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Original Article

Experimental Studies on Tee Weldment Joints (Non-Destructive Testing)

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Abstract *- The quality of the welding joint has an essential effect on the manufacturing and assembling industry. Due to the increasing use of welding in all aspects of manufacturing, it must be constantly improved, experimented with, and upgraded. The weld joint quality is highly dependent on the process parameter. Welds inspect to see if they meet specifications. Firstly, this study employs the NDT to assess an artisan on the quality of weldment joints in Takoradi-Kokompe fabrication shops. Secondly, an experimental approach is equally adopted to achieve the set goal of this study. Besides, specimens of steel welded Tee joints were created and tested with selected Non-destructive testing. Nevertheless, the AWS D1.1 code of acceptance for structural steels was used to assess the results of NDT testing on the welded joints. The results showed that all fabricator welded joints fall below the acceptance criteria according to AWS D1.1:2000 and, therefore, must be rejected.*

Keywords *- Visual inspection, Liquid penetrant inspection, Magnetic particle testing, Weldment joint.*

1. Introduction

Welding technology has obtained access to every part of manufacturing, such as rail, roads, shipbuilding, construction of large dams, various projects, pipelines, power plants, and automobile industries. Besides, because of the rising use of weldment in all facets of manufacturing, it needs to be constantly improved, experimented with, and upgraded. [1]. Additionally, samples of X-ray energy spectra were examined, focusing on W and Ta Fluorescence X-rays, Compton scattering, and elastic scattering X-rays. Moreover, these findings suggest that high-energy X-ray spectrum analysis could be used as an NDT technique to evaluate precipitates at the HIP interface of F82H steel[2]. However, with the continuous development and demand for various parts such as automotive, aerospace structures, various machine components, etc., and the high production rate of those parts, one of the most desired demands is automation and accuracy [3]. Furthermore, joining is one of assembling operations' most essential manufacturing requirements. Methods such as material joining are necessary technologies in many manufacturing industries [4]. Nonetheless, most products, machines, or structures are put together and fastened from parts to create highly reliable devices, and the joining of these parts can be done using rivets, seaming, clamping, soldering, brazing, welding, or the use of adhesives[5]. Moreover, many factors influence decisions, ranging from production costs to mechanical properties like strength, vibration damping, durability[6], corrosion or erosion resistance, and the ability to correct defects. Nevertheless, mechanical joining, welding, and adhesive bonding are the three main types of joining processes[7, 8]. Besides, fusion welding, brazing and soldering, and solid-state welding are all types of welding[9]. Also, melting occurs in both the workpieces and the filler material for metals and plastics. Brazing and soldering are methods of joining materials that involve adding melted filler material between the joined surfaces [10]. Because it only involves plastic deformation and diffusion, solid-state welding does not necessitate melting the filler material's base [11, 12]. However, every manufacturing process must be improved and innovative with modern technologies and increasing product quality demands. Also, when one thinks of the welding process, one immediately thinks of the Arc, Spatter, weldment, Weld bead, and surface finish [13]. The input process parameter significantly impacts weld joint quality [29, 30]. Meanwhile, controlling the input process parameters is a common issue for the manufacturer to achieve a good welded joint with the required weld quality. Historically, skilled operators or engineers chose parameters through trial and error, which is time-consuming for each new welded product to obtain a welded joint that met the required specifications. However, weldments are evaluated to see if they adhere to the specifications [16]. Nowadays, it is common practice to use computational networks, design of experiments (DoE), and evolutionary algorithms to create mathematical relationships between welding process input parameters and weld joint output variables to determine the welding input parameters that lead to the desired weld quality[27].

There are numerous methods for evaluating materials, such as metals and engineering material components, but non-destructive methods are a significant category with numerous applications[18]. Non-Destructive Evaluation (NDE) or Non-Destructive Testing (NDT) is the identification and characterization of damages on a welded portion [19], surface, and interior of material without cutting it apart or otherwise altering it [20]. In other words, NDT refers to evaluating and inspecting engineering materials components to characterize or find defects and flaws compared to some standards without altering the original attributes or harming the tested object [21]. NDT techniques are a low-cost method of testing a sample for individual investigation or checking the entire material in a production quality control system [28]. Besides, welded joint surface from the welding electrode is necessary to obtain reliable NDT assessments of aluminum joints [23]. These artifacts have various welded joints that form the complete artifacts. The operations of the artifacts are associated with vibrations, rotations, etc.

