Journal of Arts & Humanities

Volume 07, Issue 08, 2018: 01-10
Article Received: 12-06-2018
Accepted: 02-07-2018
Available Online: 29-08-2018
ISSN: 2167-9045 (Print), 2167-9053 (Online)
DOI: http://dx.doi.org/10.18533/journal.v7i8.1428

Reconstructing a Five Mould Semi-Centrifugal Casting Machine for the Local Foundry Industry in Ghana

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ABSTRACT

Most cast objects produced by the Ghanaian local foundries are of low quality, and it is because they utilize the wrong method of casting (mould feeding). The local foundries were looked into to find out the casting techniques they employed, and centrifugal casting machines were investigated to be able to come up with a design that best suited the operations of the local foundries to improve their work- and a miniature of it was fabricated. Qualitative research design (descriptive, studio based, and experimental) was used to collect data from a sample size of 70 foundry men from an accessible population of 180 professional foundry men. It was found that the local foundries limit themselves to sand casting and cuttlefish bone casting, but most foundry workers are willing to learn and apply any new technique to improve their productivity. Also, gravitational mould feeding mostly produces casts with poor surface quality, and because mass production is done manually and hurriedly, the foundries end up discarding and reproducing most casts. It is recommended that the local foundries should employ centrifugal casting techniques as practiced in this research to improve their production and services. Also, centrifugal casting, which uses centrifugal force is an ideal way of mould feeding in the foundries and must be utilized in the foundries to improve product quality, and multiple mould-feeding centrifugal casting machines as fabricated in this study should be employed by the local foundries to improve the effectiveness of their mass productions. It is also recommended that the local foundries must form a more organized and structured association with delegated tasks and functions in order to get the attention of the government for aid, should the need be.

Keywords: Casting, Centrifugal Casting, Foundry, Gravity, Investment Casting, Machine.

1. Introduction

Amongst the traits of human nature is the hunger for survival, and as long as man lives through time, change is inevitable-this is why things evolve. The theory of evolution elucidates this to a point, but it is from simple beginnings that man finds ways and means of accomplishing ultimatum. Through

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various researches conducted, it is proof that these procedures were physically exhibited in flint, and went through successive modifications and applications to conceive what man now call machines. A machine is any tool to make work easier. No matter how you see it, the human being is a machine (Paz et al, 2010). Complex machines as opposed to simple ones however are quite difficult to track as to when they came into existence. Wash (1997) opined that they had been in around since 100BC, as Freeth et al (2006) back him up with the Antikythera mechanism which they estimated to have been created around the late second century BC. Roger (1999), however argued they were introduced in the Industrial Revolution, but the fact that modern scientists and archaeologists have no clue as to how the stones were conveyed to and at the construction site of the Egyptian Pyramid of Giza which was built in the 4th dynasty (Petrie, 1883) is its own assertion of when complex machines were in existence. The analogies are exquisite, but let's be analytical-machines have always been around and are now being relied upon to carry out most precision related tasks- especially in the metal casting industry. Metal casting which is amongst man's footprints in the sands of time also forms the ribcage to house the very heart of every civilization; from coin making to complex objects as Chinese brass vases, casting plays a vital role in many areas to the development of a nation. Having been allegedly invented three hundred years after the discovery of metal in 3,500 BC (Turkeli, 2016), foundries were formed from the metal working process when ways of reaching higher temperatures and forming new alloys of suitable characteristics were invented to produce various casts.

In Ghana, foundries cannot be traced as to when they started, but metal casting is a culture that walks with people. Most of the foundries still rely on the primitive ways of working, though a few modern modifications have been made-for instance, the use of the cupola furnace. Although the nature of the local foundries in the country is looked down on, they are a major contributor to the nation's economy- profitability ventures and important job creation avenues, serving as the threshold of industrial revolution. Despite the fact that the services of these local foundries have a large market demand, the products are not as they are supposed to be in terms of quality. This leaves them recasting many works because they simply lack the proper quality control measures (Andrews and Gikunoo, 2011). Simply put; they try to use a method known best to them to cast the wrong products, and it in turn, affects not just the cast quality, but their production rate also. The techniques employed by these local foundries were carefully observed and investigated, and it was made clear that they all employed the sand casting technique to coincidentally produce one same product the most, but the circular nature of the corn mill grinding plates they cast suggests that they would be cast much better if the metal was introduced into the mould cavities by force.

In making primarily hollow cylindrical metal casts, centrifugal casting/spin casting/rotocasting employs centrifugal force to push and keep molten metal away from the centre of the rotating mould, resulting in a pipe cast. This invention from A. G. Eckhart would produce casts which would be free from defects and also possess better mechanical properties at a high production rate (Joshi, 2015), but the hindrance is how they would acquire a centrifugal casting machine. According to Romanoff (1981), centrifugal casting is considered to be a relatively inexpensive process with a $20,000 investment requirement in comparison to a process such as die casting which costs a lot more, but no matter how relatively inexpensive that is, it is quite expensive for the local foundries. In Ghana, Akoma Company is the only import/export company that has ties with a centrifugal casting machine supplier, and they don't have any for sale readily. So, even if anyone could afford the machines, acquisition would be the problem. This leaves the foundries and the jewellery industries with the sling method which would not only pose extreme health hazards, but interfere production rate. This is why working procedures must be tweaked in the local foundries, considering how they work.

The study therefore seeks to identify, design and fabricate a suitable centrifugal casting machine for the local foundries using the most relatively cheap materials. This will be a revolutionary step into advancing the nature of the industry since a new simple and custom casting mechanism will be introduced to the industry. Not only would their production rates increase, the quality of the products the cast would also undergo a massive improvement. Since their working techniques and products were pretty clear, designing a machine was no problem. A careful investigation was done into the centrifugal casting variants and machines to fully capture a suitable machine design for the foundries. It was found that the foundries limit themselves to sand casting and cuttlefish bone casting just because that's what is best known to them, but they are willing to learn new and innovative ways to work. That's because they acknowledge that the gravitational mould feeding mostly produces casts with poor surface quality. Also, because the mass production is done hurriedly, the foundries end up discarding and reproducing most casts.

The rest of this paper will explain as to how data was gathered for a successful design research and fabrication with the methodology, concept and fabrication. It will end with conclusion and policy implementation.

2. Methodology

This research made use of the studio-based, descriptive and exploratory research methodologies. This part however gives a descriptive detail as to how casting is done in the local foundries in Suame and Asafo.

2.1 Investigating the casting techniques employed by the local foundries

It is no doubt that the casting industry in the country has undergone some form of change. Tools and equipment for the casting processes have changed most, ever since the country's independence (Andrews and Gikunoo, 2011). Techniques however remain in terms of their working procedures and material compositions. To have an accurate understanding of the techniques employed by the local foundries, their working activities were carefully observed and further knowledge was acquired by face to face interactions.

From observation, it was deduced that the foundries in Suame used only sand casting while the jewellers at Asafo use cuttlefish bone for their castings. Both being semi-production workshops, the Suame foundries are able to produce a large number of castings, and quickly as compared to those at Asafo which is because the jewellers don't usually mass produce. In both areas, every setup follows the same working process (even mould design and material composition). In Suame, cast patterns are made in carved wood. A mixture of a trip moist sand is added to a barrowful of clay and poured into a short, hollow cylinder with handles on opposite ends. The pattern (a split half of the intended cast) is placed in the middle of the cylinder and sand is poured into it to cover the wooden pattern. The sand is ramped to make it compact.

At the top of the sand, a copy of the pattern is pressed onto it so it appears on both sides of the cope or drag. A hole is made through the sand touching the cavity at its edge to serve as a sprue. About six of these are made and stacked atop one another so that the half pattern cavities will create a cavity for a complete one. Sand is used to seal the seams and the stacked moulds are left to dry for a while. As the mould is being made ready, hammers are used to break the cast iron scraps into pieces. Coke is added to it and the mixture is fed into a cupola furnace. There is no exact ratio as to the furnace feeding. When the metal is molten, ladles are used to convey the molten metal and it is fed into the moulds. In case of spillage, a worker on standby covers the melt with sand to avoid any accident. The moulds are opened up to retrieve the casts. In some foundries, polishing brushes are used to finish the casts after the sprues are cut off.

