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DESIGN AND FABRICATION OF A MANUAL CENTRIFUGAL CASTING DEVICE PROTOTYPE FOR POST COVID-19 RECOVERY GROWTH OF THE TRADITIONAL GOLD JEWELLERY INDUSTRY IN GHANA

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Abstract
Innovation in equipment and technology development has been identified as a powerful trigger for SMEs resilience and recovery in the context of the Covid-19 pandemic crisis. This paper presents the design, fabrication and operationalization of a simple but effective centrifugal casting device prototype, for the traditional gold jewellery industry in Ghana. The design process commenced by the conceptual design phase; detailed design phase followed by the embodiment design stage. The device was constructed using local materials. The device is easy to manufacture, maintain and relatively cheap. It can therefore be easily replicated or fabricated by ''wayside'' welders. It is also easily transportable and can be used for teaching and demonstration purposes for students of tertiary institutions. The merit of this project is its innovative concept and constitutes a fundamental and important contribution to the research and development of new pioneering centrifugal casting machine for the local gold jewellery industry in Ghana.

Keywords: *Centrifugal casting, Covid -19, fabrication, jewellery, technology*

INTRODUCTION

The viability of SMEs in developing countries remain an issue of major concern to governments as the global economic recovers from Covid -19 pandemic. While various governments support and policy measures have lessened the impact of the pandemic on some large firms, that of SMEs are still insufficient or nonexistence resulting in huge losses and in certain cases a shutdown of business. It has however been suggested that SMEs can power a stronger recovery from the pandemic through innovative opportunity seeking initiatives (Caballero-Morales, 2021). While short term support measures such as task relieve, subsidy wage, credit and extended debt delay are certainly needed and should be continued, it is also important to invest in long term structural projects such as modern equipment capacity and technology development that will enhance their resilience and competitiveness.

The traditional gold jewellery industry is one of the ancient and most important SMEs in Ghana. The industry is however, constrained by lack of appropriate equipment such as casting machines due to their relative high cost and hence inability of the craftsmen to acquire (Fening et al,. 2023). In a recent post Covid-19 impact studies of the gold jewellery industry in Ghana, Fening et al,. (2023) observed that only a hand full of jewellery workshops in Ghana undertake ‘modern’ lost wax casting, utilising modern equipment. Majority of Ghanaian goldsmiths and jewellers use the soft calcareous bone of the cuttlefish (*Sepia officinalis*) called ‘kakadiamaa’ in Ga and ‘kwaakwaa danwoma’ in Asante, as moulding material for casting gold and silver jewellery. A few others use the traditional lost wax and sand-casting process in which the mould cavities are filled by gravity. The use of these unreliable methods results in the production of low /poor quality products that lack market competitiveness. That notwithstanding the ever-increasing gold price factor couple with the national economic uncertainties has impacted negatively on the industry with 86% of the industry experiencing lower demand for their products and thus struggling to survive in the post Covid-19 era (Fening, et al.,2023).

The irony of the situation is that the industry has difficulty accessing funds and sourcing for operational inputs to overcome these challenges to stay in business. Fening et al., (2023) further reiterated that the industry has not been in the position to benefit from the Million Stimulus Package to SMEs established by the Covid-19 Alleviation Programme by Government. To help overcome the equipment challenge of the industry and allied craftsmen, this study was carried out with the objective of designing and fabricating a ‘simple-to fabricate’ and ‘simple-to-to-use’ centrifugal casting machine that could be easily and cheaply constructed by local ‘wayside’ welders using locally available materials including scrap metal.

LITERATURE REVIEW

Jewellery casting machinery

Jewellery casting machines have come of age and become available to the jewellery industry over the years, partly due to research in the dental industry which also utilises the casting process in making dental prosthetics (Bovin, 1979). Modern lost wax casting equipment utilise a variety of means to accelerate the inflow of molten metal into the mould cavity. This piece of equipment come in variety of models (Chamberlin, 1985; Kallenberg, 1981; Unthract, 1985).

There are basic manual and electric centrifugal machines, highly sophisticated electric centrifugal casting varieties, as well as hi-tech vacuum assisted types including those with facilities for inert gas cover over the molten metal and the casting flask. The primary functional requirement of a casting machine is to ensure the integrity of cast items through effective mould cavity filling among others.

Vacuum Assisted Machines

A vacuum assisted casting set-up creates vacuum ahead of the in-flowing molten metal. The metal is thus forced into the mould cavity by the full force of gravity since the mould cavity is practically void of air or gases ahead of the molten metal.

