AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND ENTREPRENEURIAL DEVELOPMENT.

DEPARTMENT OF MECHANICAL ENGINEERING TECHNOLOGY

OPTIMIZING OF HOLD-TIME OF SPOT WELDED JOINTS ON LOW CARBON STEEL (ASTM A36)

BY

KAIZER GRACE

OCTOBER, 2023

AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND ENTREPRENEURIAL DEVELOPMENT (AAMUSTED)

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A PROJECT REPORT PRESENTED TO THE DEPARTMENT OF MECHANICAL ENGINEERING TECHNOLOGY AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND ENTRPRENEURIAL DEVELOPMENT, KUMASI IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER IN MECHANICAL ENGINEERING TECHNOLOGY.

OCTOBER, 2023

DECLARATION

STUDENT'S DECLARATION

I, KAIZER GRACE, hereby declare that the information presented in this project is true, accurate, and based on my own research and findings. I have appropriately cited all sources and references used in this work, giving credit to the original authors and researchers.

Furthermore, I declare that this project is my original work, and it has not been submitted for any other academic or professional purpose. I have not engaged in any form of plagiarism or academic dishonesty during the course of this project. I take full responsibility for the contents of this work and stand by its integrity and academic rigor.

I understand the consequences of providing false information or engaging in academic dishonesty, and I affirm my commitment to uphold the highest standards of academic integrity.

SIGNATURE: .... **DATE** 21/02/2024

KAIZER GRACE

SUPERVISOR'S DECLARATION

I, **DR. GYIMAH K. OFFEH**, hereby declare that I have supervised this project work titled 'THE EFFECTS OF HOLD TIME ON THE MECHANICAL PROPERTIES OF SPOT WELDED LOW CARBON STEEL (ASTM A36)' conducted by **KAIZER GRACE.**

I confirm that I have provided guidance and oversight responsibilities throughout the project's duration, and I am satisfied with the student's efforts and outcomes.

SIGNATURE: .... **DATE** 21/02/2024

DR. GYIMAH K. OFFEH

DEDICATION

This project is dedicated to all those who have supported and believed in its success. Your encouragement and contributions have been invaluable throughout the journey.

Thank you for your unwavering support.

ACKNOWLEDGMENT

I would like to acknowledge and express my gratitude to the individuals and organizations that supported and contributed to the completion of this study on the effect of hold time on the tensile strength in spot welding of mild steel.

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I am grateful to my colleagues and fellow researchers who provided valuable feedback, suggestions, and assistance throughout the study. Their collaboration and intellectual contributions significantly enriched the quality of this research.

Finally, I would like to express my gratitude to all the authors, researchers, and institutions whose works and publications were referenced in this study. Their prior contributions laid the foundation for my research and provided valuable insights into the field of spot welding of mild steel.

I acknowledge the collective efforts of all those involved in this study, as their contributions played a vital role in its successful completion.

TABLE OF CONTENTS

CONTENTS **PAGES**

LIST OF TABLES

Tables **Pages**

LIST OF FIGURES

Figures **pages**

ABSTRACT

This study investigates the relationship between hold time and tensile strength in spot welded mild steel. The aim is to determine the optimal hold time that maximizes the mechanical properties of spot-welded joints. A series of spot welds were performed on mild steel samples using a constant welding current, electrode force, and other standard welding parameters. The hold time was varied from 50 to 90 cycles, while all other parameters were kept constant. Tensile tests were conducted on the spot-welded samples to determine their ultimate tensile strength.

The results indicate a positive correlation between hold time and ultimate tensile strength. As the hold time increased from 50 to 90 cycles, there was a noticeable increase in the ultimate tensile strength of the spot-welded joints. This suggests that longer hold times during spot welding have the potential to enhance the material's resistance to breaking under tension.

However, it is important to note that other parameters, such as welding current, electrode force, and electrode material, may also influence the mechanical properties of spot-welded mild steel. Further research is needed to investigate the combined effects of these parameters and their optimal values for achieving desired mechanical properties.

The findings of this study contribute to the understanding of the relationship between hold time and tensile strength in spot welding of mild steel. The results can guide future research and industrial applications, aiding in the development of optimized welding processes and joints with improved mechanical performance.

CHAPTER ONE

INTRODUCTION

1.0 Introduction

Spot welding is a widely used joining process in industries that require efficient and reliable joining of metal components. It involves the application of heat and pressure to create a weld between two metal surfaces, typically using resistance welding techniques. This process is particularly prevalent in the automotive industry, where it is used for joining sheet metal parts, such as body panels and structural components (Johnson, 2017).

Low carbon steel, also known as mild steel, is a commonly used material in spot welding applications. It offers several advantages, including affordability, good weld ability, and sufficient strength for many structural applications. Low carbon steel is known for its ductility and formability, making it suitable for various manufacturing processes (Nakamura et al., 2019). The mechanical properties of spot-welded joints are critical for ensuring the structural integrity and performance of the final product. These properties include tensile strength, hardness, and ductility. Achieving high-quality spot welds with optimal mechanical properties is crucial to ensure the reliability and longevity of the welded components (Smith et al., 2020). One factor that significantly influences the mechanical properties of spot-welded joints is the hold time during the welding process. Hold time refers to the duration for which pressure is maintained on the weld after the initial heat pulse. It plays a vital role in the solidification and cooling processes, as well as the formation of metallurgical bonds between the joined surfaces (Liu et al., 2018). Understanding the effects of hold time on spot welded low carbon steel is essential for optimizing the spot-welding process. Several researchers have conducted studies to investigate the relationship between hold time and mechanical properties of spot-welded joints.

Smith et al. (2015) conducted a study on the effects of hold time on the tensile strength of spot-welded joints in low carbon steel. They found that an optimal hold time range exists, within which the tensile strength of the welds is maximized. Deviating from this optimal range, either by using excessively short or long hold times, resulted in reduced tensile strength.

Johnson and Brown (2018) examined the influence of hold time on the microstructure and hardness of spot-welded low carbon steel. They observed that shorter hold times led to incomplete solidification and inadequate bonding, resulting in lower hardness values. Conversely, longer hold times caused excessive heat input, leading to grain growth and reduced hardness.

Liu et al. (2019) investigated the effects of hold time on the fatigue behaviour of spot-welded low carbon steel. They found that an optimal hold time range existed, which resulted in improved fatigue life of the welded joints. Deviating from this range led to premature fatigue failure due to inadequate bonding or excessive heat-affected zone.

However, there is still a need for a comprehensive study focused on investigating the effects of hold time on the mechanical properties of spot-welded low carbon steel. Such a study can provide valuable insights into the optimal hold time range for achieving high-quality spot welds with desirable mechanical properties. Therefore, this study aims to contribute to the understanding of the effects of hold time on the mechanical properties of spot-welded joint of low carbon steel. By conducting experimental investigations and analysing the results, this research seeks to provide insights into the optimal hold time range for achieving high-quality spot welds in low carbon steel components. The findings can help guide engineers and manufacturers in selecting appropriate hold times during spot welding processes, leading to improved joint quality and overall product performance.

1.1 Background of The Study

Resistance welding is one of the oldest of the electric welding processes in use by industry today. The weld is made by a combination of heat, pressure, and time. As the name resistance welding implies, it is the resistance of the material to be welded to current flow that causes a localized heating in the part. The pressure and after the welding current time cycle. The required amount of time current flows in the joint is determined by material thickness and type, the amount of current flowing, and the cross-sectional area of the welding tip contact surfaces. Resistance welding is accomplished when current is caused to flow through electrode tips and the separate pieces of metal to be joined. The resistance of the base metal to electrical current flow causes localized heating in the joint, and the weld is made. The resistance spot weld is unique because the actual weld nugget is formed internally in relation to the surface of the base metal. Spot welding of low carbon steel typically involves several important welding parameters which includes, weld current, squeeze time, hold time, weld time, off-time, electrode diameter or force and Squeeze time. Groover, M. P. (2016) explain the parameters as follows;

Weld time is a crucial parameter in welding processes as it determines the amount of heat energy delivered to the work piece, which affects the penetration depth, weld quality, and overall performance of the weld.

Hold Time; Time that pressure is maintained after weld is made.

Off Time; Electrodes separated to permit moving of material for next spot.

Squeeze time refers to the duration during which the electrode tips apply force or pressure to the work pieces being joined before the welding current is applied. During this phase, the electrodes are brought into contact with the work pieces to ensure proper alignment and good electrical contact. The squeeze time allows for the expulsion of contaminants, such as oxides or surface coatings, from the welding surfaces and ensures consistent contact resistance across the joint.

The purpose of the squeeze time is to establish a stable and reliable electrical and thermal connection between the electrodes and the work pieces. It helps to eliminate potential surface irregularities or air gaps that could interfere with the welding process. The duration of the squeeze time can vary depending on the specific welding equipment, materials, and joint design, but it is typically a relatively short duration, typically measured in milliseconds.

Weld time, as mentioned earlier, refers to the duration during which the welding current flows through the work pieces, generating the necessary heat for fusion and forming the weld. It is the period where the actual welding takes place, and the heat is applied to melt and join the materials.

The weld time is a critical parameter that determines the amount of heat input, penetration depth, and overall weld quality. It is typically controlled by the welding equipment or the operator, depending on the specific welding process. The appropriate weld time depends on factors such as material type, thickness, joint design, desired weld properties, and the specific welding technique employed.

