Exploring Die and Punch-Making Out of Scrap Brass

Thomas Bruce[1*] Charles Adu-Boachie[2]
1. Faculty of Applied Arts and Technology, Takoradi Technical University - Ghana
2. College of Art and Built Environment, Kwame Nkrumah University of Science and Technology - Ghana
E-mail of the corresponding author: thomasabruce@yahoo.com

Abstract
This study seeks to expose the making of dies and punches using local technology and materials available to goldsmiths and silversmiths in Ghana. Making of dies and punches is an art which has been in existence for a long time. Currently, it is practised with much complexity and tremendous improvement and the technology is associated more closely with industrial engineering than with handicrafts. Dies and punches are metal matrices which are used for stamping metals either in intaglio or cameo form. In Ghana, the majority of goldsmiths and silversmiths do not use this method to convert their original designs into jewellery, in part because they have little knowledge of it. The technique for production is sand casting using scrap brass. Studio-based practice and descriptive research methods were employed in this study. It was evident in the research that local studio technology supports the uses of scrap brass for making dies and punches. The study recommends that goldsmiths and silversmiths should use studio-based practice to fabricate basic tools such as dies and punches to increase the spectrum of jewellery designs produced.
Keywords: Dies, punches, brass and sand casting

INTRODUCTION

In Ghana, jewellery making has served as a form of livelihood for many through the ages. These people, who are mainly goldsmiths and silversmiths are accustomed to the traditional techniques of jewellery production such as lost wax casting, cuttlefish bone casting, piercing and forging. These techniques are sometimes time consuming and the weight of each piece of work produced using these techniques is difficult to control, especially in situations where many pieces of the same weight and size are desired. Admittedly, each traditional technique used by goldsmiths and silversmiths has its own direct influence on the character of the jewellery pieces which come out of it. For instance, the aesthetic qualities of a pierced work are different to those of a lost wax casting piece. While cast works are heavy and look three dimensional, pierced works are flat and look two dimensional unless they are filed or slightly domed to give them a three dimensional effect which makes it difficult to standardise their weights. Although the making of dies/punch sets could be explored by Ghanaian goldsmiths and silversmiths for jewellery-making for the reproduction of design ideas in mass quantities in a considerable period of time, a survey conducted by Bruce (2015) indicates that, currently, goldsmiths and the majority of contemporary Ghanaian jewellers are not employing these die/punch forming methods because they do not have enough knowledge about them.

Untracht (1985) states that a die and punch set has been used since antiquity to make a stamped pattern in relief on sheet metal or thicker blanks of circular form; it has been used especially by the Greeks in the 2nd century B.C. who employed a two part, closed, bronze stamping die and punch to make coins and medallions. Burto (1963) and Raput (2007) explain that a die and punch set is a metal matrix which is used for stamping metals either in cameo or intaglio form and it has desired contours, so that when the punch and the die meet, the clearance between them is the same as that of the sheet's thickness. Codina (2007) also reveals that stamping is commonly used in manufacturing processes since most daily objects are made using some production process based on stamping and die stamping. He admits that contemporary stamping with complex dies has evolved tremendously and that, presently, the technology is associated more closely with industrial engineering than with handicrafts. He adds that, with the use of older production methods and taking advantage of the resources and products that are available and affordable in today's market, one can produce very attractive, interesting shapes and decorative features at a reasonable cost. Though McCreight (1991) explains that dies could be made to generate shapes, dies could also be made to produce forms which would have length, width and depth and could be used as jewellery components.

Dies are grouped based on different functionalities. Schwan et al. (2002) state that dies are classified broadly as single operation dies and multi-operation dies. They explain that single operation dies are further classified into the following:

Cutting Dies: these dies are meant to cut sheet into blanks. The operation so performed is called the blanking operation.

Forming Dies: these dies are used to change the shapes of the work piece material by deforming it. No cutting takes place with these dies. These dies are used to change the shape- and size-related configuration of metal blanks. McCreight (1991) says that a silhouette die is simply an outline shape cut from a tough material such as masonite, plywood or steel. He adds, though, that there are several families of dies but gives two basic types: conforming dies and non-conforming dies. Conforming dies consist of two corresponding parts. They are generally held in a superstructure of some sort to guarantee that the parts line up when they are brought together. This die controls every aspect of the form and ensures exactly duplicated units time after time. Non-conforming dies which are also called silhouette dies consist of rigid material pierced with an outline silhouette of a desired shape. The process is extremely versatile because the contour and depth of the image can be changed each time the die is used.

Different materials can be used to produce dies or punches to achieve a particular purpose. Davis (1995) discusses how materials for dies and punches for fabrication range from plastics for low-quantity production of simple to moderate parts to the most wear-resistant (nitride) tool steels for making severely formed parts. Parts of even greater severity or those running to quantities greater than one million may require dies or inserts of cemented carbide. Miller and Miller (2004) state that a good grade of tool steel is used for making punches and dies. The steel should be free of harmful impurities. Sometimes, the body of the die can be made of cast iron with inserted steel bushings to reduce the cost of the materials used. They continue that the advantage of this type of construction is that an insert can be replaced when it becomes worn out. Soft steel that has been case hardened does not change its form as readily as tool steel, and any mint changes in form can be corrected readily because the interior is soft. Internal strains or stresses are set up in steel during the manufacturing process. In die making operations, these stresses must be relieved before the die is made into its final size, else they will cause distortion. The presence of stresses cannot be determined in the steel beforehand, but the die maker can relieve the stresses in the steel by annealing after the die has been roughed out.

According to Sharma (1999), hot forging dies operate under very severe service conditions since the forging process is characterised by high interface pressure coupled with high temperatures; therefore, the tool and die materials are selected and manufactured with the greatest care. The materials used for making dies must be heat resistant, possess adequate strength with a low wear rate and lend themselves to machining with cutting tools. A compromise between hardness and ductility must be struck since the dies are exposed to thermal shock. Die blocks used for the production of forging dies are manufactured from high grade special tool steels. Youssef et al. (2011) state that another attractive feature of die making is the versatility in die making procedures using castable die materials, such as glass reinforced plastics (GRP), urethane, epoxy resin, ductile cast iron, kirksite (a zinc-based casting alloy) or concrete. A simple wood or styro-foam pattern can be used to manufacture such dies. For higher pressures and longer tool life, hardened steel dies are used. Altan (2011) explains that steels are used mainly for hot dies due to their ability to retain their hardness at elevated temperatures with sufficient strength and toughness to withstand the stresses that are imposed during forging. There have also been some successful applications of other materials such as ceramics, carbides and super alloys, though their application is limited due to design and the cost of manufacturing them. Selection of die material grade and subsequent treatment affects the mode of failure and rate of tool failure. The literature reveals an array of materials which can be used to manufacture dies and punches. These materials could be grouped into metallic and non-metallic materials. Non-metallic ones include plywood or hard wood, ceramics, plastics, cement carbide, nitrides, mesonite, carbides, GRP, urethane, epoxy resin and styro foam and hardware cloth. The metallic materials are steel, ductile cast iron, super alloy and kirksite (zinc-based casting alloy). Other materials such as plywood or hard wood, ceramics and cement can be obtained locally but it is apparently clear that the majority of these materials can only be obtained by importation which makes them expensive to acquire. Secondly, the materials mentioned above are mostly used for manufacturing industrial dies and punches. In the initial investigation conducted by the researchers, it was revealed that all the doming blocks used by goldsmiths and silversmiths are made in brass.

This study explores locally accessible materials, tools and develops methods at studio level and produces samples of dies and punches. It has been necessary to expose the concept of die and punch creation to local Ghanaian goldsmiths and silversmiths with the understanding that their usage offers the opportunity to reduce the time needed for mass production of jewellery and their accompanying labour cost.

MATERIALS AND METHODS

Materials

There are different materials which were identified locally and can be used as materials for fabricating dies and punches. Examples of these materials are pvc plastics, steel, cast iron and expoxy resin. Other materials are concrete, wood and brass. Each of these materials has its own qualities, meaning that the selection of any individual material for making dies/punches is suitable for particular purposes. For example, it is easy to make dies from wood but their life span cannot be compared to those fabricated from steels. Though the above mentioned materials could be sourced locally, scrap brass was selected as a material for tehf ollowing reasons: its availability in Ghana makes it easy to source as scrap; its physical and mechanical properties make it conducive to the making of dies and punches at the studio level (for instance, it is resilient and hard enough to ensure fairly long life in dies and punches); and brass is able to withstand rusting. The selection of brass in this study for the making of dies and punches also stems from the fact that the available local facilities and technology support the casting of brass more than other materials such as steel. According to Margot et al. (1998) brass is an alloy made from a mixture of copper and zinc. Cobb (2012) explains that brass is noted for its beauty and corrosion resistance. Wagner (1992) defines scrap metal as bits and pieces of material parts, for instance bars, turnings, rods, sheets, wire or brass metal pieces that may be combined together with bolts or soldering, for example from radiators, scrap automobiles, railroad box cars which when worn or superfluous can be recycled. In Ghana, scrap metals especial scrap brass can be obtained from scrap dealers who are usually located in places where metal artisans work such as Takoradi Komkompe, Kumasi Magazine and Accra Abossey Okai.

METHODOLOGY

Descriptive and studio-based experimental methods of research have been employed in the qualitative design. Leedy and Ormrod (2010) describe how descriptive research examines a situation as it is. It does not involve changing or modifying the situation under investigation, nor is it intended to determine cause-and-effect relationships. Descriptive research was, therefore, used to examine the local materials and technologies suitable for the study.

The studio-based experimental method used in this sense does not mean scientific enquiry through quantitative research but rather, art studio-based experiment and description. Niedderer and Roworth-Stokes (2007) discuss the role of practice within research in particular regarding its use for the purpose of generating and communicating experiential knowledge. Candy (2006) also adds that practice-based research is an original investigation undertaken in order to gain new knowledge partly by means of practice and the outcomes of the practice. Marshall (2010) explains that the goal during the studio-based research process is to achieve synergy of words and art so that the entire arts enquiry (i.e., the praxis and exegesis) together through synthesis and evaluation is more than the sum of its parts. In this study, the studio-based research design was used to discover concepts, ideas and themes involved in the design and production of dies and punches from scrap brass.