Centrifugal Machine

Centrifugal casting machine are designed to ‘’shoot’’ molten metal into the mould cavity. The pressure exerted by the incoming molten metal is able to force out any gasses presented ahead of the in-flowing molten metal through microscopic pores of the moulding material. Even though the centrifugal casting machines’ rotary motion should generate adequate centrifugal force to effectively ‘’shoot’’ molten metal into the mould cavity, excessive pressure on the molten metal can cause the mould surface to erode (Faccenda, 2001).

Principles of centrifugal casting

When a body moves on a circular path two types of forces act on it namely centripetal force, which act along the radius towards the centre of the body and centrifugal force which acts outwards and draws a rotating body away from the centre of rotation. The high gravity forces involved in centrifugal casting enables less dense materials including impurities forced into the centre where they are subsequently removed and gas related defects and shrinkage porosity are reduced producing objects of improved uniformity and physical qualities.

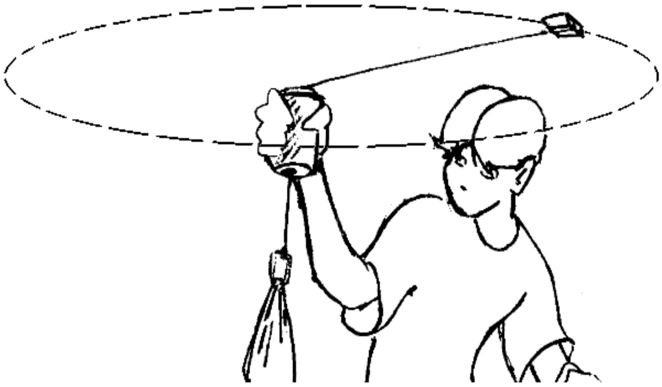
Centrifugal casting offers a substantial saving on capital equipment compared to forged products. It reduces manufacturing cost by reducing machine time and material waste and does not require highly skilled labour. It also allows economical production of a wide range of sizes, shapes and quantities of products and requires fewer steps and less energy input. Furthermore, it allows production of complex shapes with intricate details that wouldn't be possible using traditional casting methods.

Types of centrifugal casting machines

Centrifugal casting devices vary, from the hand-swinging of a mould tethered to a string (Fig. 1 a and 1 b) to basic table to manual model (Plate 1) and elaborate technologies incorporating induction metal furnaces, motorise rotatory mechanisms and built-in microprocessor controls that regulate important functional parameters. In addition, there are sophisticated semi-automated production-line versions suitable for factory situations. These versions are expensive and outside the reach of many Ghanaian goldsmiths and jewellers since they have to be imported in foreign currency. Modern manual centrifugal casting machines are actuated by the release of stored wind-up energy. This project prototype centrifugal casting device is actuated when a coil spring under tension is release to the tension.

Sling casting (hand-swinging)

The sling casting may be used where there is no casting machine (Utrecht, 1985; McCreight, 1991). Basically, this method utilises a hand sling (Figs. 1a and 1b) to propel molten metal into mould cavity. The lower part of the contraption has a flat-bottom cradle on which the casting flask containing the mould is placed. For sling casting, the sprue diameter should be about 1.29mm in diameter or slightly similar. This ensures that the metal (which is melted on top of the sprue), balls up as a result of surface tension, and remains so without running sprue into the mould cavity prematurely until it is forced to do so by the centrifugal force during the swing (McCreight, 1991). Although the hand sling centrifugal process is fairly effective, it requires dexterity on the part of the operator and it is cumbersome in operation.



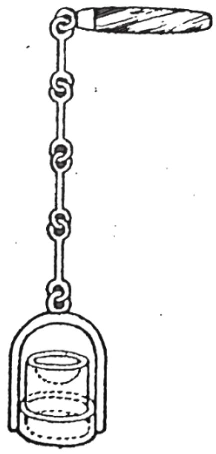


Fig. 1a. Sling casting (source: McCreight, 1991) **Fig. 1b.** Detail of Sling Caster (Source: Unttracht, 1985)

Plate 1: Centrifugal castting

Jewellery casting equipment situation in Ghana

Only a hand-full of jewellery workshops in the country undertakes ‘modern’ lost wax casting, utilising modern casting equipment. The Precious Minerals Marketing Company Limited, Accra, utilises a vacuum assisted casting machine incorporating a water-cooled medium frequency melting furnace (Plate 2). Emefa Jewellery Ltd, Letap Jewellery Ltd also all in Accra are among the few companies that utilise imported vacuum and/or centrifugal casting machinery.

Majority of Ghanaians goldsmiths and jewellers use the soft calcareous bone of the cuttlefish (*Sepia officinalis*) called Kakadiamaa in Ga and rendered Kwaakwaa Danwoma in Asante Twi, as moulding materials for casting gold and silver jewellery. A few others utilise the traditional lost wax and sand-casting processes in which the mould cavities are filled by gravity.

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The Metal product Design Section of Department of Industrial Art, CABE, