American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS)
ISSN (Print) 2313-4410, ISSN (Online) 2313-4402

http://asrjetsjournal.org/

Analysis of Skills Needs in Repair Welding of Low-Alloy, High Tensile Steels Using the Manual Metal Arc Welding (MMAW) Process

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Abstract

There is actually critical skills gap in repair welding of low-alloy, high tensile steels among welding craftsmen within the Tamale metropolis. A skills gap is perceived to be the difference between the skills needed and the skills already acquired. This study seeks to analyze the skills gap in the repair welding of low-alloy, high tensile steels component parts in the informal sector within the metropolis, especially when using the MMAW process. A total of 120 questionnaires including structured interview were then administered to welding craftsmen. However, 111questionnaire were returned, representing a response rate of 92.5%. Welders perceive that a lot of repair welding is present in both automotive and structural steel industries (87.7%). The study was posed to determine whether welders were able to make the right choice of electrode for low-alloy steel welding. Also to find out whether level of education of the welder or age in the profession influences one's ability to weld low-alloy steel successfully. The study revealed that those who could not identify the right electrode for low-alloy steel welding were at the higher side. The inferential statistics output indicated that quality of weld is independent of level of education, likewise age in the welding profession. It is therefore recommended that artisanal training be organized for welding craftsmen within the metropolis in order to address this critical gap. Education institutions could take up this challenge to ensure that they offer the requisite skills to this category of welders who had not passed through technical education. It is also recommendable to ensure that repair welding of alloy steels in its entirety be given a place in the technical curriculum.

Keywords: Electrode; Low-Alloy High tensile Steel; Manual Metal Arc Welding (MMAW); Repair Welding; Skills Gap;Tamale Metropolis.

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1. Introduction

Repair welding of low-alloy, high tensile steel calls for an enterprising and experience welder. This occupation is perceived to be highly lucrative, especially within the automotive and structural steel industries. However, there are all indications that the industry is bedeviled with skills shortage within the Tamale metropolis. It is very common to find in the Metropolis heavy-duty automotive machinery such as the wheel loaders, track loaders, forklifts, combine harvesters, cranes, road graders, bulldozers, tractors, tipper trucks, articulated trucks and farm implements of various kinds. More often than not, component parts of this machinery are made of alloy steels to withstand certain forces such as wear by impact, wear by abrasion or wear by corrosion, and to resist certain failures such as creep and fatigue. It is evident that adding alloying elements to steel increases tensile strength, hardness and toughness, and obviously component parts with these characteristics can be welded only with some kind of expertise. It is observed that there is skill shortage within the metropolis when the need arise for alloy steel welding. This study focuses on the analysis of skills gap that exists on repair welding of low-alloy, high tensile steels within the metropolis. Skills gap analysis is seen as an evaluation tool for determining training needs of an individual, group or organization. A gap is believed to be the difference between the skills needed and the skills already acquired. It is a perceived mismatch between the needs of employers for skilled talent and the skills possessed by the available workforce. The first step in performing an analysis is to identify all the skills required by an individual to carry out their job role effectively [1]. Skills gap is defined as a significant gap between an organisation's current capabilities and the skills it needs to achieve its goals [2].

1.1 Alloy Steels

Alloy steel may be defined as steel which owes its properties to the presence of elements other than carbon, manganese up to 1.1% and silicon up to 0.5% [3]. The chief alloying elements which are added to iron and carbon to produce alloy steel are nickel, chromium, manganese, molybdenum, tungsten, vanadium, copper and silicon. The purpose of the alloying elements is to give the steel a distinct property which in every case is to increase its toughness, hardness or tensile strength, and to give cleaner and more wear-resistant castings [3]. Alloy steel is often subdivided into two groups: high-alloy steels and low-alloy steels. The difference between the two alloy-steels is defined somewhat arbitrarily. However, most agree that any steel that is alloyed with more than eight percent of its weight, being other elements beside iron and carbon, is high alloy steel. Low alloy steels are slightly more common. The physical properties of these steels are modified by the other elements, to give them greater hardness, durability, corrosion resistance, or toughness as compared to carbon steel. If the carbon level in low-alloy steel is in the medium to high range, it presents some difficulties during welding. If however the carbon content is lowered to a range of 0.1% to 0.3%, and some of the alloying elements are reduced, the steel can achieve greater weldability and formability while maintaining the strength that the steel is known for. Such metals are classified as low-alloy, high tensile steels [4]. However, steels are arbitrarily divided into five groups: Plain carbon steels (low carbon steel, Medium carbon Steel and High carbon Steel), alloy steels (sometimes referred to as low-alloy steels), stainless steels, tools steels, and special-purpose steels [5].