According to W. Oppong (personal communication, May 25, 2017), a jeweller in Asafo, the cuttlefish bone method of casting is not ideal for mass production, but since they know not any other means of casting their jewellery, it is the only method they resort to. Regardless the little complaint, the technique proves to be quite efficient, but "...the jewellers here don't really cast that much...." says B. Asare (personal communication, May 25, 2017), a jewellery shop owner. In the process, the cuttlefish bone is prepared before the pattern is imprinted into its surface: if by chance, the bone happens to be moist, it is put near heat to draw out every moist from it. It is cut to the desired shape and the inner surface is rubbed against any surface suitable to make it flat and smooth. The pattern is then pressed into it to register its negative onto the surface of the bone and is retrieved. A gate is made by carving out a part of the bone from the edge of the pattern to the edge of the bone itself (and is carved to taper in width and depth). If the pattern imprinted is more than one, a line is carved from pattern to pattern to serve as sprues (metal passageways). A wooden block, or a similarly prepared cuttlefish bone is placed on the bone possessing the patterns and both are tied together. The molten metal is poured into it, and upon solidification, the mould is taken apart, sprues cut off from the casts retrieved and polished further. If the pattern is two-faced, it is sandwiched between two prepared bones and pressed firmly against each other to register the patterns negatives. A mark is drawn at the edge of the bones so the patterns can be closed perfectly after the original's removal.

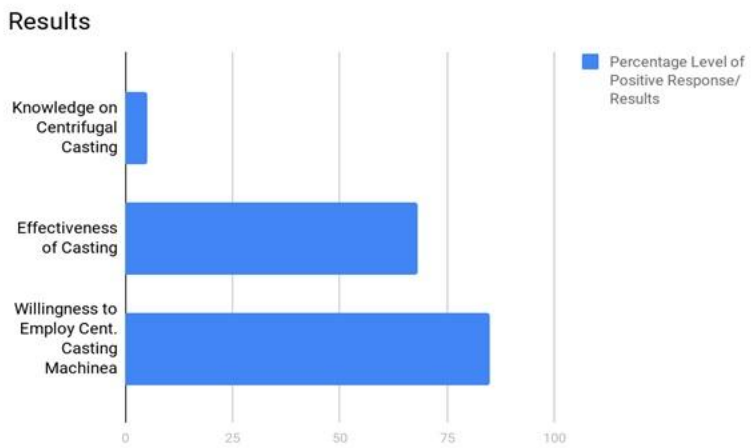

Figure 1: Results chart

Figure 2: Mould Preparation

Figure 3: Breaking down cast iron scraps

Figure 4: Collecting molten metal

Figure 5: Feeding moulds with molten metal

Figure 6: Cast retrieval

Figure 7: Waste casts and mould flasks

2.2 Identifying and designing a centrifugal casting machine

First off, all centrifugal casting machines made are only grouped into either vertical rotation or horizontal rotation, but the design solely depends on the manufacturer's strengths and the client's specifications. Nonetheless, there are other basic factors that will help one identify a machine which falls under which variant of centrifugal casting. Because of this, the researcher had to consider the casting techniques and nature of castings the foundries normally produce in order to come up with a suitable design.

An improvement in productivity rate and mould material cost were also considered- for instance, if the jewellers had a centrifugal casting machine that came with its own huge investment flasks, they would spend relatively much less on mould materials (lead, wax, plaster) than bags of cuttlefish bone of which a third could be in bad shape for work, cast even much more patterns than they would with the cuttlefish and also, much faster. Although a foundry worker at Suame expressed his dislike to the idea of using a centrifugal casting machine because it would capture the jobs of other workers, its employment would be rather an advantage. Also, the foundries wouldn't have to deal with recasting large numbers of products due to poor surface quality, and more casts would be produced within a short time Allen (1979).