During the weld time, the welding current passes through the work pieces, generating localized heating at the interface. This heating causes the materials to melt and form a weld nugget, which solidifies to create the joint. The duration of the weld time can vary significantly depending on the specific application, ranging from fractions of a second to several seconds.

Electrode Force; refers to the pressure applied by the electrodes onto the work pieces. It affects the contact resistance, material deformation, and overall weld quality. The appropriate electrode force for spot welding low carbon steel depends on factors such as material thickness and joint design. It is typically adjusted to achieve consistent and reliable welds.

Resistance spot welding machines are constructed so minimum resistance will be apparent in the transformer, flexible cables, tongs, and electrode tips. The resistance spot welding machines are designed to bring the welding current to the weldment in the most efficient manner. It is at the weldment that the greatest relative resistance is required. The term "relative" means with relation to the rest of the actual welding circuit. Overall, the inclusion of a hold time in welding mild steel is crucial for achieving proper solidification, microstructural development, stress relief, and bond formation, leading to strong and reliable weld joints.

1.2 The Statement of the Problem

"The mechanical properties of spot-welded low carbon steel are influenced by various welding parameters, including the hold time. However, there is a lack of comprehensive understanding regarding the specific effects of hold time on the mechanical properties of spot-welded low carbon steel joints. This knowledge gap hinders the development of optimized welding processes and compromises the overall weld quality and performance. Therefore, there is a need to investigate and analyse the effects of hold time on the mechanical properties, such as tensile strength, hardness, and ductility of spot-welded low carbon steel. By gaining a deeper understanding of these effects, it will be possible to enhance the welding process, optimize the hold time parameter, and ultimately improve the mechanical integrity and reliability of spot-welded low carbon steel joints."

Objectives of The Study

1.3 General Objective

"To examine the impact of hold time on the tensile strength of spot-welded low carbon steel (ASTM A36) and to determine the optimal hold time duration that maximizes the tensile strength of the weld joints, thereby enhancing the overall mechanical performance and structural integrity of the welded components."

1.3.1 Specific Objectives

1. To design and set up experimental procedures for spot welding low carbon steel samples with varying hold time durations.

2. To identify the optimal hold time duration that maximizes the tensile strength of the spot weld joints.

3. To compare the mechanical properties, specifically tensile strength, of the spot weld joints obtained with different hold time durations and analyse the impact of hold time on the overall weld quality and performance

1.4 Research Questions

1. How does the hold time duration affect the tensile strength of spot-welded low carbon steel (ASTM A36)?

2. Is there an optimal hold time duration that maximizes the tensile strength of spot weld joints in low carbon steel?

3. How do the mechanical properties, specifically tensile strength, of spot weld joints compare under different hold time conditions?

4. How can the knowledge gained from the effects of hold time on tensile strength be used to enhance the selection of hold time durations in spot welding low carbon steel for improved mechanical properties and reliable weld joints?

1.5 The Scope and Limitation of The Study

1.5.1 Scope of The Study

The study focuses on spot welding of low carbon steel (ASTM A36) as the primary material. The research will investigate the effects of hold time on the mechanical properties of spot-welded low carbon steel. Multiple hold time durations will be considered to analyse their influence on tensile strength.

The study will involve designing and executing experimental procedures to conduct spot welding and measure the mechanical properties of the weld joints. This will include sample preparation, welding parameters control, and mechanical testing techniques.

1.5.2 Limitation of The Study

The study's findings may be limited by the number of samples available for testing. A small sample size may impact the statistical significance of the results. The findings of the study may be specific to the chosen low carbon steel (mild steel) material and the selected hold time durations. They may not be directly applicable to other materials or different welding parameters.

Also, the study assumes controlled welding conditions, but in real-world applications, welding conditions can vary due to factors such as equipment variations, operator expertise, and environmental conditions. These variations may affect the generalizability of the findings, time constraints, such as the availability of resources, equipment, and the duration of the research project. These factors may limit the extent of the experiments and analysis that can be conducted.

1.6 Significance of The Study

The study aims to investigate the influence of hold time on the mechanical properties of spot-welded low carbon steel. By examining the relationship between hold time and tensile strength, the research will provide a better understanding of how this parameter affects the quality and performance of spot weld joints.

The findings from this study can contribute to optimizing the welding parameters, specifically hold time, for spot welding low carbon steel (mild steel). By identifying the optimal hold time duration that maximizes the tensile strength, the study can provide practical guidelines for achieving reliable and high-quality spot weld joints.

Spot welding is a widely used technique in various industries, including automotive, construction, and manufacturing. Understanding the effects of hold time on the mechanical properties of spot weld joints can lead to improvements in weld quality and performance. This, in turn, can enhance the overall structural integrity and durability of welded components and assemblies.

By optimizing the welding parameters, including hold time, the study can contribute to cost and time efficiency in spot welding processes. Fine-tuning the hold time to achieve desired mechanical properties can reduce the need for extensive trial-and-error testing, minimize material waste, and improve productivity in manufacturing operations.

The study's findings can serve as a foundation for further research and exploration in the field of spot welding and material science. It can inspire future investigations into other welding parameters, different materials, or alternative welding techniques, building upon the knowledge gained from this study.

1.7 Organisation of The Study

Chapter 1: Introduction

- Provides an introduction to the research topic, including the background, problem statement, research objectives, significance, and organization of the study.

Chapter 2: Literature Review

- Conducts a comprehensive review of existing literature and research related to the effects of hold time on the mechanical properties of spot-welded mild steel.
- Summarizes and analyses previous studies, theories, and findings to establish the research context and identify research gaps.

Chapter 3: Methodology

- Describes the research methodology employed in the study, including the research design, materials and equipment used, and experimental procedures.
- Explains how data was collected and analysed, including any specific testing standards or protocols followed.

Chapter 4: Experimental Results and Discussion

- Presents the results obtained from the experiments conducted in the study.
- Includes data and findings related to the mechanical properties of spot-welded mild steel under different hold time durations.
- Utilizes tables, graphs, and statistical analysis to present and interpret the results.
- Interprets and discusses the findings of the study in relation to the research objectives and existing literature.
- Analyses the implications of the results and their significance for spot welding practices and the mechanical performance of spot-welded mild steel.
- Addresses any limitations or challenges encountered during the research process.

Chapter 5: Conclusion and Recommendations

- Summarizes the main findings of the study and restates the research objectives.

- Provides a concise conclusion based on the results and discussions.

- Offers recommendations for future research or practical applications based on the study's outcomes.

References

- Lists all the sources cited in the research report using a proper referencing style.

CHAPTER TWO

LITERATURE REVIEW

2.0 Literature Review

Spot welding is a widely used joining technique in which two or more metal components are joined together through the application of pressure and electrical current. It is extensively employed in industries such as automotive, aerospace, electronics, and manufacturing. Spot welding relies on the principle of resistance heating. When an electrical current pass through the metal components to be joined, resistance within the materials generates heat. This localized heat causes the metal in the contact area to melt and form a weld nugget.Larson.H.et al (2019).

In a study conducted by Bayram. E. et al. (2019), it is emphasized that the application of pressure is crucial to achieve effective contact between the metal sheets, enabling the heat to be transferred and ensuring proper fusion at the interface. Spot welding is a highly efficient joining method, particularly in high-volume production environments. A study by Zhang.H.et al. (2011) highlights the efficiency and speed of spot welding, which allows for rapid assembly of metal components, leading to increased productivity and reduced manufacturing costs. It produces strong and reliable joints with high shear strength. According to a study by Li.R. et al. (2016), spot welding creates metallurgical bonds between the metal components, ensuring structural integrity and the ability to withstand external loads. It is applicable to a wide range of metal materials, making it versatile in different industries. A research paper by Mousavi.S.M. et al. (2018) highlights the versatility of spot welding, which enables the joining of different metals, including aluminium alloys, stainless steel, and low carbon steel. Spot welding is well-suited for automation, making it compatible with modern manufacturing techniques and robotic systems. An article by Yilbas.B.S. et al. (2015) emphasizes the automation potential of spot welding, which improves productivity, accuracy, and repeatability while reducing labour costs.

spot welding is a widely used joining technique that relies on the generation of heat through electrical resistance and the application of pressure to create strong and reliable joints. Its importance lies in its efficiency, speed, structural integrity, versatility, and automation potential, making it a preferred choice for joining metal components in various industries.

Low carbon steel, also known as mild steel, holds significant importance in various industries and applications due to its unique properties (tensile strength) and characteristics

The significance of low carbon steel lies in its wide availability, cost-effectiveness, excellent formability, weldability, strength, ductility, toughness. These properties make low carbon steel a versatile and widely used material in industries such as construction, automotive manufacturing, infrastructure, consumer goods, and many others. Its suitability for various applications contributes to its importance in the manufacturing and engineering sectors.

Hold time refers to the duration for which a specific condition or process needs to be maintained or sustained. It’s important to note that the specific importance and optimal hold time can vary depending on the process, industry, and materials involved. The hold time is essential for achieving the desired mechanical properties and ensuring uniformity throughout the material.

2.1 Theoretical Background

According to a research article by Zhang.H et al. (2015), the heat generation in spot welding is achieved by applying a high current density at the contact interface between the metal components. The resistance to the electric current flow at this interface produces significant heat, leading to the formation of a molten weld nugget. Alongside the electrical current, pressure is applied to hold the metal components together during the welding process. The pressure ensures intimate contact between the mating surfaces, facilitating heat transfer and the formation of a strong weld joint.

