Experimental Investigation of The Mechanical Properties of Dissimilar Welding of Metals (A Case of Mild Steel with Galvanized Steel)

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Abstract- In engineering work, sometimes it is essential to join two dissimilar metals for reasons such as cost effectiveness, convenient to mix and match for mechanical properties benefit. This study focused on investigating the mechanical properties of post weld heat treatment of dissimilar welded joint (mild steel with galvanized steel). The aim of this work is to carry out post weld heat treatment of two dissimilar metals welded together to determine its effect on the mechanical properties (Tensile strength and impact strength) of the welded joint. The welding process of mild steel and galvanized steel was done using Electric Arc welding process after which heat treatment process was employed using normalizing and quenching. Mechanical tests (Tensile test and impact test) were carried out after the post weld heat treatment processes. The research revealed that the heat-treated samples had better tensile and impact strength. The normalized heat treatment sample has higher energy at break to be 46. 46.83347 J for a load of 5015.09383 N for tensile test and higher impact strength of 61.35 J. This implies that where tensile and impact strength is required then, heat treatment (normalizing) should be carried out after the welding processes otherwise quenching can be employed. This research contributes to knowledge in the area of application of the homogeneity of the two different metals in design, fabrication and manufacturing of interchangeable components in developing countries.

Indexed Terms- Dissimilar, Heat treatment, Mechanical Properties, Mild Steel, galvanized Steel Welding.

I. INTRODUCTION

Welding is a metal joining technique used in fabrication. Material welding can be divided into welding the same material and, welding different materials (Afriansyah and Arifin, 2020). Dissimilar metal welding is the joining of two metals that have different chemical and mechanical properties and is significant metal joining process with wide application in industrial domain. Welding of dissimilar metals, especially steel materials become very important in the manufacturing industries due to its advantages such as the production of lightweight machine parts in the automotive industries, production of engineering components with satisfactory corrosion resistance in the chemical, petrochemical and power generation industries (Echezona et al., 2021; Bystriansky et al., 2020). Welding is a crucial joining process used to produce dissimilar metallic components. The ability to join dissimilar metals will open new doors with regards to product design and manufacturing as well as enable the replacement of parts of a component with lightweight materials through joining (Arbo et al., 2024). The need for minimizing general production cost as well as to reduce energy consumption by adopting lighter materials for engineering application imposes the demand for dissimilar metal weld joint (Hayatu et al, 2024). Welding of dissimilar alloys is very important for the cost effectiveness manufacture of components with complementary structural and functional characteristics. The different challenges of dissimilar welding come from the difference in physical and metallurgical properties of the participating alloys (Supriyo, 2023). The quality of the welded joint is of critical important in this application and quite an issue since the base metals are different primarily due to different physical, chemical and mechanical characteristics (Chaudhari et al., 2020).

The evolving interface formed between two different liquids during dissimilar metal welding can critically influence the development of the as-solidified microstructure and determine the mechanical properties of the joint (Wu et al., 2023). The purpose of this research is to know the possibilities of dissimilar metal welding when the issue of corrosion and cost consideration of manufacturing a product is considered.

Galvanized steel is among the most popular steel types because of its extended durability, having the strength and formability of steel plus the corrosion protection of the zinc-iron coating. The zinc protects the base metal by acting as a barrier to corrosive elements and the sacrificial nature of the coating results in a long-lasting and high-quality steel product. This versatility makes it applicable to a variety of products in the manufacturing industries, including agriculture, solar, automotive, construction, and so on (McClements, 2023). The primary aim of this research is to evaluate the mechanical properties of the welded joint of the dissimilar metals. Specifically, this study seeks to determine the tensile properties and the impact resistance of the welded joint to provide a comprehensive understanding of their suitability for use. Tensile properties, including maximum tensile stress, load at maximum tensile stress and tensile strain at maximum tensile stress are crucial indicators of a material's strength and ductility (ASM International, 2008) (Davis, 2004).

II. MATERIALS AND METHODS

The materials used for this research are mild steel and galvanized steel. The mild steel and the galvanized steel were cut into sizes of 150 mm by 150 mm. Galvanized steel was considered for this research due to cost effectiveness otherwise stainless steel would have been preferred. The purpose of the galvanized steel was for corrosion control. The mild steel was welded to the galvanized steel using Electric arc Welding techniques. This was followed by heat treating the samples using Normalizing and Quenching heat treatment methods so as to have good comparison. After the heat treatment, the mechanical tests were carried out on the welded joint.

