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Analysis, Design And Fabrication Of Bellow And Burner For The Metalsmith Industry

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Abstract: ***Bellows and burners are combinations that assist in heat generation for many metalsmiths across the globe. They are structured into two compartments: a flexible integrated material-made structure that strong air to oxidise any fuel media and a seat made of heat-resisted or high melting point material which serves as a container of heat on which the science and technology of metal takes place as far as metalsmithing is concerned. The need for bellow and burner is very important blasts from the point of view of metalsmiths. They are widely used by the metalsmith industry for service provision and income generation. However, the mechanisation and operation of bellow and its burner have not been given much attention to assist the industry operators particularly the small scale industries' to fully extract operational and financial benefits. This paper describes and analyses the metalsmith industry vis-à-vis bellow and burner significant challenges based on design and operational difficulties. But gives room for new designs and operational benefits across the sphere of the metalsmith industry. The study was conducted using descriptive and experimental methodology to detail the procedure used and how the new bellow and burner was produced in line with the objectives of the study. Purposive sampling was used to collect data from 480 respondents via interview and observation. Based on the study, a detachable two-way mechanised operational bellow with its burner was produced.***

Keywords: Metalsmith, Bellow, Metallurgy

I. BACKGROUND TO THE STUDY

The emerging trend of socio-economic development of the metalsmithing industry has awakened the need of improving the basic necessities that will empower those who engage in it to advance production. On the broader scale, metalsmithing is the process of exhibiting knowledge and the capacity of working with almost all kinds of metals by turning it into functional items (Parkinson, 2003). In the process, heat is often required to make the metal malleable to submit to formation and deformation. This industry has grown to a very large extent to occupy the curriculum and forms part of Technical and Vocational Education and Training (TVET) programmes in developed and developing countries in the world. According to Sackey and Amoakohene (1996), the industry rides on fundamental equipment and tools and the key among them is bellow and its associated burner.

In a quest to provide heat to manipulate a metal into functional item, the local metalsmith cannot ignore bellow and its associated burner. A bellow or pair of bellows is a device constructed to provide enough air that serves as one of the means to fuel materials to produce heat. The simplest type consists of flexible bag comprising a pair of rigid boards with handles joined by leather sides enclosing an approximately airtight cavity which can be expanded and contracted by operating the handles, and fitted with a valve allowing air to fill the cavity when expanded and with a tube through which the air is forced out in a stream when the cavity is compressed. A burner is the refractory or high temperature material that contains the fire that provides the heat for the metal fabrication.

Across Ghana, bellow has a significant role it plays in the works of the metalsmith. Although necessary, the mode of operation of bellows has led to migration from bellow to

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electrically operated air blast machines to those who can afford it but yet struggling to purchase power to operate the machines. This has posed a challenge and a threat to the local metalsmith industry.

II. STATEMENT OF THE PROBLEM

The use of bellow has a great impact on the metal industry since time immemorial. The creative ability to use metal to produce functional and ornamental items depends largely on the ability of bellow and burner especially in the local metal industries. Although modern tools are made to replace the functions of bellow and burner in large metal industries, the use of bellow and burner can never be underestimated in the metal industry. In Ghana, metal products have helped to make use of metal substances such as gold, silver, aluminum, brass, copper, and others, but most of the design processes would not have been possible without the use of bellow and burner.

The functions of a bellow and burner have contributed a lot to metal industries and the society at large. In many communities, metalsmiths depend on the bellow and burner to produce metal products including farm tools, kitchen accessories, jewellery among others. There is no doubt that studies of indigenous metalsmithing have advanced both the theories, methods, and other issues related to bellow and burner to a very large extent. With all the undisputed use of bellow and burner in our local metal industries, yet bellow and burner are not exploited to its mechanical and operational limits.

Most of the bellows and burners used in our local industries have only one form of operation, either with the hand or leg. Due to a lack of flexibility of operating most bellows, once the operator losses energy in either the hand or leg, production stops until he or she regains energy. When the hands or legs get tired the metalsmith production stops. This leads to low productivity and income for the metalsmith. For those who are unable to operate the manual bellow, they have resorted to electrical air generation to assist fuel their burners. This has brought a financial burden to the metalsmiths who are striving to make a living. No attention has been given to a bellow that can be both hand and leg operated that will enable the metalsmith to choose which one to operate in time and preserve energy. It is for these reasons that the researchers are undertaking this study.

III. OBJECTIVES OF THE STUDY

- ✓ To identify types of bellows and its burners used in local metalsmithing industries in Ghana.
- ✓ To identify problems associated with the use of bellows and burners in Ghana.
- ✓ To design and produce a multi-operational bellow with a burner for the local metalsmithing industry.

IV. METALSMITH IN GHANA

Metalsmithing started many years ago during the Pre-Historic Age. Even before the pre-Industrialisation Age of 1750 to 1850 AD, metalsmithing has gained industrial and commercial recognition (Childs, 1991). All over the world, metalsmiths play a significant role in the socio-economic development of every country of which Ghana is no exception. One of the longest crafts industries known to man immediately after creation was metalsmithing (Childs, 1991). It is believed that processes that led to civilization include metalsmithing. The first evidence of smithing work made of iron was found in Egypt and it dated 1350BC (Blandford, 1998; Miller & Killick 2004; Chirikure & Rehren, 2006).

As far as Garrard (1989) is concerned the industrialization of this ancient craft industry permeated the boundaries of Ghana in the nineteenth century in the northern part of the country precisely Savelugu and its environs. Farm implements, utensils and basic tools were being manufactured by the local metalsmiths for the survival of mankind. The contemporaneous situation, and the changes and developments in the structure and organization of this ancient industry led to the spread and diversification of the metalsmithing across the sixteen regions of Ghana (Tetteh, 2017). Not forgetting the arrival of the colonial masters from Europe who did not only come for socio-economic and political exchange benefits but also introduced precious metal jewellery fabrication industry.

Since the introduction of metalsmithing in Gold Coast the now Ghana in the early 1800's by the Mande's there has been significant progress in terms of equipment and tools (Garrard, 1989). There are sixteen regions in Ghana with various industries one way or the other (Ghana Statistical Service, Geographical Information Systems Section, 2019). Although the economic growth is centered on oil, agriculture among others (Financial Report, 2019), one of the small scale industry sector that is contributing to the growth of the economy according to the 2010 Census, is the metalsmithing industry. All the sixteen regions in Ghana can boast of metalsmithing workshops in various forms. Many lives depend on this profession (metalsmithing) especially in the rural areas of the country. According to Nsiah (1993), Ashanti Region can boost of blacksmithing which is a component of metalsmithing as one of the oldest industrial jobs established in the region; specifically at Suame, Kroforom, Bantama among others. Metalsmith in the Ashanti region is highly esteemed due to its contribution to the establishment, strength and stability of the Ashanti kingdom in terms of defence against war or possessions, and food security.

The socio-economic benefits of metalsmithing cannot be over-emphasized as it is highly esteemed and regarded in the Ghanaian society because of its products such as weapons; gun, bow and arrows, knives, traps, chains, locks, shields and devices like hoes, shovel, spade, pickaxe, mattock, sickles, cutlasses, musical instrument etc. Aside the spread of the metalsmithing in the Ashanti region; Volta, Western, Eastern and Greater Accra regions got involved with the specialty of jewellery fabrication and blacksmithing as far back 1903 (Jaggar, 1978). Larbi and Ansah (2008) describe the Ahafo, Bono East, Bono, Central and Western North regions as the Modern Age metalsmith industry since the account of their

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works were influenced by the traditional and forerunners in the metalsmithing industry in Ghana. In metalsmithing one of the major necessities either to establish or to keep production is the bellow and the burner (en.wikipedia.org/wiki/Pre-industrial_society). The challenge among the metalsmiths in Ghana evolves around the cost of fuel on one hand and the mode of operating of the bellow and burner on the other hand.

A. BELLOW

Bellows are indispensable variables in the metalsmithing industry and need no emphasis (Chirikure, Burrett & Heimann, 2009). A pair of bellow is a device constructed to provide enough air that serves as one of the means to fuel materials to produce heat. It is mostly made of integrated materials of wood, leather and metal. It is constructed to have a flexible leather airbag that can be compressed or expanded and contracted with rigid boards with handles and a valve and pipe tube (tuyere) as an inlet and outlet of air to fuel the combustible materials (Childs, 1991; Herbert, 1993). Bellows are usually produced in pairs or multiple sets respectively to provide enough continuous flow of air for smelting and metal fabrication.

It must be noted that the word bellow is also associated with other fields of importance but the focus of this study is in relation to bellow used in the metalsmithing industry.

B. HISTORY OF BELLOW

There have been several transformations in what was used as bellow since time immemorial along the history of metals and metallurgy. In the olden days of metal technology, smelting was rare, as such bellows were rarely used. The early metalsmiths during the Prehistoric Age used open natural air, wind and human mouth as a source of bellow (Ball & Nostrand, 1972). The process then was like that of open firing of pottery ware (http://www.persee.fr/web/revues/home/prescript/article/paleo). The era of the Stone Age defined the use of woven palm branches, stems of trees and pliable materials to supply good enough air to metalsmithing. But there was a turn around when technology through civilization and man being sophisticated led to the invention of the now form or design type of bellow in the 1200 BC along the Iron Age by the Hittites and the Babylonians metalworkers using it to extract iron from their ore and also smelting copper. In this era, a compressed animal skin were folded without a tube. Several of them made and used replaceable in one single melting process.

The style of the type of bellow currently in existence was invented around 1000 BC by the Hittites and the Babylonians when metal gained economic status with wide variations in types, temperatures and economic needs. Various looks of bellow have since evolved and invented through series of research strands (Fagan, 1965). Box bellows were traditionally used in East Asia particularly in China. Pot bellows were used in ancient Egypt and Tatara foot bellows used in Japan. Others were bag and pump bellows. In Africa according to Chirikure, Burrett & Heimann (2009) the most common bellows were concertina, bag and bowl bellows. Evidence of these were seen in an Egyptian painting from the tomb of Rekhmire dated 1450BC (http://ancienttools.net/tag/bellows/). By Cline (1937) assertion the bellows used in Africa; Cameroun, Zimbabwe, Uganda, Ghana, Nigeria, Benin, Togo, Mali, Zambia, Ethopia, Malawi and South Africa seem to be homogenous transversing the types of metalworks produced during the pre-colonial era.

C. TYPES OF LOCAL BELLOWS

Bowl bellows were made by attaching an animal skin diaphragm to the top of solid bowl-shaped chambers. They can be divided into pot (clay bowl) and drum (wooden bowl) bellows (Miller and van der Merwe 1994). The most popular variant of drum and pot bellows had a stick attached to the skin diaphragm (Kense 1985). Raising the stick up and down in a consistent manner drove the air through an integral exit pipe into the tuye`res. The long sticks were used in a standing position, while in some instances shorter ones allowed the operator to work from a squatting position (Friede and Steel 1986) (see Figures 3 and 4 There are three local types of bellows of historical discovery records noted in Africa since the pre-colonial era. Some of which have been modified to meet the demand of the twenty first century.

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Concertina bellows are sub-type of bowl bellows. Rather it has double bodied drum bellows with a bigger size and spacious skin enclosing stacks of rings which are separated and allowed to close together in upward and downward movements (Chirikure, Burrett & Heimann, 2009). This type of bellow was mostly used in West Africa as well.

Bag bellows are produced from the whole skin of animals such as deer, antelope, goat, sheep or cow. A large opening is created at one end to admit air and a nozzle is made at the other end of the fold through which the admitted air is forced out into the burner (Kense, 1985). The use of this bellow was wide spread in the Sub-Saharan latitudes from West Africa to Southern Africa.

D. TYPES OF CURRENT BELLOWS IN EXISTENCE

Bellows have taken a new form of look in the twenty first century. The mechanism, operation and material composition have advanced all over the world. The now bellow are made of leather particularly natural leather, wood, metal, and nails. The mechanism has assumed four different forms namely axial, angular, lateral and torsional movement. The difference lies in the design and movement within the bellows. Below are some of the bellows used by metalsmiths across the world.

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Figure 1: Hand operated bellow

Figure 2: Hand operated bellow

Figure 3: Hand operated bellow

Figure 4: Leg operated bellow

E. TYPES OF BURNERS

Burners are the structures that accommodate the combustion that supply the heat in fabrication of metal in metalsmithing. According to Chirikure, Burrett & Heimann (2009) burners emanated from furnaces. To them burners are new invention with multiplicity of functions and airy chambers to fuel combustion for easy metalsmithing. Burner or furnace was invented during the pre-historic age. It developed from the use of stones, clay mould and dug out grounds as furnace. But in this current dispensation, burners have taken different forms in terms of materials and styles. High melting point metal and refractory materials like clay mixed with fibres are now being used to produce burners. Figures 5 to 7 give pictorial evidence of the current types of burners.

Figure 5: Clay made burner

Figure 6: Metal made burner

Figure 7: Metal made burner

Figure 8: Metal and clay made burner

Figure 9: Clay-fibre made burner

Figure 10: Metal made burner

V. DESIGN

Merriam-Webster (2019) describes design as the means to create, fashion, execute, or construct according to plan. In buttressing the above explanation, Amenuke, Dogbe, Asare, Ayiku and Baffoe (1995) opine that design is a master plan or blueprint that is used in all forms of production. Although design has different inferences amongst different fields of knowledge, it converges at one end as a plan.

Bellow design is an important section of metallurgy as it makes it possible for almost all activities relating to metalsmithing and metallurgy to be done. Bellow can be design from the physical composition of metals (ferrous and non-ferrous metals), wood, leather and many others. In the area of metalsmithing and metallurgy, bellows are produced in order to supply heat for effective smelting and fabrication of metalworks. These bellows come in different types. For example, some are hand operated and others are leg operated manually but not combined and this gives the bases for this study.

A. TYPES OF BELLOWS AND THEIR DESIGNS

There are four different types of bellows produced. The axial, angular, lateral and torsional movement types of bellows. The difference lies in the design and movement within the bellows.

a. AXIAL TYPES OF BELLOWS

Axial types of bellows are mostly in cylindrical shape with movement along the cylindrical shape. The movement at the cylindrical portion of the axial bellow is the change in dimensional length of the bellow from its free length in a direction parallel to its longitudinal axis when in use (www.ke-burgmann.com and www.keb-ejs.com).

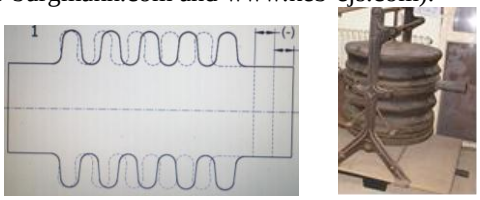

Figure 11: Axial Types of Bellow

b. ANGULAR TYPES OF BELLOWS

Angular types of bellows are compressed at one end of the design. In this type of bellow the movement is dimensional length change displacement of the longitudinal axis of the bellows towards one point when in use (www.ke-burgmann.com and www.keb-ejs.com).

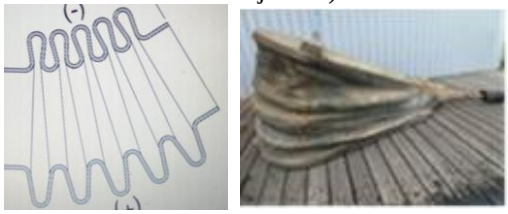

Figure 12: Angular Types of Bellow

c. LATERAL TYPES OF BELLOWS

Lateral types of bellows are those with a movement relatively displaced at one end of the bellows to the other end in a direction perpendicular to its longitudinal axis when in use (www.ke-burgmann.com and www.keb-ejs.com).

Figure 13: Lateral Types of bellow

d. TORSIONAL TYPES OF BELLOWS

Torsional types of bellows are the types with rotational movement on the axis through the center of the bellows when in use (www.ke-burgmann.com and www.keb-ejs.com).

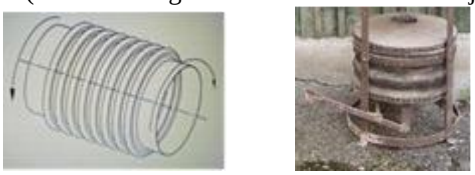

Figure 14: Torsional Types of bellow

VI. SOCIO-CULTURAL AND ECONOMIC IMPORTANCE OF BELLOWS AND BURNERS

The value of bellows and burners cannot be over-emphasized. The science and technology of metal among others gave birth to bellow from the prehistoric days till now. There are numerous processes that require the use of bellows and burners. In the prehistoric time, bellows were used to provide additional air to fire so as to keep it burning; for preparing food and fashioning weapons.

Today, many processes still require the use of bellows and burners. In this current dispensation bellows and burners are used for metal extraction, jewellery making, furniture making, kitchen accessories making, farm tools and implements making, weapon making, casting, tools making in general, for cooking and many others.

Inferring from the kinds of items produced with the assistance of bellow and burners, the economic and social benefits of bellow and burners for the professionals such as metallurgists, jewellers, blacksmiths, metal fabricators, metal castors in these fields cannot be overlooked. These professionals make their living out of the use of bellow and burners. It is the use of bellow and burners in producing farm tools and implements at the urban and rural areas that is serving as a backbone for the growth in Agriculture produce in Ghana (Bradley & Corwyn, 2002). Most food vendors depend on the blacksmith and the metal fabricator for their utensils, and coal pots. Without bellow and burners the survival of many would have been in jeopardy.

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VII. MATERIALS USED IN BELLOW PRODUCTION

For the purpose of this study, the following materials were employed in order to come out with the desired results of the study. Materials such as metal, wood, leather and clay were considered.

A. METALS

A metal is a material element, compound, or alloy that is typically hard, opaque, shiny, and has good electrical and thermal conductivity (Scott, 2016 & Helmenstine, 2010). Metals are generally malleable that is, they can be hammered or pressed permanently out of shape without breaking or cracking as well as fusible and ductile. There are two types of metals, these are; Ferrous and Non-ferrous metals.

Ferrous metals are metals that contain high amount of iron. This can include pure iron, such as wrought iron, or an alloy such as steel. Ferrous metals are often magnetic, but not exclusively. Tetteh (2009) stated the various types of ferrous metals; some of them are steel, carbon steel, alloy steel, cast iron and wrought iron. These metals are prized for their tensile strength and durability. Carbon Steel also known as structure steel is a staple in the construction industry and is used in the tallest skyscrapers and longest bridges. Ferrous metals are also used in shipping containers, industrial piping, automobiles, railroad tracks, and many commercial and domestic tools.