Moreover, if the welded joints have defects internally [24] during fabrication, there is a tendency for deformation to occur within that defected zone. So, there is a need to conduct an assessment of the quality of weldment joints using NDT techniques on the weldment done by the artisans at Kokompe in Sekondi-Takoradi Metropolis. In testing the materials, a wide range of NDT methods is used. This research article gives an overview of the need for various NDT Non-Destructive Proved and the evaluation procedures used for weldment that can be used in various applications such as shipping, construction, and railway industries. Firstly, this study focuses on NDT techniques for inspecting. Secondly, this study aims to determine the response of various NDT techniques for detecting weldment defects and also assesses the welding quality of welded Tee joints by artisans from some selected fabrication shops at Kokompe in Sekondi-Takoradi Metropolis in Ghana's Western region. Finally, the study's objectives are to assess and identify defects in the weldment joint using NDT and determine whether the weldment joint meets the code of acceptance.

2. Experimental Methods and Materials

2.1. Experimental Design

The experiment used three (3) specimens of joints (Tee joints) and welded using a manual metal arc welding (MMAW) process with an alternating current machine (ACM). The materials samples selected for the experiment are Ferro-magnetic materials because of the chosen measurement and analysis tools used to assess the quality of the welded joint. Mild carbon steel material samples with dimensions of 75mm × 50mm × 10mm were chosen for the formation of the experiment's specimen joints. Besides, four non-destructive methods were chosen for the experiments, namely, visual testing (VT), liquid penetrant testing (LPT), magnetic particle testing (MPT), and radiography inspection or testing (RT). Three measurement tools (VT, LPT, and MPT) produce results when the discontinuities or flaws are visible and open to the surface, while the RT produces results when the discontinuity is on both the surface and subsurface. The experiment considers the E6013 and E4310 electrodes based on the material, type of weld, welding current, and voltage.

2.1.1. Material Properties

Mild steel was selected for the analysis with a carbon content between 0.16% and 0.29 % maximum with a relatively high melting point between 1450°C to 1520°C. Tables 1 and 2 display the chemical composition and mechanical properties of the material sample chosen [25]:

Table 1. Chemical composition of mild steel (experimental specimen)

Element	Content
Carbon, C	0.14 – 0.20 %
Iron, Fe	998.81 – 99.26% (as remainder)
Manganese, Mn	0.60 – 0.90 %
Phosphorous, P	≤ 0.040 %
Sulfur, S	≤ 0.050 %
Carbon, C	0.14 – 0.20 %

Table 2. Mechanical properties of mild steel (experimental specimen) [26]

Mechanical properties	Metric	Imperial
Tensile Strength, Ultimate	440 MPa	63800 psi
Tensile Strength, Yield	370 MPa	53700 psi
Elongation at Break (In 50 mm)	15.0 %	15.0 %
Reduction of Area	40.0 %	40.0 %
Modulus of Elasticity (Typical for steel)	205 GPa	29700 ksi
Bulk Modulus (Typical for steel)	140 GPa	20300 ksi
Poisson's Ratio (Typical For Steel)	0.290	0.290
Machinability (Based on AISI 1212 steel. as 100% machinability)	70 %	70 %
Shear Modulus (Typical for steel)	80.0 GPa	11600 ksi

2.1.2. Material Preparation

A power hacksaw machine Ercole 280 (PS01) with the following specifications was selected to facilitate the cutting of the material samples. Besides, weight approx.: 900 kg, saw blades number: 5, angular cut degrees: +45, length of saw blade: 575 mm, motor 380 volt, power: 3 ps, cut range round diameter: 320 mm, strokes per minute number: 6, size of machine width/depth/height approx.: 1850 x 800 x 1600 mm, a speed of 7 strokes per minute is utilized in this study. The material size is 150 mm × 100 mm × 10 mm.

2.1.3. Surface Preparation of Samples

The samples obtained were taken to the workshop and held in bench vice in support of soft jaws to prevent dents on the material surface. A smooth file single cut was initially used for deburring for square corners and for removing the rust on the surface first. After a DESC Blue Emery Clothe Sheet, 230 ×280 mm (9" ×11") Grit P60 (Grade 2) was used for the surface finish.