A. Heat Treatment Process

Normalizing and quenching heat treatment processes were carried out separately on the welded specimens for each dimension of the test piece welded together. The specimen for normalizing was charged into the furnace, heated to a temperature of 930 °C and then soaked for 1 hour. This soaking was done to allow homogenization. The furnace was switched off after attaining the time and then the specimens were brought out of the furnace to cool in the still air.

The specimen for quenching (heat treatment process) was charged into the furnace; heated to a temperature of 930 °C and then soaked for 1 hour. The furnace was switched off after attaining the soaking time and the specimen was brought out of the furnace and rapidly cooled in water.

After the heat treatment processes, the specimens were subjected to mechanical tests such as tensile test and impact test. The tensile test was carried out in accordance with ASTM standard.

Figure 1: Heat Treatment Electric Furnace

B. MECHANICAL TEST

Mechanical test was carried out on the heat treated samples. The mechanical test carried out on the specimens were tensile test and impact test. Tensile test was done to determine the three (3) primary properties of the specimen, which includes strength, ductility and elasticity. This was carried out in such a way that the specimens were loaded to destruction, while it is been observed, a graph of tensile stress against tensile strain was plotted. It was done the specimens (control, normalized, and quenched specimens respectively). Universal Instron machine was used for the test as shown in Figure 2.

Figure 2: Universal Instron Machine, Model 3369, Maker (Instron)

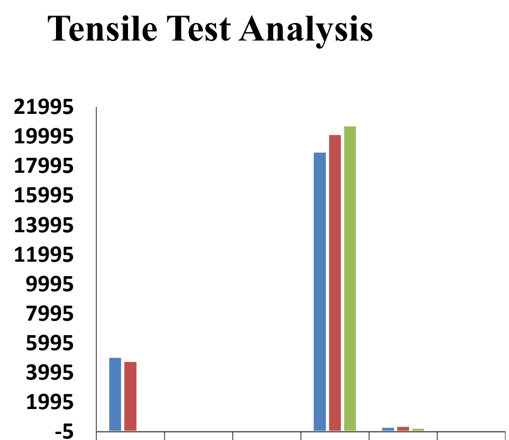
Impact test was done after the specimens were machined to the capacity of the impact testing machine and heat treated. A notch of 2 mm at an angle 45° was carved on the specimen at the notched point that is where stress is initiated. Izod impact testing machine was used for the test as shown in figure 3.

Figure 3: Izod Impact Testing Machine

III. RESULTS AND DISCUSSION

Tensile Test

Figure 4 shows the analysis of the tensile test which reveals that the normalized heat treated sample gave higher energy at break to be 46. 46.83347 J with greater load to be 5015.09383 N while energy at break of the quenched sample was 17.32182 with a load of 4716.941805. The control sample result was to checkmate the outcome of the results of both the normalized and quench samples. The extension and tensile strain were higher for the normalized specimen than the quenched specimen indicating that the normalized specimen was more ductile and could withstand more load. The results show that the normalized sample could withstand more load before breakage.



	Load (N)	Extension (mm)	Tensile Strain (mm/mm)	Modulus of elasticity (MPa)	Tensile stress at Yield (MPa)	Energy at Break (J)
Normalized	5015.1	5.9016	0.1686	18914	271.71	46.833
Quenched	4716.9	2.5002	0.0714	20090	321.24	17.322
Control	-5.593	7.4133	0.2118	20675	206.61	10.88

Figure 4: Tensile Test Analysis

Figure 5 shows tensile test result on normalized specimen. A is the tensile stress without load, between B and C is the elastic region. From C to D is the yield region but point C is the upper yield point and point D is the lower yield point; between D and I is the plastic region. From F to H is the lower plastic region and between point I to J is the fracture stage. Capital letters were used instead of the small letters in the graph to explain for easy understanding.