Fahlman (2011) explains, a non-ferrous metal is a metal including alloy that does not contain iron in appreciable amounts. Generally, more expensive than ferrous metals, non-ferrous metals are used because of desirable properties such as low weight (aluminum), higher conductivity (copper), non-magnetic property or corrosion (zinc). Some non-ferrous materials are also used in the iron and steel industries. For example, bauxite is used as flux for blast furnaces, while others such as wolframite, pyrolusite and chromite are used in making ferrous alloys. Non-ferrous metals include aluminum, copper, lead, nickel, tin, titanium and zinc, and alloys such as brass. Precious metals such as gold, silver and platinum and exotic or rare metals such as cobalt, mercury, tungsten, beryllium, bismuth, cerium, cadmium, niobium, indium, gallium, germanium, lithium, selenium, tantalum, tellurium, vanadium, and zirconium are also non-ferrous. They are usually obtained through minerals such as sulfides, carbonates, and silicates. Non-ferrous metals are usually refined through electrolysis (Bradley, 2011).

B. WOOD

Wood is a porous and fibrous structural tissue found in the stems and roots of trees and other woody plants. It is an organic material, a natural composite of cellulose fibers that are strong in tension and embedded in a matrix of lignin that resists compression. Wood is sometimes defined as only the secondary xylem in the stems of trees, or it is defined more broadly to include the same type of tissue elsewhere such as in the roots of trees or shrubs (Greenbook.com).

There are many different types of wood and the categorization is based on their basic characteristics. In this case, there are two known categories of wood; hardwood and softwood. Hardwood is a type of wood that is leaf bearing while softwood on the other hand is any wood that bears cone (typelist.com). Soft woods are woods obtained from coniferous trees such as cedar, fir, and pine and tend to be somewhat yellow or reddish. Because most coniferous trees grow fast and straight. Softwoods are generally less expensive than hardwoods. Hardwood is a type of wood that is leaf bearing, such as mahogany, oak, cherry, maple and birch.

C. LEATHER

Leather is a naturally durable and flexible material created by tanning animal rawhides and skins. The most common raw material is cattle, sheep and goat hide. It can be produced at manufacturing scales ranging from artisan to modern industrial scale. Leather is used to make a variety of articles, including bellows, footwear, automobile seats, clothing, bags, book bindings, fashion accessories, and furniture. It is produced in a wide variety of types and styles and decorated by a wide range of techniques. The earliest record of leather artifacts dates back to 2200 BC.

The leather manufacturing process is divided into three fundamental sub-processes: preparatory stages, tanning, and crusting. A further sub-process, finishing, can be added into the leather process sequence, but not all leathers receive finishing. The preparatory stages are when the hide is prepared for tanning. Preparatory stages may include: soaking, unhairing, liming, deliming, bating, bleaching, and pickling.

VIII. THE STUDY AREA

The study covered Ghana with a focus on the regional capitals. Ghana has sixteen regions as such, sixteen regional capitals were studied. These include Ahafo Region – Goaso, Ashanti Region – Kumasi, Bono East Region – Techiman, Bono Region – Sunyani, Central Region - Cape Coast, Eastern Region – Koforidua, Greater Accra Region – Accra, North East Region – Nalerigu, Northern Region – Tamale, Oti Region – Dambai, Savannah Region – Damango, Upper East Region – Bolgatanga, Upper West Region – Wa, Volta Region – Ho, Western Region – Sekondi and Western North Region-Sefwi Wiawso (Figure 1 and Table 2). All the regions have a history one way or the other in metalsmithing and thus make use of bellows and burners. In each regional capital town blacksmith, jewellery and metal casting workshops were visited for data collection.

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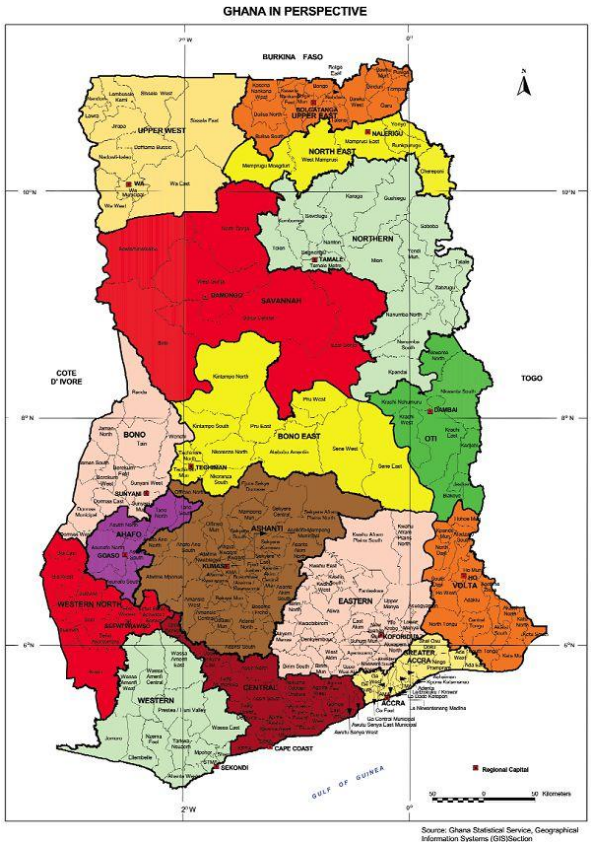

Figure 15: Map of Ghana

IX. MATERIALS AND METHODS

This section defines the approach and the processes used to put together all the working concepts for analysis and results. Methodology is the technique used in carrying out a study of work to improve the existing standards among others. The research methods used in this study were descriptive and experimental. In an attempt to redefine the operational use of a bellow, the researchers adopted strictly, methodologies that focused on the angular types of bellows, systemic operation, material composition, tools and equipment in bellow fabrication. Socio-economic variables settings of communities under study also influenced the methods.

Descriptive research as used in the study is a type of research that relies on presenting accurate and detailed clarification of people, events, or works of art. Descriptive research provides the reader the complete details of events and emotions as they happen (Burns and Grove, 2003). Another function of descriptive research is to make an effort to present events, emotions, ideas and images to the readers as realistically as possible (Anto, 2016). The main goal of this type of research is to describe the data and characteristics of what is being studied. It is also to study and describe bellows and burners, their types, design, mode of operation and construction of it.

Experimental research is a collection of research designs which use manipulation and controlled testing to understand causal processes. Generally, one or more variables are manipulated to determine their effect on a dependent variable (Crossman, 2014). Bakari (2008) state that experimental research is a systematic and scientific approach to research in which the researcher manipulates one or more variables, as well as controls and measures any change in other variables. The study experimented design, mode of operation and construction of bellows and burners.

