Welding Practices in Selected Metal Welding Industries in Ghana

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Abstract— Welding is essentially a repair, maintenance, manufacturing and constructional engineering activity. In the last several decades, welding has evolved as an interdisciplinary activity requiring synthesis of knowledge from various disciplines and incorporating the most advanced tools of various basic and applied sciences. This paper discusses the current welding processes and investigates welding practices in some selected metal welding industries in Ghana. The project covers the categories of welding and welding techniques, welding quality control methods, welding process type used and general challenges that hamper welding productivity in Ghana. Two hundred and fifty (250) welding industries across the regions of Ghana both in the formal and informal sectors were selected for the study. Designed inquiry forms or questionnaires were administered to the selected welding industries. Two hundred (200) out of the two hundred and fifty (250) selected firms, representing 80% responded to the inquiry. The study revealed the different proportions of different industry groups and areas of application of welding activities. About ninety percent (90%) of the industries practice manual welding with little automated or robotic welding systems and much welded fabrications still relies on manual metal arc (MMA) welding. Majority (about 80%) of the industries use only visual inspection to ascertain the quality of welded products. The paper recommends that since welding is an important manufacturing, maintenance and construction engineering activity, the government of Ghana should take a critical look at the activities of especially the small scale welding industries by coordinating their operations under one industrial estate and giving them support in terms of land and space, training, welding equipment, low interest loans, etc., to improve their rate of productivity and also encourage manufacturing and innovations in different products in the country.

Index Terms— Welding processes, welders, Arc welding, Gas welding, Resistance welding, Ghana.

1.0 INTRODUCTION

Welding first evolved as a technique of primary economic importance when the use of iron became widespread, it being required not only in order to make finished products but also as part of the iron-making itself [5]. Welding consists of fusion or uniting of two or more pieces of materials (metals or plastics) by the application of heat and/or pressure.

Welding is the principal means of fabricating and repairing metal products. The process is efficient, economical and dependable as a means of joining metals.

This is the only process which has been tried in the space. The process finds its applications in air, underwater and in space [7].

Worldwide, welding is a multibillion-dollar fabrication technology used extensively in the construction of buildings and bridges and in the automotive, aircraft, aerospace, energy, shipbuilding, and electronic industries. Perhaps because welding is a construction technique, it is viewed by many as a primitive science. In the last several decades, welding has evolved as an interdisciplinary activity requiring synthesis of knowledge from various disciplines and incorporating the most advanced tools of various basic and applied sciences. Scientists from diverse disciplines such as arc and plasma physics, thermodynamics, high-temperature chemistry, materials science, transport phenomena, mathematical modeling, computer science, robotics, economics, and a variety of engineering fields including mechanical, chemical, and electrical engineering are currently making new contributions [2]. Welding involves more sciences and variables than any other industrial process. The principal sciences involved in welding are Physics, Chemistry and Metallurgy [1].

In some industries, notably automotive, welding is done primarily by robots or automated machinery. In many industries such as shipbuilding, heavy equipment production, and small parts fabrication, welding is still largely a manual process done by human operators.

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2.0 AN OVERVIEW OF WELDING PROCESSES

Various welding processes differ in the manner in which temperature and pressure are combined and achieved. Welding processes can also be classified as follows (based on the source of energy): 1.Gas Welding - Oxyacetylene, Oxy-hydrogen 2.Arc Welding – Carbon Arc, Metal Arc, Submerged Arc Welding (SAW), Inert-gas-Welding, Tungsten Inert Gas (TIG) and Metal Inert Gas (MIG) – Plasma Arc, Electro-slag 3.Resistance Welding – Spot, Seam, Projection, Butt Welding, Induction Welding 4.Solid State Welding – Friction Welding, Ultrasonic Welding, Explosive Welding, Forge and Diffusion Welding 5.Thermo-chemical Welding – Thermit Welding, Atomic H_2 Welding (also arc welding) 6.Radiant Energy Welding – Electron Beam Welding, Laser Beam Welding [7].

Arc welding occupies the most important position in the group of fusion welding processes, and due to its flexibility and cost effectiveness, it is an indispensable technology for the construction of steel-framed buildings, ship building, motor vehicle manufacture, power plants and other industries. The quality of the weldments produced is particularly dependent on the welding materials utilized and improvement in performance is required. Arc welding will occupy the most important position in the group of fusion welding processes [11]. Out of the 18 existing traditional welding techniques only MIG, TIG and SAW will continue to dominate in the near future [6]. The quality of TIG welds ranks higher than that of any of the arc-welding processes, due to the reliability, clearance and strength of the weld. The quality of TIG welds is greatly dependent on the selection of process parameters such as arc gap, inert gas flow rate, welding current, welding speed and cleaning percentage [14].

However, the last couple of decades have seen the significant development in the fields of laser welding, hybrid welding (especially laser-Metal Inert Gas (MIG)/Metal Active Gas (MAG)-hybrid), electron beam welding, brazing, Friction Stir Welding (FSW), multi-thread techniques, powder plasma, narrow gap techniques, TOPTIG and cold-arc technology and have been introduced into many fields of manufacturing.

Laser and electron beam welding can deliver the most concentrated heat sources for welding. The benefits brought by a more concentrated heat source come at a price: the capital cost of the equipment is roughly proportional to the intensity of the heat source as it can be deduced from Figure 1 [15].

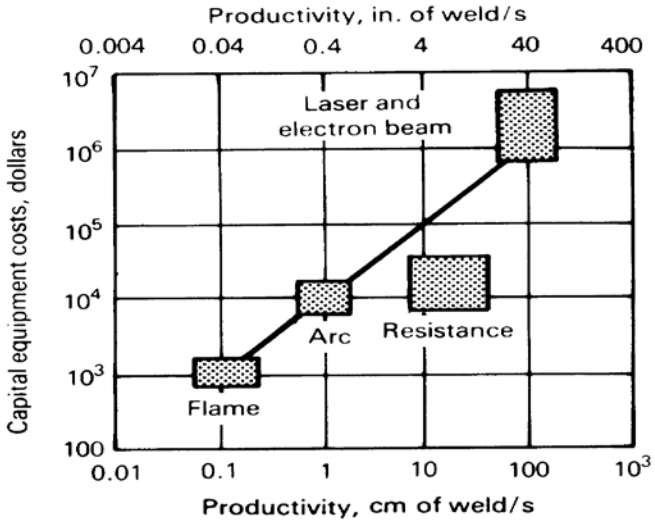


Figure 1: Capital cost of welding equipment as a function of productivity [15].