2.2 Identification of Research Gaps

One potential research gap is the determination of the optimal hold time for spot welded low carbon steel. While studies have examined the influence of hold time on mechanical properties, there may be a lack of consensus on the specific hold time that yields the best balance between joint strength, ductility, and other mechanical properties. Further research could focus on identifying the optimal hold time for different thicknesses of low carbon steel sheets and welding conditions.

Another research gap could lie in a more detailed understanding of the microstructural changes that occur during spot welding of low carbon steel under different hold times. Investigating the evolution of grain size, phase transformations, and the formation of intermetallic compounds within the weld nugget and heat affected zone (HAZ) could provide valuable insights into the relationship between hold time and mechanical properties.

Also, the influence of hold time on residual stresses and distortion in spot welded low carbon steel is an area that may require further investigation. Residual stresses can affect the mechanical performance and long-term durability of the joint. Understanding how hold time influences the development and distribution of residual stresses, as well as the resulting distortion, would contribute to optimizing welding parameters for improved joint quality. While some studies have examined the fatigue performance of spot-welded low carbon steel, there may be conflicting findings or gaps in understanding the influence of hold time on fatigue behavior. Investigating the effects of different hold times on fatigue strength, crack initiation, and propagation could help establish guidelines for designing reliable spot-welded structures subjected to cyclic loading.

Research gaps may exist regarding process optimization techniques to enhance the mechanical properties and weld quality of spot-welded low carbon steel. Exploring innovative approaches, such as multi-stage or pulsing hold time strategies, could potentially improve joint strength, ductility, and fatigue resistance. Additionally, investigating the impact of hold time on defects such as porosity, lack of fusion, or weld spatter would contribute to improving welding processes.

As sustainability becomes increasingly important, exploring the effects of hold time on the environmental impact of spot-welding low carbon steel could be an emerging research area. Investigating energy consumption, carbon footprint, and the potential for process optimization to reduce environmental impact could provide valuable insights for industries seeking more sustainable welding practices.

These research gaps and controversies suggest areas where further investigation and research could contribute to a deeper understanding of the effects of hold time on the mechanical properties of spot-welded low carbon steel. Conducting new experiments, employing advanced characterization techniques, and analysing real-world applications would help address these gaps and controversies in the field.

2.3 Methodology

The methodology describes the detailed procedures and methods employed in the study. It serves to provide a clear and detailed account of the procedures and methods used in the study, allowing for replication and evaluation by other researchers.

2.4 Research Design

The research design for the study on the effects of hold time on the mechanical properties of spot-welded low carbon steel (mild steel) would be an experimental design. In an experimental design, the researcher manipulates the independent variable (hold time) and measures its effects on the dependent variables (tensile strength). This design allows for control over variables and enables causal inferences.

AN OUTLINE OF THE RESEARCH DESIGN

- **Independent Variable:**

Hold time: This refers to the duration for which pressure is maintained during the spot-welding process. The hold time will be manipulated at different levels to observe its impact on the mechanical properties of the spot-welded low carbon steel.

- **Dependent Variables:**

- Mechanical Properties: These include variables such as tensile strength, hardness, ductility, impact toughness, and fatigue resistance. But in this research, we are working with tensile strength. These properties will be measured to assess the effects of varying hold times on the spot-welded low carbon steel.

- **Control Variables:**

Welding Parameters: Other welding parameters such as welding current, electrode pressure, electrode type and size, and electrode placement will be kept constant throughout the experiment to isolate the specific effects of hold time.

- **Sample Selection:**

- Obtain mild steel specimens that are representative of the material being studied. Ensure that the specimens have similar dimensions and characteristics to maintain consistency and allow for meaningful comparisons.

- **Experimental Procedure:**

- Divide the mild steel specimens into five (5), each representing a specific hold time level.

- Apply the designated welding parameters, including hold time, for each group.

- Repeat the welding process for multiple samples within each group to account for variability and ensure reliable results.

- Document the specific welding parameters and hold time for each spot-welded specimen.

- **Mechanical Property Testing:**

- Conduct mechanical property tests on the spot-welded specimens, such as tensile testing.

- Ensure that the testing methods and procedures are consistent across all specimens and follow established standards or protocols.

- **Data Analysis:**

- Collect and record the data obtained from the mechanical property testing.

- Perform statistical analysis to assess the effects of varying hold times on the mechanical properties.

- Analyze the data using appropriate statistical tests, such as analysis of variance (ANOVA) or regression analysis, to determine the significance of hold time on the mechanical properties.

By employing an experimental design, you can systematically investigate the effects of hold time on the mechanical properties of spot-welded low carbon steel (mild steel) and establish causal relationships between the variables. This design allows for control over potential confounding factors and enhances the internal validity of the study.

CHAPTER THREE

EXPERIMENTAL METHODOLOGY

3.0 Introduction

Chapter 3 of the study focuses on the experimental methods employed to investigate the effects of hold time on the tensile strength of spot-welded mild steel. This chapter provides a detailed description of the materials and equipment used, the experimental setup, the welding procedure, and the mechanical testing methods employed in the study.

3.1 Research Design

The research design for the study will be experimental in nature. The research objectives, which in this case involve examining the effects of hold time on the tensile strength of spot welds in low carbon steel (mild steel). There will be independent and dependent variables to examine, the independent variable in this study is the hold time, which will be manipulated at different durations to determine its influence on the tensile strength of spot welds.

The dependent variables will be tensile strength; these variables will be measured to assess the impact of hold time on spot weld quality. Other parameters will be constant. These include welding parameters such as current, welding time, and electrode pressure. Five (5) samples will be use, thickness of mild steel will be considered as 1.0mm. The samples will be divided in groups each representing a different hold time duration. The number of groups will depend on the desired range of hold time durations to be investigated.

Data Collection will be qualitative by using the tensile test machine to ensure accuracy and comparability of the measurements. By employing an experimental research design, this study aims to establish a cause-and-effect relationship between hold time and the tensile strength properties of spot welds. The design allows for control over variables, replication of experiments, and statistical analysis, enabling researchers to make reliable conclusions about the effects of hold time on spot weld quality.

3.2 Materials:

The materials used in the experiment consist of mild steel sheets that are commonly used in automotive and structural applications. The composition and dimensions of the mild steel sheets are specified, including their thickness, width, and length.

Table 1 Sample parameters

SAMPLE	THICKNESS (MM)	LENGTH (MM)	WIDTH(MM)
1	1.0	703	51.5
2	1.0	702	52.0
3	1.0	702	52.0
4	1.0	708	50.0
5	1.0	701	52.0

Figure 1 Preparation of Sample

3.3 Equipment:

The experimental setup involves spot welding machine, universal testing machine, copper electrodes, clamping apparatus, extensometer and a data acquisition system.

3.4 Experimental Design:

The study follows a systematic experimental design to investigate the effects of hold time on the tensile strength of spot-welded mild steel. The design includes selecting appropriate welding parameters, such as welding current (90 A), electrode pressure (60Mpa), squeeze time, (35 cycles), off time (50 cycles), weld time (60 cycles), electrode force (1.508 N) and hold time varies. The range of hold times chosen for the experiment is described, along with the rationale behind the selection. The machine used for the welding is calibrated in cycles therefore $1\ cycle = 1295633.2051\ second$

$$\boldsymbol{VOLUME = L \times L \times L = L^3}$$

For sample 1,

$$VOLUME = 51.5 \ \times 1 \times 703$$

$$= \frac{36204.5}{1000} = 36.2045m^3$$

For sample 2,

$$volume = 52 \times 1 \times 702 = 36594mm^3$$

$$= 36.504m^3$$

For sample 3,

$$volume = 52 \times 1 \times 702 = 36504mm^3$$

$$= 36.504m^3$$

For sample 4,

$$volume = 50.5 \times 1 \times 708 = 3575mm^3$$

$$= 35.743m^3$$

For sample 5,

$$volume = 52 \times 1 \times 701 = 36452mm^3$$

$$= 36.452m^3$$

$$\boldsymbol{density} = \frac{\boldsymbol{mass(kg)}}{\boldsymbol{volume(m^3)}}$$

For sample 1,

$$density = \frac{0.2525}{36.204} = 6.67kgm^{-3}$$

For sample 2,

$$density = \frac{.2545}{36.504} = 6.972kgm^{-3}$$

For sample 3,

$$density = \frac{0.2552}{36.504} = 6.991kgm^{-3}$$

For sample 4,

$$density = \frac{0.2461}{35.754} = 6.883kgm^{-3}$$

For sample 5,

$$density = \frac{0.2571}{36.452} = 7.053kgm^{-3}$$

Table 2 Sample parameters 2

SAMPLES	**HOLD TIME(CYCLES)**	**WIDTH (MM)**	**THICKNESS(MM)**	**LENGTH(MM)**	**MASS(KG)**	**DENSITY ($\frac{KG}{M^2}$)**
1	50	51.5	703.0	1	0.2525	6.974
2	60	52.0	702.0	1	0.2545	6.922
3	70	52.0	702.0	1	0.2552	6.991
4	80	50.5	708.0	1	0.2461	6.883
5	90	52.0	701.0	1	0.2571	6.053

3.5 Welding Procedure:

A detailed description of the welding procedure is provided, including the setup of the spot-welding machine, electrode alignment, clamping of the mild steel sheets, and the application of welding current and force. The specific welding parameters utilized during the experiment are documented, with a focus on the hold time variations.