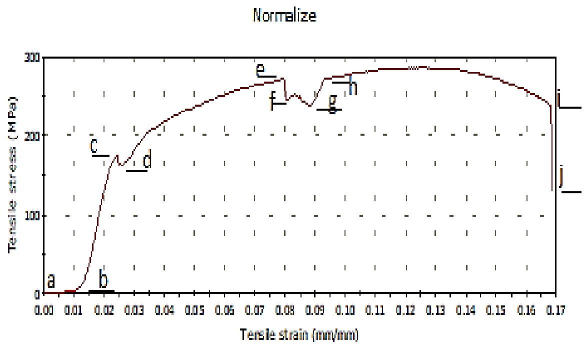


Figure 5: Tensile Test on Normalized Specimen

Figure 6 shows tensile test result of the quenched specimen where point A is the tensile stress without load, between B and C is the elastic region, and from C to D is the yield region but point C is the upper yield point while point D is the lower yield point. Also, between D and E is the plastic region while E to F is the ultimate stress region. F is the fracture point. Again, the use of capital letters is for easy comprehension while reading.

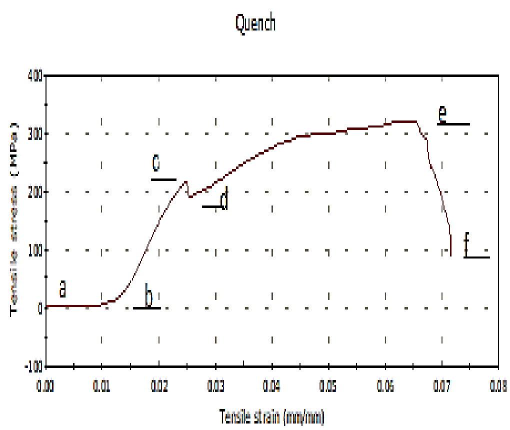


Figure 6: Tensile Test on Quenched Specimen

Figure 7 shows tensile test on control (the control is the welded sample that was not heat treated), point A is the tensile stress without load; between point B and C is the elastic region. From C to D is the yield stage, between C and E is upper yield stage while E to D is the lower yield stage. From D to G is the plastic region and between F and H is the plastic deformation.

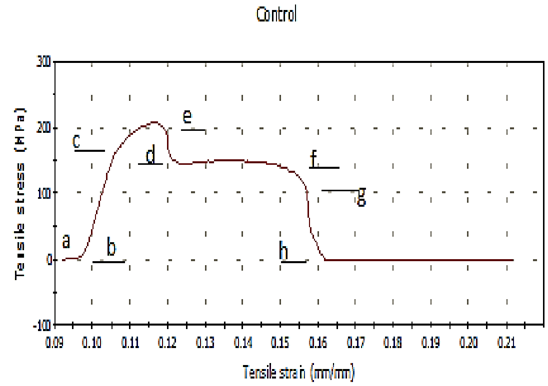


Figure 7: Tensile Test on Control Specimen

Impact Test

Figure 8 depicts the analysis of the impact test which reveals that the normalized heat treated specimen impact energy to be 61.35 joules. Other impact energy results from the same Figure are 43.21 joules for the quenched specimen, 35.9 joules for control (galvanized steel), 45.46 joules for control (mild steel) and 57.39 joules for control (welded joint). From the results, the normalized specimen has higher value which indicates better resistance to impact.

	Impact (Joules)
Normalized	61.35
Quenched	43.21
Control (Galvanized Side)	35.9
Control (Mild Steel Side)	45.46
Control (Welded Joint)	57.39

Figure 4: Impact Test Analysis

CONCLUSION

From the results above, the following conclusion can be drawn:

(i) During the process of welding mild steel and galvanized steel using the Electric Arc welding, the galvanized steel received greater heat because of the presence of zinc in it which protects the base metal by acting as a barrier to corrosive elements. The welding process cause fusion on both metal and this allow it to weld together.

(ii) The research revealed that the heat-treated specimens (normalized specimen and quenched specimen) had better tensile test and impact test. The normalized heat treatment specimen has higher energy at break to be 46. 46.83347 J with greater load to be 5015.09383 N for tensile test and higher impact strength of 61.35 J. This infer that normalizing should be carried out on the welded joint where the material will be subjected to impact load but where hardness is required, then quenching should be done.

(iii) Also, this research of dissimilar metal welding could be applied in case when cost effectiveness is needed

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