Electron beam welding (EBW) has been applied increasingly and has been able to bring its advantages to bear. These advantages are an extremely high power density and thus a low heat input even in the case of the thickest welds of up to 250 mm and above. The availability of large vacuum chambers, up to 630m^3, permits the welding even of large-volume machine components. The possibility of splitting the beam allows the execution of several welds on one component at the same time. Laser-beam material processing will in all likelihood evolve rapidly to take advantage of the laser's exceptional flexibility, high efficiency, and precise process control. Laser beam welding has the great advantage that it can be used outside a vacuum but in general it is only suitable for material thicknesses below 25mm. The process is suitable for the manufacture of tailored blanks of different steel qualities and material thicknesses. Another advantage is the low heat input resulting from the high energy density. By means of remote techniques, it is possible to use the effect of the laser beam over relatively long distances between the beam source and the welding position (up to 500mm). It is to be expected that laser beam welding will be increasingly used in automobile fabrication. It will also be utilized in the processing of plastics because of requirements with regard to the light absorption of the plastics to be processed. At present an extension of the Laser application takes place based on the rapid development of the fibre Laser because of its outstanding advantages namely, beam quality, capacity, efficiency, reliability and compactness. No other Laser type has experienced a faster development in material processing than the fibre Laser. In 2004 the first 10 kW-fibre-Laser worldwide was put into service. Only two years later the availability of 20 kW-

fibre-Lasers is reported. This indicates the rapid development of Lasers in this field [11] [16].

There has recently been a series of new developments relating to friction stir and resistance welding processes in the aeronautics and automotive industries respectively. Friction stir welding is a solid-state process that joins metals through mechanical deformation. In this process a cylindrical, shouldered tool with a profiled probe is rotated and slowly plunged into the joint line between two pieces of sheet or plate material, which are butted together. This process can weld previously reported unweldable aluminum alloys such as the 2xxx and 7xxx series used in aircraft structures. The strength of the weld is 30%-50% than with arc welding. The fatigue life is comparable to that of riveted panels. The improvement derived from the absence of holes is compensated by the presence of a small Heat Affected Zone (HAZ), residual stresses, and microstructural modifications in the welding zone. Boeing made a $15 million investment in the use of FSW to weld the booster core tanks for the Delta range of space launch vehicles, which was the first production FSW in the USA. The first launch of a FSW tank in Delta II rocket happened in August 1999. This process is currently being considered for the joining of aluminum–berilium alloys such as 2195 for the central tank of the Space shuttle, and also titanium alloys for other aeronautical uses. As FSW becomes better established, it can replace plasma arc welding (PAW) and electron beam welding (EBW) in some specific applications in aluminum and titanium respectively [10].

Resistance welding will continue to advance rapidly (with pressure from the automobile industry to weld higher strength steels and Al alloys) with improvement in inverter power supplies, improved process regulation or control, and improved quality assurance. Spot welds made by resistance welding are the primary method of joining in automobile industry, although some other joining techniques are more and more being used, spot welding still remains the primary joining method in automobile manufacturing so far. Improvements in machine control and computer technology have made different process variants (flash butt welding, stud welding, etc.) more reliable [11] [12].

The future of welding holds even greater promise as methods are devised for joining dissimilar and nonmetallic materials, and for creating products of innovative shapes and designs. There are a number of "drivers" that will help determine this future favorable position of welding. The use of information technology will grow to help develop a "virtual manufacturing plant," in which technologies for design, fabrication, and inspection are seamlessly integrated with welding technology where they are needed. This will reduce the average cost of welding by about one-third, by providing better process selection guidance, increasing the use of automation and robots, and lowering reject and repair rates; increase the use of welding by about 25% in the near future [17].

3.0 THE WELDING INDUSTRY IN GHANA

In Ghana welding as repair, maintenance, manufacturing and constructional engineering activity is done by the formal and informal sector. The formal sector is made up of companies that are registered with the registrar generals department. It also includes government institutions such as educational, health, research, mining, refineries, agro-processing etc. that has welding shops with trained or qualified welders to undertake welding projects for the institutions. The Government of Ghana infrastructural projects as captured in the 2016 financial statement expenditure highlights Roads and Highways (e.g. construction and completion of roads in the Western Region Oil Enclave to support the operation of the Gas Plant etc.), Water and Housing (e.g. construction of 368 housing units for the security services etc.), Transport (e.g. construction of the Kwame Nkrumah Interchange, the Kasoa Interchange, etc.) and Communication (e.g. installation of meteorological equipment etc.) [9]. Most parts of these projects construction stages involve welding.

Modern and sophisticated welding equipment are brought in by foreign companies to execute most governmental capital intensive infrastructural developmental projects involving welding with little involvement of the local industries. Examples of such infrastructural projects that involve welding that are currently being executed by foreign companies are the Kwame Nkrumah Circle Interchange Project work being executed by Queiroz Galvao; a Brazilian company, the Kotoka International Airport Expansion project by the Amandi Holdings Limited an Israeli company undertaking the project at terminal 2 and Mapa Construction and Trade Company Incorporated a Turkish company constructing terminal 3, the Ghana Western Corridor Gas Infrastructure Development project by the China Petroleum & Chemical Corp (Sinopec), the Takoradi Thermal Power Plant Expansion Project by the Mitsui & Co (Japan) and

KEPCO E&C (Korea) and the Takoradi Port Expansion Project being executed by Belgian firm, Jan De Nul.