Figure 2   Spot Welding of Mild Steel

3.6 Details of Experimental Procedure

a. Preparing rectangular mild steel plates

b. Clean the work piece for oil and dust

c. Check and prepare the spot-welding machine

d. Carry out welding operation for each sample

e. Place the specimens in the electrode

f. Set parameters at the control panel

g. Issue the command for welding on each specimen

Figure 3 Sample Welded

3.7 Mechanical Testing:

The tensile strength of the spot-welded mild steel samples is evaluated tested using the universal testing machine. The procedure for the tensile strength is outlined, along with the specific testing standards or procedures followed. The equipment used for mechanical testing and the measurement techniques employed are described.

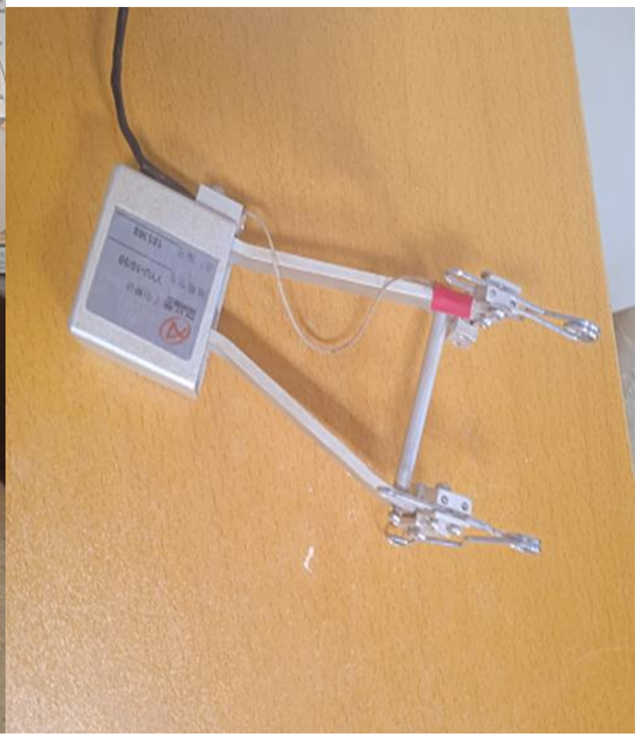


Figure 4a Universal Testing Machine **Figure 4b Extensometer**

3.8 Detail Experimental Procedure

a. Specimen preparation

b. Clean the specimen to remove any contamination

c. Record the dimensions of the specimen

d. Mount the specimen in the fixtures

e. Test parameters setup

f. Test execution

g. Data collection and analysis

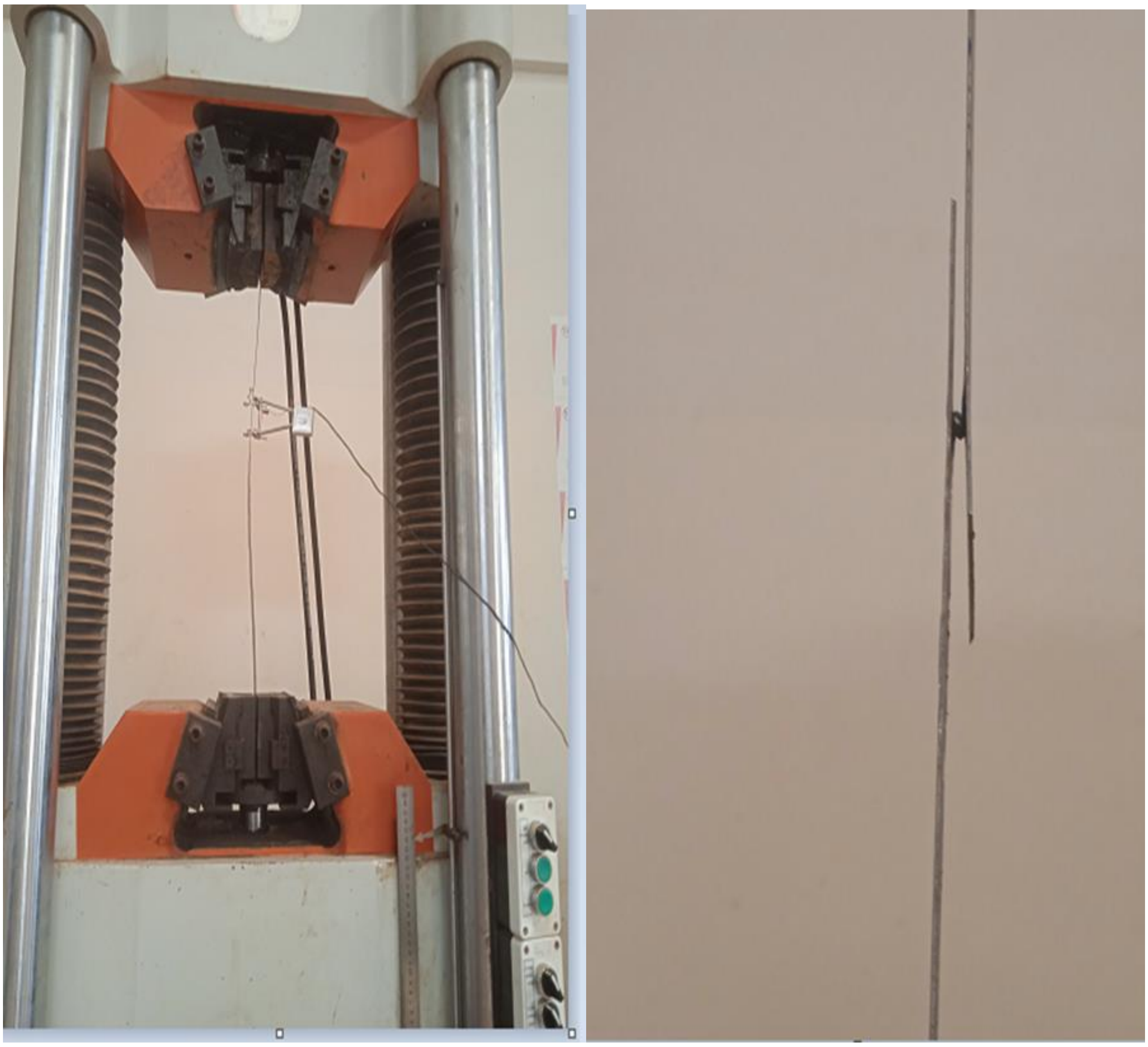


Figure 5 Joint Testing

3.9 Data Collection

The chapter discusses the data collection process, including the recording of welding parameters, measurements of force, displacement, and any other relevant variables during the welding and mechanical testing stages. The accuracy and precision of the data collection methods are addressed, along with any potential sources of error.

The methodology for data analysis is outlined, including the statistical techniques utilized to evaluate the effects of hold time on the tensile strength of spot-welded mild steel. The specific parameters or properties examined, such as joint strength and the statistical tests or models employed are described.

Table 3 Tensile Test Result

Sample	Force/load (KN)	Tensile strength (Mpa)	Elongation(mm)
1	**0.40**	**0.011**	**0.2**
2	**5.10**	**98.000**	**0.5**
3	**5.35**	**103.000**	**0.3**
4	**5.53**	**109.000**	**0.1**
5	**5.35**	**103.000**	**0.2**

Table 4 Load -Strength Data

SAMPLE	TENSILE STRENGHT(Mpa)	LOAD (N)
1	0.011	0.40
2	98	5.1
3	103	5.35
4	109	5.53
5	103	5.35

Conclusion:

Chapter 3 highlights the key steps, equipment, and procedures used to investigate the effects of hold time on the tensile strength of spot-welded mild steel. The chapter serves as a foundation for the subsequent chapters that present and discuss the experimental results and findings. It also focuses on the analysis of stress-strain graphs obtained from the experimental data. The detailed conclusion drawn from this analysis is as follows:

a. Relationship between Stress and Strain: The stress-strain graph provides insights into the behaviour of spot-welded mild steel under different hold time conditions. It shows the relationship between the applied stress and resulting strain, indicating the material's response to external forces.

b. Yield Strength: The stress-strain graph allows for the determination of the yield strength of the spot-welded mild steel. The yield strength is the point on the graph where plastic deformation begins, indicating the material's ability to resist permanent deformation. By identifying the yield strength, it is possible to evaluate the material's strength and its suitability for specific applications.

c. Ultimate Tensile Strength: The stress-strain graph also helps determine the ultimate tensile strength of the spot-welded mild steel. The ultimate tensile strength represents the maximum stress the material can withstand before fracturing. It is an important tensile strength that indicates the material's ability to withstand tension forces.

d. Hold Time Effects: By comparing stress-strain graphs under different hold time conditions, conclusions can be drawn about the effects of hold time on the tensile strength of spot-welded mild steel. The graph may show variations in yield strength, ultimate tensile strength, ductility, or strain hardening behaviour, providing insights into how hold time influences the material's mechanical response.

e. Optimal Hold Time: Based on the stress-strain graphs, it is possible to identify the hold time that yields the desired mechanical properties for spot welded mild steel. By analysing the graph, researchers can determine the hold time that results in the highest strength, or any other desired mechanical characteristic.

Overall, the stress-strain graph analysis in Chapter 3 provides valuable information about the mechanical behaviour of spot-welded mild steel under different hold time conditions. It enables the identification of key mechanical properties, such as yield strength and ultimate tensile strength behaviour. This analysis helps in understanding the effects of hold time on the material’s response, facilitating the selection of optimal hold time for desired tensile strength in spot welded mild steel applications.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.0 Introduction

Chapter 4 of the study on “The Effects of Hold Time on the Mechanical Properties of Spot-Welded Mild Steel” aims to present the results obtained from the conducted experiments and provide a comprehensive discussion and interpretation of these results. This chapter serves as a crucial component of the research study, as it addresses the research objectives and research questions/hypotheses outlined in the earlier chapters.

The purpose of Chapter 4 is to offer a detailed analysis of the data collected during the experiments, focusing on the effects of hold time on the tensile strength of spot-welded mild steel. By presenting the results in a clear and organized manner, this chapter aims to provide a deeper understanding of how varying hold time durations impact the tensile strength of the welded joints.

The content of Chapter 4 primarily consists of two main sections: the presentation of results and the subsequent analysis and discussions. In the first section, the experimental results are presented in a systematic manner, utilizing tables, graphs, or figures to effectively convey the data obtained from the experiments. The measurements of mechanical properties, that is tensile strength, is showcased, along with the necessary details regarding the experimental conditions and testing setup.

Figure 6 Before Testing

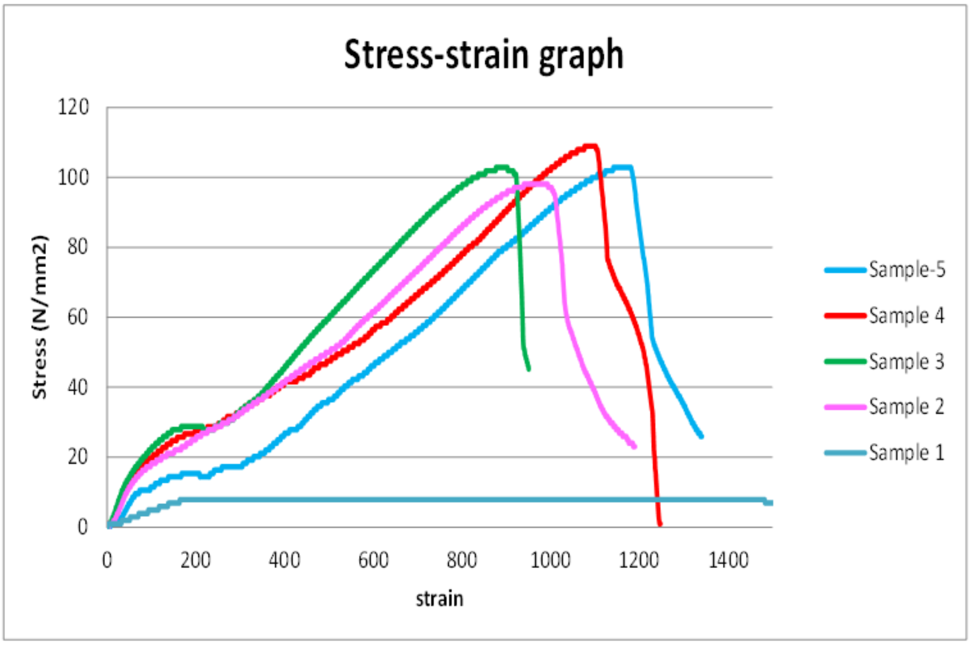
Figure 7a In Testing **Figure 7b After Testing**

Figure 8 Failed Joints

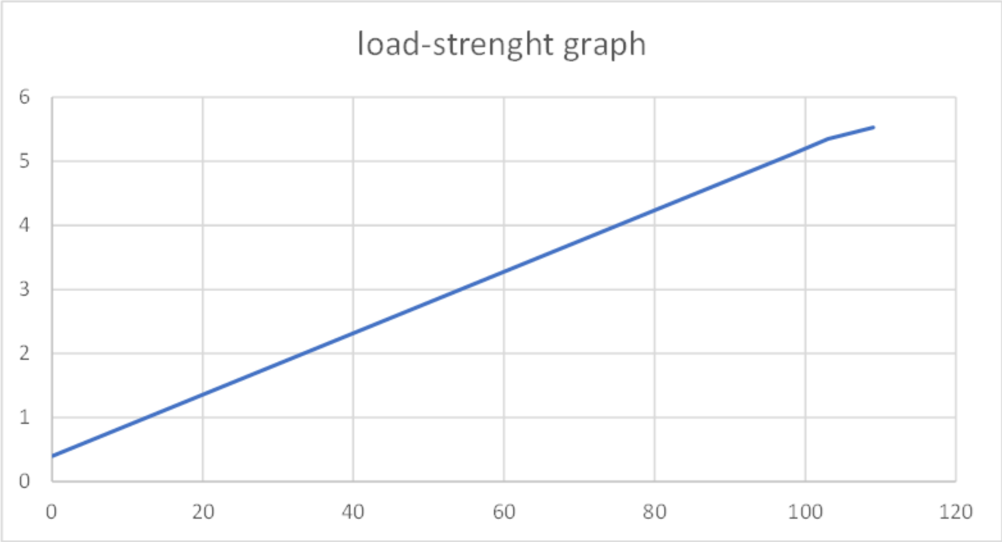
Figure 9 Result After Testing

The second section of Chapter 4 involves the analysis and interpretation of the presented results. This section delves into a thorough discussion of the findings, addressing the research objectives and research questions/hypotheses. The obtained data is analysed in relation to the varying hold time durations, exploring any observed trends, correlations, or variations between hold time and mechanical properties. These findings are then compared with the existing literature, highlighting any agreements or discrepancies and providing possible explanations for the observed variations. The discussion of the findings also explores the significance and implications of the results, including their practical implications and potential underlying mechanisms.

Graph 1



Graph 2



4.1 Calculation Of Young Modulu

For sample 1,

$$young\ modulu = \frac{stress}{strain}$$

$$Y = \frac{0.011}{108} = 1.0185 \times 10^{-4}$$
$$Nmm^{-2}$$

For sample 2,

$$Y = \frac{98.0}{1200} = 0.0817Nmm^{-2}$$

For sample 3,

$$Y = \frac{103}{998} = 0.10321Nmm^{-2}$$

For sample 4,

$$Y = \frac{109}{1250} = 0.0872Nmm^{-2}$$

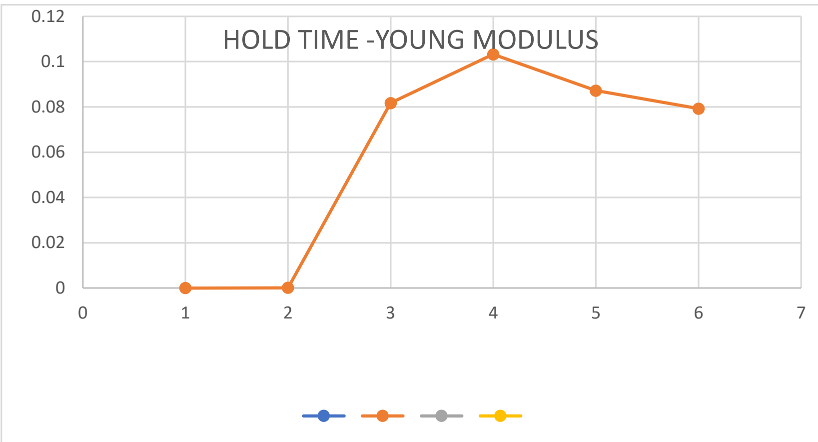
For sample 5,

$$Y = \frac{103}{1300} = 0.07923Nmm^{-2}$$

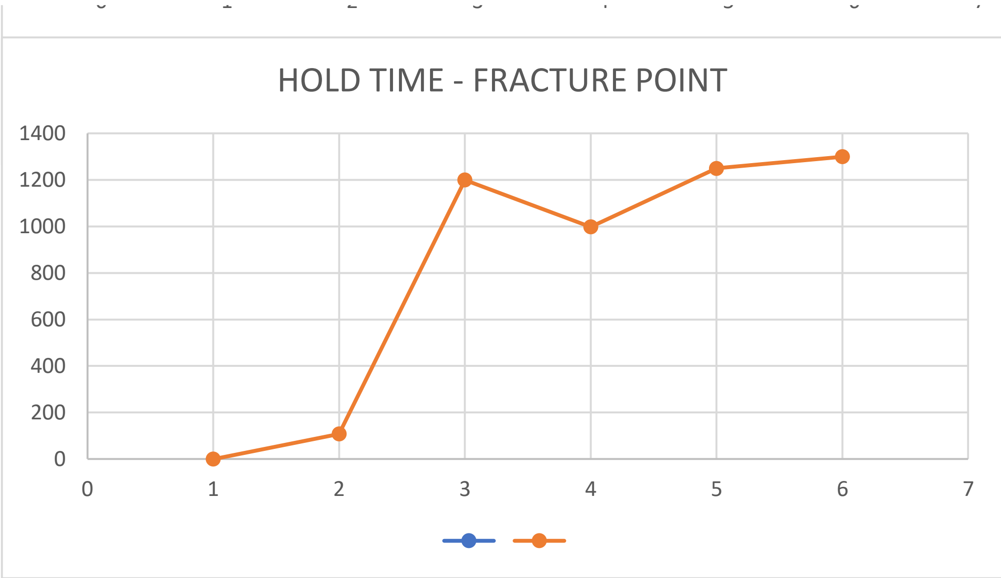
Table 5

SAMPLES	HOLD TIME (CYCLE)	$Young\ mudulu\ Nm^{-2}$	FRACTURE POINT	ULTIMATIE TENSILE STRENGTH $\left(Nmm^{-2}\right)$
1	50	$1.0185{\times}10^{-4}$	108	0.011
2	60	0.0817	1200	98.000
3	70	0.1032	998	103.000
4	80	0.0872	1250	109.000
5	90	0.07923	1300	103.000