Design Stages

Idea development in this study began with sourcing ideas. A variety of sources was relied on to generate shapes and forms for creating dies and punches. The first source of idea emanated from the idea of how Ghanaian traditional symbols (Adinkra) could be used to develop dies and punches since such symbols are the most commonly used images by goldsmiths and silversmiths. The second source of ideas came from the manipulation of natural objects from the environment into dies and punches. Another challenge which served as a third source of ideas was the use of geometric shapes to create a die and punch.

Though a lot of the Adinkra symbols were used in the course of the experimentation, few were finally selected based on their popular uses. These symbols included: *Gye Nyame* (Except God) (see Figure 1); *Ako-ben* (War horn) (see Figure 2); *Biribi wo soro* (There is something in heaven) (see Figure 3); *Kra Pa* (Good fortune and sanctity) (see Figure 4); *Konsonkonson* (Link or chain) (see Figure 5) and *Ntesie Mate Masie* (I have heard and kept it) (see Figure 6).



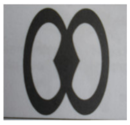


Fig.1: Gye Nyame Fig.2: Ako-ben Fig.3: Biribi wo soro

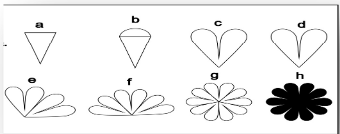


Fig.4: Kra Pa Fig.5: Konsonkonson Fig.6: Ntesie Mate Masie

To establish how an organic material could be used for making of a die and punch, a shell was selected due to its aesthetic appeal. The type used is called a prickly cockle shell pointed snail (cochlicella acuta). Figure 7 shows a pointed snail shell.

Fig.7: Pointed snail shell

In the case of geometric shapes, the first idea was sourced from a triangle and a semi-circle (ID1). After going through six developmental stages, the final one was made as a silhouette (see Figure 8).



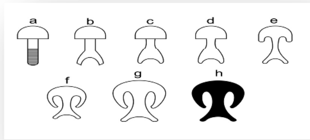
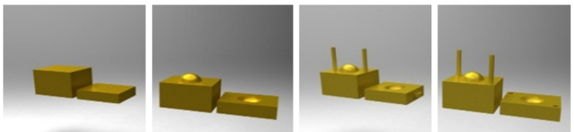


Fig. 8: An image from ID 1. Fig.9: An image developed from ID 2

The second idea also started with a semi-circle and rectangle (ID2). The development of the idea went through eight stages before the desired image was obtained and the final developed shape was made into a silhouette. Figure 9 shows the various steps in the developmental stages of the image from a semi-circle and rectangle.

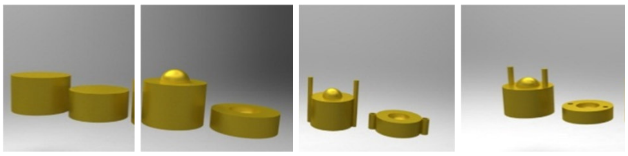
Designing the Dies and Punches (Form and Configuration)

The design of the dies and punches in different configurations were done in pencil and finished using rhino software on a computer. The semi domes represent cameo (punches) and those with round intaglio represent dies. Four design concepts inspired by geometric forms were created and developed. The four design concepts (DC) were labelled DC 1, DC 2, DC 3 and DC 4 respectively. The first design began with rectangles and developed into two rectangular forms – one for the die and the other for the punch. In the second step, the image was developed in high relief as a punch and sunk in the rectangular form as a die. See Figure 10 for the design stages for the die/punch with rectangular forms. The next stage was done with the attachment of two pilots on the punch and two corresponding external holes on the die. The last development was made by repeating the punch but altering the key in this mechanism. With this, the two holes to hold the two pilot pins were created inside the die at the two opposite ends.



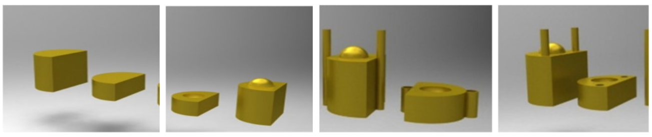
Stage 1 Stage 2 Stage 3 Stage 4

Fig. 10: DC 1 Design stages from rectangular forms



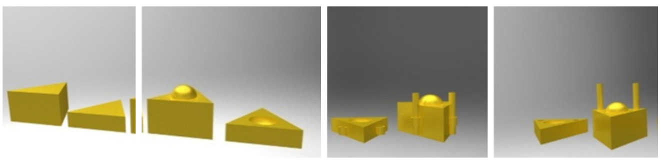
Stage 1 Stage 2 Stage 3 Stage 4

Fig. 11: DC 2 Design stages from cylindrical forms



Stage 1 Stage 2 Stage 3 Stage 4

Fig. 12: DC 3 Design stages from semi-cylindrical forms



Stage 1 Stage 2 Stage 3 Stage 4

Fig.13: DC 4 Design stages from triangular forms

The design process continued with other geometric forms such as cylindrical forms, semi-cylindrical forms and triangular forms. See Figures 11, 12 and 13 for the rest of the design stages from other geometric shapes. In the designing of dies/punches for this study, two operating systems were considered and used by the researchers: externally keying mechanism and internally keying mechanism. With the externally keying mechanism, pilot pins and their corresponding holes were designed to be an added part of the die and the punch. The internally keying mechanism was made to have both the pilot pins and its holes as integral parts of both the die and punch.