For the informal sector, a greater number of welders in the welding industry in Ghana operate as micro and small scale enterprises with employee strength of less than 30. Most of these firms are located in industrial areas in cities like Kumasi, Accra, Tema and Takoradi and also in the villages. A visit taken to some industrial estates in Ghana such as "Suame Magazine", in Kumasi, "Kokompe", in Accra and in most villages in Ghana reveal thousands of welders busy at work in the construction and fabrication industries in the country. These welders use simple implements such as chipping hammer, brushes, chisels, bench vices, metal cutting pliers etc. as part of their welding activities.

In Ghana welding is extensively used in the manufacturing industry for producing agricultural processing machinery, vehicle body structures and seat frames, burglary-protection shields, compressed gas cylinders, metal containers etc. In the construction industry it is used for constructing bridges, buildings, billboards, railroad rolling stock, electric metal poles, telecommunication antennas etc., and in carrying out maintenance and repair in the mining industry, refineries, and in the automotive industry.

4.0 PROBLEM STATEMENT AND RESEARCH RELEVANCE

A contributing factor to the low status of manufacturing in Ghana may be due to the fact that manufacturing engineering activities such as welding practices have not been developed to the level that it should be. Meanwhile, data on these welding practices such as the category of welding and welding technique the welders practice, type of welding processes the welders use, safety practices of the welders and the general technology of welding in the country is not readily available.

It is therefore not certain statistically, the characterization of the welding industry groups, the workforce within this groups, the different areas of application of welding, the type of welding technique or method employed by the industry groups, type of welding process employed by the various industries, the extent to which these processes are used in the industries, quality control mechanisms for evaluating welds and generally the challenges within the welding manufacturing sector in Ghana has been documented or reported. Lack of statistical data of these welding practices of the local welding industry in Ghana hamper the development of this sector and hence defective welded components and parts are carried out by the local welders. Losses of life and property due to catastrophic failure of structures are often traced to bad welding practices and hence defective welds [2].

An industry survey of Ghanaian industries engaged in welding in the metal fabrications sector would help expose the extent to which this important support function is being performed in that sub-sector, as well as identify weaknesses and other inherent problems of the sector.

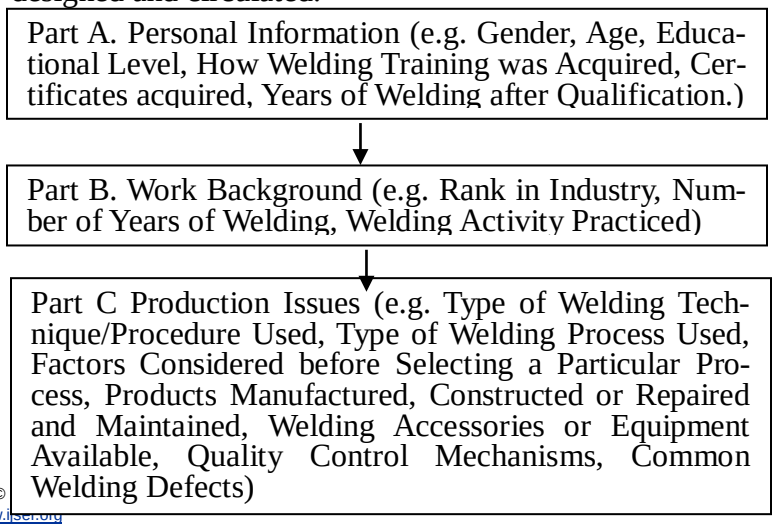
The main objective of this study is to establish statistically some of the welding practices of the Ghanaian welding industry and thus help plan adequately to boost the level of welding manufacturing and productivity.

5.0 METHODOLOGY

5.1 Overview of Method

- Study visits to some industries that use welding as a maintenance and repair, manufacturing and constructional activity in Ghana mostly in Kumasi, Accra, Tema and Takoradi.
- Preparation and distribution of questionnaires and interviewing of industries and Micro, Small and Medium scale Enterprises (MSMEs) that practice welding.
- Collection of data, and analysis of data using STATA: Data Analysis and Statistical Computer Software Package.

Figure 2 presents the structure of the questionnaire designed and circulated.



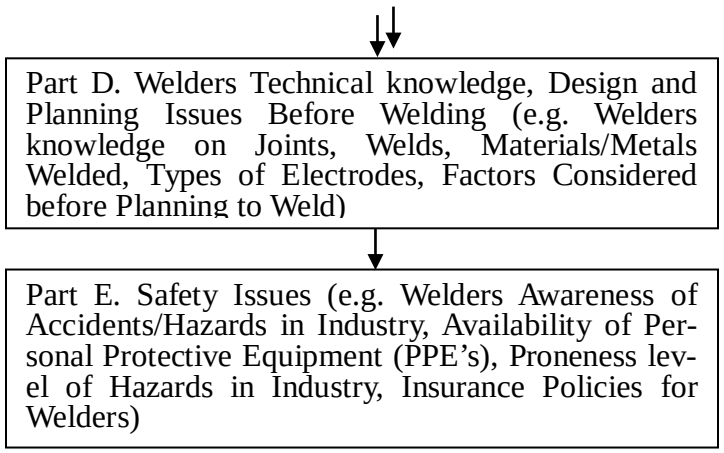


Figure 2: Structure of the questionnaire

The paper analyses some of the results obtained through Part B and C of the questionnaire.

5.2 Survey Distribution

Engineering firms were selected from the Association of Ghana Industries (AGI) database, National Board for Small Scale Industries (NBSSI) records, firms suggested by interviewees, website pages and telephone directory. This formed the population for the study. 'Simple Random Sampling' technique was used based on the scope of work. The primary purpose in taking a random sample is to obtain information about the unknown population parameters in order to make an inference regarding the true proportion of the parameters under investigation, and use the observed parameters in the sample to predict the larger population [3]. This was done to have a broad base spectrum of metal joining industries to investigate the practices of welding engineering which is common to all categories of the industries.