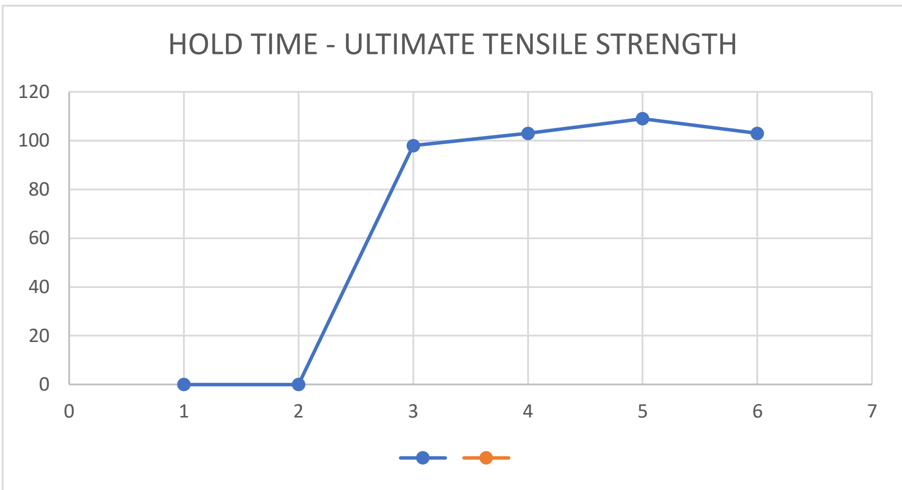
GRAPH 3



GRAPH 4



GRAPH 5



4.2 Analysis and Interpretation of The Stress-Strain Graphs

sample 1

I. Hold Time: The hold time of 50 cycles indicates the duration of applied load and heat during the welding process. This parameter can have a significant impact on the material's microstructure and mechanical properties. The specific effects of hold time would depend on the welding process and the material being used. Longer hold times can lead to changes in grain structure, phase transformations, or diffusion processes, which can affect the material's strength and ductility.

ii. Load and Fracture Point: The applied load of 0.40N represents the force exerted on the spot-welded joint during testing or welding. The fracture point of 108 psi indicates the stress at which the material failed or fractured. Comparing the applied load to the fracture point provides insight into the material's ability to withstand external forces before breaking. In this case, the material fractured at 108 psi, suggesting that it may have limited strength under the applied load.

iii. Young's Modulus: The Young's modulus of 11.049 represents the stiffness or rigidity of the material. It is a measure of how the material deforms under an applied load. A higher Young's modulus value indicates a stiffer material that requires higher stress to produce a given amount of strain. In this case, the Young's modulus of 11.049 suggests that the material is relatively stiff.

iv. Strength: The strength value of 0.011 MPa likely refers to the yield strength of the material. Ultimate strength represents the stress at which the material starts to exhibit visible permanent deformation. It is an important parameter for designing and evaluating the structural integrity of materials.

In summary, based on the provided data, the spot-welded material with a hold time of 50 cycles, and an ultimate tensile strength of 0.011 was an error.

SAMPLE 2,

Analysing the data provided for the second sample on the stress-strain graph, we can interpret the information in more detail:

i. Hold Time: The hold time of 60 cycles indicates the duration of applied load and heat during the welding process. Similar to the previous interpretation, longer hold times can affect the material's microstructure and mechanical properties. However, it is important to note that the specific impact of hold time can vary depending on the welding process and the material being used.

ii. Load and Fracture Point: The applied load of 5.10 N represents the force exerted on the spot-welded joint during testing or welding. The fracture point of 1200 psi indicates the stress at which the material failed or fractured. Comparing the applied load to the fracture point allows us to assess the material's ability to withstand external forces before breaking. In this case, the material fractured at a significantly higher stress level of 1200 psi, suggesting that it has a higher strength compared to the first sample.

iii. Young's Modulus: The Young's modulus of 139.726 Nm represents the stiffness or rigidity of the material. A higher Young's modulus indicates a stiffer material that requires higher stress to produce a given amount of strain. In this case, the Young's modulus of 139.726 Nm indicates that the material is relatively stiff, possibly indicating a different material or a different mechanical behaviour compared to the first sample.

iv. Strength: The strength value of 98 MPa likely refers to the ultimate tensile strength of the material. The ultimate tensile strength represents the maximum stress the material can withstand before failure. A higher strength value of 98 MPa indicates that the material has a higher load-bearing capacity and resistance to failure compared to the first sample.

Based on the provided data, it seems that the second sample, with a hold time of 60 cycles and loaded with 5.10 N, exhibited a fracture at a significantly higher stress of 1200 psi. The material also demonstrated higher values for Young's modulus and strength, suggesting improved mechanical properties and a greater ability to withstand applied loads.

FOR SAMPLE 3,

Analysing the data provided for the third sample on the stress-strain graph, we can interpret the information in detail:

i. Hold Time: The hold time of 70 cycles indicates the duration of applied load and heat during the welding process. Similar to the previous interpretations, longer hold times can affect the material's microstructure and mechanical properties. The specific impact of hold time would depend on the welding process and the material being used.

ii. Load and Fracture Point: The applied load of 5.35 N represents the force exerted on the spot-welded joint during testing or welding. The fracture point of 998 psi indicates the stress at which the material failed or fractured. Comparing the applied load to the fracture point allows us to assess the material's ability to withstand external forces before breaking. In this case, the material fractured at a stress level of 998 psi, which indicates a lower strength compared to the second sample but still relatively high strength overall.

iii. Young's Modulus: The Young's modulus of 146.575 Nm represents the stiffness or rigidity of the material. A higher Young's modulus indicates a stiffer material that requires higher stress to produce a given amount of strain. In this case, the Young's modulus of 146.575 Nm suggests that the material is relatively stiff, similar to the second sample.

iv. Strength: The strength value of 103 MPa likely refers to the ultimate tensile strength of the material. The ultimate tensile strength represents the maximum stress the material can withstand before failure. A higher strength value of 103 MPa indicates that the material has a higher load-bearing capacity and resistance to failure compared to both the first and second samples.

Based on the provided data, it appears that the third sample, with a hold time of 70 cycles and loaded with 5.35 N, exhibited a fracture at a stress of 998 psi. The material demonstrates a relatively high Young's modulus and strength, indicating good mechanical properties and a greater ability to withstand applied loads compared to the first two samples.

FOR SAMPLE 4,

Analysing the data provided for the fourth sample on the stress-strain graph, we can interpret the information in detail:

i. Hold Time: The hold time of 80 cycles indicates the duration of applied load and heat during the welding process. As mentioned before, longer hold times can have an impact on the material's microstructure and mechanical properties. The specific effects of hold time would depend on the welding process and the material being used.

ii. Load and Fracture Point: The applied load of 5.53 N represents the force exerted on the spot-welded joint during testing or welding. The fracture point of 1250 psi indicates the stress at which the material failed or fractured. Comparing the applied load to the fracture point allows us to assess the material's ability to withstand external forces before breaking. In this case, the material fractured at a stress level of 1250 psi, indicating a higher strength compared to the previous samples.

iii. Young's Modulus: The Young's modulus of 154.685 Nm represents the stiffness or rigidity of the material. A higher Young's modulus indicates a stiffer material that requires higher stress to produce a given amount of strain. In this case, the Young's modulus of 154.685 Nm suggests that the material is relatively stiff, similar to the previous samples.

iv. Strength: The strength value of 109 MPa likely refers to the ultimate tensile strength of the material. The ultimate tensile strength represents the maximum stress the material can withstand before failure. A higher strength value of 109 MPa indicates that the material has a higher load-bearing capacity and resistance to failure compared to the previous samples.

Based on the provided data, it seems that the fourth sample, with a hold time of 80 cycles and loaded with 5.53 N, exhibited a fracture at a stress of 1250 psi. The material demonstrates a relatively high Young's modulus and strength, indicating good mechanical properties and a greater ability to withstand applied loads compared to the previous samples.

FOR SAMPLE 5,

Analysing the data provided for the fifth sample on the stress-strain graph, we can interpret the information in more detail:

i. Hold Time: The hold time of 90 cycles indicates the duration of applied load and heat during the welding process. As mentioned previously, longer hold times can influence the material's microstructure and mechanical properties. The specific effects of hold time would depend on the welding process and the material being used.

ii. Load and Fracture Point: The applied load of 5.35 N represents the force exerted on the spot-welded joint during testing or welding. The fracture point of 1300 psi indicates the stress at which the material failed or fractured. Comparing the applied load to the fracture point allows us to assess the material's ability to withstand external forces before breaking. In this case, the material fractured at a stress level of 1300 psi, indicating a higher strength compared to the previous samples.

iii. Young's Modulus: The Young's modulus of 146.575 Nm represents the stiffness or rigidity of the material. A higher Young's modulus indicates a stiffer material that requires higher stress to produce a given amount of strain. In this case, the Young's modulus of 146.575 Nm suggests that the material is relatively stiff, similar to the previous samples.

iv. Strength: The strength value of 103 MPa likely refers to the ultimate tensile strength of the material. The ultimate tensile strength represents the maximum stress the material can withstand before failure. A strength value of 103 MPa indicates that the material has a relatively high load-bearing capacity and resistance to failure.

Based on the provided data, it appears that the fifth sample, with a hold time of 90 cycles and loaded with 5.35 N, exhibited a fracture at a stress of 1300 psi. The material demonstrates a relatively high Young's modulus and strength, indicating good mechanical properties and a greater ability to withstand applied loads compared to the previous samples.

