THE INTERNATIONAL JOURNAL OF SCIENCE & TECHNOLEDGE

Improved Core Composition for Traditional Lost Wax Casting at Krofofrom, Ghana

Samuel Baah Kissi
Lecturer, Department of Industrial Art,
Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
Dr. Peggy Ama Fening
Lecturer, Department of Industrial Art,
Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
Kofi Asomaning
Lecturer, Department of Industrial Art,
Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

Abstract:
The composition of casting mould cores used by Krofofrom artisans comprises charcoal, cow dung and clay. Although this composition results in a very stable core that disintegrates easily after casting, defects in the form of pin holes are a common occurrence on the inner walls of the cast artefacts, thereby ruining the finish. In many instances these pinholes are difficult if not impossible to remove or seal. To improve the performance of the existing core, experiments were carried out to determine suitable materials and the proportions required to reformulate and enhance the core composition. The addition of Plaster of Paris (P.O.P) to the composition prevented shrinkage and fracture while the presence of saw dust provided microscopic holes in the core structure to facilitate easy core disintegration after casting. High content aluminous clay component served to improve the refractory properties of the core. The new core composition comprising charcoal, P.O.P, saw dust and aluminous clay showed an improvement over the existing Krofofrom core composition. The improved composition yielded efficient cores that disintegrated easily after casting and impart smoother inner wall surface devoid of pinholes.

Keywords: *Lost wax casting, core composition, disintegration, pinholes, clay*

1. Introduction

Lost wax casting has been practiced all over the world by various cultures since prehistoric times. The basic technique is always the same although there might be slight changes either in the core materials, mould making or in how the cast pieces are finished (Apley 2009, Waters, 1993). A recent improvement in the craft for modern industrial use is referred to as 'investment casting'. Casting is of crucial importance especially where mass production and accuracy of artefacts are desired to satisfy demand and supply (Waters, 1993).

In Ghana, gold-weights are associated with lost wax casting, just as the craft of gold smithing itself is associated with the Asante kingdom (Garrard, 1980; Doran, 1977). Until the change of currency in the Ashanti kingdom from gold dust to paper notes and metal coins, casting was used to produce gold-weights which served as counter-weights for weighing the gold dust used for making regalia for the Asantehene (Ashanti King) and his sub chiefs (Martha, 1989). Krofofrom artisans initially made their mould cores from 3 parts charcoal and 2 parts clay. This core composition cast perfectly but did not disintegrate easily after casting thus making retrieval of cast artefacts rather cumbersome. The toughness of this Krofofrom core can be attributed to the fact that clay tends to gain strength when subjected to heat during casting. The subsequent difficulty encountered by artisans as they try to disintegrate cores after casting not only slows down production but can also precipitate the marring of precious cast works. To improve the core's performance some artisans began adding fresh cow dung to the composition presumably to aid in the disintegration of the core after casting. Although cow dung appears to perfectly bind the other components within the composition and apparently allows it to disintegrate easily, it causes the core to retain water even after de-waxing. This moisture in the core turns into vapour as it encounters the molten metal and this interaction affects the integrity of the cast artifacts. The added cow dung does not appear to impart smoother inner walls to hollow cast objects. Other artisans in a bid to improve the core's performance modify the ratio of the core composition to 3 parts charcoal and 1 part clay. When the core composed with these components was tested, it was found that it collapsed even before the molten metal solidified completely in the mould causing parts of the core to be filled with molten metal. This outcome indicated that the core lacked the strength to withstand the heat and pressure of the molten metal (Collins, 2007). Another option exercised by the artisans was to completely burn out the cow dung-containing core before introducing molten metal into the mould while a third test was to increase the amount of clay in the cow dung composition but then fire the core before covering it with wax. In both experiments the outcome was simply unacceptable. Pre-heating the cow dung composition to completely burn out the dung before pouring in the molten metal still resulted in a weakened core unable to withstand the pressure of the molten metal.

