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College of Engineering
Chemical-Petrochemical Engineering Department

Study the Effect of Welding Current on Mechanical Property of Stainless Steel

A Project Submitted to the Chemical-Petrochemical Engineering Department

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Abstract

This study investigates the impact of welding current on the mechanical properties of Stainless Steel 304. The mechanical properties analyzed include tensile strength, yield strength, and impact toughness. Welding processes commonly used for Stainless Steel 304 are employed, varying the welding current within a (60, 80 and 100 Amper). The experimental results are then compared and analyzed to determine the optimal welding current that maximizes mechanical performance while minimizing defects and brittleness in the welded joints.

The findings of this research contribute to enhancing the understanding of welding parameters' influence on Stainless Steel 304's mechanical behavior.

Keywords: Welding, Stainless steel, Arc welding

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Lastly, we thank all individuals, organizations, and entities whose work and publications were referenced and consulted, as their insights and findings significantly contributed to the depth and breadth of our study.

Supervisor's Certificate

I certify that the engineering project titled " Study the Effect of Welding Currenton Mechanical Property of Stainless Steel" was done under my supervision at the Chemical-Petrochemical Engineering Department, College of Engineering - Salahaddin University–Erbil. In the partial fulfillment of the requirement for the degree of Bachelor of Science in Chemical-Petrochemical Engineering

Supervisor

Signature:

Name: Mrs. Dlveen

Date: 28/April /2024

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Nomenclature

1. SS304: Stainless Steel 304

2. WC: Welding Current

3. TS: Tensile Strength

4. YS: Yield Strengt

5.IT: Impact Toughness

6.MMA: Stick welding

7.ASTM: American Society for Testing and Materials

8.J:Joule

9.P:Pascal

Chapter One

1.Introduction

Stainless steel 304, renowned for its corrosion resistance and mechanical strength, plays a pivotal role in various industries, including automotive, aerospace, and construction. The mechanical properties of stainless steel 304 are crucial for determining its performance under different operating conditions. Among the factors that significantly impact these properties, welding current stands out as a key variable that demands meticulous investigation.[1]

Welding is a fundamental process in the fabrication of stainless steel components. It involves the application of heat and pressure to join two or more pieces of metal, altering their microstructure and consequently affecting their mechanical behavior. The welding current, representing the flow of electricity during welding, is a parameter of paramount importance. Varying the welding current can lead to notable changes in the heat input, fusion zone characteristics, and ultimately, the mechanical properties of the welded joint.[2]

Numerous studies have delved into the relationship between welding parameters and the mechanical properties of stainless steel, yet a comprehensive understanding of how welding current specifically influences stainless steel 304 remains an ongoing pursuit. Therefore, this research aims to bridge this gap by conducting a systematic analysis to elucidate the effects of welding current on the mechanical properties, including tensile strength, hardness, impact toughness, and microstructural changes, of stainless steel 304 weldments.

Figure 1 welding

By meticulously controlling welding parameters and rigorously testing the resulting welds, this study seeks to provide valuable insights that can inform optimized welding practices for stainless steel 304, enhancing its structural integrity, durability, and performance across diverse applications.[3]

Figure 2 Arc welding

1.1Welding:

Welding is a cornerstone process in the fabrication and construction industries, enabling the joining of materials to create complex structures and assemblies. Various welding techniques have been developed to suit different materials, applications, andproject requirements. Understanding these techniques and their unique characteristics is crucial for achieving high-quality welds and ensuring the structural integrity of fabricated components.[4]

The spectrum of welding techniques encompasses methods such as arc welding, gas welding, resistance welding, and laser welding, each offering distinct advantages and applications. Arc welding, in particular, is widely used and encompasses several subcategories, including Metal Inert Gas (MIG) welding, Tungsten Inert Gas (TIG) welding, Submerged Arc Welding (SAW), and Manual Metal Arc (MMA) welding.[5]

Manual Metal Arc (MMA) welding, also known as Shielded Metal Arc Welding (SMAW), stands out as a versatile and widely employed welding method. In MMA welding, an electric arc is established between a consumable electrode and the workpiece, creating intense heat that melts the electrode and the base metal, forming a fusion zone upon solidification. The process is shielded by a flux coating on the electrode, which prevents atmospheric contamination and stabilizes the arc.[6]

MMA welding finds extensive use in industries ranging from construction and shipbuilding to automotive and pipeline fabrication. Its portability, adaptability to various metals including carbon steel, stainless steel, and alloys, and suitability for onsite repairs make it a preferred choice for many welding applications.

