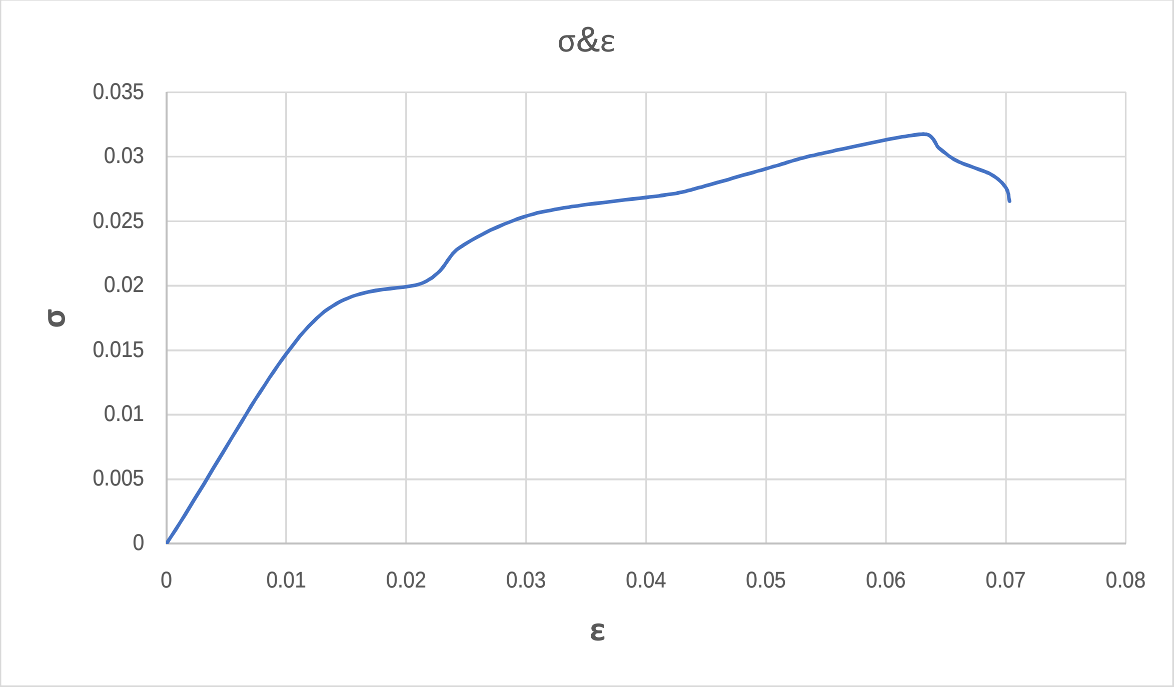


Figure 3.10. σ&ε of (60s) experiment.



P= pressure (KN)

ΔL= Elongation (mm)

σ= stress ($\frac{\mathrm{KN}}{\mathrm{mm}^2}$)

ε= strain

A= Cross section area (mm^2)

L= length (mm)

w= width (mm)

σ_y= Yield stress (Mpa)

σ_u= Tensile stress (Mpa)

σ_f= Fracture stress (Mpa)

A= L*w

A= (32*6)