Taking into consideration the fact that 80% of the foundry workers had no formal training, the researcher sought to make the machine very simple to operate. To make up for the time that would be wasted if the products were cast depending on only gravity, a concept of 5-feeding gates was considered. This concept meant that the casting variant chosen was centrifuge, and that more casts would be produced at a go. To make this effective, a central sprue (a molten metal receiver which would in turn distribute it) with clay lining was designed to have five sides, onto which five moulds possessing the pattern cavities would be attached. The clay was to receive the heat of the molten metal and also help feed the attached moulds faster.

The central sprue would rotate and distribute the metal into the attached moulds. The attached moulds were designed to be in a cylindrical flask to keep the mould material compact so the force from its spinning wouldn’t disintegrate it. Clamps were designed to favour a rectangular mould in case a rectangular flask was needed instead. Ideally, large vertical centrifugal machines used in the industries are pit-mounted, but the 5-mould centrifuge machine was designed with a ground-mounted turntable with a protective housing around the mould area. To have an effective working condition, an electric motor not below the speed of 1300rpm was considered to be used to power the machine. The nature of the machine was created so that moulds could be attached to the turntable directly for semi-centrifugal casting.

True Centrifugal	Semi- Centrifugal	Centrifuge
Long horizontal mould	Short single mould	Central sprue with attachment moulds
Rotates on X-Axis	Rotates on Y-Axis	Rotates on Y-Axis
Casts possess Rotational Symmetry	Casts possess Rotational Symmetry	Casts may or may not possess Rotational Symmetry
For pipes exclusively	For casts with central parts worked out hollow	For free form casts

