# Effect of Welding Current Variation on Hardness in S45c Steel with Galvanized Steel A653

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**ABSTRACT**

The development of modern manufacturing industry technology era is increasingly rapid. In the era of modern technology when welding is a manufacturing process that is widely used with various types of materials that are increasingly diverse. This study aims to determine the hardness value and strength level of welding on different materials. The materials used in this study are S45C steel and galvanized steel A653 using Gas Metal Arc Welding technology, with different welding current variations, the current variations used are 75A, 100A, 125A, and 150A. From the results of compressive tests that have been carried out, the highest strength value of the 125A current variation with an average value of 12.42 kg/mm$^2$, the second highest value with a variation of 100A current with an average value of 10.80 kg/mm$^2$, the third rank with a variation of 75A current with an average value of 8.83 kg/mm$^2$, while at the lowest value with a variation of 150A current with an average strength value of 7.26 kg/mm2 and the results of hardness tests that have been carried out on welding metal, steel and galvanized steel there is a significant difference. This is due to the influence of current variations carried out during the welding process, the greater the current strength given does not make the welding have strength, the greater the current given will cause damage to the material. Although the hardness test results show fairly high hardness value. However, the area around the welding has a fairly low level of hardness

## I. INTRODUCTION

Construction can be defined as a comprehensive description of the development process that encompasses both static and dynamic elements. Effective construction practices are characterized by the integration of high-quality and appropriately designed connection components that adhere to established technical specifications and guidelines. The connection components employed in construction are diverse, yet they share a common purpose: to facilitate the interconnection of various structural elements, thereby ensuring the integrity and stability of the overall assembly. Among the various types of connection methods that have evolved over time, welding stands out as a particularly significant technique. Welding is a process that involves the joining of metals through the application of heat, which induces penetration and fusion at the molecular level. This method not only provides a robust and durable connection between metal components but also allows for the creation of intricate and complex structures that are essential in modern construction. The advancements in welding technology have led to the development of various welding techniques, each tailored to specific applications and materials, thereby enhancing the versatility and efficacy of this joining method. The importance of welding in construction cannot be overstated, as it plays a crucial role in the assembly of structural frameworks, pipelines, and various mechanical systems. By enabling the seamless integration of metal components, welding contributes significantly to the overall performance, safety, and longevity of constructed facilities. As construction practices continue to evolve in response to technological advancements and changing industry demands, the role of welding as a fundamental connection method remains pivotal, underscoring the necessity for ongoing research and innovation in this field..

Welding is a critical connection process employed to join two or more metal components through the application of heat energy. This technique is fundamentally characterized by its ability to create a robust bond between metals by either heating or melting the surfaces to be joined. In typical welding procedures, the ends of the metal parts are prepared to achieve a suitable fit, often referred to as being "luered," which facilitates the effective fusion of the materials. The welding process involves the use of various heat sources, including flames, electric arcs, or other forms of thermal energy, to achieve the desired melting point of the metals. When the metal surfaces reach their melting temperature, they coalesce to form a strong joint, resulting in a continuous mass that exhibits enhanced mechanical properties. This fusion creates a bond that is not only durable but also resistant to separation under typical operational conditions. Welding techniques can vary significantly, encompassing methods such as arc welding, gas welding, and resistance welding, among others. Each method employs distinct mechanisms for generating heat and achieving fusion, tailored to the specific materials and applications involved. The versatility of welding makes it an indispensable process in numerous industries, including construction, manufacturing, and automotive engineering, where the integrity and strength of metal joints are paramount..