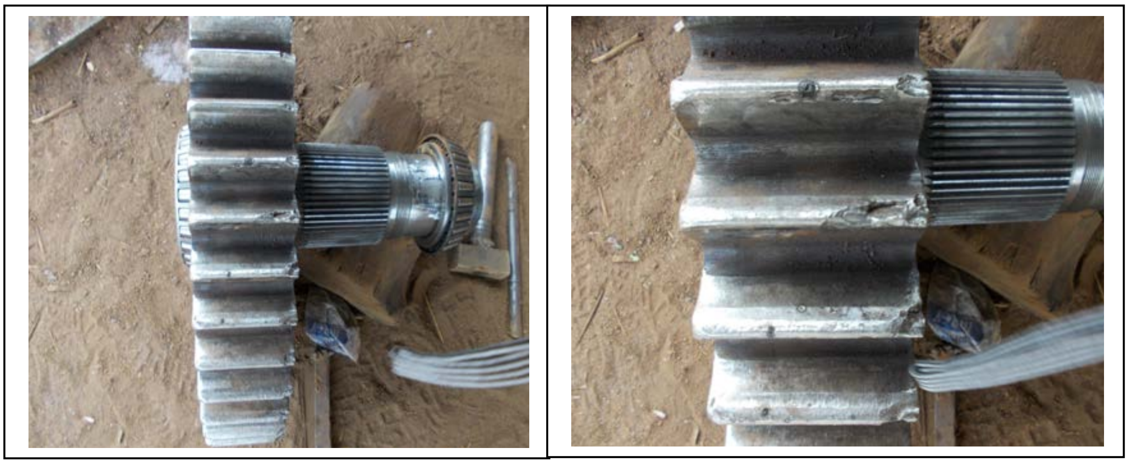

Figure 1: Hub gear of Bulldozer to be Rebuilt Using the Thj506 or E7018 Electrode

1.2 Low-Alloy Steels

Low-alloy, high-tensile steels are widely used because of high yield strength, low carbon content and good weldability. However, welding heat of the MMAW process changes the mechanical properties and microstructure of the weld metal, also the heat-affected zone (HAZ) could be easily modified as reported [6],example, developments such as welding softening, residual stresses and grain coarsening could happen could occur. Welding softening often generates low strength and poor fatigue behavior. High tensile stress leads to loss of performance in fatigue. It is found that restraints had important influence on residual stresses distribution of welded component, e.g. additional restraint increased the value of stresses [7, 8]. It is known that tensile overload considerately increased the total fatigue life [9]. Compressive residual stress is the main cause of fatigue crack growth retardation, and that the grain coarsening and precipitation in the HAZ reduces its toughness and fatigue strength [10]. The low-alloy, high tensile steel group of alloy steels have brought about many desirable properties which may be regarded as better than that of plain carbon steel [4], these produce higher yield point, toughness and tensile strength, at the same time maintaining adequate ductility. Typical elements include manganese, silicon, nickel, chromium, molybdenum and vanadium. Generally these steels possess welding properties similar to carbon steels and care must be taken to avoid hardening. In this category of steels carbon equivalent plays a significant role in determining the aggregate percent of alloying elements. Low alloy steels are so called because, besides iron, carbon, silicon and manganese, they include other alloying elements such as (Cr, Mo, Ni, etc.) but usually in cumulative proportion under 5%. To achieve this, usually use is made of the carbon equivalent formula:

$$CE\% = C\% + \frac{Mn\%}{6} + \frac{Cr\% + Mo\% + V\%}{5} + \frac{Ni\% + Cu\%}{15}$$

Where CE is Carbon Equivalent and C is carbon, Mn is manganese, Cr is chromium, Mo is molybdenum, V is vanadium, Ni is nickel and Cu is copper. The combined effect of all these elements should not exceed 5%. The group of low-alloy steels with which this study is concerned is those that are hardenable by heat treatment. In effect these are low-alloy, high tensile steels. Low-alloy steels should not be confused with high-alloy steel groups such as 18/8 austenitic stainless steels.

Figure 2: Repair Works on Pinion Bearing of Caterpillar Using E7018 Electrode

Source: personal visits to welding craftsmen

When welding is carried out cold on low-alloy, high tensile steels, hardening occurs in the heat affected zone, caused by rapid rate of cooling. This implies that preheating promotes slow cooling after welding. A typical example of an alloy steel which possesses the properties of weldability constitute 0.1% carbon, 0.7% manganese, 0.3% nickel and 0.3% molybdenum. Molybdenum has the effect of reducing brittleness throughout the entire range of cooling, therefore assisting in the retention of ductility [4]. Molybdenum is usually included in the electrode to assist in reducing the cracking risk associated with the welding of low-alloy, high tensile steels.

Figure 3: Back-hold Driller: Pieces Formed By Lathe. E6010electrode for Penetration and E7018 for Build Up

1.3 Heat Treatment of Alloy Steels

Heat treatment in welding is either carried out before welding (pre-heat) or carried out after welding (post-heat). Preheat is used to reduce the rate at which welds cool, slower rate of cooling allows the contraction stresses to spread throughout the HAZ, or else it can result in cracking. usually preheat provides two beneficial effects; it lowers residual stresses and reduces cracking [11]. If a welded alloy steel component is allowed to cool very fast, brittle effects of a rapid quench will result, causing the possibility of cracking. In the course of welding these steels, hardening and brittleness occur in the heat affected zones on either side of the weld. To avoid the possibility of cracking preheating may be carried out using the oxyacetylene torch, furnace or any appropriate heat source for preheating. It is pertinent to understand that cracking phenomenon decreases the lifetime of weld repaired components drastically. This is why it is important to understand the factors affecting crack nucleation and propagation during welding, and to optimise the welding process to prevent cracking [12]. The preheat temperature of alloy steels is usually between 150^0C and 300^0C which, largely dependent on steel thickness and chemical composition. Without preheat before welding, it is likely to result in a failure. This is carried out at times to remove internal stresses in the work caused by shrinkage stresses (contraction) during the cooling of the component, in this situation the stresses are more evenly distributed throughout the heat affected area. Post-heat treatment also promotes slow rate of cooling, for that matter avoiding hard and brittle zones in the weld. Underbead cracking is as a result of hydrogen being trapped in the heat affected zone, especially when the structure produces martensite along side contraction stresses. This comes about as a result of rapid cooling after welding low-alloy, high tensile steel.

1.4 Application of MMAW in Repair Welding

The type of arc welding process commonly used in the Tamale Metropolis is the Manual Metal Arc Welding (MMAW). It is also known variously as Shielded Metal Arc Welding (SMAW), Flux Shielded Arc Welding or informally as the Stick Welding. This is a manual arc welding process that uses a consumable electrode, coated in flux to lay the weld. An electric current, in the form of either alternating current or direct current from a welding power supply, is used to form an electric arc between the electrode and the parent metal. The MMA process is widely used and produces excellent results in the welding of low-alloy steels. It is against this background that this survey takes sole cognizance of MMAW process in the study area to examine the extent to which this process is used to achieve optimal results in repair welding of low-alloy steel. In MMAW, electrodes extensively used in welding low-alloy, high tensile steels possess a core wire; the hydrogen controlled type is used. This is to prevent hydrogen being absorbed into the weld metal resulting in a brittle weld. This study considers two category of electrodes, thus those with low tensile and those with high tensile strength, designated as E60 and E70 respectively. The E70 electrodes are predominantly used in welding alloy steels, this is to increase or maintain the tensile characteristic of the weld metal. Table 1 and 2 present a simple outline of the electrodes.

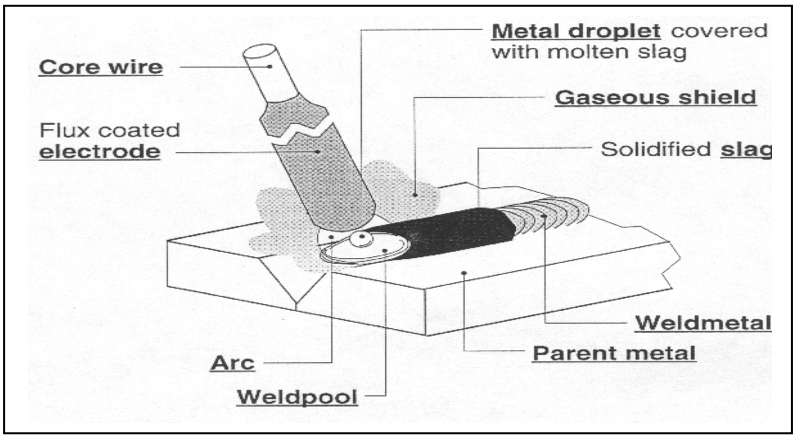

Figure 4: A diagrammatic sketch of a Manual Metal Arc Welding. **Source:** (IAEA, 2001)

Table 1: E60 Series of Electrode Classification

Classification	Type of Covering	Welding Position	Type of Current
E6010	High cellulose sodium	F, V, OH, H	DC, reverse polarity
E6011	High cellulose potassium	F, V, OH, H	AC or DC reverse polarity
E6012	High titania sodium	F, V, OH, H	AC or DC straight polarity
E6013	High titania potassium	F, V, OH, H	AC or DC either polarity

Table 2: E70 Series of Electrode Classification

Classification	Type of Covering	Welding Position	Type of Current
E7014	Iron powder, titania	F, V, OH, H	AC or DC either polarity
E7015	Low hydrogen sodium	F, V, OH, H	DC reverse polarity
E7016	Low hydrogen potassium	F, V, OH, H	AC or DC reverse polarity
E7018	Low hydrogen potassium, iron powder	F, V, OH, H	AC or DC reverse polarity

Source: Jeffus, 1993

Considering the American Welding Society (AWS) classification, the abbreviations F,V, OH and H stand for the following positions: F =Flat, V =Vertical, OH= Overhead and H= Horizontal. AWS classification for carbon steel covered arc electrodes is A5.1 and that of low alloy steels is 5.5. Generally electrodes are identified by a system of classification: Example E7018 where E stands for electrode, 70 stands for high tensile strength, 1 stands for welding position and 2 stand for welding current. These electrodes have moderate penetration and build up.

1.5 Repair Procedure

When a repair welding procedure is required, the procedure shall be established and qualified to demonstrate that a weld with suitable mechanical properties and soundness can be produced. This shall be determined by destructive testing and the type and number of such tests shall be at the discretion of the welding enterprise. The repair

procedure, as a minimum, shall include the following [14]: Method of exploration of the defect, method of defect removal, the repair groove shall be examined to confirm complete removal of the defect, requirements for preheat and interpass heat treatment, welding processes and other specification information, requirement for interpass nondestructive testing.

Before Repairs After Repairs

Figure 5: Repair Welding on **Tilting Arm of Dozer** Using E7018 for Build-up and E6010 for Penetration

Proven welding techniques that are procedurally correct and metallurgically sound involve the following factors: Characteristics of the alloy type; Choice of filler material; Preparation of the weld cavity or joint; the welding process to be used; Preweld and postweld heat treatment; Methods of demonstrating weld quality [15].

2. Statement of the Problem

Majority of welding craftsmen in the informal sector within the Tamale metropolis still lack the requisite skills for welding low-alloy, high tensile steels, especially when the need for repair work arises. Even though some have been in the trade for several years and even regard themselves as “experienced”. Jobs that come in any form involving low-alloy, high tensile steel welding are always a failure to welders; as a result they regard those steels as “unweldable”. This explains, in part, why majority of welders in the informal sector within the metropolis often lose a great deal of jobs that were to their credit. Consequently, there is low-income earning on the part of those welder, and also manifest the “inexperience” of the welder within the metropolis. Apparently a very expensive component part may need to be repaired to save high cost of replacing a new one. Definitely a quality workmanship can prolong the lifetime of a repaired component at a reduced cost. The questions this research study posed were: What then was the cause of this inability to weld low-alloy steels? Was it lack of understanding about heat treatment and the right procedure in low-alloy steel welding? Or lack of selecting the right electrode for the right job?

3. Purpose of the Study

The study seeks to analyze the skills gap in the repair welding of low-alloy Steel Component parts in the informal sector, especially when using MMAW process. The study shall survey the inability of welding craftsmen in the informal sector to weld low-alloy steel components. The study seeks to find solution that can address the skills gap in the informal sector, and enhance the job prospects of the informal sector welders, via the income levels, especially within the Tamale metropolis.

4. Objectives of the Study

The objectives of this study were: To identify the demographic characteristics of welders within the metropolis; to investigate the perception of welders about low-alloy steel welding; to examine welders' ability to select the right electrode for low-alloy steel welding; also to find out whether the quality of low-alloy steel welding is influenced by level of education, or one's age in the welding profession.

4.1 Hypotheses

Ho: Quality of low-alloy steel welding is not influenced by individual's level of education.

Hi: Quality of low-alloy steel welding is influenced by individual's level of education.

Ho: Success of low-alloy steel welding is independent of one's age in the welding profession.

Hi: Success of low-alloy steel welding is dependent on one's age in the welding profession.