The composition comprising 3 parts charcoal, 2 parts cow dung and 1 part clay when tested showed that cow dung in the composition did not only help in the disintegration of the core but provided strength and acted as a binder for the other components. However, when this composition was pre-heated to completely burn out the cow dung the core lost strength and could not withstand the pressure and temperature that the molten metal entering the mould exerted. When the clay content was increased in the composition, the core showed signs of cracks during drying and sometimes during casting and its disintegration was difficult. Also even when the core was subjected to a high temperature to completely burn out the cow dung in the composition (before the application of wax patterns), partial erosion of the core occurred during de-waxing. Core erosion again occurred during pouring of the molten metal. These core failures prompted the investigation into materials suitable for producing cores with adequate strength, ease of disintegration and pinhole-free casting.

Despite the attempts to improve quality, hollow cast objects from traditional lost wax casting have been characterized by pin holes on the inner walls.

2. Materials and Methods

To prevent pinholes and enhance core disintegration, there was the need to evaluate the materials being used by Krofofrom artisans for mould, core and wax pattern preparation: bee's wax, charcoal, cow dung and clay. The new composition formulated to improve the core consist of charcoal, clay, saw dust and Plaster of Paris (P.O.P) which replaces the cow dung in the original composition. The selection of the materials for the research did not pose much of a challenge since clay in ancient times was used as investment material and later the introduction of gypsum which is now known as Plaster of Paris as binder in most investments for casting (Sias,2005). The method used for the study was the Lost Wax Casting. Plaster of Paris did not go through any preparation process since its grain particle was already fine. Beeswax was used for making wax pattern.

3. Experimental Procedures

3.1. The Core Composition of Traditional Metalsmith

Clay, charcoal and fresh cow dung are the three materials prepared and used by the traditional artisans for the production of cores. Beeswax is used for producing wax patterns. The wax is drawn out either in wire or sheet form. Beeswax usually contained sand particles due to improper handling by beeswax collectors (Leclarcq, 2008). Two methods used in purifying bees wax from dirt was to skim the lump of wax with the aid of a sharp knife and the second method was to melt the wax over a heat source until it was completely melted. It was then poured through an 80 mesh sieve into a bowl full of cold water. The wax on cooling and hardening was kneaded for use.

The charcoal was pounded in a metal mortar with wooden pestle into powder. It was sieved through 120microns to obtain fine grains. Clay was also prepared in the same vein and reduced into slip. Cow dung was generally collected from the rearers. The composition comprises 3 parts charcoal, 2 parts cow dung and 1 part clay. Charcoal helps in providing porosity to the core and prevents shrinkage. Fresh cow dung was used because of the fresh fibre which leaves microscopic pores in the core after casting and aids in its easy disintegration. Cow dung helps in proper binding of all the constituent materials, facilitates the drying of the core. Clay in the composition strengthens and hardens the core when fired. Fig. 1 and 2 shows a core composition of cow dung, charcoal and clay. The addition of cow dung although serves the purpose of binding other components within the composition perfectly, yet retains water in the core even after de-waxing. This moisture in the core turns into vapour which is trapped during casting and manifest as pin holes on the inner walls of the cast item. The core retained its former "green" or natural characteristics of being sticky and pliable when wet even after casting. It was revealed that cow dung even when pulverized still contains some amount of moisture. The study also showed that the amount of heat used in de-waxing and the pre-pouring state was not able to completely burn out cow dung. Cow dung core surfaces when in contact with the hot molten metal (e.g. brass) undergoes further combustion and the cow dung releases carbon dioxide, water vapour and ashes. "Micro blow holes" on the surface of the inner walls of the cast item which manifest themselves as pinholes are probably caused by this water vapour released from the combustion of cow dung.


Figure 1: Cow dung mixture


Figure 2: Cow dung core

3.2. Improving the Core Composition

In improving the traditional core composition, the study replaced cow dung with P.O.P and sawdust. The study made a composition of clay, charcoal powder, sawdust and P.O.P with varied proportions. Clay was used as a binder and a refractory in the composition in order to withstand heat without fracture. In this regard clay with high alumina content such as Kenyasi Adwumem was used. Its properties include plasticity, shrinkage, fineness of grain, colour after firing, hardness, cohesion and capacity of the surface to take decoration. Clay often forms colloidal suspensions when immersed in water and becomes hard and lose its plasticity when subjected to heat.

Burning wood less of oxygen produces charcoal. Charcoal in the composition helps in the burning of the core and minimizes shrinkage. Sawdust as fine as 80 mesh was also used for the study. Sawdust provides microscopic holes in the core which facilitates disintegration of the core after casting. Plaster of Paris (P.O.P) is prepared from gypsum (calcium sulphate dehydrate). Plaster of Paris in the core composition helps in drying of the core, prevents shrinkage and provides strength to withstand fracture.

Saw dust was obtained from saw mills within Krofofrom and clay also from Kenyase a suburb of Kumasi in the Ashanti region all without a cost except charcoal and P.O.P which were bought. It was observed that a bag of P.O.P when obtained could be used for a number of works since its percentage in the core composition is not that great and another observation made was that the first coat and the core after coming into contact with the high temperature of the molten metal during casting, burns and they can serve as charcoal for subsequent casting.

3.3. Fabrication of Samples

Four samples of varied proportions were made from Charcoal, Plaster of Paris, Saw Dust and Clay. The four samples were labelled according to the beginning alphabet of the materials hence CPSC 1-4. The materials were weighed in 1500g batches based on the recipes presented in Table 1. The materials were dried and mixed in a plastic bowl and water was added to an even constituency. In order to break the lumps and trapped air pockets, the hand was used in kneading the constituent. Sample cores were made in flat biscuit shapes which were then weighed. A measurement of 25mm was marked on the four recipes. They were dried and then heated to the melting point of brass to test for shrinkage and ability to withstand heat.

SAMPLE	CHARCOAL	P.O.P	SAWDUST	CLAY
CPSC 1	293.7g / 3parts	78.5g / 1part	18g / 1/2parts	52.4g / 1/2parts
CPSC 2	391.6g / 4parts	39.3g / 1/2parts	18g / 1/2parts	26.2g / 1/4part
CPSC 3	293.7g / 3parts	78.5g / 1part	18g / 1/2part	314.1g / 3parts
CPSC 4	342.7g/31/2parts	39.3g / 1/2parts	18g / 1/2parts	314.1g / 3parts

Table 1: Recipes of Core Samples 1 to 4

4. Results

The four sample cores were injected into each of the four (4) hollow wax models weighing 65 grams each. These models were all similar in size, shape, fineness and embellishment. The amount of metal needed for casting an object is calculated by weighing the wax pattern with its sprues (without the core) and multiplying this weight by the specific gravity of the metal to be cast. Brass for example has a specific gravity of 8.56.

The casting results for CPSC 1 and CPSC 2 were undesirable (see figure 5). The cores got burnt and parts of the core were filled with metal. All the sample cast objects had this deformity. This can probably be due to the cores not being able to withstand the pressure and high temperature of the molten metal as it solidified. When one considered the properties of the materials used for the sample cores, it would be observed that when clay, charcoal, sawdust and P.O.P are subjected to high temperature they with the exception of clay, lose strength and break down into ashes. Clay when subjected to high temperature loses plasticity but becomes very hard. A review of all the core samples, shows that although they disintegrated easily after casting and created smooth inner walls yet they could not withstand the high temperature of brass during solidification. The core was very light, lacked strength and could not withstand the high temperature and pressure of molten brass as the molten brass solidified upon casting.

Samples CPSC 3 and CPSC 4 (figures 3, 4 & 6) after the injection into the hollow wax model and casting revealed desirable results. The core disintegrated very easily after casting, smooth inner walls, heavy, very strong and could withstand high temperature without fracture.

Figure 3: CPSC 4 after casting (No pinholes)

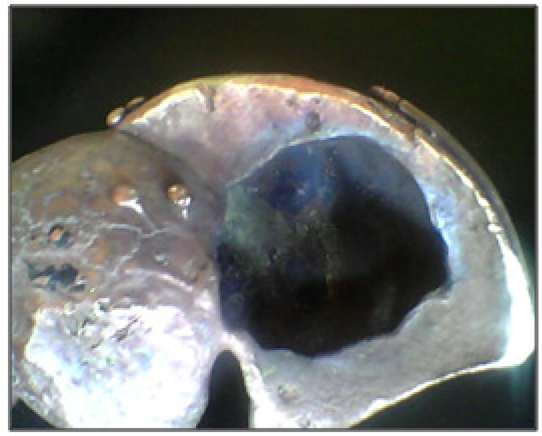

Figure 4: CPSC 3 after casting (No pinholes)