To delve deeper into the intricacies of MMA welding and optimize its outcomes, comprehensive research encompassing welding parameters, electrode selection, arc characteristics, and post-welding processes is essential. This research aims to contribute valuable insights that can enhance weld quality, productivity, and operational efficiency in MMA welding applications.[7]

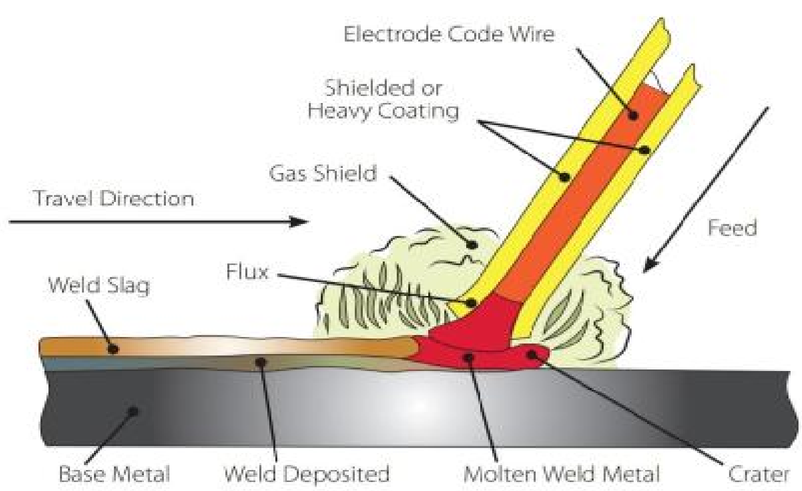


Figure 3 welding process

1.2Material Selection

Stainless steel 304 is a popular choice for MMA welding due to its exceptional combination of mechanical properties, corrosion resistance, and weldability. Among stainless steel alloys, 304 offers a balanced composition that makes it suitable for a wide range of applications, from structural components to equipment in corrosive environments.

One of the key reasons for choosing stainless steel 304 for MMA welding is its excellent corrosion resistance. This alloy contains chromium and nickel, which form a passive oxide layer on the surface, providing protection against rust, pitting, and chemical attacks. This inherent corrosion resistance makes stainless steel 304 ideal for applications where exposure to moisture, chemicals, or harsh environments is a concern.

Furthermore, stainless steel 304 exhibits good weldability characteristics, making it compatible with various welding processes, including MMA welding. The low carbon content in 304 minimizes the risk of carbide precipitation and sensitization during welding, reducing the likelihood of intergranular corrosion in the heat-affected zone. Additionally, its thermal conductivity and heat dissipation properties contribute to stable welds with minimal distortion and residual stresses.

The mechanical properties of stainless steel 304 also make it a favorable choice for MMA welding. It offers high tensile strength, excellent toughness, and good ductility, ensuring welded joints maintain structural integrity and withstand mechanical loads.

In summary, stainless steel 304's corrosion resistance, weldability, and mechanical properties make it a preferred material for MMA welding in various industries, including construction, automotive, food processing, and

Figure 4 Stainless Steel

Figure 5 SS 304

pharmaceuticals.[8]

Chapter Two

2.Methodology

Here are some practical works, first we brought a sample of steel that was 304 steel, it took us a long time to get in the market and also expensive, with different samples and at the same time with 60A, 80A and 100A within 85 seconds We repeated the welding process on the plates several times and cut them again until they turned out the way we wanted them and then we did some tests…

2.1Impact Test

The impact test is a method used to determine the toughness and brittleness of a material, usually metals. The impact test assesses a material’s ability to absorb energy when subjected to a sudden load or impact.

The most common type of impact test is the Charpy or Izod test. We use charpy test is considered as the in this work, It requires a pendulum-type impact tester equipped with a striker (hammer) and anvil.

We use this material which is selected comes under ASTM

A240(55mmX10mmX2mm)machined to standardized dimensions, V shaped, with precise notch locations to ensure consistency.

Figure 6 Impact Test

Figure 7 sample of Impact Test

based on the difference in the pendulum's initial and final heights The Testing producer:

- The specimen is securely clamped in the testing machine, positioned so that the striker will hit the notched area.

- The pendulum is raised to a specific height, creating potential energy.

- The pendulum is then released, allowing it to swing freely and strike the specimen.

- The impact energy absorbed by the specimen causes it to fracture.

- The pendulum continues to swing upward after the impact, and the energy absorbed by the specimen is calculated.

-The energy absorbed by the specimen is measured in joules or foot-pounds. -The fracture surface is examined to determine the type and extent of fracture, whichhelps in understanding the material's behavior under impact loading.