2.1.4. Welding Procedure of Sample Material

The sample materials were taken to welding artisans for welding. MMAW was chosen as the Tee-joint welding process for the weldment. The artisans used two different types of electrodes for the Arc welding process.

- Carbon Steel Electrodes/Low Alloy Steel Electrodes, as defined by AWS E4310. 2.5 mm/3.2 mm/4.0 mm/5.0 mm diameter, 300 mm, 350 mm, 400 mm length, titanium electrode coating, welding current – 80 – 90 a, voltage – DC+ is employed in the process.
- AWS E6013 - Carbon Steel/Low Alloy Steel Electrodes. Diameter of 2.5 mm/3.2 mm/4.0 mm/5.0 mm, length: 300 mm, 350 mm, 400 mm, welding current: 50-90A, voltage: AC 50V, DC+ is equally employed. Moreover, the machines' current and voltage were based on the material and electrode. However, the sample materials were held on a welding plate, and the arc welding process was completed successfully at all shops visited, and an engineering square was used to check for correct edges.

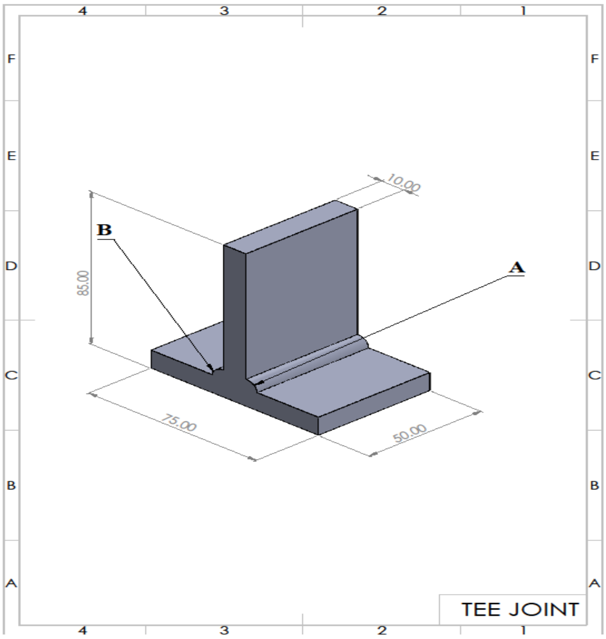

Fig. 1 Graphical illustration of the welded sample joint specimen.

2.1.5. Sample Preparation and Testing Flow Chart

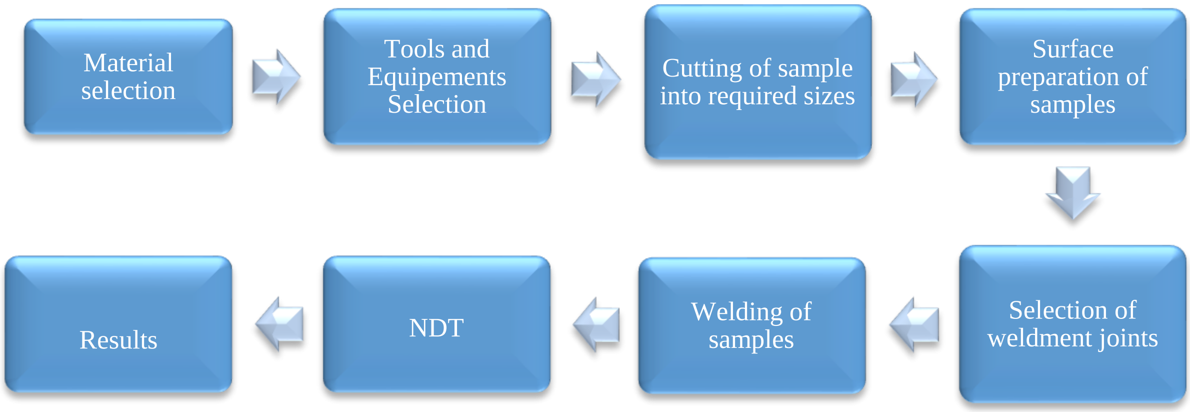

Fig. 2 Sample preparation and testing flow chart

2.1.6. Number of Sample Joints Selected

A total of six (6) 75 × 50 × 10 mm material samples were selected after the cutting process to produce tee welded joints. Meanwhile, out of the six (6) samples selected, three (3) welded samples were produced.

2.2. Measurement and Analysis Tools

2.2.1. Measurement Processes

The welded joint must be inspected and measured for quality and reliability. Besides, a visual inspection can detect undercuts, uncertified craters, surface cracks, lack of fusion, flows, and other defects. Meters of welded joints and welding templates were used to determine the size of joints, joint width and height, bevel angle, preparation depth, and width, including angle, root gap, root face depth, convexity, and leg length. The experiment was carried out using four of the six commonly used NDT evaluation methods: visual, liquid penetrant, magnetic particle, and radiography.

2.2.2. Analysis Tools

The analysis tools for NDT evaluation are selected based on the kind of joint and flaw to be detected. However, four different methods were used for the experiment to evaluate the samples, and the tools for each test method were also different.

2.2.3. Visual Testing

Visual inspection (VT) relies upon detecting surface imperfections using the eye. VT is generally applied without any other equipment, but its effectiveness and scope can be enhanced by using aids such as a magnifying glass. The basic requirement of VT is a good vision, good lighting, and experience to be able to recognize problems.

2.2.4. Liquid Penetrant Testing

Further testing with liquid penetrants yielded more concrete results. The experiment used a water-soluble visible penetrant. ABRO products were chosen for liquid penetrant testing. Moreover, water washable red dye penetrant – ARDOX 907 PB 400ml, Penetrant remover/solvent cleaner – ARDOX 9PR5 400ml, and Non-aqueous developer – ARDOX 9D1B 400ml were considered in this study. The ARDOX 907 PB penetrant was sprayed on the surface of the pre-cleaned welded samples. The penetrant was allowed to dwell on the surface for approximately five (5) minutes. Afterwards, an ARDOX 9D1B non-aqueous developer was sprayed onto the penetrant for a maximum of ten (10) minutes to help detect flaws. Besides, after a visual inspection is applied for flaw determination. Finally, the welded samples were cleaned with ARDOX 5319 remover.

2.2.5. Magnetic Particle Inspection

The magnetic particle inspection aids in the detection of surface and subsurface flaws up to a depth of 6mm. The magnetic dye pigment was chosen as ARDOX 8903W white contrast paint. An alternating current (AC) and direct current (DC) yoke was used to generate the magnetic field for the experiment because it produces both a longitudinal and circular magnetic field. Nonetheless, half-wave direct current (HWDC) is the most effective for creating subsurface and surface flaws. The test procedure was as follows: The welded samples were pre-cleaned, magnetic media (magnetic dye pigment) was applied, the yokes introduced magnetic particles, and magnetic particle indication was interpreted visually.

2.2.6. Radiography Testing

The study adopted x-ray radiation using a current of 5 mA and a voltage source of 250 kVA since it has a low radiation risk compared to gamma rays. An x-ray exposure time of 0.4mins with geometrical unsharpness of 0.51 was used. This was selected based on the density and thickness of the material. Also, a focal spot size of 2×2 was selected using a 600 mm source to film distance. The specification selected was ASME SEC V, using a single weld single image technique (SWSI). A KODAK type of AA 400 film with a size of 100 × 125 mm lead screen with a density range of 1.8 – 4 was selected. However, a penetrometer with a specification of ASTM 1A06 was used to develop the x-ray film at a time of 5mins at 20°C. Furthermore, film sensitivity is 2% on a wire-type image quality indicator (IQI).

2.2.7. Welding code of Acceptance Criteria Adapted

The experimental specimen is steel, and the defect acceptance criteria used for the study is the AWS code for structural steel. This code specifies the specifications for the fabrication and erection of welded steel structures. This code covers steel with a thickness of 1/8 inch (3.2mm) or greater. The majority of the provisions in this code are mandatory when specified in a contract. Furthermore, AWS D1.1/D1.M 2010 clause 6, inspection for VT, MPI, DPI, and AWS D1.1:2000 is the code parts used. Inspections are performed by structural steel code 6.0 (part C) and 6.12 for radiographic inspection.

3. Discussion of Experimental Data

3.1. Experimental Data Presentation

The results are presented considering the proposed objectives outlined in the research. The data acquired from the experiment are presented in table 3, according to the joint and NDT technique used.