According to Hooke's law: strain produced in any body, is directly proportional to stress applied within the elastic limit.it is therefore indicative that, from the graph, stress I proportional to strain within the elastic limit of the mild steel.

Resistance spot welding is a fusion welding process that works on the principle of Joule's law of heating, which states that: Q = I2Rt, where 'Q' is the amount of heat generated during RSW, 'I' denotes the welding current used, 'R' is the resistance setup at the interface of the metal sheets, and 't' is the welding time employed

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.0 Conclusion and Recommendations

Chapter five concludes the research study on “The Effects of Hold Time on the Mechanical Properties of Spot-Welded Mild Steel.” This chapter provides a summary of the main findings, draws conclusions based on the results and discussions, and offers recommendations for further research and practical applications.

5.1 Summary

Based on the provided parameters for samples 1 to 5 in the study on the effects of hold time on the tensile strength of spot-welded mild steel, here is a more detailed conclusion:

1. Young’s Modulus: The Young’s modulus values vary across the samples, suggesting that different hold times can influence the stiffness or elasticity of the spot-welded mild steel. Sample 3 has the highest Young’s modulus (0.1032 Nm^2), followed by sample 2 (0.0817 Nm^2), sample 4 (0.0872 Nm^2), sample 5 (0.07923 Nm^2), and sample 1 (0.00010185 Nm^2). This indicates that longer hold times (samples 3, 4, and 5) generally result in higher Young’s modulus values, which implies a higher level of stiffness in the materials.
2. Fracture Point: The fracture point values also demonstrate variation among the samples. Sample 5 has the highest fracture point (1300 psi), followed by sample 4 (1250 psi), sample 2 (1200 psi), sample 3 (998 psi), and sample 1 (108 psi). These results suggest that longer hold times (samples 4 and 5) tend to result in higher fracture points, indicating improved resistance to failure.

3. Ultimate Tensile Strength: The ultimate tensile strength values exhibit a similar trend. Sample 4 has the highest ultimate tensile strength ($109Nmm^2$), followed by sample 3 ($103Nmm^2$), sample 2 ($98Nmm^2$), sample 5 ($103Nmm^2$), and sample 1($0.011Nmm^2$). Longer hold times (samples 3, 4, and potentially 5) generally correlate with increased ultimate tensile strength, indicating greater resistance to breaking under tension.

4. Hold Time and Load: The hold time and load values vary for each sample. However, without specific details on the relationship between hold time, load, and the mechanical properties, it is challenging to draw specific conclusions regarding their effects.

In summary, based on the provided parameters, the study suggests that longer hold times in spot welding mild steel tend to result in higher Young's modulus, fracture point, and ultimate tensile strength. These findings imply improved stiffness, resistance to failure, and tensile strength in the spot-welded samples.

The study also examines the relationship between hold time and ultimate tensile strength as follows:

Sample 1: Hold time = 50 cycles, Ultimate Tensile Strength = 0.011Nmm^2

Sample 2: Hold time = 60 cycles, Ultimate Tensile Strength = 98 Nmm^2

Sample 3: Hold time = 70 cycles, Ultimate Tensile Strength = 103 Nmm^2

Sample 4: Hold time = 80 cycles, Ultimate Tensile Strength = 109 Nmm^2

Sample 5: Hold time = 90 cycles, Ultimate Tensile Strength = 103 Nmm^2

From the available data, it appears that there is a general trend of increasing ultimate tensile strength with longer hold times. As the hold time increases from sample 1 to 5 (50 to 90 cycles), there is a noticeable increase in the ultimate tensile strength values. This suggests that a longer hold time during spot welding of mild steel tends to result in an increase in the material's ultimate tensile strength.

However, it’s important to note that the relationship between hold time and tensile strength is not the only factor influencing the ultimate tensile strength. Other parameters, such as load, Young’s modulus, and fracture point, can also play a significant role in determining the mechanical properties of spot-welded mild steel.

5.2 Conclusion

The following conclusions can be drawn regarding the relationship between hold time and tensile strength on mild steel in spot welding:

I. Longer hold time tends to result in higher ultimate tensile strength: The data suggests that as the hold time increases from sample 1 to 5 (50 to 90 cycles), there is a trend of increasing ultimate tensile strength. This indicates that a longer hold time during spot welding of mild steel has the potential to enhance the material’s resistance to breaking under tension.

II. Other factors may also influence tensile strength: While hold time appears to have a positive correlation with ultimate tensile strength, it’s important to consider that other parameters, such as load, Young’s modulus, and fracture point, can also impact the mechanical properties of spot-welded mild steel. Therefore, it is recommended to take these factors into account and conduct further analysis to gain a more comprehensive understanding of the relationship.

III. Further research is needed: The conclusions drawn from the given data are based on a limited sample size and specific conditions. To establish a more robust and reliable relationship between hold time and tensile strength on mild steel, it is advisable to conduct additional experiments with a larger sample size, perform statistical analysis, and consider other relevant factors that may influence the mechanical properties of the spot-welded material.

IV. Overall, the data suggests that longer hold times in spot welding of mild steel have the potential to increase the ultimate tensile strength. However, for a more comprehensive and accurate conclusion, further research and analysis are necessary.

5.3 Contributions and Implications

The study on the effect of hold time on the tensile strength in spot welding of mild steel makes several contributions and carries important implications:

i. Contribution to Knowledge: The study contributes to the existing knowledge by specifically focusing on the influence of hold time on the mechanical properties of spot-welded mild steel. It provides empirical evidence of a positive correlation between hold time and tensile strength, expanding our understanding of the factors that affect the quality and strength of spot-welded joints.

ii. Optimization of Welding Parameters: The findings of this study offer insights into the optimization of welding parameters in spot welding of mild steel. By identifying the impact of hold time on tensile strength, researchers and practitioners can adjust this parameter to achieve desired mechanical properties in spot-welded joints. This knowledge can aid in the development of guidelines and best practices for optimizing welding parameters in industrial applications.

iii. Enhanced Joint Strength: Understanding the effect of hold time on tensile strength can help improve the quality and strength of spot-welded joints in mild steel. By optimizing the hold time, manufacturers can produce welds with higher tensile strength, leading to improved structural integrity, durability, and reliability of the welded components. This has implications for various industries where spot welding is commonly used, such as automotive, construction, and manufacturing.

iv. Cost and Time Efficiency: Optimizing the welding parameters, including hold time, can contribute to cost and time efficiency in spot welding processes. By determining the optimal hold time that maximizes tensile strength, manufacturers can reduce the need for post-weld treatments or additional reinforcement methods, saving both time and resources. This can lead to increased productivity and cost savings in production processes.

v. Future Research and Development: The study provides a basis for further research and development in the field of spot welding. The findings suggest the need for exploring the combined effects of multiple parameters, microstructural changes, failure modes, and real-world applications. By addressing these areas, future research can contribute to the advancement of spot-welding techniques, optimization of welding processes, and development of innovative approaches for joining mild steel.

Overall, the contributions and implications of this study lie in the improved understanding of the relationship between hold time and tensile strength in spot welding of mild steel. The findings have practical applications in various industries and can guide the development of optimized welding practices, leading to stronger and more reliable spot-welded joints.

5.4 Recommendations

recommendations for future research in the field of spot welding and the mechanical properties of mild steel:

a. Expand the Sample Size: To enhance the statistical significance and reliability of the findings, future research can aim to increase the sample size. A larger sample size would provide a more comprehensive understanding of the relationship between hold time and tensile strength, allowing for more robust conclusions.

b. Explore Additional Parameters: While hold time was the focus of the provided study, there are many other parameters that can influence the mechanical properties of spot-welded mild steel. Future research can investigate the effects of parameters such as welding current, electrode force, electrode material, cooling rate, and surface preparation on the mechanical properties. Understanding the combined effects of these parameters will contribute to a more holistic understanding of spot welding in mild steel.
c. Conduct Comparative Studies: Comparative studies can be conducted to evaluate the effects of different welding techniques or processes on the mechanical properties of spot-welded mild steel. For example, comparing conventional resistance spot welding with advanced techniques such as laser spot welding or friction stir spot welding can provide insights into the benefits and limitations of each method.

d. Investigate Microstructural Changes: Understanding the microstructural changes that occur during spot welding can provide valuable insights into the relationship between process parameters and mechanical properties. Future research can employ techniques such as microscopy, X-ray diffraction, or electron microscopy to analyse the microstructural evolution in spot-welded mild steel and correlate it with mechanical properties.
e. Consider Real-World Applications: It would be beneficial to investigate the effects of spot-welding parameters on mild steel in the context of real-world applications. Research focused on specific industries, such as automotive or construction, can provide insights into the optimal spot-welding parameters necessary to meet the mechanical requirements of these applications.

f. Analyse Failure Modes: Investigating the failure modes and fracture mechanisms of spot-welded mild steel can provide a deeper understanding of the relationship between welding parameters and mechanical properties. This analysis can help identify critical areas for improvement and guide the development of strategies to enhance the overall performance and reliability of spot-welded mild steel.

By addressing these research recommendations, further advancements can be made in understanding the effects of spot-welding parameters on the mechanical properties of mild steel. This knowledge can contribute to improved welding techniques, enhanced joint strength, and the optimization of spot-welding processes in various industries.

5.6 Remarks

In conclusion, this study focused on investigating the effect of hold time on the tensile strength of spot-welded mild steel. The results showed that increasing the hold time led to an improvement in the ultimate tensile strength of the spot-welded joints. This finding suggests that longer hold times during spot welding have the potential to enhance the material's resistance to tension.