The results we get from Impact test are shown in TABLE 3

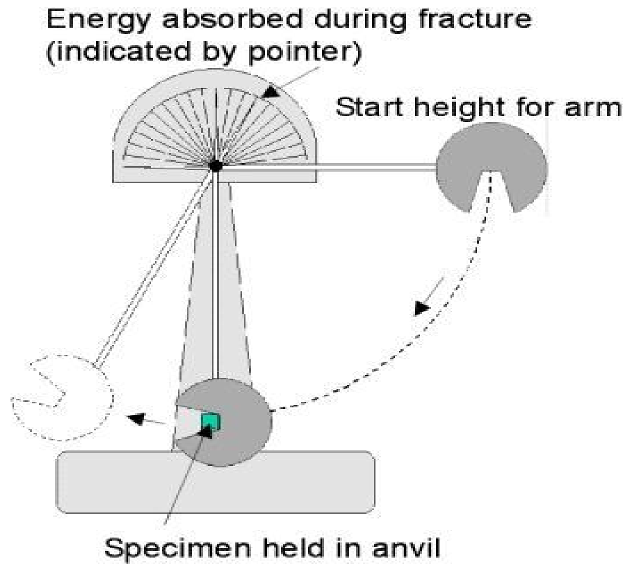


Figure 8 Impact Test equipment

2.2Tensile Test

A mechanical test called a tensile test is performed to evaluate a material's strength and ductility. A specimen of the material is put under controlled tension until failure in a tensile test. This test aids in understanding the behavior of a material under different loading scenarios. In order to perform a tensile test on stainless steel, we prepared three sample of the material in the shape of a standardized specimen comes under ASTM 240 (100mmX10mmX2mm) we welding with current rating (60A, 80A,100A) However,

After that, the specimen is put into a tensile testing apparatus, which gradually increases the specimen's tensile force. The stainless steel specimen elongates as the tensile force is applied until it reaches its ultimate tensile strength (UTS), which is the highest stress the material can endure without failing. Numerous factors are measured during the test, such as the force exerted and the specimen's subsequent elongation. Stainless steel is renowned for its long lifespan, high tensile strength, and resistance to corrosion. For engineering and design applications, the tensile test yields useful information by helping to quantify these mechanical properties.

The results we get from Tensile test(60A) are shown in TABLE 5

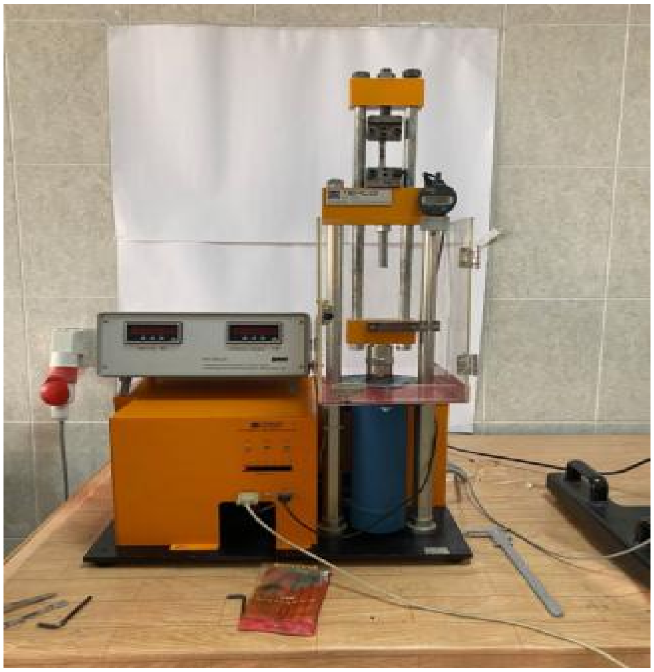


Figure 9 Tensile Test

The results we get from Tensile test(80A) are shown in TABLE 6

Chapter Three

3.Examples of Analysis and Design

Steel is capable of welded in SMAW procedures, leading to varying strengths. Thus, the SMAW welding technique modifies the properties of steel by Possession.Studies on microstructure are conducted on shielded metal arc welding weldments in order to demonstrate the microstructural effects of welding.

TABLE 1

CHEMICAL COMPOSITION OF BASE METAL (% BY WEIGHT)

Composition	C	Mn	Si	S	P
SS 304	0.08	2	0.75	0.03	0.045

The percentage of material composition in the electrode and weld metal is displayed in Tables 1 and 2, respectively, first sample of SS304 welding there plates that each one having dimension 55 mm x 10 mm x 2 mm thick, with current ratings of 60A, 80A, and 100A with constant times of 1:25 s. It is joined with arc welding techniques. By employing the best welding conditions, SMAW, also known as arc welding, joins two plates. The specimens are machined to generate a V-groove with a 2 mm weld depth at a 45° angle to each plate during the welding process.Whencurrent is passed, an electric arc is produced between the electrode and the work piece. The electrode and work piece is melted by the arc.

Figure 10 Thickness of Sample

Figure 11 Sample of SS

Another sample, There are 3 stainless steel plates with different current (60A,80A,100A) having the length and width 100mmX10mm and 2mm thick plate. The pieces are cut in such a way that each piece is 100mm apart. We have made a 30mm arc R6 is 32mm long. But while cutting, one of the pieces broke with current 100A because the welding with 100A is not strong enough so it breaks. So we have made two pieces in this way, having the SMAW welding is an electric arc welding process in which the fusion energy is produced by an Electric arc burning between the work piece and the tungsten electrode. During the welding process the Electrode, the arc and the weld pool are protected against the damaging effects of the atmospheric air by an inert Shielding gas. By means of a gas nozzle the shielding gas is lead to the welding zone where it replaces the atmospheric air.