For the entire research survey, 250 questionnaires were administered and 200 responded and retrieved from firms both in the formal and informal sector. For the firms in the formal sector; 68 firms responded. From the Ashanti region, 29 responded, Greater Accra 19 (Accra 7, Tema 12), Western region 8, Eastern region 7, Brong Ahafo region 3, Upper East region 1 and Central region 1. No questionnaires were administered in the Volta, Northern and Upper west regions. For the engineering firms in the informal sector (wayside welding industries); out of the 250 questionnaires administered in the entire research, 132 were retrieved. Majority of the questionnaires in the informal sector were administered in the Ashanti region, with about 57 retrieved from respondents at the Suame Magazine in Kumasi.

Field officers visited the engineering firms at their places and assisted them in filling the questionnaire. Questions on the questionnaire which were not clear to respondents were clarified. Each respondent spent about an hour during the administration of the questionnaire.

The survey approach of using personal interviews by a single data collector questionnaire ensured consistency of interpretation of the questions. It also enabled the adaption of the survey questions to meet the goal of exposing and exploring issues of most relevance to this research.

6.0 RESULTS

6.1 Welding Practices in Industry

The surveyed industries range from refineries, research and educational institutes, motor vehicle and equipment, mining, food processing, wood processing, construction and metal fabrication industries. The results of some of the responses of their welding practices are presented in the remaining part of this section.

6.1.1 Number of Years Firm has been Practicing Welding

The ranges of years industries under study have been practicing welding: 1-10 years are 66 (33.00%), 11-20 years are 54 (27.00%), 21-30 years are 40 (20.00%), 31-40 years are 18 (9.00%), 41-50 years are 11 (5.50%) and above 50 years are 11 (5.50%). In percentage terms, the ranges of years are shown in Figure 3.

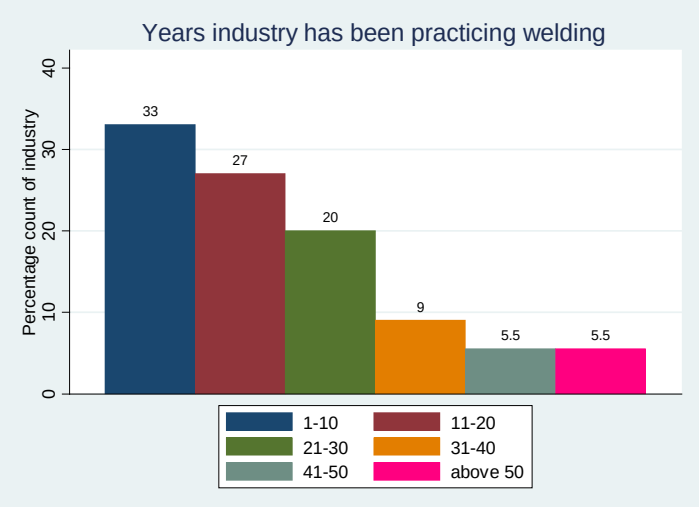


Figure 3: Percentage count of industry against the

ranges of year's industry practice welding.

6.1.2 Proportions of Welders Employed by Different Industry Groups

The proportions of welders employed by different industry groups under this study shows that the largest number of welders 129 (64.50%) in one group is employed by the "Fabricated Metal Products" group. A total of 35 (17.50%) is employed by the group known as "Machinery", 3 (1.50%) is employed by the "construction" industry, the "Motor Vehicle and Equipment and Auto Repair" group employ 31 (15.50%) while the "Primary Metal Industry" employs 2 (1.00%). Figure 4 is a histogram of the percentages of welders employed by the different industry groups.

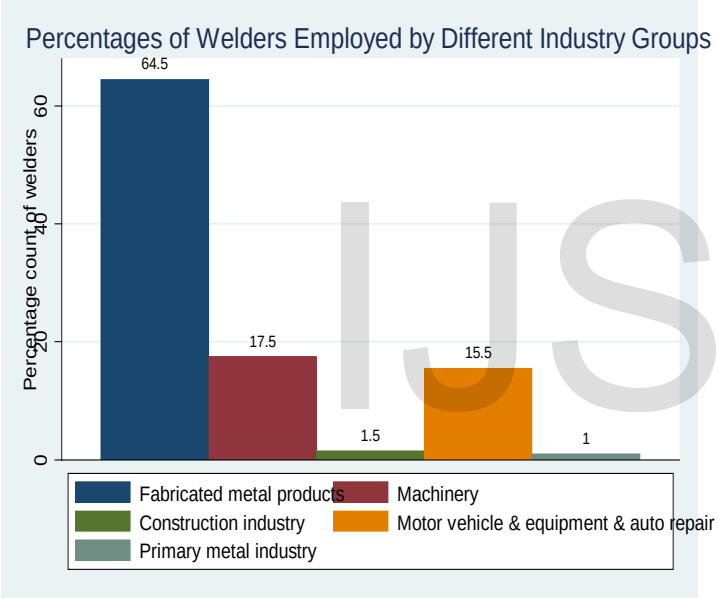
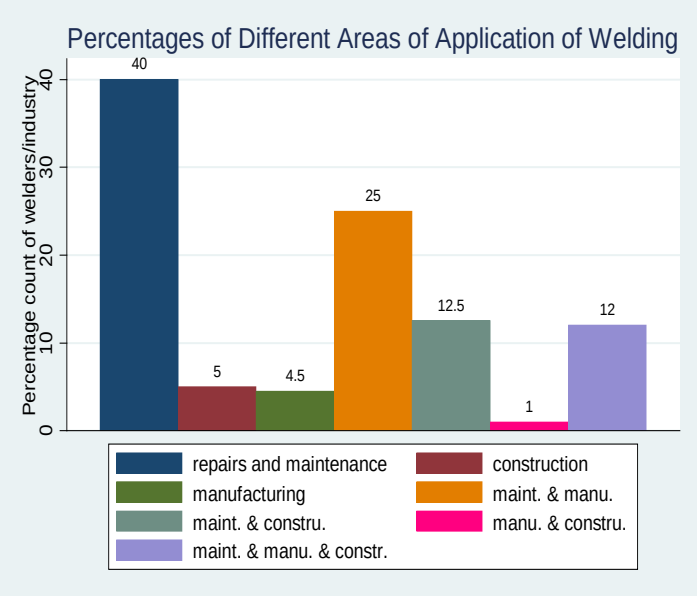


Figure 4: The percentages of welders employed by the different industry groups

6.1.3 Proportions of Welders/Industry Involved in Different Areas of Application of Welding.

The proportions of welders or industry involved in different areas of application of welding under this study shows that repair and maintenance welding, account for 80 (40.00%), constructional welding 10 (5.00%), manufacturing 9 (4.50%), maintenance and manufacturing 50 (25.00%), maintenance and construction 25 (12.50%), manufacturing and construction 2 (1.00%) while welders and industry that practice all three categories constitute 24 (12.00%). Figure 5 shows the various categories of the welding practiced by the welders and industry under study.