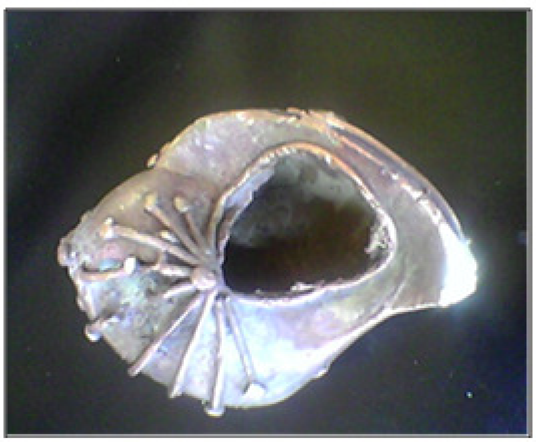

Figure 5: CPSC 1 (Poor inner walls)

Figure 6: CPSC 3 (Smooth Inner wall)

4.1. Casting with the Improved Core Composition

Models were made before casting began. The wax pattern was cast into metal, one of the first steps that the pattern went through was sprueing. Sprueing is the process whereby wax rods or "sprues" ranging from say 1/8 of an inch up to more than 1/4 of an inch, depending on the size of the wax pattern to be cast, is permanently attached to the wax pattern (Gupta, 1983; Kallenberg, 1981)). The wax sprues jutting out of the pattern converged to form a thick rod of wax which served as gate from the reservoir (*Fig 9)*. After wax burn-out, the sprues became conduits through which molten metal run to fill the cavity in the mould. Coating the wax model before attaching sprues strengthened and prevented possible fracture or deformation of the model. In the case of casting hollow works, the core was pierced with spikes (made of iron nails) whose melting point is above that of the metal to be cast so as to hold the core within the mould even before attaching sprues.

Wax rods were formed and a metal spatula was heated for welding the sprues to the model. The models were given the first coat of refractory material made up of 3 parts fine charcoal powder (120 mesh) to 2 parts clay slip. Fine grades were used for the first coat to give the cast a smooth surface. After drying, sprues were attached by first scraping the bare contact point. The moulds were then given a second coat. The second coat provided additional strength and support. This second coat was mixed in the same proportion but with coarser grains of 60 mesh. A third coat comprising a mixture of palm fibre and clay was applied to the second coat after it had dried. The mould was left to dry for about 6 to 8 days before de-waxing.

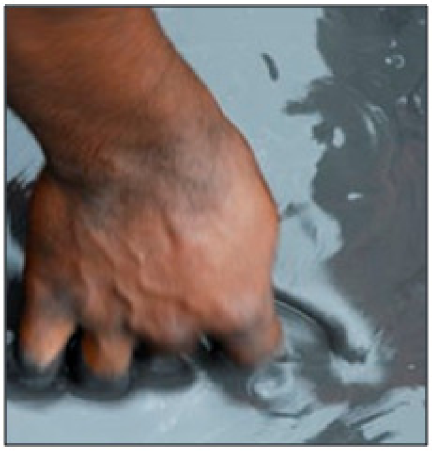

Figure 7: Coating with slurry

Figure 8: Items after coating

Figure 9: Sprueing gate

Figure 10: Mould with palm fibre coating

Figure 12: Drying completed moulds

4.2. De-Waxing

De-waxing also known as burn-out is the process whereby wax is evacuated from the mould. To de-wax, the furnace was packed with fire wood and set alight. The moulds were then arranged in the furnace with the gates pointing downward. The temperature in the furnace was gradually raised by blowing in air until the wax inside the mould began to flow out. After the wax pattern in the mould had melted out, the temperature of the furnace was raised further so that any wax residue in the form of carbon still clinging to the walls of the mould cavity was completely burnt out. Some firewood was taken out of the furnace to reduce the temperature in order for the moulds receive the molten metal.