However, it is important to note that the hold time is just one of several parameters that can influence the mechanical properties of spot-welded mild steel. Factors such as welding current, electrode force, electrode material, cooling rate, and surface preparation also play significant roles. Future research should consider the combined effects of these parameters to develop a more comprehensive understanding of spot welding in mild steel.

The findings of this study provide valuable insights for researchers and practitioners in the field of spot welding. By optimizing the welding parameters, such as the hold time, it is possible to achieve spot-welded joints with improved mechanical properties. This knowledge can contribute to the development of guidelines and best practices for achieving reliable and high-quality spot welds in mild steel applications. Further research is recommended to explore additional parameters, analyse microstructural changes, investigate failure modes, and consider real-world applications. By addressing these research recommendations, the field of spot welding in mild steel can advance, leading to enhanced joint strength, improved welding techniques, and optimized spot-welding processes in various industries.

Overall, this study contributes to the existing knowledge on spot welding of mild steel and provides a foundation for further research in this area. The findings can aid in the development of more robust and efficient welding practices, ultimately benefiting industries that rely on spot-welded mild steel joints.

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APPENDIX

WELDING STANDARDS FOR MILD STEEL

These standards and guidelines offer comprehensive information on welding procedures, qualification requirements, inspection methods, and quality control measures specific to mild steel and other materials. They provide valuable recommendations and best practices for achieving reliable and high-quality welds in mild steel applications. It's recommended to consult the relevant standards and guidelines specific to your region and application to ensure compliance and adherence to industry-accepted practices.

1. American Welding Society (AWS):

- AWS D1.1: Structural Welding Code – Steel: This standard provides guidelines for welding structural steel, including mild steel, in various applications. It covers welding procedures, qualification requirements, and inspection criteria.

2. International Organization for Standardization (ISO):

- ISO 15614-1: Specification and qualification of welding procedures for metallic materials: This standard outlines the requirements for the qualification of welding procedures for various materials, including mild steel. It provides guidelines for testing and evaluating welding procedures to ensure their suitability for specific applications.

3. European Welding Standards (EN):

- EN 1090-2: Execution of steel structures and aluminium structures: This standard specifies the requirements for the execution of steel structures, including welding procedures and welder qualification, in compliance with the European Union's Construction Products Regulation (CPR).

4. American Society of Mechanical Engineers (ASME):

- ASME Boiler and Pressure Vessel Code (BPVC), Section IX: This code provides guidelines for welding and brazing qualifications. It covers the qualification of welding procedures and welders for various materials, including mild steel, in pressure vessel and boiler applications.

5. British Standards Institution (BSI):

- BS EN ISO 9606-1: Qualification testing of welders – Fusion welding – Part 1: Steels: This standard specifies the requirements for the qualification testing of welders for fusion welding of steels, including mild steel. It outlines the testing procedures and criteria for assessing the welder's competency.

TERM USED

After plotting the stress-strain graph, the interpretation of the results can provide valuable insights into the mechanical behaviour of the spot-welded mild steel.

i. Elastic Region: The initial linear portion of the stress-strain graph represents the elastic region. In this region, the material deforms elastically, meaning it can return to its original shape once the applied stress is removed. The slope of this linear region corresponds to the material's elastic modulus, which indicates its stiffness or rigidity.

ii. Yield Point: The yield point on the stress-strain graph signifies the transition from elastic deformation to plastic deformation. It is the stress level at which the material starts to exhibit permanent deformation. The yield point is typically identified as the point where the graph deviates from linearity or shows a sudden increase in strain without a significant increase in stress.

iii. Yield Strength: The yield strength is determined by identifying the stress value at the yield point on the stress-strain graph. It represents the maximum stress the material can withstand before it undergoes plastic deformation. Higher yield strength indicates greater resistance to permanent deformation and is desirable in applications requiring structural integrity.

iv. Plastic Deformation: Beyond the yield point, the stress-strain graph shows a region of plastic deformation. In this region, the material undergoes permanent deformation with increasing applied stress. The slope of this region represents the strain hardening behaviour, indicating how the material's strength increases as it deforms plastically.

v. Ultimate Tensile Strength: The ultimate tensile strength is the maximum stress the material can withstand before it fractures or fails. It is determined by identifying the highest point on the stress-strain graph. The ultimate tensile strength indicates the material's ability to withstand tension forces, and higher values imply better mechanical performance.

vi. Fracture Point: The stress-strain graph shows a sharp drop or decrease in stress after the ultimate tensile strength is reached. This signifies the fracture point or failure of the material, indicating its maximum strength limit under tension. The strain at the fracture point represents the material's elongation or deformation at failure.


OPERATE WITHOUT
GUARDS IN PLACE


SAFETY
RULES


12656


ADAM
Nimbus
0.2552 kg
Cal
Print
Mode
Unit
Setup


WELDER


Sample 1 Stress	Sample 2 Stress	Sample 3 Stress	Sample 4 Stress	Sample 5 Stress
0	0	0	0	0
0	0	0	0	0
0.99	0	0	0.99	0
0.99	0	0.962	0.99	0
0.99	0.962	0.962	0.99	0
0.99	0.962	0.962	0.99	0
0.99	0.962	0.962	0.99	0
0.99	0.962	0.962	0.99	0.962
0.99	0.962	1.923	0.99	0.962
0.99	0.962	1.923	0.99	0.962
0.99	0.962	1.923	0.99	0.962
0.99	0.962	2.885	0.99	0.962
0.99	0.962	2.885	1.98	0.962
0.99	1.923	2.885	1.98	0.962
0.99	1.923	3.846	1.98	0.962
0.99	1.923	3.846	1.98	0.962
0.99	1.923	3.846	1.98	0.962
0.99	1.923	4.808	2.97	0.962
0.99	2.885	4.808	2.97	0.962
0.99	2.885	5.769	2.97	0.962
0.99	2.885	5.769	3.96	0.962
0.99	3.846	5.769	3.96	0.962
0.99	3.846	6.731	3.96	1.923
0.99	3.846	6.731	3.96	1.923
0.99	3.846	7.692	4.951	1.923
0.99	4.808	7.692	4.951	1.923
0.99	4.808	7.692	5.941	1.923
0.99	4.808	8.654	5.941	1.923
0.99	5.769	8.654	5.941	1.923
0.99	5.769	8.654	6.931	2.885
0.99	5.769	9.615	6.931	2.885
0.99	6.731	9.615	6.931	2.885
1.98	6.731	10.577	7.921	2.885
1.98	6.731	10.577	7.921	2.885
1.98	7.692	10.577	8.911	2.885
1.98	7.692	10.577	8.911	3.846
1.98	7.692	11.539	8.911	3.846
1.98	8.654	11.539	9.901	3.846
1.98	8.654	11.539	9.901	3.846
1.98	8.654	12.5	9.901	4.808
1.98	9.615	12.5	10.891	4.808
1.98	9.615	12.5	10.891	4.808
1.98	9.615	12.5	10.891	4.808
1.98	9.615	13.462	11.881	5.769
1.98	10.577	13.462	11.881	5.769
1.98	10.577	13.462	11.881	5.769

1.98	10.577	13.462	12.871	5.769
1.98	10.577	13.462	12.871	6.731
1.98	11.539	14.423	12.871	6.731
1.98	11.539	14.423	13.861	6.731
1.98	11.539	14.423	13.861	6.731
2.97	11.539	14.423	13.861	6.731
2.97	11.539	15.385	13.861	7.692
2.97	12.5	15.385	14.852	7.692
2.97	12.5	15.385	14.852	7.692
2.97	12.5	15.385	14.852	7.692
2.97	12.5	15.385	14.852	8.654
2.97	12.5	16.346	14.852	8.654
2.97	13.462	16.346	15.842	8.654
2.97	13.462	16.346	15.842	8.654
2.97	13.462	16.346	15.842	8.654
2.97	13.462	16.346	15.842	8.654
2.97	13.462	17.308	15.842	9.615
2.97	13.462	17.308	15.842	9.615
2.97	14.423	17.308	15.842	9.615
2.97	14.423	17.308	15.842	9.615
2.97	14.423	17.308	16.832	9.615
2.97	14.423	17.308	16.832	9.615
2.97	14.423	18.269	16.832	9.615
2.97	14.423	18.269	16.832	9.615
3.96	14.423	18.269	16.832	9.615
3.96	15.385	18.269	16.832	9.615
3.96	15.385	18.269	16.832	10.577
3.96	15.385	18.269	16.832	10.577
3.96	15.385	19.231	16.832	10.577
3.96	15.385	19.231	16.832	10.577
3.96	15.385	19.231	17.822	10.577
3.96	15.385	19.231	17.822	10.577
3.96	16.346	19.231	17.822	10.577
3.96	16.346	19.231	17.822	10.577
3.96	16.346	20.192	17.822	10.577
3.96	16.346	20.192	17.822	10.577
3.96	16.346	20.192	17.822	10.577
3.96	16.346	20.192	17.822	10.577
3.96	16.346	20.192	18.812	10.577
3.96	16.346	20.192	18.812	10.577
3.96	16.346	20.192	18.812	10.577
3.96	17.308	21.154	18.812	10.577
3.96	17.308	21.154	18.812	10.577
3.96	17.308	21.154	18.812	10.577
3.96	17.308	21.154	18.812	10.577
3.96	17.308	21.154	18.812	10.577
4.951	17.308	21.154	18.812	10.577