Figure 8: Identifying a centrifugal machine variant

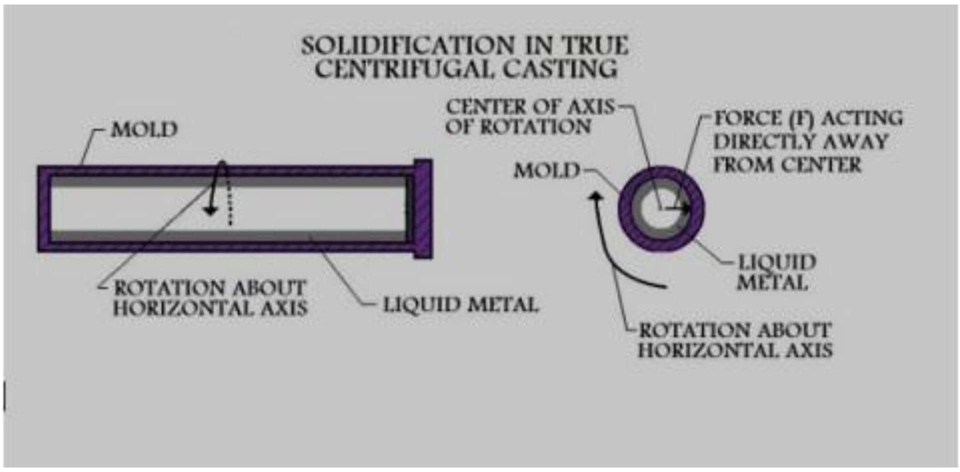

Figure 9: True centrifugal casting machine

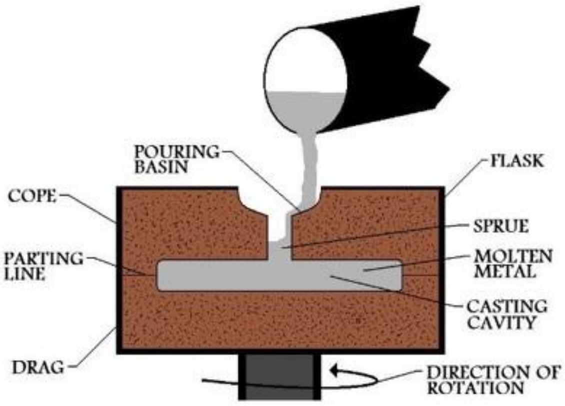

Figure 10: Semi- centrifugal casting machine

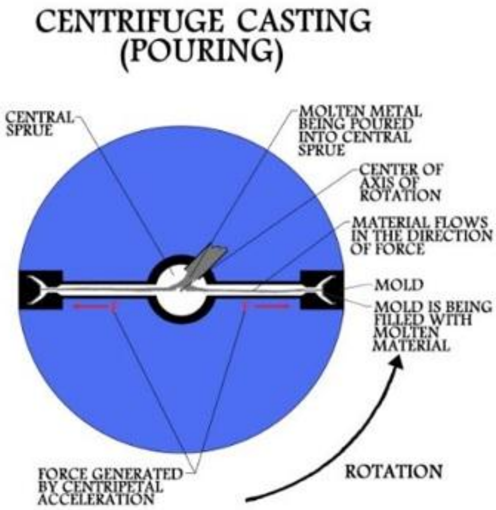

Figure 11: Centrifuge casting machine

3. Machine concept development and fabrication

3.1 Concept development

A concept possessing vertical rotation was chosen due to the recommendation from Wei (2008) that horizontal spin casting sometimes result in a parabolic shape since the molten metal takes a little time to catch up with the speed of the rotating mould while in the vertical, the metal picks up the same speed as the mould as soon as it is introduced into it. Taking this knowledge forward, it also means that the metal might not be able to reach the bottom of the attached moulds before cooling.

The concept has three parts- the main (central sprue) and attached moulds, the turntable powered by a 13000 rpm electric motor, and the housing. Instead of the traditional cylindrical mould, the central mould was formed into a pentagonal box onto which five moulds can be attached to the sides. Aluminium glue cans were thought of to be used as the flasks (attached moulds). The mould was designed to be fastened temporarily onto the turntable disc so that it can be detached for preheating and/ or cleaning. The turntable is made of a square pipe framework with a sheet covering the top, out of which the disc is cut. The disc is connected to a spinner which runs through a ball bearing (for steady rotation) and is in turn connected to an electric motor by a belt for rotational power. The sheet housing encloses the moulds for safety while the moulds spin. The project stands at 23.5" x 24" x 29.7" but the proposed size would stand at 4ft x 4ft x 6ft.

Considering making the machine a very inexpensive one, scrap material was used for almost every part of the work. Being a huge advantage in terms of cost, it however came with its own major demerit as galvanized steel couldn't be welded properly with the welding machine employed. Nonetheless, bolts and nuts were used to hold firmly the parts that could've been welded. The brackets on the sides of the central sprue were attached with bolts and nuts for easy removal and tight mould attachments. The mould mount was fixed into a four-corner track and away from being just below the central sprue. This is to make sure that the belt rather effects the rotation to prevent weakening the motor if it were to be connected directly to the central sprue. Metal plates were fixed onto the tracks and mounts at the end of the turntable base so the mount can be fixed into position with bolts and nuts on both sides (up and down).