TABLE 2

CHEMICAL COMPOSITION OF ELECTRODE METAL (% BY WEIGHT)

Composition	C	Mn	Si	S	P
SS E6013	0.06	0.45	0.2	0.02	0.02

Figure 12 Broken Pieces

Figure 13 Sample of Tensile Test

3.1Impact Test Calculation

For calculating Impact strength:

Impact Strength = U(in J) / A (mm^2)

U=charpy impact energy (J)

A=Cross-sectional area of the specimen (mm^2)

This formula helps determine the material's ability to absorb energy during fracture under impact loading conditions.

A=Width X thickness

=8X2

A=16mm^2

Impact strength(60A) =0.1 J/16mm^2 =0.0062 J/mm^2

The resalts are shown in TABLE 4

3.2Tensile Test Calculation

Cross-sectional area = L X W

=32 X 6 =192mm^2

Yield stress (60A)= P/A

=2.4x10^3/192 =12.5 Mpa

Yield Stress (80A)=3.9x10^3/192 =18.75 Mpa

Tensile strength UTS (60A)=3.5x10^3/192=16.14 Mpa

Tensile strength UTS (80A)=5.1x10^3/192=26.56 Mpa

Elongation =delta L=Lf – Lin =1.1

1.23

Strain(60A) =(delta L/L) x100

=(1.1/32)x100

=3.44%

Strain(60A) =(delta L/L) x100

=(1.1/32)x100

=3.84%

Reduction in area={ (original area – minimum final area)/original area}x100

Minimum final area(60A)=final gauge X w

=33.1 x 2=66.2

Reduction in area (60A)=(192-66.2)/192

=65.5%

Reduction in area (80A)=(192-66.46)/192

=(192-56.491) /192

= 70.58%

The results for Tensile Test are shown in TABLE 7

TABLE 8 & 9 shown the relation between strain(ε) and stress(σ)

Chapter Four

4.Results and Discussion

Impact testing is a critical aspect of assessing the mechanical properties, particularly the toughness and fracture resistance, of welded materials. In this study investigating the effect of welding current on stainless steel 304, impact tests were conducted to evaluate the material's ability to withstand sudden loading and absorb energy during fracture. The results of these impact tests provide valuable insights into how welding current influences the mechanical properties of stainless steel 304 weldments.Shown in Graph 1

4.1Impact Test Results:

The impact test results revealed a clear correlation between welding current and the impact toughness of stainless steel 304 weldments. As the welding current increased, there was a noticeable decrease in the impact toughness of the welded joints. This trend was observed across multiple test specimens, indicating a consistent effect of welding current on the material's fracture resistance.

Discussion:

1. Effect of Heat Input: The decrease in impact toughness with higher welding currents can be attributed to the increased heat input during welding. Higher welding currents lead to greater heat generation, resulting in larger heat-affected zones (HAZ) and potential changes in microstructure. The rapid cooling rates in the HAZ can promote the formation of brittle phases or microstructural defects, reducing the material's ability to absorb energy during impact.

2. Microstructural Changes: The impact test results also suggest that variations in welding current influence the microstructure of stainless steel 304 welds. Excessive heat input can lead to grain growth, segregation of alloying elements, and the formation of undesirable phases such as delta ferrite or martensite. These microstructural changes cancompromise the material's ductility and toughness, leading to lower impact toughness values.

3. Optimization of Welding Parameters: The impact test results underscore the importance of optimizing welding parameters, including welding current, to achieve welds with superior mechanical properties. Balancing heat input, cooling rates, and microstructural transformations is crucial to maintain the desired mechanical performance of stainless steel 304 weldments.

4. Practical Implications: From a practical standpoint, these findings highlight the need for welders and engineers to carefully select welding parameters based on the desired mechanical properties of the welded joints. Adjustingwelding currents within optimal ranges can help

mitigate the negative impact on impact toughness while ensuring satisfactory weld quality and integrity.

In conclusion, the impact test results demonstrate a significant influence of welding current on the impact toughness of stainless steel 304 weldments. By understanding and optimizing welding parameters, it is possible to enhance the mechanical properties and overall performance of welded structures in various industrial applications.[9]

Tensile testing is a fundamental method for evaluating the mechanical properties, including strength and ductility, of welded materials. In this study focused on investigating the influence of welding current on stainless steel 304, tensile tests were conducted to assess the material's response to applied tensile stress. The results obtained from these tests offer valuable insights into how welding current affects the mechanical properties, specifically tensile strength and elongation, of stainless steel 304 weldments.Shown in Graph 2

4.2Tensile Test Results:

The tensile test results revealed a distinct relationship between welding current and the tensile properties of stainless steel 304 weldments. As the welding current increased, there was a noticeable variation in both tensile strength and elongation values of the welded joints. These variations highlight the significant impact of welding current on the material's mechanical behavior under tensile loading conditions.