3.1.1. Data Presentation for Tee joint (Visual Inspection)

Table 3 displays Tee joint visual inspection results for visual inspection. The result indicates that all three welded specimens and parts labeled A (front side) and B (backside) showed defects for analysis under the acceptance code. Also, for the T1 joint, both parts showed a lack of fusion, slags, and surface depression. Besides, Joint T2 had both faces showing overlaps, undercut, and surface depression. Finally, joint T3 had faces recording under-fill, undercut, and depressions. Compared with the acceptance criteria code adopted, all three tees welded joints were unacceptable per the welding standard code and must be rejected.

Table 3. Visual inspection results of tee joint

SPECIMEN	LOCATION FROM O (mm)	LENGTH (mm)	DEFECT	RESULTS
T1 A	0-5	5	LACK OF FUSION	REJECT
	0-30	20	LACK OF FUSION/SLAGS	REJECT
	0-40	10	DEPRESSION	REJECT
T2 A	0		OVERLAP	REJECT
	0-39	10	UNDERCUT	REJECT
	0	10	DEPRESSION	REJECT
B	0-40	5	UNDERCUT	REJECT
T3 A	0		DEPRESSION	REJECT
	0-46		OVERLAP	REJECT
B	0-8	39	LACK OF FILL	REJECT
	0-30	15	UNDERCUT	REJECT
	0-40	5	DEPRESSION	REJECT

Key: T1- Tee joint specimen 1, T2- Tee joint specimen 2, T3 – Tee joint specimen 3

Figure 3 shows Visual Inspection, and table 3 displays the results obtained from the inspection of the tee welded joint specimen visually. For easy identification and presentation of results, the tee joints were also coded according to the number of specimens chosen. The nature of the tee joints produced two welded parts which were also given labels as parts A and B, where A represents the front and B for the backside, as shown in the results presented in table 3. After the visual inspection, all three welded specimens and parts labeled A and B showed defects recorded for analysis under the acceptance code. For the T1 joint, both parts showed a lack of fusion, slags, and surface depression.

Fig. 3 Visual Inspection

Moreover, Joint T2 had both faces showing overlaps, undercut, and surface depression. Finally, joint T3 had faces recording underfill, undercut, and depressions. It was observed that the weldment joint surface from the welding electrode was necessary to obtain reliable NDT assessments of steel Tee-Joints. Per careful comparison with the acceptance criteria code adopted, all three tees welded joints are unacceptable per the welding standard code and must be rejected.

Figure 4 shows the Dye penetrant inspection results of the tee joint, and table 4 displays the results obtained from the inspection of the tee joint welded specimen; again, for easy identification and presentation of results, the tee joints were coded according to the number of specimens chosen. The nature of the tee joints produced two welded parts which were also given labels as parts A and B, as shown in the results. After conducting the dye penetrant inspection, all three welded specimens and parts labeled A and B showed rounded and linear indications defects recorded for analysis under the acceptance code. Per careful comparison with the acceptance criteria code adopted, all three welded joints are unacceptable per the welding standard code and must be rejected except for specimen T1 and part B, which recorded a defect within the standard of acceptance. It implies that the weldment joints were not done under acceptable welding processes.

Figure 5 shows Magnetic particle inspection, and table 5 displays the results obtained from a magnetic particle inspection of the tee welded joint specimen; again, for easy identification and presentation of the results, the tee joints were coded according to the number of specimens chosen. The nature of the tee joints produced two welded parts, which were also labeled as parts A and B, as shown in the results in table 5. After conducting the magnetic particle inspection, all three welded specimens and parts labeled A and B showed defects such as lack of fusion, undercuts, and cracks recorded for analysis under the acceptance code. Nonetheless, it was detected that the weldment joint surface from the welding electrode was essential to obtaining reliable NDT assessments of steel Tee-Joints. Per careful comparison with the acceptance criteria code adopted, all three welded joints are unacceptable per the welding standard code and must be rejected. This implies that the weldment joints were not done under acceptable welding processes.