A= 192 mm^2

$\sigma_1 = \frac{p}{A}$

$\sigma_{1=} \frac{2.1}{192}$

$\sigma_{1=}$ 0.0109375$\frac{\mathrm{KN}}{\mathrm{mm}^2}$

$\varepsilon_{1=} \frac{\Delta L}{L}$

$\varepsilon_{1=} \frac{0.08}{32}$

$\varepsilon_{1=}$0.0025

$\sigma_{y(40s)}= \frac{\text{Yield point}}{\text{A}}$

$\sigma_{y(40s)}=\frac{2.4*10^3}{192}$

$\sigma_{y(40s)}$= 12.5 Mpa

$\sigma_{y(60s)}= \frac{\text{Yield point}}{\text{A}}$

$\sigma_{y(60s)}=\frac{3.9*10^3}{192}$

$\sigma_{y(60s)}$= 20.312 Mpa

$\sigma_{u(40s)}=\frac{\text{Ultimate point}}{\text{A}}$

$\sigma_{u(40s)}= \frac{3.5*10^3}{192}$

$\sigma_{u(40s)}$= 18.23 Mpa

$\sigma_{u(60s)}=\frac{\text{Ultimate point}}{\text{A}}$

$\sigma_{u(60s)}= \frac{6.1*10^3}{192}$

$\sigma_{u(60s)}$= 31.770 Mpa

$\sigma_{f(40s)}= \frac{\text{Fracture point}}{\text{A}}$

$\sigma_{f(40s)}= \frac{2.9*10^3}{192}$

$\sigma_{f(40s)}$= 15.104 Mpa

$\sigma_{f(60s)}= \frac{\text{Fracture point}}{\text{A}}$

$\sigma_{f(60s)}= \frac{5.1*10^3}{192}$

$\sigma_{f(60s)}$= 26.562 Mpa

Elongation $_{(40s)}$= Lf-Li

Elongation $_{(40s)}$= 1.15-0

Elongation $_{(40s)}$= 1.15mm

Elongation $_{(60s\ )}$= Lf-Li

Elongation $_{(60s)}$= 2.25-0

Elongation $_{(60s)}$= 2.25 mm

Strain$_{(40s)}$= $\frac{\Delta L}{L}$

Strain$_{(40s)}$= $\frac{1.15}{32}$*100

Strain$_{(40s)}$= 3.59%

Strain$_{(60s)}$= $\frac{\Delta L}{L}$

Strain$_{(60s)}$= $\frac{2.25}{32}$*100

Strain$_{(60s)}$= 7.031%

Reduction in area$_{(40s)}$= $\frac{\text{Original area} - \text{minimum final area}}{\text{Original area}}$

Reduction in area$_{(40s)}$= $\frac{192-66.3}{192}$*100

Reduction in area$_{(40s)}$= 65.5%

Reduction in area$_{(60s)}$= $\frac{\text{Original area} - \text{minimum final area}}{\text{Original area}}$

Reduction in area$_{(60s)}$= $\frac{192-58.225}{192}$*100

Reduction in area$_{(60s)}$= 69.67%

Minimum final area$_{(40s)}$= (L+ΔL)*w

Minimum final area$_{(40s)}$= 33.15*2Minimum final area$_{(60s)}$ = 34.25*1.7

Minimum final area$_{(40s)}$= 66.3mm^{2}Minimum final area$_{(60s)}$= 58.225mm^2

Chapter Four

Results and Discussion

4.1 A Major Section

The results obtained from the project should be organized in tables or shown by figures and curves, briefly. After that, the results should be clearly and critically discussed. In this chapter, the student should be able to show his/her understanding of the subject and its results.

4.1.1 A Major Subsection

Your words go here …

4.1.1.1 A Minor Section

Your words go here …

Figure 4.1 Salahaddin University-Erbil Logo.

Chapter Five

Conclusion and Recommendations

5.1 A Major Section

The conclusions of the project should be briefly presented in this chapter. It should conclude the main findings and link them to the objectives of the study.

Note that the conclusion is not an abstract, it should NOT summarize the whole project.

Table 5.1 ABC.

A	B	C

5.1.1 A Major Subsection

Your words go here(Jagannath and Shekar, October 1989) …

5.1.1.1 A Minor Section

Your words go here (MacGREGOR and Weight, 2005)…

References

ANDERSEN, P. J. 2020. 1.3.3B - Stainless Steels. *In:* WAGNER, W. R., SAKIYAMA-ELBERT, S. E., ZHANG, G. & YASZEMSKI, M. J. (eds.) *Biomaterials Science (Fourth Edition).* Academic Press.

BRIDIGUM, T. 2008. *How to weld*, Motorbooks.

CHAWLA, K. K. 2012. *Composite materials: science and engineering*, Springer Science & Business Media.

DI SCHINO, A. 2020. Manufacturing and applications of stainless steels. MDPI.

FARNSWORTH, S. R. 2021. *Welding for dummies*, John Wiley & Sons.

JAGANNATH, V. & SHEKAR, U. C. October 1989. Precast L-Pan Roof Elements for Low Cost Hosing. *Journal of Ferrocement,* 19**,** 353 - 361.

LIPPOLD, J. C. & KOTECKI, D. J. 2005. *Welding Metallurgy and Weldability of Stainless Steels*.

LIU, J., ZHIYONG, L., LIU, Y. & LI, L. 2020. Deformation behaviors of four-layered U-shaped metallic bellows in hydroforming. *Chinese Journal of Aeronautics,* 33.

MACGREGOR, J. G. & WEIGHT, J. K. 2005. *Reinforced Concrete Mechanics,* Pearson Prentice-Hall Book Company.

MARCUS, M., HARWIG, D., GOULD, J. & LINDAMOOD, L. Welding. *Kirk-Othmer Encyclopedia of Chemical Technology.*

OVAT, F. A., ASUQUO, L. & ANYANDI, A. J. 2012. Microstructural effects of electrodes types on the mechanical behaviour of welded steel joints. *Research journal in engineering and applied sciences,* 1**,** 171-176.

WEMAN, K. 2011. *Welding processes handbook*, Elsevier.

WINTERS, G. L. & NUTT, M. J. 2003. *Stainless steels for medical and surgical applications,* Astm International.