Discussion:

1. Effect on Tensile Strength: The increase in welding current generally resulted in higher tensile strength values for stainless steel 304 welds. This can be attributed to the increased heat input during welding, which promotes better fusion and penetration at higher currents. The formation of a sound weld joint with strong metallurgical bonding contributes to enhanced tensile strength properties.

2. Influence on Elongation: Conversely, the tensile tests also indicated a reduction in elongation values with higher welding currents. This decrease in elongation suggests a potential decrease in ductility or the material's ability to deform plastically before fracture. Excessive heat input can lead to changes in microstructure, such as grain growth or increased presence of brittle phases, which can contribute to reduced elongation values.

3. Optimization of Welding Parameters: The tensile test results underscore the importance of optimizing welding parameters, particularly welding current, to achieve desired mechanical properties in stainless steel 304 weldments.Balancing the trade-off between tensile strength and ductility is crucial in selecting welding parameters that meet the specific performance requirements of the welded components.

4. Practical Implications: From a practical perspective, understanding the impact of welding current on tensile properties helps in the informed selection of welding parameters during fabrication processes. Adjusting welding currents within optimal ranges can result in welds that exhibit both high tensile strength and adequate ductility, ensuring structural integrity and performance in service.

In conclusion, the tensile test results highlight the significant influence of welding current on the tensile properties of stainless steel 304 weldments. By considering and optimizing welding parameters, it is possible to achieve welds with tailored mechanical properties suitable for diverse applications in various industries.[10]

figure 14 Salahaddin Universty-Erbil

Chapter Five

Conclusion and Recommendations

In conclusion, this study has provided valuable insights into the effect of welding current on the mechanical properties of stainless steel 304. Through a systematic investigation and analysis of tensile and impact tests, the following conclusions can be drawn:

1. Impact of Welding Current: Welding current significantly influences the mechanical properties of stainless steel 304 weldments. Higher welding currents tend to result in decreased impact toughness while potentially increasing tensile strength. These effects are attributed to variations in heat input, microstructural changes, and the formation of brittle phases.
2. Optimization Considerations: Balancing welding parameters, including welding current, is crucial to achieving welds with optimal mechanical properties. Careful selection and control of welding parameters are essential to minimize negative impacts on impact toughness and elongation while maximizing tensile strength and overall weld quality.

Based on the conclusions drawn from this study, the following recommendations are proposed for further research and practical application:

1. Continued Research: Further research is warranted to explore the effect of welding current on other mechanical properties, such as fatigue strength, fracture toughness, and corrosion resistance, of stainless steel 304 weldments. Comprehensive studies encompassing a range of welding parameters and material conditions can provide a holistic understanding of weld performance.
2. Advanced Microstructural Analysis: Utilizing advanced microscopy and characterization techniques can offer deeper insights into the microstructural changes induced by welding currents. Quantitative

analysis of grain size, phase distribution, and defect morphology can enhance the correlationbetween microstructure and mechanical properties.

3. Welding Procedure Optimization: Industry practitioners should consider implementing optimized welding procedures based on the findings of this study. This includes conducting pre-welding trials, monitoring welding parameters during fabrication, and implementing quality control measures to ensure consistent weld quality and mechanical performance.
4. Training and Education: Training programs and educational initiatives should emphasize the importance of understanding welding parameters and their impact on mechanical properties. Empowering welding professionals with knowledge and skills in optimizing welding processes can lead to improved weld quality and performance.

TABLE 3

Results of the Impact Test

Sample	Charpy Impact test
60A	0.1 J
80A	4.7 J
100A	0.2 J

TABLE 4

Results of the Impact strength

Sample	Impact Strength
60A	0.0062 J/mm^2
80A	0.293J/mm^2
100A	0.0125J/mm^2

This shows that SMAW welding Process with 80A it's has a better impact strength than others.

In summary, the impact test evaluates a material's ability to withstand sudden loading conditions and is crucial in assessing its suitability for various applications, particularly in industries where safety and reliability are paramount, such as construction, automotive, and aerospace.