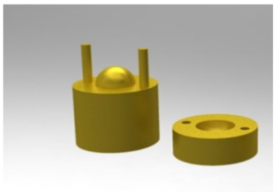


Fig. 14: DC 2 Selected die/punch set design

However, DC 2, which was made from cylindrical forms, was selected for execution for the following reasons: it was appealing to the researcher. It had a wide space to contain images with varied parts and, also, the two pilot pins could stand firm on it. Figure 14 shows the selected die/punch design set with pilot pins and two holes for keying. Also, the designer chose the die/punch set in Figure 14 because the pilot pins and holes were inbuilt; it made them stronger than the ones which would have been attached to punches and dies externally. More importantly too, the selected design was supported by available facilities thus casting facilities.

Die and Punch Production Stages

The fabrication processes used in this study began with the identification of tools and materials. Resources needed were hacksaw and blades, galvanised pipes, files, bench vice, gas torch, bees wax, leather hard clay, steel plate, copper sheet, lead, sand, drill press, scratch brush, jeweller's saw, blades, hammer, flexible shaft, engraving tools, lathing machine and wood.

In considering the technique to employ in the fabrication of the dies and punches, two thoughts came to mind: the first one was to use thick scrap metal to create a die and use it to create a pattern which could be used subsequently to cast the male counterpart (punch). The conviction was that it would enable the researchers to test and see off hand the depth of the dies and the punches.

The first experiment was to test whether or not an engraved image could be used to produce the opposite part to serve as a punch. An image was sunk on 5mm brass plate.

In the course of sinking the die, the appearance of the image was evaluated at intervals by pressing leather hard clay into the depression. Figure 15 shows a sunk image on brass plate of 5mm thickness. This ensured that the desired appearance of the relief on the metal was achieved. It enabled the sinker to make alterations where necessary. Figure 16 shows a high relief impression on leather hard clay.


Fig. 15: Sunk image as die model Fig. 16: High relief impression

The engraved image was cast in wax to establish how the sunk image could be turned into the male part (punch) (see Figure 17).

Fig. 17: Cast wax image in a flask

The procedure used in the first experiment one: producing wax punch with engraved images except that the galvanised pipe (flask) used as a measure for the circumference of the dies was 5cm which was bigger in size than that of the first one which measured 3.5cm (see Figure 18).


Fig.18: Finished blank samples Fig. 19: Pasted designs

All the blanks were annealed, pickled and scratch-brushed under running water. The designs on paper were cut and pasted on the metal blanks using white glue and left to dry. See Figure 19 for the pasted designs on brass blanks. Each piece was fixed in a bench vice and, using carving tools, each image was sunk by removing the intaglio portions bit by bit (see Figure 20). Having initially cut the design using an improvised cutting tool, a flexible shaft machine was used to cut further in order to define the sections more accurately and, in the course of sinking the die, the appearance of each image was evaluated at intervals by pressing leather hard clay into the depression (see Figure 22).


Fig. 20: Sinking of the die's models Fig. 21: Sinking of Nkonsonkonson symbol

a b

Fig. 22a: Sunk die model Fig.22b: boss in clay

Based on the designs, two holes were drilled at both ends for the key in mechanism. This method was used to create a die model using ideas sourced from the Adinkra symbols and designs made from the geometric shapes.

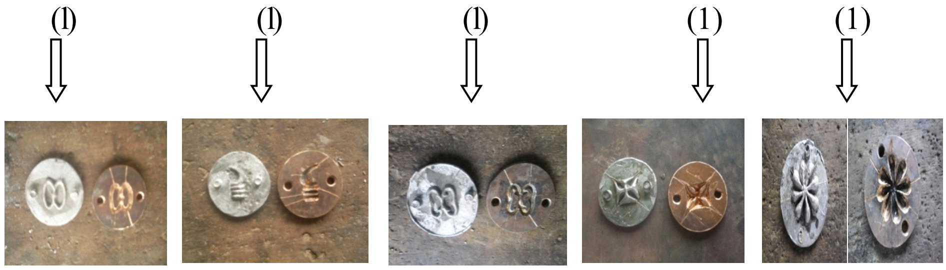
Fig. 23: Cast pattern in lead

From the results obtained from the experiment conducted, the researcher concluded that lead would be used for making the patterns for onward casting for three reasons:

1. Lead has a low melting point (327.5^{o}c) which makes it easy to melt and cast.
2. Though the cast pattern sample came with some defects, they were easily corrected (see Figure 23).