A. DATA COLLECTION

Purposive sampling method was employed for collecting the data for this study. Respondents for this study were 480 in number, out of a total population of 656. Participatory observations as well as one-on-one interview were conducted in soliciting the primary data from the workshops of blacksmith, jewellery and metal casters. Libraries in Wa, KNUST, University of Ghana, UDS, UCC and UEW were consulted for secondary data. Data was collected within a period of thirteen months; from October, 2018 to November, 2019. The researchers trained 64 enumerators for two weeks on how to collect the data across the country. Local language was used to ensure that indebt information was collected. Data was transcribed, themes were deduced and interpretations given. The Statistical Package for the Social Sciences (SPSS) was used to analysed the components of the data.

Region/Capital	Frequency	Percentage (%)
Ahafo Region – Goaso	30	6.25
Ashanti Region – Kumasi	30	6.25
Bono East Region – Techiman	30	6.25
Bono Region – Sunyani	30	6.25
Central Region - Cape Coast	30	6.25
Eastern Region – Koforidua	30	6.25
Greater Accra Region – Accra	30	6.25
North East Region – Nalerigu	30	6.25
Northern Region – Tamale	30	6.25
Oti Region – Dambai	30	6.25
Savannah Region – Damango	30	6.25
Upper East Region – Bolgatanga	30	6.25
Upper West Region – Wa	30	6.25
Volta Region – Ho	30	6.25
Western Region – Sekondi	30	6.25
Western North Region- Sefwi Wiawso	30	6.25
Total	**480**	**100**

Table 1: Category of population by the study areas

Table 1 gives the names of regions and their capitals and number of respondents

Region	No of Jewellers /metalsmiths	Angular bellow	Axial bellow	Lateral bellow	Torsional bellow	No Response	Frequency	Percentage
Ahafo	30	27	1	0	0	2	30	6.25
Ashanti	30	26	4	0	0	0	30	6.25
Bono East	30	25	0	0	0	5	30	6.25
Bono	30	24	0	0	0	6	30	6.25
Central	30	25	2	0	0	3	30	6.25
Eastern	30	26	0	0	0	4	30	6.25
Greater Accra	30	27	3	0	0	0	30	6.25
North East	30	21	0	0	0	9	30	6.25
Northern	30	26	4	0	0	0	30	6.25
Oti	30	22	0	0	0	8	30	6.25
Savannah	30	23	0	0	0	7	30	6.25
Upper East	30	19	0	0	0	11	30	6.25
Upper West	30	25	0	0	0	5	30	6.25

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Volta	30	27	1	0	0	2	30	6.25
Western	30	25	0	0	0	5	30	6.25
Western North	30	23	1	0	0	6	30	6.25
Total	**480**	**391**	**16**	**0**	**0**	**73**	**480**	**100**
Percentage	**100**	**81.46**	**3.33**	**0**	**0**	**15.21**	**100**	**100**

Table 2: What type of bellow and burner do you use?

Table 2 indicated that angular bellow (81.46%) is the most used in Ghana. The axial bellow is the second most known bellow (3.33%) but out of 16 recorded, only 7 was in use. Interestingly the metalsmith industry in Ghana have little or no knowledge on the types of bellow they use but can to some extent trace the history of the one they know or use. The researchers educated the metalsmiths on the types leading to informed decision.

Table 3: How has bellow and burner benefited you?

Region	No of Jewellers/metalsmiths	Economical	Fabrication	Employment	Others	Frequency	Percentage
Ahafo	30	2	2	24	2	30	6.25
Ashanti	30	2	0	28	0	30	6.25
Bono East	30	2	1	26	1	30	6.25
Bono	30	1	8	20	1	30	6.25
Central	30	3	6	19	2	30	6.25
Eastern	30	6	9	12	3	30	6.25
Greater Accra	30	12	8	10	0	30	6.25
North East	30	6	2	22	0	30	6.25
Northern	30	0	0	30	0	30	6.25
Oti	30	12	2	16	0	30	6.25
Savannah	30	0	0	25	5	30	6.25
Upper East	30	8	4	18	0	30	6.25
Upper West	30	0	0	27	3	30	6.25
Volta	30	5	7	18	0	30	6.25
Western	30	3	5	20	2	30	6.25
Western North	30	0	2	24	4	30	6.25
Total	**480**	**62**	**56**	**339**	**23**	**480**	**100**
Percentage	**100**	**12.92**	**11.66**	**70.63**	**4.79**	**100**	**100**

Bellow has been beneficial to many professions and it still is. In Table 3 it was realized that the function of bellow and its burner serve as a source of employment (70.63%) to many metalsmiths in Ghana; meaning their lives depend absolutely on it. The economic benefit of bellow recorded 12.92%. According to respondents they adopted metalsmithing using bellow and burner in order to support their other businesses and live comfortably (Bradley & Corwyn, 2002).

The zeal for metal fabrication and creativity was the focus of 11.66% of the respondents for the benefit of using bellow and burner. Those who had other reasons were 4.79%.

Region	No of Jewellers/metalsmiths	Fuel/energy	Operational	Efficiency	Others	Frequency	Percentage
Ahafo	30	4	23	2	1	30	6.25
Ashanti	30	9	21	0	0	30	6.25
Bono East	30	5	20	4	1	30	6.25
Bono	30	0	25	3	2	30	6.25
Central	30	6	18	2	4	30	6.25
Eastern	30	2	22	3	3	30	6.25
Greater Accra	30	7	23	0	0	30	6.25
North East	30	3	27	0	0	30	6.25
Northern	30	4	26	0	0	30	6.25
Oti	30	6	21	1	2	30	6.25
Savannah	30	8	22	0	0	30	6.25
Upper East	30	4	26	0	0	30	6.25
Upper West	30	7	23	0	0	30	6.25
Volta	30	3	19	4	4	30	6.25
Western	30	4	21	3	2	30	6.25
Western North	30	0	28	1	1	30	6.25
Total	**480**	**72**	**365**	**23**	**20**	**480**	**100**
Percentage	**100**	**15**	**76.04**	**4.79**	**4.17**	**100**	**100**

Table 4: What challenges do you face in using your bellow and burner

There are challenges with the use of bellow and its burner according to the statistic of this study. The challenges identified were categorized into four. Deduced from the respondents, the major challenge of the metalsmiths who use bellow and its burner was operational (76.04%). Operating the bellow for easy and comfort was a big stress for many of the metalsmiths. Some also have challenges in fueling and energizing the burner and the bellow to function (15%). In this instance respondents complained about money to buy charcoal and the human strength required to finish a metal fabrication work; be it large or small number. The efficiency of how the bellow and the burner work was a big concern for (4.79%) of the respondents. According to them the bellows and burners do not give them good results they expect. The study realized that this was due to faults and overuse of the bellows and burners. A new one perhaps could have changed their responses. Other reasons outside the bracket of operation, fuel/energy and efficiency recorded (4.17%) as shown in Table 4.