Graph 1

Show the relation between Current & Impact strength

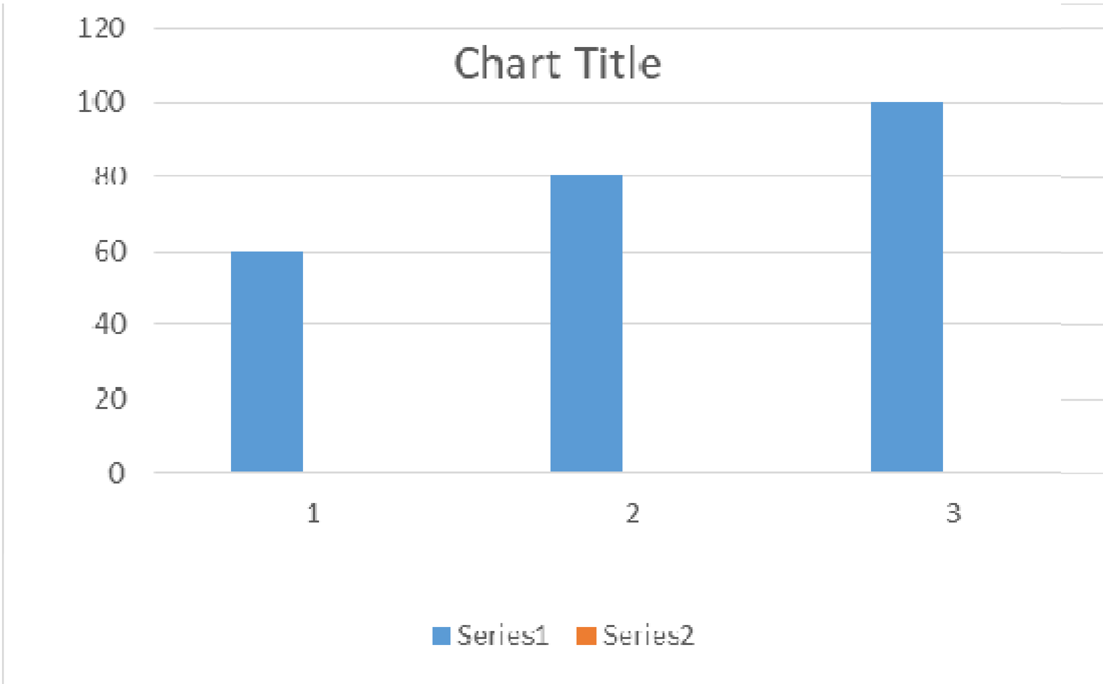


TABLE 5

The results we get from Tensile Test (60A)

No.	P(KN)	ΔL
0	0	0
1	1.8	0.1
2	2.1	0.13
3	2.3	0.18
4	2.4	0.28
5	2.5	0.34
6	2.6	0.4
7	2.8	0.53
8	2.9	0.69
9	2.9	0.7
10	3	0.84
11	3.1	0.93
12	3.1	1.03
13	2.9	1.05
14	2.8	1.06
15	2.6	1.1

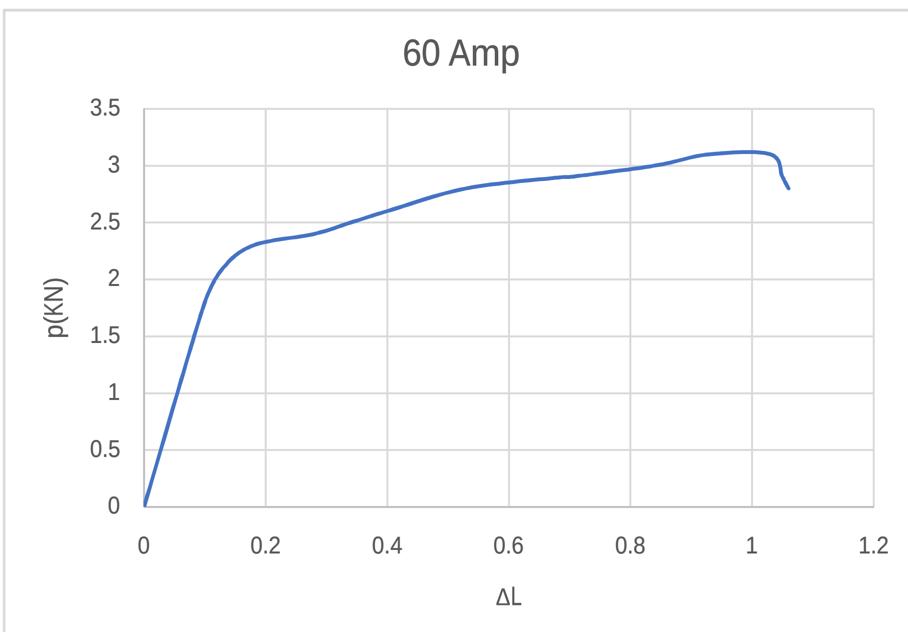


TABLE 6

The results we get from Tensile test(80)

No	P(KN)	ΔL
0	0	0
1	3	0.24
2	3.6	0.4
3	4.1	0.56
4	4.5	0.75
5	4.7	0.86
6	4.9	0.96
7	5.1	1.12
8	4.9	1.16
9	4.7	1.18
10	4.6	1.2
11	4.4	1.23