5. Materials and Methods

The study took place within the Tamale Metropolis, the largest city in the northern part of Ghana, and capital of northern region. The (2010) population and Housing Census indicated that the population of the metropolis now stands at 371,351 with a growth rate of 2.9. The Metropolis is divided into sub-metros such as Tamale North, Tamale central and Tamale South [16]. The southern part of the city has the highest concentration of welding craftsmen. Also there is a cluster of manufacturing industries located at this area. This survey research was conducted using the quantitative approach to solicit the views of participants. By definition, survey research method uses questionnaire or interview to collect data from a sample that has been selected to represent a population to which the finding of the data analysis can be generalized [17, 18]. The main study was preceded by visits to some prominent welding craftsmen within the study area. The total population of welding craftsmen within the metropolis was 200 and a sample of 120 was drawn based on the sample size determination table [19]. A sum total of 120 questionnaires including structured interview were then administered to welding craftsmen to collect data regarding low-alloy steel welding within the metropolis. However 111 were returned, representing a response rate of 92.5%. This research design was considered suitable since the study solicited information from welders on the work skill needs of repair welding of low-alloy, high tensile steels. The data were then analysed with the SPSS using descriptive statistics. In terms of Validation and reliability of the Instrument, The instrument was subjected to face and content validation by some experts within the faculty of engineering and built environment to identify ambiguities and proffer suggestions for improving the instrument towards meeting the objectives of the study. The experts' suggestions were taken into consideration in the final draft of the questionnaire. Validation is carried out to ascertain the appropriateness of the questionnaire items or to ensure that questionnaire is appealing to the eye and that it appears valid for its intended purpose [20, 21]. Reliability is defined as the extent to which data are free from errors and also portray consistent results [21]. For surety of reliability, the instruments were trial tested on 12 repair and fabrication welders within the metropolis.

6. Results

6.1 Demographic characteristics of welding craftsmen

This section of the results discusses the demographic profile of welding craftsmen within the metropolis. With respect to gender, the data did not been able to capture even a single woman welder within the metropolis; the welding industry is dominated by male master craftsmen. In considering age, the age distribution of welders was as follows: fourteen (14) participants, representing 12.6% had their ages between 20 – 24 years, and 23 participants, representing 20.7% had their ages between 25 – 29 years, 19 of them, representing 17.1% had their ages within the range of 30 – 34 years. Also 35 of the participants, representing 31.5% had their ages between 35 and 39, while 20 representing 18.0% were 40≥ in age. The data showed that the distribution is well spread. However, majority of the respondents were in the age range of 35 – 39, 25-29, 40 ≥ and 30-34years respectively. Exactly 14 of the participants between the age group of 20-24 recorded the lowest percentage of 12.6%. The researchers were also interested in determining the educational background of welding master craftsmen within the metropolis. Levels of education of the respondents were distributed as follows: For level of education, 17 of the participantss, representing 15.3% had basic education. Those with secondary/ technical education were 53 representing 47.7%, those with NVTI was 1only, representing 0.9%. Those with tertiary education was only 1participant, representing 0.9%, while those without formal education were 39 participants, representing 35.1% (Table 3)

Table 3: Characteristics of Respondents

Characteristic	count	percentage
Gender		
Male	111	100.0
Female	-	
Total	111	100.0
Age of Respondents in Years		
20-24	14	12.6
25-29	23	20.7
30-34	19	17.1
35-39	35	31.5
40 ≥	20	18.0
Total	111	100.0
Level of Education		
Lack of Formal Education	39	35.1
Basic Education	17	15.3
NVTI	1	0.9
Secondary/ Technical	53	47.7
Tertiary	1	0.9
Total	111	100.0

The study considers the use of MMAW process of the AC or DC type for welding within the area. Obviously this welding process is widely used (table 2). The study revealed that 107 participants out of 111 use the MMAW process of the AC type for both fabrication and repair works, representing 96.4%, while the DC registered 3participants out of 111, representing 2.7% (table 2). The study made an investigation into the preferred area of welding operation, and it revealed that 77 out of 95 participants, representing 81.1% were engaged in fabrication works. The rest of the participants, 18, representing 18.9% were engaged in repair welding of low-alloy steels (table 4).

Table 4: Type of Welding Machine and Skill Operation Area

Characteristic	count	percent
AC Welding machine	107	96.4
DC Welding machine	3	2.7
Both	1	0.9
Total	111	100.0
Preferred Skills of Operation in Welding		
Fabrication works with low-carbon steel	77	81.1
Repair welding of low-alloy steels	18	18.9
Total	95	100.0

6.2 The Perception of Repair Welding of Low-Alloy Steel

The study was posed to investigate the perception of welders regarding low-alloy steel welding.. A five point rating scale involving 5 variables was used to solicit the opinion of welders (Table 5). Welders perceive that there is a lot of repair welding involved in respect of low-alloy steel in both automotive and structural work industries. Those who rated "agree" or "strongly agree" were 74 and 19 respectively out of a total of 106; a sum total of 93 participants, representing 87.7%. Participants also disagree with the fact that repair welding is a tiresome operation; this represents a sum total of 57 for both agree options (54.3%) while 39 participants disagree, representing 37.2%. The results indicate that there is high income involved in repair welding of low-alloy steel. An overwhelming majority of 98 participants out of 107 rated the "two agree" options, representing 91.6%. In terms of special skills needed for repair welding, the "two agree options" attracted 67 and 36 respectively, an aggregate of 103 participants out of 105, representing 98.1%. In terms of special tools involved in repair welding, the two "agree options" attracted 56 and 15 respectively, an aggregate of 71 participants out of 87, representing 81.6%. Those who agree were 12, representing 13.7%(table 3).

6.3 Ability to Select the Right Electrode for Low-Alloy Steel Welding

Using a five point rating scale, the researchers tried to find out whether welding craftsmen have requisite knowledge to select the right electrode for a given job (table 6). Exactly 56 participants out of 108, representing 51.9%, indicated that they do not identify the right electrode for a given job, and 38 agree the fact that they identify the right electrode for the right job, representing 25.9%. Those who neither agree nor disagree were 24 participants, representing 22.2%. To determine whether welders were able to read the alpha-numeric coding on the electrode, an a total sum of 83 out of 105 disagree the fact that they read the coding on the electrode, representing 79.1%, while those who agree were 18 participants, representing 17.1%. Participants were asked to rate their opinion as to whether each number or digit on the electrode has an operational meaning (Table 6). Those who rated the "two disagree" options were 56 out of a total of 104, representing 53.9%, 34 participants neither agree nor disagree, representing 32.7%. However those who agreed to the fact that they can read the "electrode coding" were 14 participant, representing 13.5%.

Table 5: Perception of Low-alloy Steel Welding

5-point rating scale	SD	D	N	A	SA	Total
a.There is a lot of repair welding in the automotive industry	-	2	11	74	19	106
	-	1.9	10.4	69.8	17.9	100(%)
b. Repair welding of alloy steels is a tiresome operation	3	54	9	28	11	105
	2.9	51.4	8.6	26.7	10.5	100(%)
c. Repair welding of alloy steels generates high income	-	4	5	70	28	107
	-	3.7	4.7	65.4	26.2	100(%)
d. Repair welding of alloy steels require special skills	-	-	2	67	36	105
	-	-	1.9	63.8	34.3	100(%)
e. Repair welding of alloy steels demand special tools	3	9	4	56	15	87
	3.4	10.3	4.6	64.4	17.2	100(%)

Table 6: Electrode identification

5-point rating scale	SD	D	N	A	SA	Total
You are capable of identifying an electrode for a given job	33	23	24	12	16	108
	30.6	21.3	22.2	11.1	14.8	(100%)
You are able to read the alpha-numeric coding on an electrode	43	40	4	8	10	105
	41.0	38.1	3.8	7.6	9.5	(100%)
Each digit or no. on the electrode has an operational meaning	45	11	34	11	3	104
	43.3	10.6	32.7	10.6	2.9	(100%)

The figure below represents choice of electrodes used by welders. Participants were asked to select the given options as E6011, E6013, E7018 and "No idea".

The electrode commonly used in the metropolis is the E6013 with various reasons given as arc being easy to strike, easy to maintain, easy to control, and that the electrode does not freeze with welding speed faster. Largely, the E6011 and E6013 category are used to perform fabrication works on low-carbon steel. However those who use the E7018 electrode normally perform repair works on low-alloy steel, since this is characterized with high tensile. These electrodes are usually associated with “magnetic field” and “arc blow” and are usually not good for the “inexperience” welder. There were few individuals who had no ideas about choice of electrode.The study tried using chi-square analysis to determine the relationship between level of education and quality of low-alloy steel welding. The inferential stat output below (Table 7) indicated that P-value= *0*.000, and χ^2 < likelihood ratio. We can therefore conclude that quality of weld is independent of level of education.

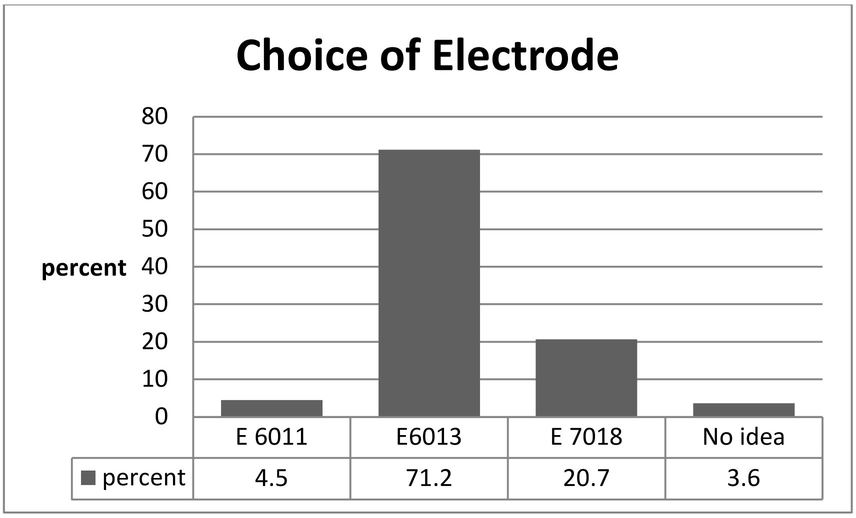

Figure 5: Choice of Electrode for Welding in the metropolis

Table 7: Chi-square statistics. Level of education and quality of low-alloy steel welding

	Value	df	Asymp. Sig. (2-sided)
Pearson chi-square	20.476	4	0.000
Likelihood ratio	25.473	4	0.000
No. of valid cases	95		

Again the study tried using chi-square analysis to determine the relationship between age in business and success of low-alloy steel welding. The inferential stat output below (Table 8) indicated that P-value< *0*.05, and χ^2 < likelihood ratio. We can then conclude that success of low-alloy steel welding is independent of age in the welding profession.

Table 8: Chi-square statistics. Age in the welding profession and success of low-alloy steel welding

	Value	df	Asymp. Sig. (2-sided)
Pearson chi-square	6.281	4	0.179
Likelihood ratio	8.472	4	0.076
No. of valid cases	95		

7. Discussion

The general objective of this study was to investigate the skills gap in the repair welding of low-alloy, high tensile steels (simply referred to as low-alloy steels in this context) within the Tamale metropolis. The research study was triggered by the apparent skills shortage within the metropolis; following the fact that repair welding of such alloy steels is noted to associate with high income. The descriptive statistics indicates that there is a lot repair welding involved in respect of low-alloy steel in both automotive and structural steel industries (87.7%).The results also indicate that there is high income involved in repair welding of low-alloy steel, since an overwhelming majority of 98 participants out of 107 attested to this fact, representing 91%. Based on the above facts the study was therefore posed to address the following objectives:

7.1 Demographic Characteristics of Welders within the Metropolis

This section of the results discusses the demographic profile of welding craftsmen within the metropolis. With respect to gender, the data had not been able to capture even a single woman welder within the metropolis, implying the welding industry is dominated by male master craftsmen. The age distribution of welders is well spread among the age groups; however, the range of 35-39 is predominant, about (31.5%). Apart from this age group the rest were well spread with differences not so significant. Using inferential statistics to determine whether success of low-alloy steel welding depends on one's age in the welding profession, $P<0.05$ and $\chi^2 <$ likelihood ratio, implying success of welding low-alloy steel is independent of one's age in the "business". By this we therefore fail to reject the hypothesis. The researchers were also interested in determining the educational background of welding craftsmen within the metropolis. Out of a total of 111 participants 53 had secondary/technical education (47.7%), followed by those who had no formal education, 39 out of 111, representing 35.1%. Using inferential statistics to determine whether quality of welding low-alloy steel is influenced by level of education of the welder, $P=0.000$ and $\chi^2 <$ likelihood ratio, implying quality of welding low-alloy steel is independent of level of education. By this we therefore fail to reject the hypothesis.

The study considers the use of MMAW process of the AC or DC type for welding within the area. Obviously this welding process is widely used. The study revealed that 107 participants out of 111 use the MMAW process of the AC type for both fabrication and repair works, representing 96.4%, while the DC registered 3participants only out of a total of 111, representing 2.7%. The study made an investigation into the preferred area of welding operation (thus, whether fabrication or repair welding of low-alloy steels), and it revealed that 77 out of 95 participants, representing 81.1% were engaged in fabrication works. The rest of the participants, 18, representing 18.9% were engaged in repair welding of low-alloy steels.