Region	No of Jewellers/metalsmiths	Stress free operation	Multi operation	No Response	Frequency	Percentage
Ahafo	30	20	7	3	30	6.25
Ashanti	30	26	4	0	30	6.25
Bono East	30	23	2	5	30	6.25
Bono	30	22	6	2	30	6.25
Central	30	25	5	0	30	6.25
Eastern	30	21	8	1	30	6.25
Greater Accra	30	19	10	1	30	6.25
North East	30	30	0	0	30	6.25
Northern	30	22	8	0	30	6.25
Oti	30	17	10	3	30	6.25
Savannah	30	28	2	0	30	6.25
Upper East	30	23	5	2	30	6.25
Upper West	30	27	3	0	30	6.25
Volta	30	21	6	3	30	6.25
Western	30	18	10	2	30	6.25
Western North	30	20	7	3	30	6.25
Total	**480**	**362**	**93**	**25**	**480**	**100**
Percentage	**100**	**75.42**	**19.38**	**5.20**	**100**	**100**

Table 5: Any idea of a new type of bellow and burner that can be more beneficial than the one in use?

It was obvious from Table 5 that the bellow and burner users in the area of metalsmithing in Ghana according to the study need a new form of bellow and burner. A total of (75.42%) called for stress-free bellow and burner in the industry. Indicating the stress of operating bellow and its burner during metal fabrication by the metalsmiths. As if that is not enough; 19.38% of the respondents are looking forward for a multi-operational bellow and its burner in order to have

enough room to operate the bellow and its burner with various parts of the body. It must be noted that 5.20% of the respondents could not state their position.

X. PROCEDURES USED IN PRODUCING THE BELLOW AND BURNER

Endeavouring to produce an improved angular type of multi-operational bellow and its burner paved way for idea development, complete design, processes to use, and how to produce it. The techniques and methods the researchers used before arriving at the finished work were grouped into idea development, production and finishing.

A. IDEA DEVELOPMENT

Coming out with a new product requires from the researchers to be well informed of the designs and operational mechanisms of the existing ones. Source of idea for the idea development were taken from the various bellows and burners used by the metalsmiths in the municipals at the capital regions. The various bellows and burners serve as the source of ideas for the design and production of the multi-operational bellow and burner. The researchers made preliminary sketches with different styles of bellows and burners using the shape of angular types of bellows as inspiration in order to enable the design of the multi-operational bellow and burner as expected. The angular types of bellows are the common type in use across the country. The preliminary sketches were made purposely to have a clear view of how the multi-operational bellow and burner would look like before selecting the appropriate bellow and burner design for the final work.

B. PICTURES OF BELLOWS AND BURNERS THAT ARE ALREADY IN THE SYSTEM

The following are different types of bellows and burners that are already in existence from which the researchers drew inspiration from in coming out with the preliminary sketches for the final bellow and burner production.

Plate 1: Identified bellow in wood, leather and plastic

Plate 2: Identified bellow in wood, leather and metal

Plate 3: A hand operated bellow in metal, wood and leather

Plate 4: *nd leather*

Plate 5: Hand operated wheel and motor air supply

Plate 6: An electric operated motor and wheel air supply

C. PICTURES OF BURNER THAT ARE ALREADY IN THE SYSTEM

Plate 7: Identified clay burner

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Plate 8: Identified metal burner

Plate 9: Identified metal burner

Plate 10: Identified metal burner

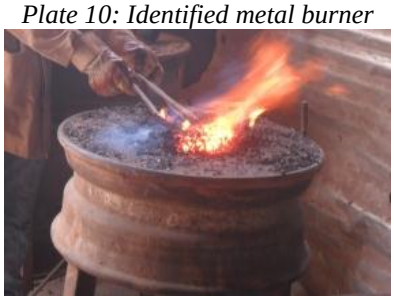

Plate 11: Identified clay and metal burner

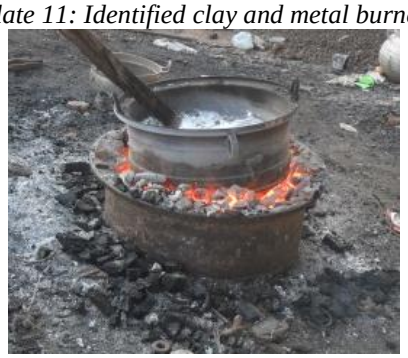

Plate 12: Identified clay and metal burner

D. SKETCHES MADE BY THE RESEARCHERS

The finished work was developed from ideas on various bellow technology. This offered the researchers the room to make several sketches to develop ideas which later was selected to fabricate the final work.