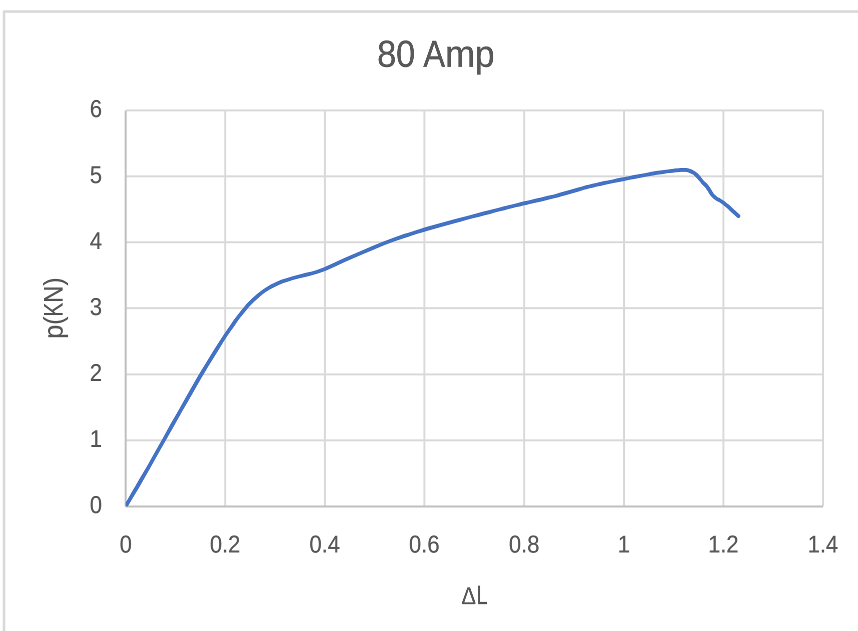


TABLE 7

Results of the Tensile Test (change in welding current)

Tested specimen datas	60A	80A	100A
Final gauge length (mm)	33.1	33.23	
Final cross sectional area(mm)	192	192	
Yield load (kn)	2.4	3.6	
Yield stress N/mm^2 (Mpa)	12.5	18.75	
Tensile strength at UTS (Mpa)	16.14	24.56	
Reduction in area %	65.5	70.58	
Strain %	3.44	3.84	
Elongation %	1.1	1.23	

TABLE 8

Relation between (σ) and (ε) at 60A

No.	P(KN)	ΔL	σ	ε
0	0	0	0	0
1	1.8	0.1	0.009375	0.003125
2	2.1	0.13	0.0109375	0.0040625
3	2.3	0.18	0.011979167	0.005625
4	2.4	0.28	0.0125	0.00875
5	2.5	0.34	0.013020833	0.010625
6	2.6	0.4	0.013541667	0.0125
7	2.8	0.53	0.014583333	0.0165625
8	2.9	0.69	0.015104167	0.0215625
9	2.9	0.7	0.015104167	0.021875
10	3	0.84	0.015625	0.02625
11	3.1	0.93	0.016145833	0.0290625
12	3.1	1.03	0.016145833	0.0321875
13	2.9	1.05	0.015104167	0.0328125
14	2.8	1.06	0.014583333	0.033125
15	2.6	1.1	0.013541667	0.034375

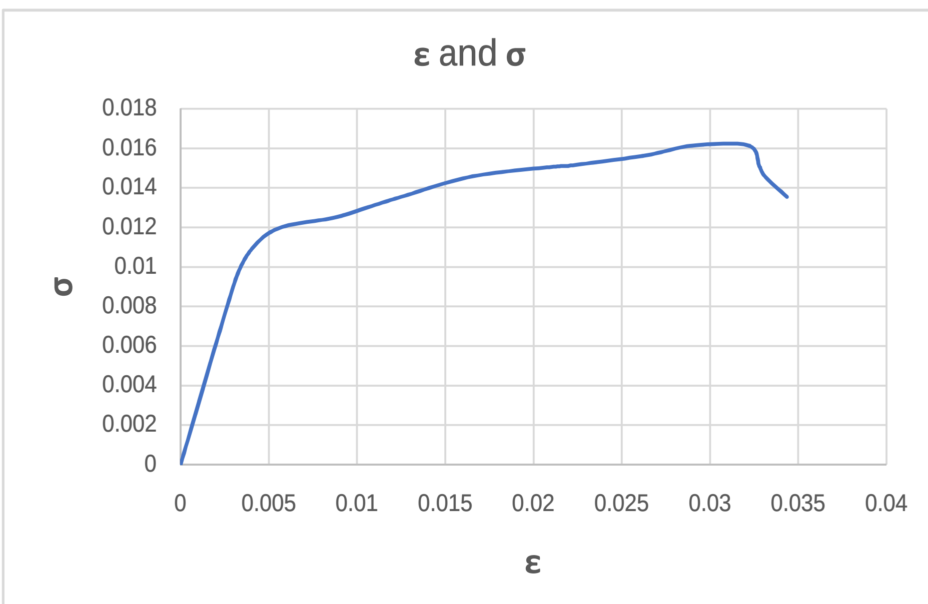
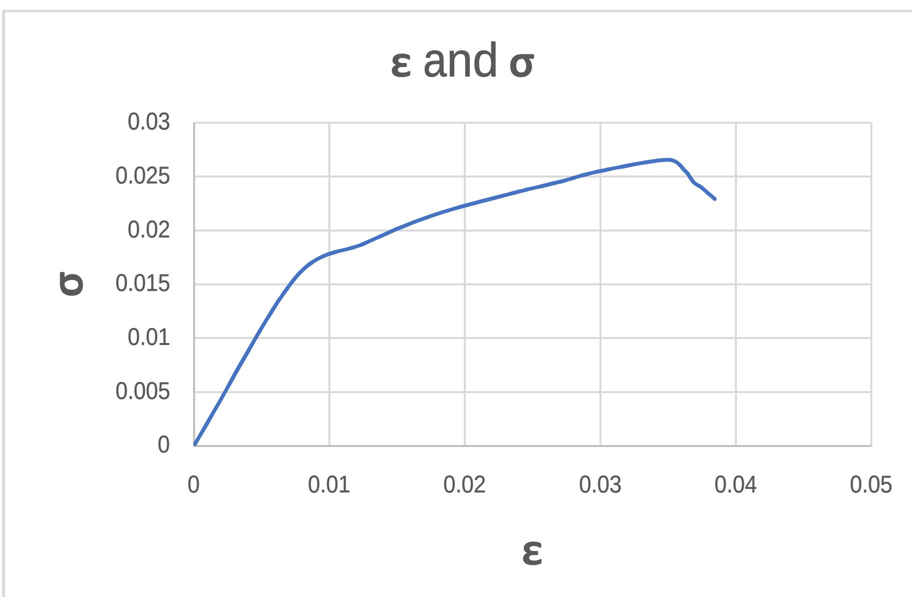