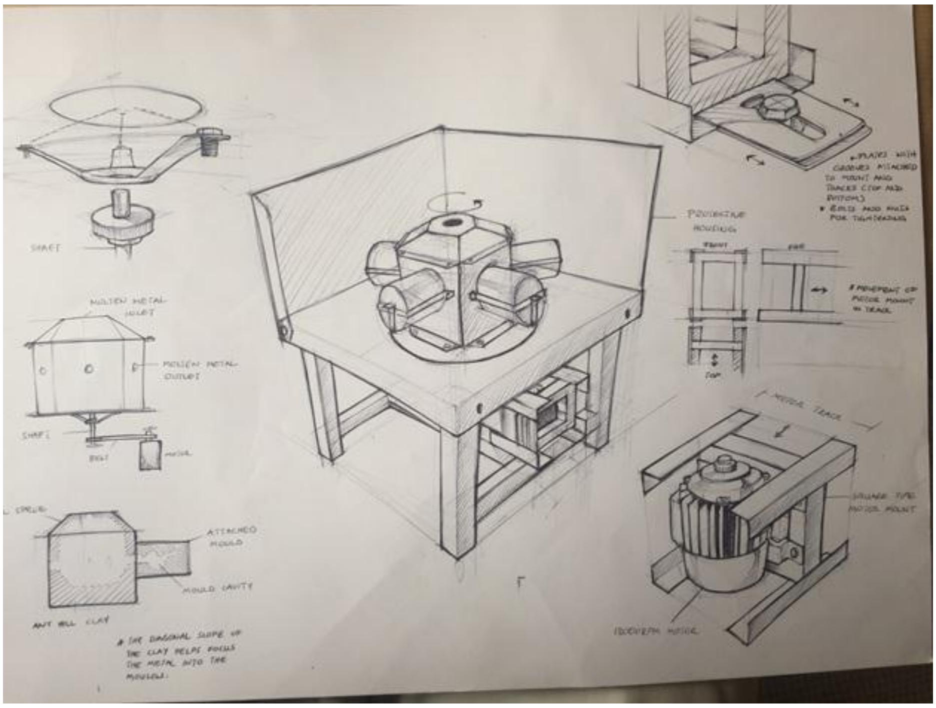

Figure 12: Design concept

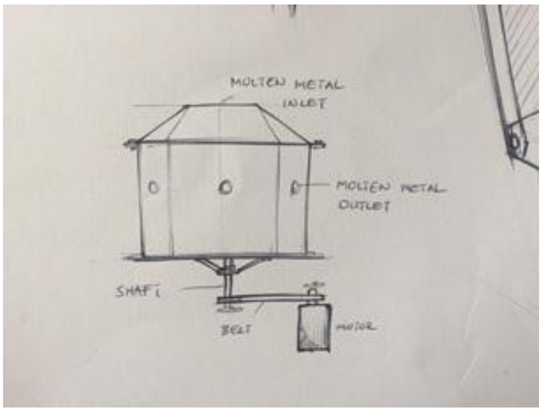

Figure 13: Basic working principle

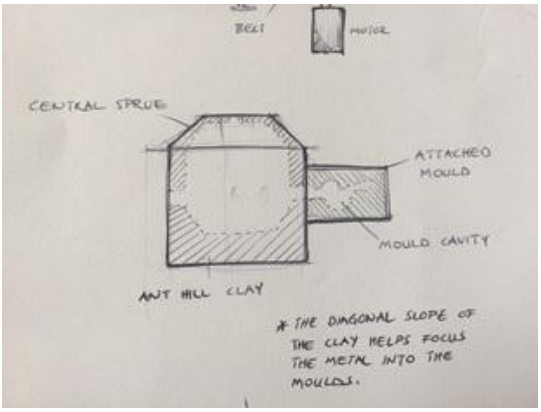

Figure 14: Cross section of mould and sprue.