Figure 5: Percentages of different areas of application



of welding by welders

6.1.4 Type of Welding Technique/Procedure Practiced in Industry

Responses to the type of welding technique practiced in industry revealed that majority 180 (90.00%) practice manual welding only**,** machine welding only 2 (1.00%), automatic welding only 1 (0.50%), manual and machine 15 (7.50%), manual and automatic 1 (0.50%) while industries that use manual, machine and automatic were 1 (0.50%). None of the industries surveyed practice the robotic welding technique. Figure 6 shows type of welding technique practiced in industry.

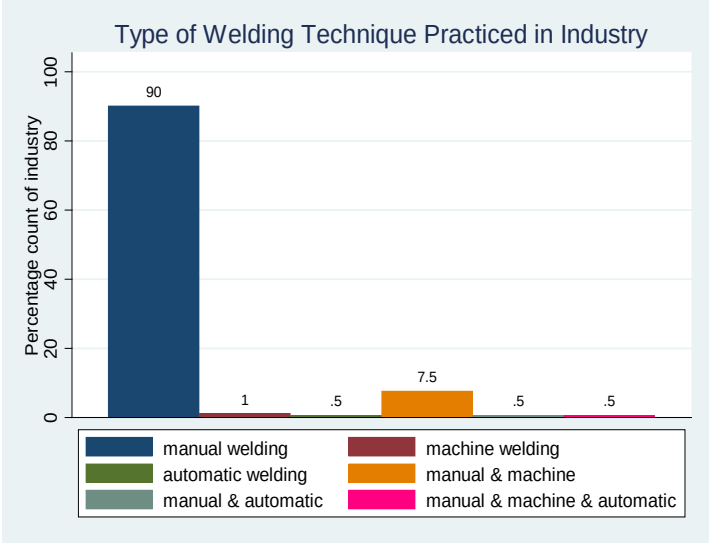


Figure 6: Type of welding technique practiced in industry

6.1.5 Type of Welding Process Used

A total of 80 (40.00%) use only the arc welding process, 19 (9.50%) use only gas welding, no industry use only resistance, 86 (43.00%) use arc and gas, 1 (0.50%) use arc and resistance and 14 (7.00%) use all three. Figure 7 shows the distribution of type of welding process used in industry by percentages.

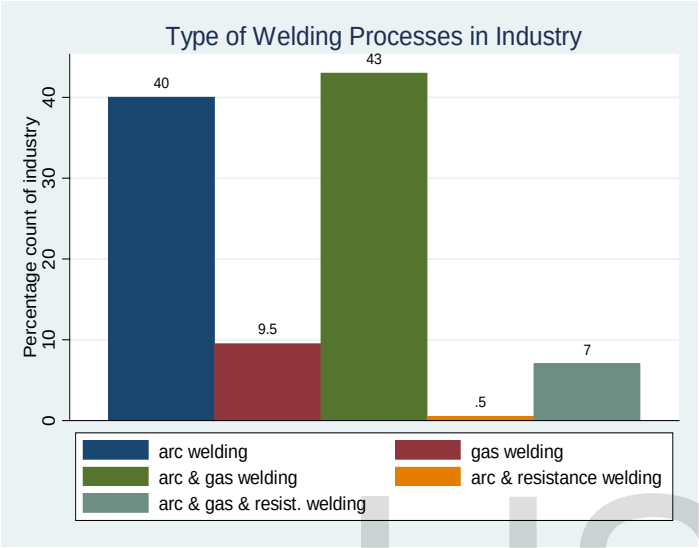


Figure 7: Distribution of type of welding process used in industry by percentages

From the above analyses of the type of welding process, the total count of industries that use arc welding is 181. The distribution of the types of arc welding processes used in industry in terms of percentages is as shown in figure 8.

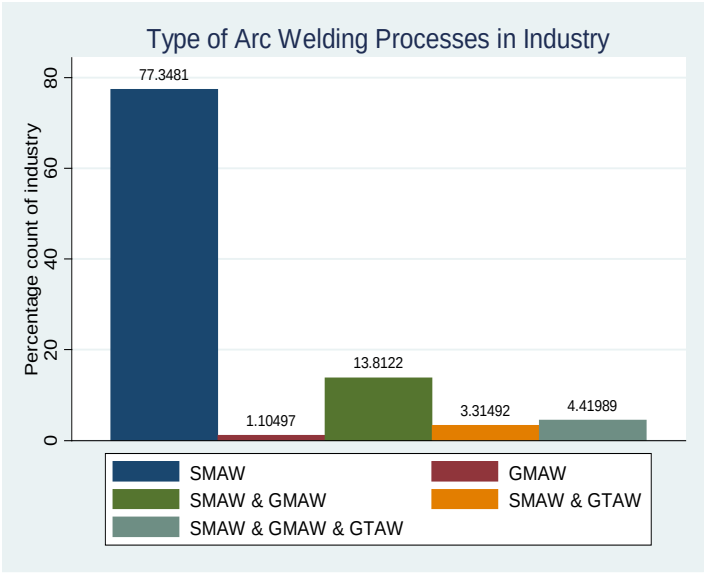


Figure 8: Distribution of type of arc welding processes used in industry by percentages

The analyses of gas welding showed that the total count of industries that use gas is 119. The distribution of the types of gas welding processes used in industry in terms of percentages is as shown in figure 9.