TABLE 9

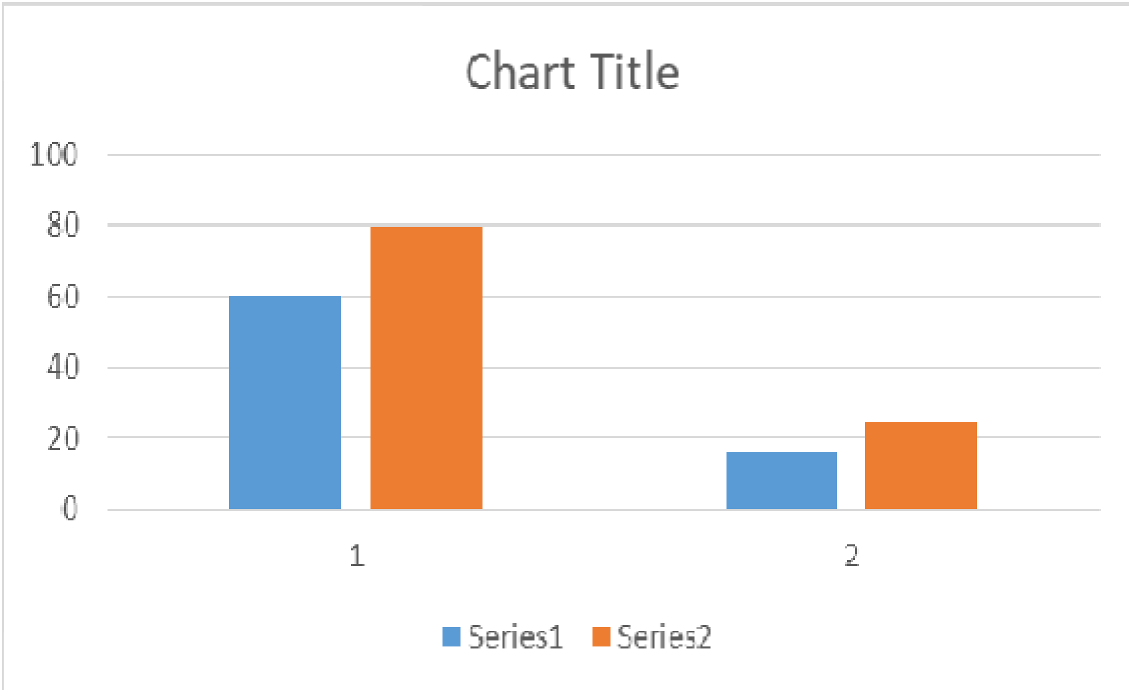
Relation between(σ) and (ε) at 80A

No.	P(KN)	ΔL	σ	ε
0	0	0	0	0
1	3	0.24	0.015625	0.0075
2	3.6	0.4	0.01875	0.0125
3	4.1	0.56	0.021354167	0.0175
4	4.5	0.75	0.0234375	0.0234375
5	4.7	0.86	0.024479167	0.026875
6	4.9	0.96	0.025520833	0.03
7	5.1	1.12	0.0265625	0.035
8	4.9	1.16	0.025520833	0.03625
9	4.7	1.18	0.024479167	0.036875
10	4.6	1.2	0.023958333	0.0375
11	4.4	1.23	0.022916667	0.0384375



Graph 2

Show the relation between current &UTS



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