Fig. 4 Dye penetrant inspection results of tee joint

3.1.2. Data presentation for Tee joint (Dye penetrant inspection)

Table 4. Dye penetrant inspection results of tee joint

SPECIMEN	LOCATION FROM O (mm)	LENGTH	DEFECT	RESULTS
T1 A	0	15	ROUNDED INDICATION	REJECT
	0-30	20	ROUNDED INDICATION	REJECT
B	0-50	5	ROUNDED INDICATION	ACCEPT
T2 A	0	10	ROUNDED INDICATION	REJECT
	0	15	LINEAR INDICATION	REJECT
B	0-45	6	ROUNDED INDICATION	REJECT
T3 A	0-47	10	ROUNDED	REJECT
			INDICATION@SIDE	REJECT
	0-10	7	ROUNDED INDICATION	REJECT
B	0-30	15	ROUNDED INDICATION	REJECT

RI= ROUNDED INDICATION LI= LINEAR INDICATION NI =NEAR INDICATION
Key: T1- Tee joint specimen 1, T2- Tee joint specimen 2, T3 – Tee joint specimen 3

3.1.3. Data presentation for Tee joint (Magnetic particle inspection)

Table 5. Magnetic particle inspection results of tee joint

SPECIMEN	LOCATION FROM O (mm)	LENGTH (mm)	DEFECT	RESULTS
T1 A	0	6	LACK OF FUSION	REJECT
	0-8	12	UNDERCUT	REJECT
	0-30	13	LACK OF FUSION	REJECT
	0-45	5	LACK OF FUSION	REJECT
B	0-35	15	UNDERCUT	REJECT
	0-42	8	LACK OF FUSION & DEPRESSION	REJECT
T2 A	0	7	CRACK/LACK OF FUSION/DEPRESSION	REJECT
	0	5	LACK OF FUSION	REJECT
B	0-40	7	UNDERCUT	REJECT
	0-43	5	LACK OF FUSION	REJECT
T3 A	0	6	LACK OF FUSION/DEPRESSION	REJECT
	0-33	6	UNDERCUT	REJECT
B	0-7	37	LACK OF FUSION	REJECT
	0-41	5	POOR START	REJECT

3.1.4. Data presentation for Tee joint (Radiography inspection)

Table 6. Radiography inspection results of tee joint

JOINT CODE	WELDER NO.	SIZE/ DIA	SCH/WT	DENSITY	SEGMENT	OBSERVATIONS	RESULT
T1			10 mm		A	LOF@1-2cm,4cm	REJECTED
					B	NRI	ACCEPTED
T2			10 mm		A	UC@0-5cm	REJECTED
					B	LOF@4.5-5cm, Slag@1cm	REJECTED
T3			10 mm		A	NRI	ACCEPTED
					B	PO@0.5cm	ACCEPTED
NOTE:- NRI = NOT RECORDABLE INDICATION, UC =UNDERCUT, SM = SCREEN MARK. LOF = LACK OF FUSION/LACK OF FILL, LOP = LACK OF PENETRATION , PO = POROSITY, CP=CLUSTER POROSITY, UG = GEOMETRICAL UNSHARPNESS; SFD = SOURCE TO FILM DISTANCE EP=EXCESS PENETRATION RUC=ROOT UNDERCUT EUC=EXTERNAL UNDERCUT Cap dep= CAP DEPRESSION WI=WELD IMPRESSION RC=ROOT CAVITY							

Key: T1- Tee joint specimen 1, T2- Tee joint specimen 2, T3 - Tee joint specimen 3

Figure 6 shows the radiographic inspection, and the results of Table 6 illustrate an x-ray radiographic inspection performed on three tee weldment specimens. For specimen T1, the first part indicated a lack of fusion at sizes 1-2 cm and 4 cm from the reference, but part B of specimen T1 had no recorded indication. Again, specimen T2 indicated undercuts, lack of fusion, and slag inclusions on the part of A, but there were no recorded indications in part B. Furthermore, specimen T3 had no indications at part A, but there are indicated porosities at a size of 0.5 cm at part B. Moreover, after a comparison of the flaws obtained on various weldments with acceptance criteria;

- ✓ Part A of specimen T1 was rejected, but part B was accepted.
- ✓ All parts of specimen T2 were rejected
- ✓ All parts of specimen T3 were accepted as a good weldment.

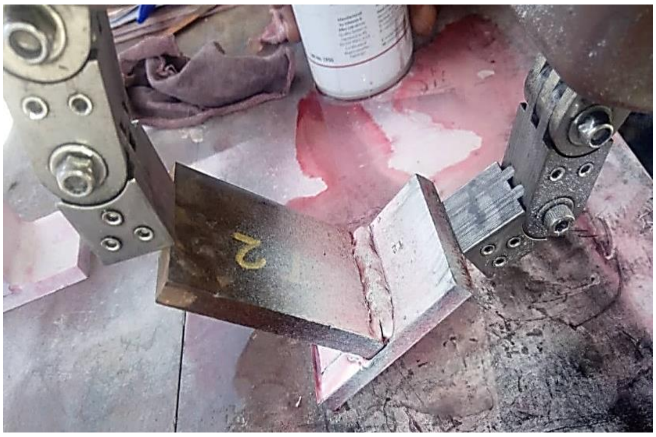

Fig. 5 Magnetic particle inspection

Fig. 6 Radiographic inspection.