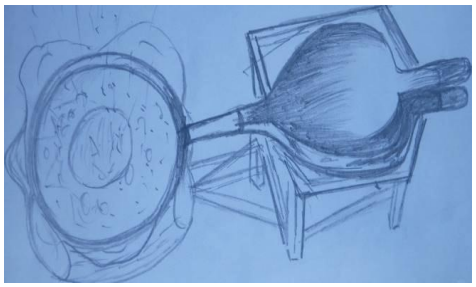

Figure 16: Sketch of bellow and burner

Figure 17: Sketch of bellow and burner

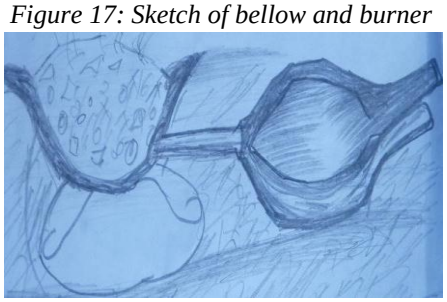

Figure 18: Sketch of bellow and burner

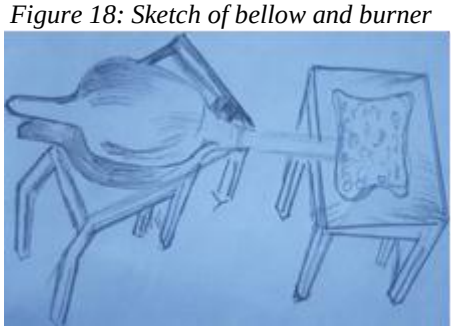

Figure 19: Sketch of bellow and burner

E. COMPONENTS OF THE BELLOW AND THE BURNER PRODUCED

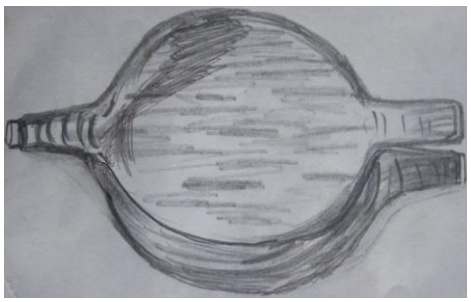

Figure 20: Sketch of bellow

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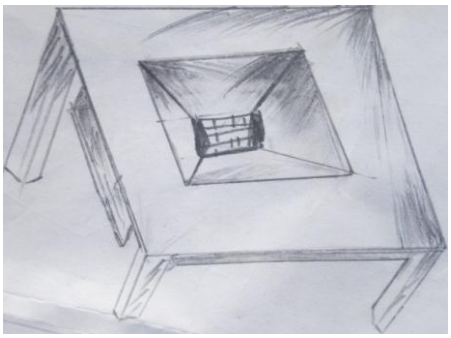

Figure 21: Sketch of stand of the burner

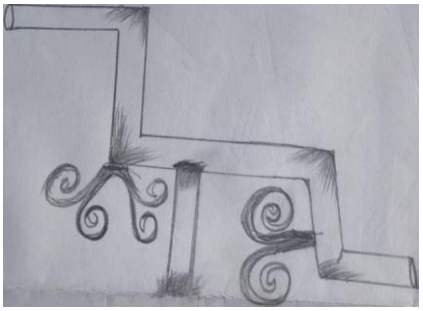

Figure 22: Sketch of round pipes

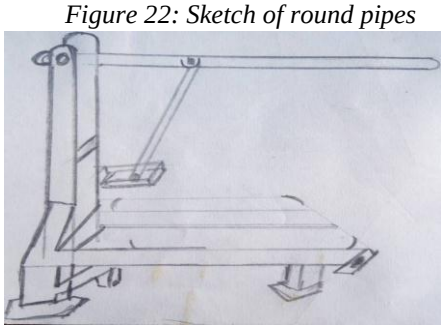

Figure 23: Sketch of bellow stand to be connected to the burner

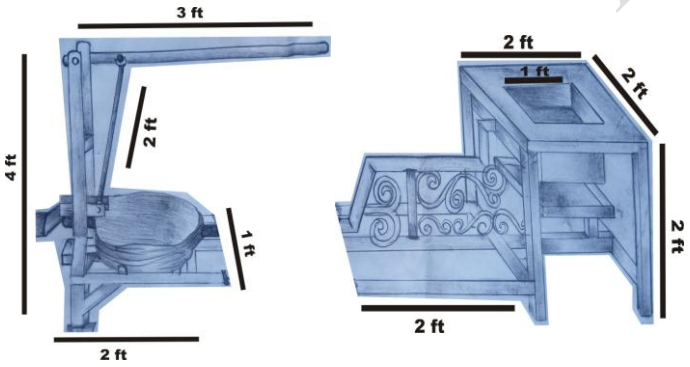

Figure 24: Measurement of the bellow and burner produced

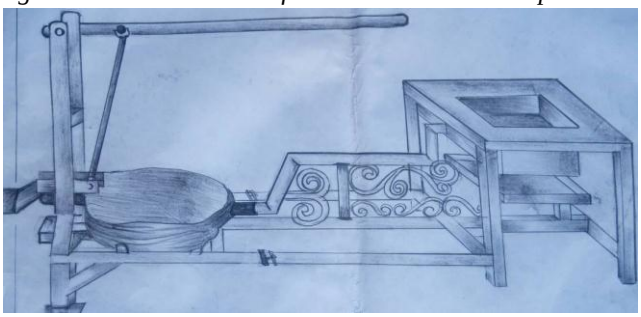

Figure 25: Final skech of multi-operational bellow and burner produced

F. TOOLS AND MATERIALS USED

Tools and materials were essential components in the production process. Without these tools and materials, the new version of the bellow and burner would not have been possible, therefore the researchers employed the following tools and materials in the production process.

G. TOOLS USED

Tools used among others were as described in Plate 3.13 to 3.21.

Plate 13: 90^{o} angle ruler was used in checking straightness of the work at its angles

Plate 14: Tape measure was used in taking the measurements of the work

Plate 15: Hammer was used in hammering the nails to hold the spring firm onto the wood

Plate 16: Hacksaw frame and blade was used in cutting round and square pipes into required measurement

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Plate 17: Welding machine and electrode were used in the joining process

Plate 18: Grinding machine was used in levelling the welded sections

Plate 19: Tacking nails were used to join the leather to the wood

Plate 20: Sand paper was used in smoothening the surface of the red wood

Plate 21: Emery paper was used insanding the metal component of the work to look smoother and shiny

H. MATERIALS USED

Materials used amongst others were as described in Plate 3.22 to 3.26.

Plate 22: Square pipe was used as the frame work

Plate 23: Galvanised sheet was used to construct the body of burner

Plate 24: Red wood was used for the bellow

Plate 25: Round pipe was used for tuyeres, handle and connection

Plate 26: Leather was used for bellow

Plate 27: Clay was used for the inside of the burner

I. PHOTOGRAPH

Photographs of the production processes were taken to show the steps used in the design and production of the multi-operational bellow and burner. These include measuring, cutting, forming, joining and finishing.

MEASUREMENT: after getting all tools and materials needed, the researchers took measurement of the multi-operational bellow and burner size that suits the study.

CUTTING: this was the second process the researchers undertook where chisel and hack saw were used manually to cut the sizes of the materials into components of bellow and burner to be joined.

FORMING: was the process that was used to form and deform the materials to the desired shapes required.

JOINING: this was the process of assembling all the cut and bended parts of the multi-operated bellow and burner together by welding and fastening to complete the multi-operational bellow and burner.

FINISHING: was the last and final process of which the researchers used grinder to grind certain rough areas, filled some areas with filler and sanded it to make it levelled and smooth for spraying. After which the bellow and burner were sprayed.

J. FABRICATION OF THE BELLOW

This segment dealt with the fitting together of pieces to give a structural support and shape of the bellow. Framing materials were round and square pipe metal, rose wood, and structural steel spring. The procedures involved in the production of the bellow from the beginning to the end were elaborated in Plate 3.28 to 3.33.