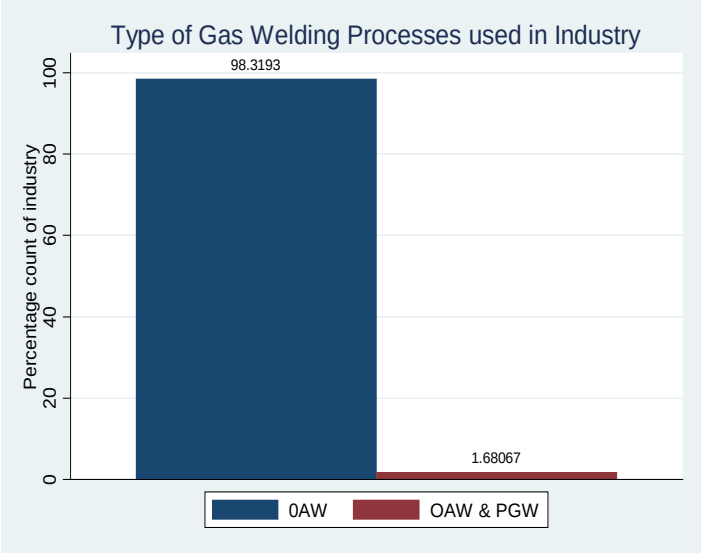


Figure 9: Distribution of type of gas welding processes used in industry by percentages

The analyses of the resistance welding processes also revealed that the total count of industries that use resistance is 15. The distribution of the types of resistance welding processes used in industry in terms of percentages is as shown in figure 10.

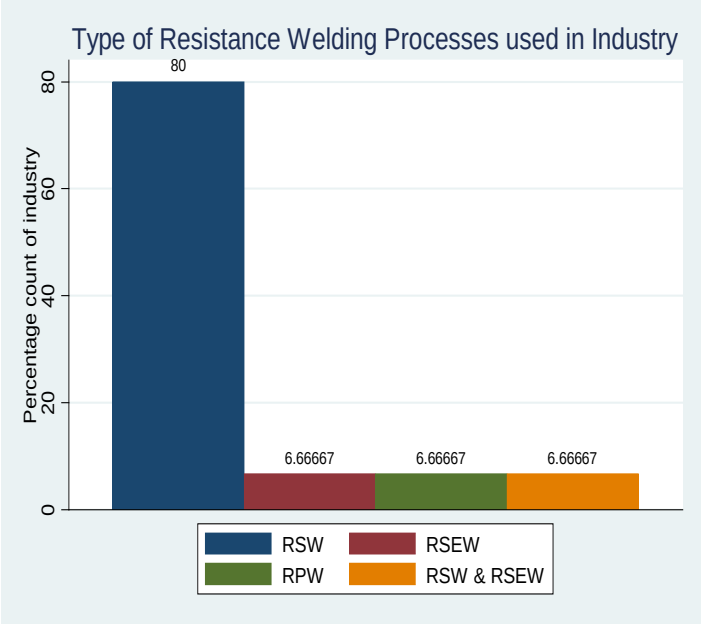


Figure 10: Distribution of type of resistance welding processes used in industry by percentages

6.1.6 Quality Control Mechanisms for Testing Welds

One fifty nine, 159 (79.50%) of the 200 respondents do not use any quality control mechanism for testing of welds but employ just visual inspection. The remaining 41 (20.50%) firms responded they use quality control mechanism for testing of welds. A total of 15 (7.50%) out of the 41 (20.50%) employ destructive testing, 10 (5.00%) nondestructive testing, 2 (1.00%) destructive and nondestructive and 14 (7.00%) employ other methods. Figure 11 and 12 below shows the percentages count of industry the responses received

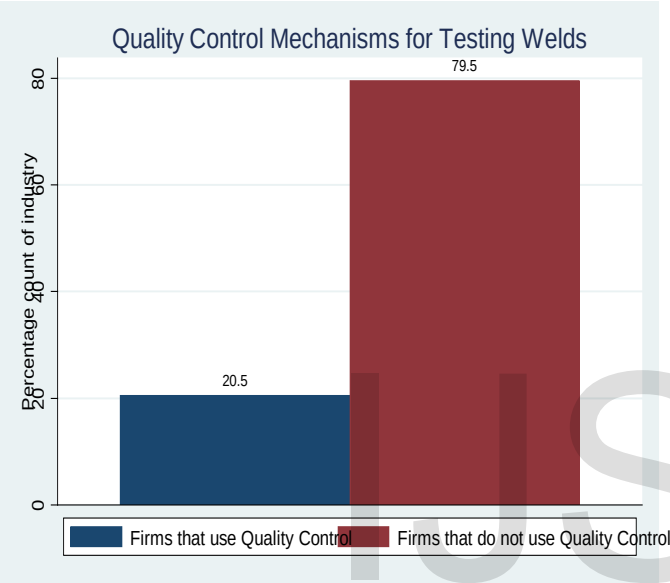


Figure 11: The application of quality control mechanisms in industry

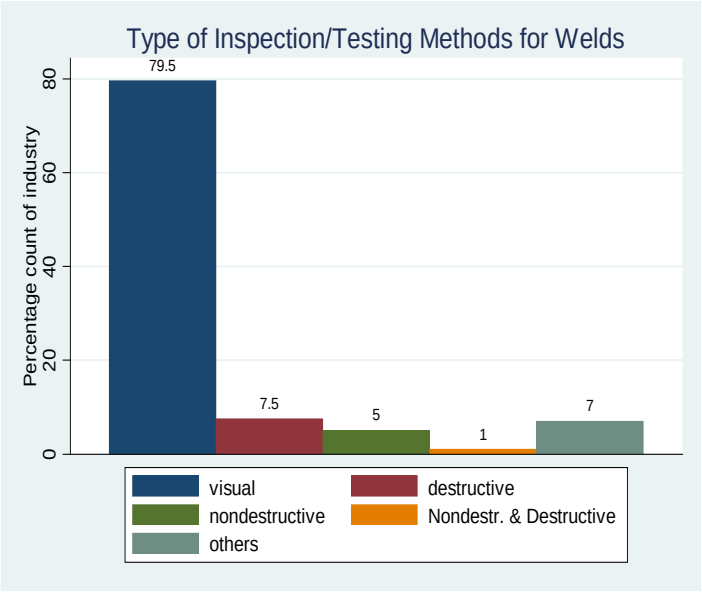


Figure 12: Distribution of quality control mechanisms inspection methods employed in industry.