Production of Patterns for Dies and Matching Punches

This process took place in two parts: the first process of making punch patterns was done for dies bearing the Adinkra symbols, which are commonly used by jewellers, and other designs developed by the researcher. Figure 24a-e shows the engraved dies and their corresponding lead patterns. All the lead patterns are labeled 'l' with arrows pointing to the lead patterns. The second process of making punch patterns using natural objects was washed, cleaned and dried. Leather hard clay was wedged and kneaded and the top neatly flattened. A casting flask was used to cut the clay and metal rods were pressed into both sides for the keys



a b c d e

Fig. 24a, b, c, d & e: Samples of lead patterns and die models

The object was pressed downwards into the clay in between the keys to register the image. The clay moulds were allowed to dry thoroughly for two weeks before they were used to cast the patterns. Vents were created on each dried clay mould using a triangular needle file. The following figures (25a-c) show the results from the clay moulds and the cast lead patterns.

a: Pointed snail shell b: Clay mould c: Lead pattern

Production of the Brass Punches and Dies

Tools and materials used: wheelbarrow, head pan, clay, sand, spade, wooden mould (drag and cope), teaspoon and spade. Additionally: ramming wood, plastic pipes, lead patterns, tongs, crucible, furnace, blower and scrap brass. The lead patterns produced in the previous process were used as patterns in this process.

The processes involved were carried out in two segments. The first segment was the fabrication of punches and the second part covered the production of matching dies. The following were the processes used to produce the punches:

1. A wheelbarrow of sand and two head pans of sieved clay were mixed uniformly with water. Figure 26 shows the prepared sand.


Fig. 26: Prepared sand Fig. 27: Sieving of sand on mould surface

2. The drag was formed by ramming sand into a wooden flask with a wooden bat until it was full. To achieve a smooth surface cast, the surface to be pressed with the pattern was covered with fine sieved sand. Figure 27 shows the covering of the mould surface with fine sieved sand.

3. Six patterns were carefully pressed into the sand mould and rammed with two wooden bats. The patterns were covered with sand again and rammed in order to obtain the details of images (Figures 28 & 29).

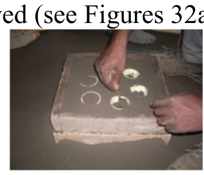

Fig. 28: Pressing and ramming processes Fig. 29: The finishing of the first mould

4. Each pattern was given a two inch plastic pipe for the purposes of creating sprues and the cope was positioned on the drag. Parting sand was then sprinkled evenly on the surface of the mould (see Figure 30).


Fig. 30:Application of parting sand Fig. 31: Ramming of the cope with sand

5. The cope was carefully filled with sand and rammed using wood (see figure 31).

6. A teaspoon was used to scoop the sand from the pipes and a metal rod was used to tap the inner part of each pipe to loosen it before it was removed (see Figures 32a and 32b).




a: Removal of sand b: Removal of pipes

Fig. 27 a & b: Removal of the sand and pipes from the mould

7. The cope was detached from the drag and the patterns were carefully removed from the drag. Figure 33 shows the prepared sand mould after the patterns had been removed and corrections had been made.

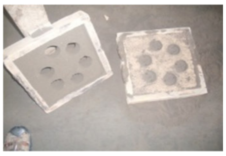


Fig. 33: Prepared sand moulds

8. The moulds were allowed to warm up while the brass was being melted in a furnace. Occasionally, iron sheets were heated and placed on the moulds to warm them up until the molten metal was poured into the individual cavities. Figures 34, 35 & 36 show the pouring of the molten metal into the sand mould, the retrieval of cast pieces and cast pieces respectively.


Fig. 34: Pouring Fig. 35: Cast items

9. The excess brass from cast pieces was cut off using a hacksaw. The surfaces were ground, filed and sanded.
10. Carving tools were used to refine the images on the punches, after which bits on a flexible shaft were employed to sharpen the contours of the images (Figures 36a,b &c). The outcome from the sand cast pieces confirms Bhandari's (2010) assertion that cast components have a rough surface finish and, therefore, require additional machining and finishing which may increase cost.

a b c

Fig. 36: Stages in finishing the punch

Second Segment: Production of the Lead Dies

The second segment involved the use of lead to cast the matching patterns. The matching patterns were cast one at a time. The process was carried out as follows:

1. Each brass punch was positioned on a metal sheet and encased with a galvanised pipe (flask). The outer space around the punch was filled with leather hard clay. Figure 37a shows a punch on a metal sheet. The gap between the metal sheet and the flask was also sealed with clay (Figure 37b).

a b

Fig. 37: Preparation stage in the casting process

2. The flask and the brass punch were heated and this ensured that, when the molten metal was poured, it flowed well into all parts of the image;
3. The lead was melted (slag swept from the surface with a piece of wood) and poured into the flask (see Figures 38a, b & c).