Melting of brass was done in a crucible lined with a refractory material. Brass was melted in a small furnace different from the one used for de-waxing. This furnace is fuelled by charcoal and the air blast was supplied by an electric blower (household mains or automobile battery). Having ascertained the weight of the metal needed, one-quarter of the metal by weight was added to it to make room for the reservoir and spills. The temperature of the furnace was then raised to melt the brass. Once the temperature has risen to the flow point of the metal, the mould was removed from the other furnace with tongs. The mould was set in sand or wedged in-between stones with the gate upward. The melting crucible held with tongs was brought close to that part of the mould containing the reservoir and tilted to an angle of about 45 degrees for pouring. Within minutes, the molten metal passed through the gate, travelled through the network of sprues and completely filled the mould.
The brass solidified gradually, from the walls inward. Solidification and cooling time of the brass depended on the volume of the cavity to be filled. The mould was subsequently broken to remove the cast object. In the case of hollow objects, a metal rod was pushed into the core to break it loose from the cast object. The gate and sprues were trimmed off and the work polished.

Figure 13: Samples of finished works

5. Discussion and Conclusion

Cores used for lost wax casting by the traditional artisan have gone through several transformations even prior to this research work which aims primarily at improving the casting of hollow objects. In this era of mass production as practiced by traditional artisan, one cannot afford to lose valuable cast objects through distortion and difficulty in core removal. Traditionally, the introduction of fresh cow dung to the composition of charcoal and clay by the traditional artisan was to improve upon the disintegration of the core after casting. Although the fibre in the dung provides microscopic holes in the core which allows heat retention and improves the disintegration of core after casting, it nonetheless creates pinholes in the inner walls of cast hollow objects. According to Kumar and Shende (2006), effective combustion of cow dung takes place when the dung is pulverized.
The increased recipe of clay in the composition helped the core to withstand high temperatures during the firing. The high amount of Al_2O_3 in KenyasiAdwumam clay helped in achieving that. Alumina is responsible for refractoriness and plasticity of a clay sample (Worral, 1986) and therefore its addition to the core composition avoided melting and fracture.

It is evidently clear that the addition of Plaster of Paris which is not a new additive of lost wax casting technique with saw dust and increased amount of high content aluminous clay served as a refractory material to the traditional core composition and helped a great deal in eliminating pinholes and providing smoother inner walls of cast artefacts. A workshop has been organized for these traditional artisans to enable them overcome these challenges

6. References

i. Apley, A. (2009). African lost Wax Casting: The Tada figure, Retrieved from www.metmuseum.org on 26th of April, 2010.
ii. Collins, N. (2007). Cow dung in Lost Wax Casting. Retrieved from www.lost-wax-casting.com on 23rd of February, 2011.
iii. Garrard, F.T. (1980), Akan weights and the Gold trade. New York and London: Longman group Ltd,p.209.
iv. Gupta P.R.B. (1983), Foundry Engineering. India, Tech India Publication, pp.19 and154 to157
v. Kallenberg, L. (1981), Modeling in Wax for Jewellery and Sculpture. New York: Chilton Book Company.Kissi, S.B. (2011), Evaluation of Bees Wax and Core Materials for Traditional Lost Wax Casting. M.F.A Thesis, KNUST: Kumasi.
vi. Kumar and Shende (2006). Cooking Stove. Madhav Institute of Technology and Science. www.appropedia.org/efficient-cooking. On 5th July,2010.
vii. Leclarcq, B. (2008). The Honeybee and Man. Retrieved from http://google-search.com on the 11th of August, 2009.
viii. Martha, E. (1989), Early Akan Gold. London, African Arts, Cambridge: Cambridge African Studies Centre, Vol. 22, p.87
ix. Ross, D.H. (1977), The Iconography of Ashanti Sword Ornament. California: African Art, African Studies Center. University of California. Vol 6, p.18.
x. Sias R.F. (2005), Lost-Wax Casting Old, New and Inexpensive Method. South Carolina, Woodsmere Press, Pendleton
xi. Waters, L. (1993), Lost Wax Casting in Ashanti, Kumasi, University Press, KNUST. p. 34.
xii. Worral, W. E. A. (1986) Clay and Ceramic Raw Materials, New York: Elsevier Applied Science. p. 14.