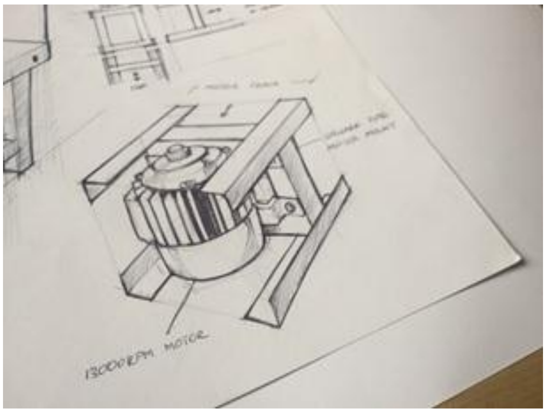

Figure 15: Motor with mount and tracks

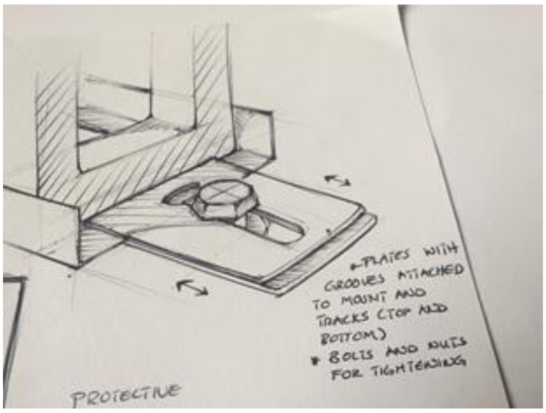

Figure 16: Mount/track locking mechanism

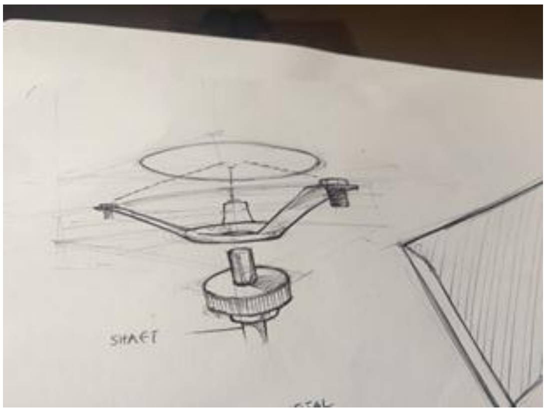

Figure 17: Rotary tripod

3.2 Fabrication of the project

After consulting the technical drawings, a paper model was made to conform to the relative size of the aluminum cans. The cardboard paper was cut in a long strip of 27.5”x9”with flaps and bent at every 1” of its length to form the open pentagonal prism. Five quadrilateral shapes having a base length of 5.5” and height of 7” was drawn touching one another on their sides, with flaps on their sides too. This strip too was bent at every meeting points of the quadrilaterals and the end flaps were stapled together to form an open truncated pentagonal pyramid for the cover of the former. After achieving these, the paper model of the central sprue was completed by cutting a pentagon to conform with the size of the prism for a base cover. When it was complete, a replica of galvanized steel was formed for the actual project in the same manner, but cutting was done with a cutting disc and bending was done with a sheet bender.

The central sprue was then held together temporarily by tucking (welding) and was later welded permanently. Conforming to the idea of fabricating with relatively cheaper materials (scraps), the researcher gathered five old cans of 4.3”x5” to serve as the attached moulds. A hole of about half an inch in diameter was made one the five sides of the central sprue by tearing through the sheet with electrically charged electrodes (welding) to make way for the molten metal into the attached moulds. Two long strips of the metal sheets as a pair were bent at critical intervals to create a clamp for the attached moulds so they would be fixed firmly onto the central sprue by means of screwing. This is so anyone using it can attach the moulds onto the central sprue firmly enough.

In the next stage, the researcher advanced to cut the scrap gate made from 1.5” square pipes of 3mm thickness in varying lengths for the turntable frame with a hacksaw, cutting disc, and a grinding disc. The fame was put up by gradually tucking the parts together starting from the stands, then braced together across from below with two pipes. The upper frame was welded together and placed on the stands to confirm the distance between them before they were braced. After that, the upper frame was then tucked to the stands. Upper braces like the lower ones were introduced to help hold the motor and the spinner in place. Two short pipes were cut and positioned critically to link the upper and lower braces at 900 and to position the motor's shaft in the exact centre of the turntable so it would rotate the disc directly but, upon careful reviewing of the variants in the working mechanism (weight and rotation speed), the two pipes were removed, linked together with shorter pipes and made into a rectangular frame onto which the motor would be attached. This meant the spinner to the motor would rather effect rotation by belt contact.

A track was then made for the motor's support so adjustment would be undeviating. The tracks were made by splitting a 1.5” square pipe into four angular rods- one was attached to each of the braces that ran across the turntable. At the end of the tracks and motor support were welded buckles fastened by means of a long bolt and nut so the motor wouldn’t move out of position. The other important reason for creating the tracks for adjustment was because in time, belts wear and sag, and so it would be ideal to tighten them for further use. Due to limited resources in the researcher's inventory, two plates were welded together to have enough for the turntable top and the disc. A tripod pivot was welded and screwed onto the motor's spinner which ran through a ball bearing to make it stable, and onto it, was the turntable disc screwed to serve as the moulds' foundation on the turntable.