Choosing the appropriate welding current parameters is critical in influencing the strength and altering the mechanical properties of metals. The selection of these parameters directly impacts the quality of the weld joint produced. Specifically, an increase in the strength of the electric current applied results in a corresponding increase in the heat input generated, which is necessary for melting both the base metal and the filler material, such as the electrode. Conversely, a reduction in the current strength leads to a decrease in the heat generated, which may insufficiently melt the parent metal and the electrode, potentially compromising the integrity of the weld. In the context of modern manufacturing, the combination of different types of materials in welding applications remains relatively infrequent. This observation presents a compelling opportunity for further research, particularly in exploring the effects of welding current variations on the hardness values of dissimilar metals. The proposed study, entitled "The Effect of Welding Current Variations on Hardness Values in S45C Steel with Galvanized Steel A653," aims to investigate this phenomenon in detail.

The focus on S45C steel, a medium carbon steel known for its strength and toughness, in conjunction with Galvanized Steel A653, which offers excellent corrosion resistance, presents a unique challenge and opportunity in the welding process. By systematically varying the welding current, this research will seek to elucidate the relationships between current parameters, heat input, and the resultant mechanical properties, particularly hardness. Understanding these dynamics is essential for optimizing welding practices and enhancing the performance of welded joints in applications where dissimilar metal combinations are utilized. This study aims to contribute valuable insights to the field of welding engineering and advance the knowledge base surrounding the welding of diverse materials.

## II. METHODS

In this study the authors used the type of experimental research which aims to determine the effect of variations in welding current on the hardness and strength of joints in S45C steel with Galvanized steel A653. The research was conducted in several places. Welding specimens were made at the Energy Conversion Laboratory, Department of Mechanical Engineering, Faculty of Engineering, Trunojoyo University, Madura. Compressive testing and hardness testing were carried out at the Mechanical Engineering Education Laboratory, Malang State. The type of connection used is disjoint with the position of galvanized material parallel to S45C steel. Disjoint was chosen because there is a difference in melting point between the materials used. The welding process that has been carried out produces specimens that will be used in compressive and hardness testing After the welding process is completed with the specified current variation, the specimen is then prepared by forming it by cutting it using a grinding wheel with a width of 20mm and an overall length of 80mm. Later this specimen will be used as a testing material.

In this research, the independent variable is the variation of welding current, namely 75 A, 100 A, 125 A, and 150 A. The dependent variables observed in this study were the compressive test value and the hardness test value. Control variables on this research is S45C steel, Galvanis steel A653, las GMAW. The tools used during the research process are as follows:

- Rilon 200 G $CO_2$ MIG welding machine
- Stainless steel wire 0,5
- License plate scissors
- Clamp
- Welding gloves
- Welding glasses
- Wire brush

Research procedure work as research flowchart show on figure 1.

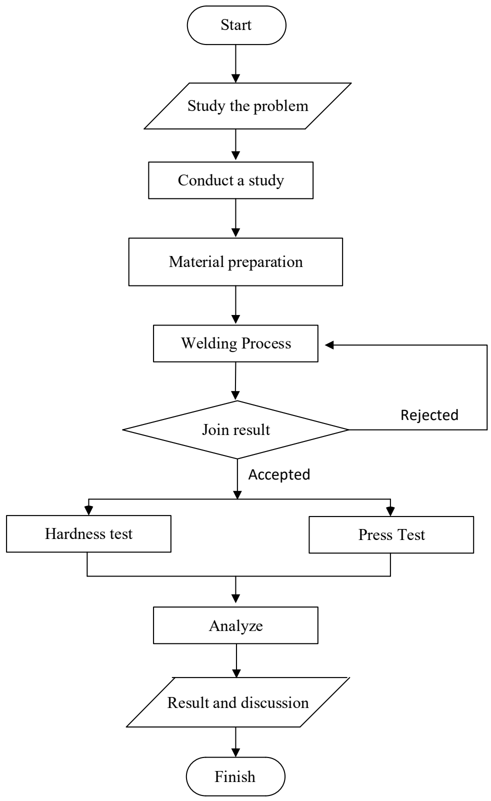


Fig.1. Research Flowchart

## III. RESULTS AND DISCUSSION

### A. *Hardness Test*

In general, hardness tests are used to express resistance to deformation and are a measure of a metal's resistance to plastic deformation or permanent deformation (Dieter, 1987). Hardness is often defined as a measure of ease and a specific quantity that says something about the strength and heat treatment of a metal. The hardness test is a test of the hardness value of a material where we can know the description of the mechanical properties of a material or material, even though the measurement is only carried out at one point or a certain area. only. To find out the hardness of steel there is a way of testing steel hardness, namely by using a hardness testing machine (Vickers).