7.2 Perception of Welders about Low-Alloy Steel Welding

The study was posed to investigate the perception of welders regarding low-alloy steel welding in terms of job availability, income and skills needs. A five point rating scale involving 5 variables was used to solicit the opinion of welders. Partcipants indicated that there is a lot repair welding involved regarding low-alloy steel in both automotive and structural steel works industries (87.7%). Participants disagree that repair welding is a laborious activity (54.3%). However a total sum of 39 out of 105 agreed that it is a laborious activity (37.2%). In terms of income, the results revealed that there is high income involved in repair welding of low-alloy steel. An overwhelming majority of 98(91.6%) participants out of 107 attested to this fact. In terms of special skills needed for repair welding, a sum total of 103 participants out of 105, representing 98.1% agreed to fact that repair welding requires special skills. Likewise special tools are needed for repair welding of low-alloy steels (81.6%).

7.3 Ability to Select the Right Electrode for Low-Alloy Steel Welding

A majority of welding craftsmen viewed the welding electrode as a “universal” filler material, thus a single rod fits for all type of jobs. In their opinion, electrodes were classified into “good” or “bad” rods. Those that are easy to strike the arc, maintain the arc and proceeds well in welding with ease were labeled good. However those that exhibit high magnetic fields and arc blow were considered bad rods. Using a five point rating scale, the researchers tried to find out whether welding craftsmen have the requisite knowledge to select the right electrode for a given job. Exactly 56 participants out of 108, representing 51.9%, indicated that they do not identify the right electrode for a given job, and 38 agreed to the fact that they identify the right electrode for the right job, representing 25.9%. Those who neither agree nor disagree were 24 participants, representing 22.2%. Implying those who could not identify the right electrode for low-alloy steel welding were at the higher side, including those who neither agree nor disagree (22.2%).

To determine whether welders were able to read the alpha-numeric coding on the electrode, a sum total of 83 out of 105 disagree to the fact that they could read the coding on the electrode, representing 79.1%, while those who agree were 18 participants, representing 17.1%. It is quite evident that majority of welders could not read the alpha-numeric coding on the electrode. As a matter of fact 53.9% agree to the fact that each number or alphabet on the electrode had no operational meaning while 13.5% accepted the fact that the alpha-numeric coding on the electrode had an operational meaning. Obviously 32.7% of the participants were not sure.

The electrode commonly used by welding craftsmen in the metropolis was the E6013 (71.2%) with various reasons given as arc being easy to strike, easy to maintain, easy to control, including the fact that the electrode does not freeze, and promotes faster welding speeds. Largely, the E6010, E6011 and E6013 category is used to perform fabrication works on low-carbon steel; they are noted to possess deep penetration characteristics. However those welders who used the E7018electrode (20.7%) normally perform repair works on low-alloy steel. This category of electrodes is characterized by high tensile strength and hydrogen controlled qualities. These electrodes are usually associated with “magnetic field” and “arc blow” and usually not good for the inexperience welder.

8. Conclusion

From the empirical data, it is evidently clear that a big gap really exists in the repair welding of low-alloy, high tensile steels within the Tamale metropolis. The results indicate that Welders in the Tamale metropolis were only capable of welding low-carbon steel in both repair and fabrication works, they however lack the requisite skills to carry out repair works on alloy steels such as low-alloy, high tensile steels, cast iron, stainless steel and so on. Clearly, welding repair works on alloy steels is always a failure. This study rather focused on low-alloy, high tensile steels. In the majority of cases, the mechanical and automotive components as well as structural steel works are usually made of low-alloy, high tensile steels which respond very well to “good welding techniques”. However the welding craftsmen developed a mindset that these materials could not be welded. Contrary to their perception, these materials can be welded with very little difficulty, only if the right techniques and procedures of welding these metals are strictly observed: the correct preheat temperature, the right electrode as well as current setting and edge preparation. It is undeniable fact that the economic consequence of this skills gap is tremendous on both the welder and the client; the welder loses a great deal of jobs whiles the client is compelled to purchase a new part at a very high cost at the expense of repairs. Evidently good repair work generally lowers cost; at the same time stands the test of time just like a new component part.

9. Recommendation

It is against this background that the researchers recommend that artisanal training be organized for welding craftsmen within the metropolis in order to address this critical gap in low-alloy steel welding. Further, educational institutions such as Technical/Vocational Institutes or Technical University within the metropolis could take up this challenge to ensure that they offer the requisite skills to this category of welders who had not pass through technical education. It is also recommendable to ensure that repair welding of alloy steels in its entirety be given a place in the technical curriculum, especially institutions where welding and fabrication programmes are offered.

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