6.2 Some Challenges Facing Welders

Table 1 presents a summary of some of the challenges respondents encounter in their chosen profession and in industry.

Table 1 Summary of the Challenges of Welders and the Welding Industry in their Practice in Ghana

Challenges	Frequency of Response
1) Lack of recognition of academic qualification for welders in industry as compared to electrical and mechanical qualification and low ratings among electricians, fitters, etc.	6
2) Most industries in the country do not have any ladder of progression for welders. The Ministry of Education does not have any course higher than advanced certificate for welders.	2
3) Difficulty in interpreting drawings and blue print.	1
4) Difficulty in acquiring welding training in Ghana and certification.	2
5) Lack of proper welding machines and materials such as guillotine machines, forming machines, bending machines, fixtures, grips, electrodes, welding shield, welding transformer machines and heat treatment furnaces and safety tools in industry and for practical work in welding training schools.	69
6) Shortage of carbide (oxy-acetylene gas) at supply stations which reduce productivity.	10
7) High cost of welding materials and equipment such as acetylene gas, iron rods etc.	14
8) Frequent power failure or fluctuations affect work schedule and hence productivity.	25
9) Industry does not organize any workshop training programmes or refresher courses for welders to update on new technology in welding and no special treatment in case of accidents due to poor safety management in industry.	3
10) Lack of proper welding materials on the market such as contaminated electrodes as a result of oxidation, rusting and/or over aged electrodes.	9
11) Lack of capital to expand.	45
12) Lack of government support especially to the small scale welding industries to grow.	9
13) High interest rate on loans from banks.	13
14) Stealing by robbers at night.	2

7.0 DISCUSSIONS

7.1 Welding Practices in Industries in Ghana

7.1.1 Number of Years Firm has been Practicing Welding

Today, welding is an important manufacturing, maintenance and constructional joining process taking its place with the metal working operations to help bring us quality metal products at economical prices. From section 6.1.1, a greater percentage count 66 (33.00%) of the welding firms have been welding for between 1-10 years and the smaller percentage 11 (5.50%) of the firms have been welding for above 50 years. This suggests that firms practicing welding for longer number of years are few as compared to the recent firms in operation. This important engineering sector needs to be developed rapidly up to best modern practices.

7.1.2 Category of Welding and Proportions of Welders Employed by Different Industry Groups

The welding process finds widespread application in almost all branches of industry. From section 6.1.3 of the research, it has revealed that, some of the welders and firms employ a combination of the category of welding (repair and maintenance, manufacturing and constructional welding) practices. However, the largest number of welders and firms employs welding for repair and maintenance, the second largest number of welders and industries employs welding for manufacturing (example, manufacturers of classroom metal desks, metal gate, block making machines, metal containers, coal pot etc.) and the third largest number of welders and industries employs welding for construction (includes construction of tunnels, subways, structural steel for bridges and buildings, metal bill board and sign board construction, etc.) according to the research.

Section 6.1.2 of this research provides categories of the number of welders employed by different industry groups. From the research it can therefore be said that:

The single largest number of welders 129 (64.50%) in one group is employed by the "Fabricated Metal Products" sub-sector. This industry group includes manufacturers of classroom metal desks, metal gate, block making machines, metal containers, coal pot, burglar protection shield, fabrication of agro-processing, environment and sanitation equipment, ice breaker machines, metal storage tanks, platforms, hoists stands, concrete mixers, corn shearer, etc.

The second largest number of welders 35 (17.50%) is employed by the group known as "Machinery". This group includes manufacturers and repair and maintenance of refinery machinery such as crude oil large diameter pipes, sterilizer, chimney, cyclone, elevator bucket, pipe manifold system, steam coils and so on, mining machinery such as elbows, cylinder tanks for mineral processing, trash screens, chutes, mill hoppers, etc., electrical machinery such as turbines, electrical generators, transformers, electric motors etc. and, construction machinery such as chipping spreader, bulldozers, cranes and etc., food processing/brewery machinery, farm machinery, woodworking machinery, as well as paper-making machinery.

The third largest number of welders is employed by the "Motor Vehicle and Equipment and Auto Repair" which employs 31 (15.50%) of the welders. This group includes manufacturers and repair and maintenance of automobiles, buses, tipper trucks, repair and building of trailers and heavy duty vehicles, vehicle chassis and exhaust welding, welding repair shops and garages, etc.

The fourth largest number of welders 3 (1.50%) is employed by the "Construction" industry. This industry group includes companies that build tunnels, subways, structural steel for bridges and buildings, metal bill board and sign board construction, etc.

The remaining 2 (1.00%) of the welders are employed by the "Primary Metal Industry". These industries include steel mills and companies that produce structural shape sheet metals.

7.1.3 Type of Welding Technique/Procedure Practiced in Industry.

A very few of the firms practice welding using a combination of techniques or procedure (manual, machine or automatic). From section 6.1.4, a total of 180 (90.00%) of the firms practice only manual welding. This significantly indicates that little automation in welding is being practiced in industries in Ghana.

Because of the hazards of manual welding and to increase productivity, and improve product quality, various forms of mechanization and automation have been developed such as machine welding, automatic welding, and robotic welding [8]. However, relatively short runs, constant changes in the position of

welding, movement across the shop floor from one fabrication to another, and a mix of different types of work or joint all encourage the use of manual welding, since the welder's skill can be deployed to the best advantage in coping with the varying requirements. On the other hand, some fabrications, especially where long joints are involved, could be designed to take advantage of higher speeds of welding or greater deposition rates by automation than those obtainable with manual techniques.

7.1.4 Type of Welding Process Used

Section 6.1.5 of this report, shows that one hundred and eighty one or approximately ninety-one percent 181 (91%) of the firms were found to use arc welding process. In addition 119 (60%) of the firms use gas welding process while only 15 (8%) use resistance welding. However, the greatest percentage of the firms 86 (43.00%) use a combination of arc and gas welding processes. This is an indication that arc welding process is the most widely used welding process practiced by industries in Ghana whilst a greater proportion of industries use the combination of both arc and gas.