### B. *Press Test*

Compressive testing is an attempt to determine the capacity of a material to withstand the maximum load when the maximum compressive strength limit is reached, the specimen experiences cracking which aims to determine the characteristics and mechanical properties of a material. This compressive test has good performance and quality to determine the strength of objects. In general, this press test is used on metals that are brittle, because this press test tool has a clearly visible breaking point when testing the object.

### C. *Press Test*

TABLE I. PRESS TEST RESULT

| Current (Ampere) | Repetition (kg/mm2) | | | Average |
|---|---|---|---|---|
| | *1* | *2* | *3* | |
| 75A | 8.80 | 8.60 | 9.10 | 8.83 |
| 100A | 10.80 | 11.00 | 10.60 | 10.80 |
| 125A | 12.40 | 12.20 | 12.80 | 12.46 |
| 150A | 7.40 | 7.60 | 6.80 | 7.26 |

Testing was carried out three times, the value obtained from the compressive test results was not so great because during the testing process the specimen was not broken but curved in the HAZ area. This is also caused by the use of thin material with a thickness of 0.6mm. The 150A current variation has the lowest strength value because the effect of welding heat makes the HAZ area quite extensive.

### D. *One Way ANOVA analysis*

The basis for one-way anova decision making is the comparison of p count with a significant $\alpha = 5\%$ (0.05). With the following conditions:

- If the sig. value of the calculated result is> 0.05, then Ho is accepted, Ha is rejected
- If the sig. value of the calculated result <0.05 then Ho is rejected, Ha is accepted.

The result of ANOVA shown on table 2

TABLE II. ANOVA TEST RESULT OF COMPRESSIVE TEST FORCE

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 46.369 | 3 | 15.456 | 167.096 | <0.001 |
| Within Groups | 0.74 | 8 | 0.093 | | |
| Total | 47.109 | 11 | | | |

Based on significant values of the calculated results in table 2 are < 0.001 Based on the Sig. results in table 2 then the decision can be drawn that Ho is rejected and Ha is accepted, or in other words, there is a significant influence significant influence between variations in welding current on the compressive test.

### E. *Hardness Test*

The hardness test was carried out at three points with the Vickers hardness test. Areas included in this hardness test include Welding Metal area, galvanized HAZ area, and steel HAZ area. The hardness result shown on Table 3.

TABLE III. HARDNESS TEST RESULT ON WELDING AREA

| No | Regional | Current | | | |
|---|---|---|---|---|---|
| | | *75A* | *100A* | *125A* | *150A* |
| 1 | Weld Metal | 205.2 | 231.9 | 243.6 | 272.6 |
| 2 | | 207.4 | 229.8 | 231.9 | 281.2 |
| 3 | | 212.5 | 231.2 | 226.4 | 262.1 |
| 4 | Galvanized | 121.1 | 128.3 | 127.9 | 119.5 |
| 5 | | 117.4 | 137.5 | 141.1 | 127.8 |
| 6 | | 131.2 | 118.7 | 119.5 | 121.1 |
| 7 | Steel | 159.2 | 179.8 | 181.2 | 177.9 |
| 8 | | 141.7 | 186.4 | 192.3 | 184.1 |
| 9 | | 132.3 | 168.6 | 183.2 | 172.5 |

This research yields promising results, particularly evident in the outcomes of the compressive tests, which demonstrate significant differences attributable to the variations in voltage current employed during the specimen welding process. The findings from these strength tests substantiate the hypothesis that the MIG welding current voltage exerts a substantial influence on the mechanical properties of the welded joints. Notably, the discrepancies in strength values correspond to variations in bending resistance among the specimens, highlighting the critical role of the welding current in determining the performance characteristics of the welds. The observed differences in strength can be attributed to the impact of the welding current on the Heat Affected Zone (HAZ) of the specimens, which exhibits variability in its thermal profile due to the differing current levels used. As a result, the distribution of heat around the welding area is also affected, leading to variations in the microstructural characteristics of the weld and adjacent base materials.