Plate 28: Taking measurement of the wood to be used for the bellow by the researchers

Plate 29: Cut out bellow shape from the leather by the researchers

Plate 30: Cut out bellow shapes from the wood

Plate 31: Joining of the bellow shapes

Plate 32: Assembling of the bellow by the researchers

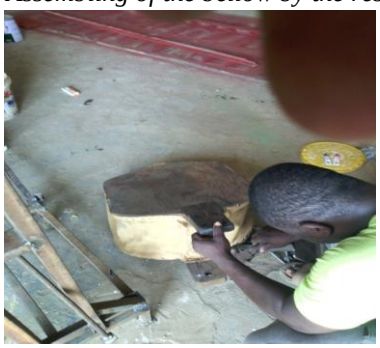

Plate 33: Complete assembled bellow

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K. PRODUCTION OF THE BURNER

The burner production was done using metal square pipe, iron rod, galvanised sheet metal and fine plastic clay soil. These materials were used for the structural support and shape of the burner. The Plates in 3.34 to 3.46 give the procedures involved in the production of the burner from preparation to the finished stage.

Plate 34: Researcher taking measurement of 2 inch square pipe

Plate 35: Cutting out of the measured pipe by one of the reseachers

Plate 36: Taking measurement of the galvanised sheet to form the burner by the researchers

Plate 37: Joining of cut pieces by the researchers

Plate 38: Complete assembled table with burner space

Plate 39: Finished joined burner

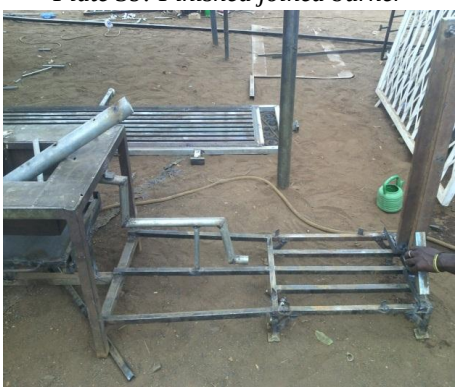

Plate 40: Finished joined burner frame with bellow stand

FINISHING: was the last and final process of which the researchers used grinder to grind certain rough areas, filled some areas with filler and sanded it to make it levelled and smooth for spraying.

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Plate 41: Spraying of the burner by the researchers

Plate 42: Finished assembled burner

Plate 43: Finished assembled bellow stand

Plate 44: Inspection of the hand air-blower on the bellow stand bythe researchers

Plate 45: Inspection of the leg air-blower on the bellow stand by the researchers

Plate 46: Complete bellow and its burner

XI. RESULTS AND DISCUSSION OF FINDINGS

This section emphasises on presentation and discussions of issues that were discovered during the study. The study uncovered findings in the areas of the objectives of the study that are worth discussing.

The researchers acknowledged that those existing bellows are basically made with the combination of wood, metal and leather. The existing types are of varied sizes and shapes depending on the uses. There is the traditional type that is made solely from leather with the tuyere made from metal. The mechanism, though the angular type, needs improvement in terms of the strength of air it releases. Across Ghana, almost all the types are angular or electrical motor machine type. It is usually one person and one side operational bellow. It is for this reason that the researchers decided to produce a different type of bellow using mixed media such as wood, leather and metal which is multi-manually operated. This was in recognition of the data collected indicating the over stressing of energy and or if not financial constraints in purchasing power for electrically operated air blast machines during fabrication of metalwork. Identified burners throughout the study were low or high shaft clay made oven or better still, for the southern part of the country, the car tyre rim types with clay coat inside.

The basic challenge of bellow was its mechanised operation and its limited option in operating it. The identified bellows were solely hand operated. The existing type gives limited body part operation. Metalsmiths either use their hands to operate the bellow while squatting or place the bellow on a

pedestal and use their hands to operate it. In this mode of operation, the smith must truncate the air blow to the burner if attending to issues on the burners. Inferably with the existing bellows, effective fabrication is best done by two persons.

Effective energy is exerted by the hand with little or no option of the use of the leg or other part of the body. This makes it very cumbersome and for those who want to avoid this challenge, they must resort to electrically operated air blast machines which demands purchasing of power thereby calling for more financial commitment. In Ghana, burners have not been an issue at all. Any form of improvised burner that can well accommodate charcoal and resist high temperature is good to use. The issue of concern is how effective air can be blown to achieve stress free metal fabrication.

After drawing inspiration from the existing bellows and burners, the researchers were able to come out with some preliminary sketches of the bellows and burners whereby box and accordion methods were put together into angular type of bellow with mechanical and pivoted rotational mechanism of which one was selected for production. It must be emphasised that the most common type of bellow used in Ghana are the angular types that combine the box and accordion to function. The selected design was used to produce the bellow and burner to make it unique from others.

The researchers found out that the existing bellows and burner are produced in different compartments. The researchers then resorted to producing a bellow and burner; although they have separate components; they can be put together as one. The operation is one-man operated and very portable to carry or dismantle after use because of its ability to detach the components. It was discovered that most of the bellows and burners are only one form operational, for that reason, the researchers produced a detachable two-way mechanised operational bellow with its burner. The researchers did not deviate from the most materials used in the bellow and burner production. Metal constituted 90%, wood 3%, leather 5% and clay 2% of the total material composition of the production.

XII. CONCLUSIONS

Technology advancement is one of the backbones of improvement. Metalsmith industry is no exception even when its industry players use bellow and burner to grow the economy; as employment and the need for the creative art industry. Arguably the stress of operating the existing bellow and its burner is of concern to 75.42% of the metalsmiths who responded to the questionnaire coupled with 19.38% who demanded for multi-operational bellow and its burner on the same instrument. With these outcomes there is no doubt that technology advancement of bellow and burner that can address these concerns is the way to go.

The study let out the various types of bellow to the metalsmith industry and their mechanism of operation; giving them options to choose from for efficiency and profit making. This result has brought enlightment since the angular type of bellow (81.46%) is the most known. Statistically, there is enough to show that bellow and burner is an economic and source of livelihood tool by many metalsmiths in Ghana. Therefore, there is a need to sustain the use of bellow and burner through the use of advance technology to make it viable for industry players.

XIII. RECOMMENDATIONS

Although the research work is both hand and leg operated, the researchers recommend for further study, an improved version that can take care of legs, hands and can be switched to electrical operation. Other forms of design and material integration can be considered when producing such works. Metalsmiths must be educated on the various types of bellows and its burner to make informed choice.

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