The research also shows that in the arc welding group the greater majority of the firms 140 (77.35%) that use arc welding use the shielded metal arc welding (SMAW) only with just a few using a combination of SMAW, gas tungsten arc welding (GTAW) or gas metal arc welding (GMAW). Within the gas welding group, the largest percentage of the firms 117 (98.32%) of the 119 firms use the oxyacetylene welding (OAW) only with just a few using a combination of OAW and pressure gas welding (PGW). Whilst within the resistance welding group, the largest percentage of the firms 12 (80.00%) of the 15 firms use the resistance spot welding (RSW) process only with just a few using a combination of the RSW, resistance seam welding (RSEW) or resistance projection welding (RPW).

According to [4] “it would be easy to say that the process chosen should provide the required quality at the lowest cost: While this must always be the aim, there are usually constraints which make this decision a compromise. In making a choice between processes, quality must be considered in terms of the skill of the welders available to do the job. Similarly, availability of equipment contributes an important restraint - the volume of work may not justify investment in new plant or retraining labour, and existing welding sets are often used even though the apparent cost may be higher” [4].

From the above discourse, a series of questions can be raised as to why many of the local fabricators choose the SMAW process which is most suitable for welding steel plates and just a few of them use the more specialized welding techniques such as the GTAW process which has more attributes for welding in the aero-engine industry and the RSW process which is always the first choice for the car-body manufacturer. This significantly indicates that Ghana as a country, need to equip its welders and the welding industry as a whole with the requisite skill and equipment to handle the more specialized welding techniques to produce more technological products in order to catch up with the more developed nations.

7.1.5 Quality Control Mechanisms for Testing Weld

Testing is usually performed to ensure that welded joints can fulfill their intended function. In fact the basis of a specification for weld quality is frequently an assessment of the number and size of the defects which can be present in a weld before it is considered to be defective and therefore rejectable. Within the defectology of materials, the study of the cracking process presents enormous importance in order to ensure the safety of structures, vehicles and machines. The cracking process is dangerous because it may end with the failure of the structural element and thus, a full collapse of the structure with drastic consequences. Therefore, the assessment and characterization of the type of crack is important for the prediction of their propagation direction and the measurement of their rate [13]. From section 6.1.6, 159 (79.50%) of the 200 firms, use only visual inspection to ascertain the quality of the welded joint, which is usually the first means of assessing quality. This figure is very high and of concern since visual inspection may not be good enough especially for critical components such as in welded parts in automobiles, refinery pipes, chemical storage tanks or cylinders, etc. which most of the local welders work on. Even with good lighting, it is often difficult to detect cracks by visual inspection. The effectiveness and indeed the speed of the examination is improved if the presence of a crack is highlighted by the use of nondestructive testing (NDT) such as say dye penetrant or magnetic particle techniques etc. and the use of destructive testing such as

microscopic test or bending test etc. Surprisingly, for both nondestructive testing and destructive testing (DT) only 27 (13.50%) of the firms use these methods. The remaining 14 (7.00%) responded that they use other methods such as using chipping hammer to remove carbon from the surface of the welded area to reveal cracks and other defects. To obtain quality products, and a fairly proper assessment of the number and size of the defects which can be present in a weld, assisted visual inspection such as NDT and DT should be of prime interest to industries that practice welding in Ghana.

8.0 CONCLUSIONS

The advancement in new welding processes is derived from acquiring processes that utilizes more concentrated heat sources such as Laser and Electron beam welding. Friction Stir Welding (FSW) appears as recent technology, and as it becomes better established, it can replace plasma arc welding (PAW) and electron beam welding (EBW) in some specific applications in aluminum and titanium respectively. Welding in Ghana has not been developed to the level required to achieve its optimum benefit as a country, especially in terms of the new technological advancement methods and equipment that are available. This paper has reviewed some current welding processes and has investigated some of the welding practices that are employed by welders in Ghana and makes the following conclusions:

1. The largest number of welders and industries practices repair and maintenance welding, the second largest number of welders and industries practices manufacturing welding and the third largest number of welders and industries practices constructional welding.
2. Among the categories of the number of welders employed by the different industry groups, the single largest number of welders 64.50% in one group is employed by the "Fabricated Metal Products" group.
3. Little automation in welding is being practiced in industries in Ghana with 90.00% of the industries practicing manual welding only.
4. One hundred and eighty one or approximately ninety-one percent 181 (91%) of the firms use the arc welding process. In addition 119 (60%) of the firms use the gas welding process while only 15 (8%) of the firms use resistance welding. However, the greatest percentage of the combination of welding process 86 (43.00%) use by the firms is the arc and gas welding process. This is an indication that the arc welding process is the most (91%) widely used welding process practiced by industries in Ghana whilst the greatest proportion 86 (43.00%) of these industries use the combination of both arc and gas.
5. Within the arc welding group, the largest percentage of about seventy-seven percent (77.35%) of the firms uses the shielded metal arc welding (SMAW) only.
6. Within the gas welding group, the largest percentage of about ninety-eight percent (98.32%) of the firms uses the oxyacetylene welding (OAW) only.
7. Within the resistance welding group, the largest percentage of eighty percent (80.00%) of the firms use the resistance spot welding (RSW) process only.
8. About eighty percent (79.50%) of the industries use only visual inspection to ascertain the quality of welded joint with only about fourteen percent (13.50%) of the firms using nondestructive testing (NDT) and destructive testing (DT) methods.

9.0 RECOMMENDATIONS

It is recommended that:

1. Welding quality standards should be adopted and firmly implemented in the welding industries in Ghana.
2. Since welding is an important manufacturing, maintenance and construction engineering activity, the government of Ghana should take a critical look at the activities of especially the small scale welding industries by coordinating their operations under one industrial estate and giving them support in terms of land and space, training, welding equipment, low interest loans, etc., to improve the rate of productivity and also encourage manufacturing and innovations in different products in the country.

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