1.75" angle iron was welded on two sides to help ground the machine firmly after the machine was powered to test its stability.

Following this, two sheets of 15”x45” were cut with flaps were cut and bent at 1” and 2” from all except one end to form a closed housing when put against each other. The flaps were added so they would be bent inwards for safety and easy joining onto each other and onto the turntable.

The electric motor saw rewired next, connecting it to a single-phase capacitor to facilitate a good working condition in relation to power and speed.

Using a grinding disc, rough areas were made smooth. A sanding disc was next used to get rid of other materials such as paint and rust off the surface of the metal. Gray oil paint was made less viscous with the addition of thinner, and was applied onto the parts of the machine with a roller and a brush. The motor, however was painted using a hand sprayer.

After drying under sunlight, the researcher put all the parts together using screws. The turntable top however had both rivets and screws.

Figure 18: Turntable Frame

Figure 19: Housing with rotary tripod

Figure 20: Central Sprue (Unfinished)

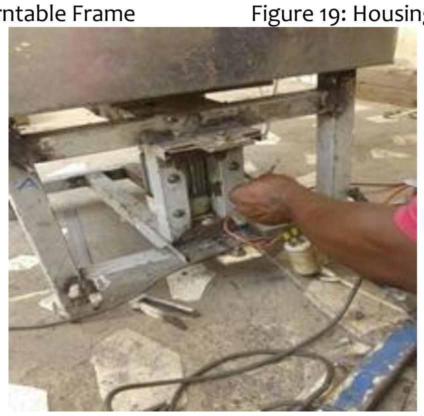

Figure 21: Rewiring electric motor

Figure 22: Finished machine with 3/5 attached moulds

4. Discussion

Table 1: Performance data

Material	Specific Gravity	Wax Weight (Grams)	Time (Minutes)	Material Weight (Grams)	Surface Quality
Brass	8.4	0.4	5-8	3.4	Very Good
		8.6	15-17	7.2	Very Good
		3.3	10-12	27.7	Good
Aluminium	2.6	0.4	10-12	1	Good
		8.6	20-25	22.4	Very Good
		3.3	15-17	8.6	Good
Silver	10.5	0.4	3-5	4.2	Very Good
		8.6	10-12	90.3	Very Good
		3.3	6-8	34.7	Very Good

From the table above, the machine was tested with 3 materials to determine its effectiveness in surface quality to time. Using investment casting, jewellery samples of rings, bangles, and pendants were cast from wax models weighing 0.4, 8.6 and 3.3 grams respectively. Note that the data presented are of the best results, which means that for example, it is ideal to let the machine spin for 5-8 minutes after feeding for best results if one intends to cast brass rings of 3.4 grams.

5. Conclusion

- The foundries are likely to not experience any industrial improvement if other casting methods are not learnt and employed.
- The employment of force-feeding methods to fill moulds would improve cast surface quality.
- A mechanised way of casting that can force-feed many moulds at a time will help save time and improve the effectiveness of mass production.
- Working on materials with time differentials, centrifugal casting machines can be designed to suit any casting technique.
- Government support can be gained if the foundries are strongly united and organized.

6. Policy implementation

- The local foundries should employ centrifugal casting techniques as practiced in this research to improve their production and services.
- Centrifugal casting, which uses centrifugal force is an ideal way of mould feeding in the foundries and must be utilized in the foundries to improve product quality.
- Multiple mould-feeding centrifugal casting machines as fabricated in this study should be employed by the local foundries to improve the effectiveness of their mass productions.
- Casting methods should be looked into, and simple centrifugal casting machines must be designed to suit and enhance them.
- The local foundries must form a more organized and structured association with delegated tasks and functions in order to get the attention of the government for aid, should the need be.

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