a: Lead melting b: Casting lead c: Cast lead pattern

Fig. 38a, b & c: Stages in the casting of the pattern

4. After pouring the molten lead, the casting was allowed to solidify and cool down for about thirty minutes before it was immersed in water to remove the clay between the punch and the flask.
5. The cast part, together with the punch, was removed from the flask and oil was applied between the punch and the pattern to facilitate the parting of the two parts.

a: Parting process b: Cast lead

Fig. 38a & b: Parting the brass punch from the cast lead die

6. The lead die was carefully and gradually parted from the punch using a flat chisel, wooden tool and a hammer. Figures 38a & b show the parting process which was accomplished in a bench vice and the liberated lead die respectively.
7. The rest of the lead dies were produced using the same method. See Figure 39 for the rest of the lead dies. All the brass punches are labelled 'P' and the lead dies are labelled 'l'. Other punches and their corresponding lead dies

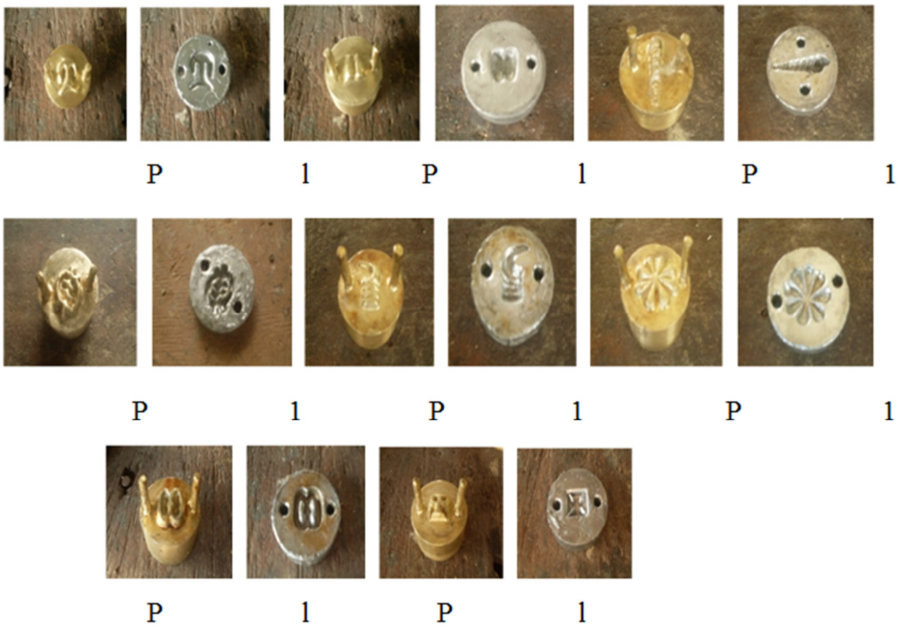


Fig. 39: Other punches and their lead dies

Second Segment: Casting of the Matching Brass Dies

The tools, materials and process used to cast the male parts or the punches, as stated earlier on, were used to produce the matching dies for the punches. It was begun with the preparation of the sand, casting of the matching dies and finishing.

The moulds were prepared and left to dry as the brass was being melted in the furnace. Iron sheets were heated and placed on the moulds to warm them up until the molten metal was ready to be poured into the individual sprues. Figures 40a, b & c. show the pouring of molten metal into the mould, removal of the cast pieces from the mould and the cast dies themselves respectively.

Fig. 40a, b, c a: Casting b: Removal of cast Dies c: Cast Brass Dies

The excess brass from the cast piece was cut off with a hacksaw. The surfaces were ground, filed and sanded (see Figure 41). Again, carving tools were used to refine the intaglio images; following this, flexible shaft bits were employed to sharpen the contours of the images. Figure 42 shows the use of the flexible shaft to clean up the intaglio images. In the course of refining the images, aluminium foil was pressed in to check for the integrity of the images. Ten punches and dies were made initially but two of them were discarded because the impressions were not accurately reproduced.

Fig. 41: Finished brass dies

Fig. 42: Refining an intaglio image with a flexible shaft

Aligning the Dies to the Punches

Aligning each die to a respective punch was not achieved because the pilot pins on the punches were not straight enough to align with the holes in the matching dies. The researcher thought of machining the pilot pins but decided not to because this would have reduced their strength. Consequently, the cast pilot pins were removed with a hacksaw. After that, each set was carefully aligned through reshaping by engraving and filing. Each die was placed on a punch and when they fitted pefectly without any gap between them, they were marked with two vertical lines at one side and three lines at the opposite side to serve as a keying mechanism. This was done to facilitate accurate matching of dies and punches.To determine the working clearance of the dies and punches, the thickness of metal sheet suitable for embossing each image – 1mm thick copper sheet – was cut into four pieces.

The pieces were annealed, pickled and scratch brushed to remove the fire scales from the surfaces. Three of the pieces were milled into 0.5mm, 0.25mm and 0.125mm thicknesses respectively. A set of dies and punches was selected and sheets of the various thicknesses were embossed in it.