In addition to assessing the strength of the welded connections, this study also evaluates the hardness values, which further reinforce the underlying hypothesis. The results obtained from the hardness testing, specifically through the collection of Vickers Hardness Number (VHN) data, reveal discernible differences in hardness across the specimens. Building upon the previous hardness assessments, it becomes evident that the HAZ exhibits varying levels of hardness, a phenomenon that can be attributed to the influence of current variations employed during the welding process. The significant differences in hardness values underscore the relationship between the welding current and the resultant properties of the welded joints, emphasizing the necessity for careful consideration of current parameters in welding applications. This research contributes valuable insights into the complex interplay between welding conditions and the mechanical properties of welded materials, thereby enhancing the understanding of how to optimize welding practices for improved performance in various industrial applications.

The relationship between welding current strength and the resultant mechanical properties of welded joints is complex and multifaceted. It is important to note that an increase in current strength does not necessarily correlate with enhanced welding strength. In fact, excessively high current levels can lead to detrimental effects on the material, resulting in thermal damage and structural weaknesses. While the hardness test results may indicate relatively high hardness values, it is critical to recognize that the regions surrounding the weld, particularly the Heat Affected Zone (HAZ), often exhibit significantly lower hardness levels. This discrepancy highlights the potential for compromised mechanical integrity in the welded joint. The implications of these findings are further evidenced by the outcomes of the compressive tests, which reveal that the strength values of the welds do not meet optimal performance criteria. This observation underscores the necessity of carefully calibrating welding parameters to achieve a balance between sufficient heat input for effective fusion and the avoidance of excessive thermal exposure that can lead to material degradation.

This study aims to elucidate the effects of varying welding current strengths on both the strength and hardness of the welds produced. The results demonstrate notable differences in mechanical properties, affirming the hypothesis that the magnitude of the welding current significantly influences the structural characteristics of the material. Specifically, the findings indicate that the welding current not only affects the strength of the connection but also alters the hardness distribution within the material structure. This research provides compelling evidence that the selection of appropriate welding current parameters is crucial for optimizing the mechanical properties of welded joints. By establishing a clearer understanding of the effects of welding current on both strength and hardness, this study contributes to the advancement of welding practices and the development of more resilient and reliable welded structures in various industrial applications.

## IV. CONCLUSIONS

Based results of the compressive tests that have been carried out, it can be seen that the highest strength of the welded joints is found in the 125A current variation with an average value of 12.42 kg/ $mm^2$, the second highest value with a current variation of 100A with an average value of 10.80 kg/mm2, ranking third with a current variation of 75A with an average value of 8.83 $kg/mm^2$, while at the lowest value with a current variation of 150A with an average strength value of 7.26 kg/ $mm^2$. From the results of hardness tests that have been carried out on welding metal, steel and galvanized steel there are significant differences. This is due to the influence of current variations carried out during the welding process, the greater the current strength given does not make the welding have strength, the greater the current given will cause damage to the material. Although the hardness test results show a fairly high hardness value. However, the area around the welding has a fairly low level of hardness. To be able to produce better research on welding, the authors provide suggestions for further research. The following suggestions need to be considered: Testing to determine the strength value should use a tensile test in order to get the highest welding value besides knowing the type of fracture and the area of the fracture. In cutting specimens, it is better to use a sitting grinder to get precise cut results. The use of filler is in accordance with the material used, and adjusts the filler size to the thickness of the material.

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