3.1.5. Discussion

The main aim of the research work was to assess the quality of the weldment joint using selected Non-Destructive Testing (NDT) in selected fabrication shops in Takoradi-Kokonpe in the Western Region of Ghana. Tee-welded joints were selected and coded according to the joint. After conducting the NDT test on various welded joints, the results were recorded based on standards that either reject or accept the welded based on the defect present. Table 7 captions the summary of all accepted and rejected results obtained based on the standard criteria under the American Welding Society (AWS) codes.

3.1.6. Defects on Weldment Joint using Selected NDT Techniques

As shown in Table 7, the selected NDT techniques found a total of rejected and accepted defects. VT, MPI, DPI, and RT were used for NDT. Three techniques only detect surface defects, while the fourth can detect subsurface defects. Nil for VT and MPI, 1 and 3 for DPI and RT. The specimen chosen for the experiment is steel, and the code used to analyze the defects is classified as structural steel. As per AWS D1.1/D1.M 2010 clause 6, most defects found during VT, MPI, and DPI testing must be rejected based on the code. The test revealed undercuts, underfills, lack of fusion, lack of penetration, porosities, surface depressions, and rounded and linear indications that were roughly above the code's acceptance value. Again, the ASME section V and AWS D1.1:2000 acceptance codes were used. Code 6.0 structural steel (part C) and 6.12 radiographic inspection compared to the code selected for analysis, flaws like lack of fusion, undercuts, slag inclusions, and porosities were the above-accepted criteria. Overall, all-welded samples collected and tested must be rejected due to defects exceeding the AWS D1.1:2000 structural steel code 6.0 inspection (part C) and 6.12 radiographic inspection acceptance code.

Table 7. Summary of rejected and accepted defects based on AWS standards

NDT Test Technique	Joints	Accepted	Rejected
Visual Inspection	Tee	Nil	12
Dye penetrant inspection	Tee	1	9
Magnetic particle inspection	Tee	Nil	14
Radiography inspection	Tee	3	3

3.1.6. Ascertaining Whether the Weldment Joint Specimen Meets the Specification of Acceptance

Based on the assessment criteria code AWS D1.1/D1.M 2010 clause 6 used for VT, MPI, and DPI and also, AWS D1.1:2000 Structural steel code 6.0 inspection (part C) and 6.12 radiographic inspection, the welded joints specimen from the various shops failed after the assessment of the various welded joints in the course of conducting the research practice. Thus the welding of the specimen at the various selected workshops, the researcher observed that;

- ✓ Most of the artisans (welders) do not have their welding electrodes stored in ovens as required by welding processes.
- ✓ The artisans do not set the current and voltage as per the material and electrode to be used.
- ✓ The electrode used is selected based on the material to be welded.
- ✓ Lack of adequate skills.

4. Conclusion

The research or study aims to assess weldment joint quality using NDT in selected fabrication shops in STMA-Kokompe. Three significant themes guided the research. The first theme examines the quality of the weldment joint using selected NDT techniques, the second theme compares the test results to an AWS code of acceptance, and the third theme examines the impact of joint type on weldment quality. From the research findings, it can be concluded that the experimental method used produced the required results for the specimen tested. All three (3) samples tested had significant flaws or discontinuities in the artisans' weldment. The accepted welded parts were minor indications that did not directly affect the welding part. Less than acceptable AWS structural code flaw indications include a lack of fusion, undercuts, slag inclusion, rounded indications, linear indications, and porosities. However, these discontinuities will cause internal stress and machine component failure if not detected and corrected. According to the research, the causes of flaws are as follows:

- Improper storage of welding consumables
- Improper regulation of current and voltage to suit prescribed material
- Low knowledge of the selection of prescribed electrodes based on material.
- Lack of adequate skills.

Also, the study revealed that most of the artisans' work produced at the selected shops does not meet the standard as per the AWS structural steel code of acceptance.

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