Metal sheets of the following thickness – 0.125mm and 0.25mm – resulted in a boss showing crevices but the one which was 0.5mm in thickness produced a clean strong boss. A repeat embossing with the 0.5mm sheet confirmed that the 0.5mm sheet metal thickness was suitable for the creation of the final jewellery elements.

It was observed during the trial process that, though the dies and the punches were able to produce the bosses as expected, it was realised that, during mass production, it would be difficult to produce them at a faster rate. This is because the blank sheet sometimes got shifted during embossing and resulted in deformed bosses. It became apparent that it would be prudent to introduce a more permanent keying mechanism to replace the malformed one removed earlier on.

Two holes initially created on the die patterns served as a guide for the creation of the keying mechanism. With a 5.5mm drill bit, a drill press was used to drill two holes through these initial holes in the dies. In order to maintain a perfect alignment between each die and punch, each drilled die was firmly placed on its corresponding punch and drilled through.

Fig. 43: Fixing the 5mm metal pins

Fig. 44: Embossed element with pilot pins

A 5mm smooth iron rod was fixed into the holes depending on the height of each die punch set. Figure 43 shows the fixing of the 5mm metal pilot pin into the die/punch set. The same process was used to key all the die/punch sets with appropriate metal rods. To enhance quick production, each die/punch set was given a master plate to be used for marking and drilling holes to be held by the pilot pins. Figures 44a &b show an embossed metal element with pilot pins and mass embossed elements. Though the testing with the pilot pins mechanism produced the necessary result, two important difficulties were identified again. These were:

1. The location of the right position of the blank sheet after annealing
2. The repositioning of the die after annealing the blank sheet for another embossing.

Owing to this, the top of each die and its corresponding punch were drilled to assist the user to position a die on a punch without any difficulty. To ensure the correct orientation of the blank sheet for embossing, one end of a blank was punched to correspond with the marks on both the punch and the die. This provision eliminated the problem of incorrect orientation of the blank in between the punch and die prior to hammering.

RESULTS AND DISCUSSION

The results and discussion from this study dwell both on the intrinsic and extrinsic qualities with reference to the efficiency of the die/punch sets in the mass production of jewellery parts and the potential benefits to Ghanaian goldsmiths and silversmiths. This conclusion also showcases the qualities of each individual die set. Each die set consisted of a die, a punch, two pilot pins and a master plate. The master plate was used to develop blanks for stamping. The main dies and punches were made from brass. Each set had two 5mm iron pilot pins. The average diameter of a die and a punch was between 4cm and 5.2cm with the average height between 5.4cm and 5.2cm. Figure 45 shows nine die sets with their bosses which have been stamped.

Fig.45: Die/punch sets and their bosses

The punch is about twice as thick as the die in each case. At both sides of a punch there are two holes in which the iron pilot pins are held. The two iron pilot pins have been made to be removed in the course of work to speed up easy removal of embossed images. Each punch goes with its corresponding die. It has two drilled holes, one on either side of the design in low relief (intaglio) form. The master plate is also made from brass. Figure 46 shows the master plates.

Fig. 46: Master plates

The dominance form of the die/punch sets is seen in the roundness of the elements: the die is circular in shape, the punch circular in shape, the master plates are circular in shape and the iron props are also circular in shape. This gives all the elements harmony in all the die sets in terms of form.

The working efficiency of the die/punch sets comes from the collective workings of all the parts. Brass was used because it is resilient, tough and this will give the die set a fairly long life. The surfaces of the die sets are rough making them easy to handle when working with them. The sets will be able to withstand rusting and this will prolong their life span. The surfaces of the die set can be cleaned easily after use because of the material they are made of. As a tool, die sets were used to emboss samples and numerous jewellery elements and they did not show any sign of wearing. This attests to the resilient nature of the tool and the brass in particular. The test runs using the die sets demonstrate that they are suitable for ensuring material economy in jewellery production because they can be used for mass production of jewellery parts using less labour and time. The embossed jewellery parts were made on 0.05mm thick metal sheet and some of the embossing could produce depths of about 5mm. This depth is an indication of the degree of three dimensionality of the elements produced with the die sets. Work pieces produced using the die sets are hollow, lightweight yet bulky. This means that, with little material, a goldsmith can emboss jewellery parts with three dimensional forms using their sheets. This supports Bawa's assertions that one of the advantages of metal stamping is that the weight of fabricated parts is low.

The use of the die sets reveals that it is efficient in reducing effort and production time needed for mass production of jewellery parts by goldsmiths and silversmiths. When metal sheet is milled to the required thickness, made into blanks and annealed, numerous copies of jewellery elements could be stamped within a short amount of time. With this, the die sets can help the user produce a lot at a lower cost using less labour. It does take a little time to align the die and punch when using them in embossing processes. During embossing, a user needs to use a hammering method to register the desired impression on a metal sheet. It shows how studio-friendly the method is and how little effort is needed to put the die sets into use. It is also an indication that the die set does not need any expensive mechanical means to operate it. The die/punch sets produce quality embossed pieces. This is evident in the samples of jewellery elements which were produced using them. This is because the metal sheets used were standardised for embossing and gave an even thickness. The tools enhance production of the same thickness and sizes of embossed elements which do not change because the same die/punch set are used for numerous copies. Embossed pieces produced from the die sets have sharp, clean contours and smooth surfaces due to the smooth die/punch surface and proper working clearance between the die, punch and pilot pins. The sharp boss outline makes it easy to remove fins around the embossed elements.

CONCLUSION

This research has explored and exposed the concept of producing dies and punches by Ghanaian goldsmiths and silversmiths with the understanding that their usage has the advantage to improve jewellery production. The outcomes of this study have demonstrated the possibilities of using locally accessible, available materials and technology to produce dies and punches for goldsmiths and silversmiths in the jewellery industry. It also epitomises the fact that a sand casting technique could be used to produce dies and punches from scrap brass. Brass as a chief material in this study is readily available locally. Its hardness, resistance to corrosion (under normal conditions) and its workability in the studio make it the material of choice. At the studio level, dies and punches could be used for mass production of jewellery elements within a fairly long possible time.

The success of this study should encourage goldsmiths and silversmiths to use studio practice to fabricate basic tools such as dies and punches to increase the spectrum of jewellery designs produced. Brass should be used by local goldsmiths to produce their dies/punches not only because it is fairly durable but also because it is locally accessible and can be worked with local studio level technology. Local goldsmiths and silversmiths could adapt this study to enable them to cut production cost by using dies/punches to broaden their production technology base.

REFERENCES

Altan T. (2011) *Selection of Die Materials and Surface Treatment for Increasing Dies Life in Hot and Warm Forging*. USA: Ohio State University. pp2

Bawa H. S. (2004) *Manufacturing Processes* – L, McGraw – Hill Education, page 120.

Bhandari V. B. (2010) *Design of Machine Elements.* McGraw – Hill Education.

Bruce T (2016) *Design and Fabrication of Embossing Dies and Punches for making Three Dimensional Jewellery Elements.* MFA Thesis, KNUST Kumasi.

Burto W. E. (1963) *Popular Mechanics.* Hearest Magazines. Pages 140-142

Candy L. (2006) Practice Based Research; A Guide. University of Technology Sydney. Pages 1-3

Cobb H. M. (2012) Dictionary of Metals. ASM International. Page 29.

Codina C. (2007) Goldsmithing and Silver Work: Jewellery, Vessels and Ornaments. Sterling. Page 49

Marshall C. (2010) A Research Design for Studio-Based Research in Art. Teaching Artists Journal 8(2) Pages 77-87.

McCreight T. (1991) The Complete Metalsmith. Davis publications. Pages 65-67

Miller R. and Miller M. (2004) audel automated machines and toolmaking. Wiley. Page 161

Davis R. J. (1995) ASM Speciality Handbook: Tool Materials Pages 174

Niedderer and Roworth – Stokes (2007) The Role and Use of Creative Practice in Research and its Contribution to Knowledge. International Association on Societies of Design Research, Hongkong Polytechnic University. Pages 3&7

Rajput R. K. (2007) A Textbook of Manufacturing Technology: Manufacturing processes. Firewall Media

Schwam et al (2002) die materials for critical applications and increased production rates. Case Western Reserve University. Page 19-25

Sharm P. C. (1999) A T B of Production engineering. S. Chand. Page 188

Untracht O. (1985) Jewelry Concepts and Technology. Doubleday. Pages 1, 118 - 142

Wallace I (2012) Liverpool Bay Marine Recording Partnership. World Museum. Pages 13&18

Leedy, P. D. and Ormrod, J. E (2010). Practical Research, Planning and Design. (9th Edition). Pearson Education, Inc., New York. Page 182

Youssef et al (2011) Manufacturing technology: materials, processes, and equipment. Page 301

Wagner P T (1992) The Hazardous Waste Q&A: An In-Depth Guide to the Resource Conservation. Wiley. Page 40.

Thomas Bruce

Thomas Bruce is a Senior Member at the School of Applied Arts and Technology, Takoradi Technical University, Takoradi - Ghana. His interests are in teaching, practicing and researching in Art. In teaching, his interest covers areas such as Drawing Fundamentals, Principles and Elements of Design, Jewellery Design and Metal Fabrication. In practice, he works mainly with metals (both precious and non-precious metals), plastics and wood. He generates and develops ideas from everyday human interactions, Ghanaian traditional maxims, natural and manmade objects from the environment and other art forms such as music and writings. Aesthetics, Art Therapy, Art Teaching Pedagogies, improving local materials and available technologies in art production especially in jewellery and metal art are some of his research interests.

Charles Adu-Boachie

Charles Adu-Boachie is a lecturer at the Department of Industrial Art, Kwame Nkrumah University of Science and Technology, Kumasi - Ghana. His research interests are in the areas of (1) Die forming Technology in jewellery production and metal smithing and (2) Exploration of forms at the boundaries between jewellery and sculpture.

Mr Adu-Boachie holds B.A and M.Phil. degrees from KNUST, Kumasi.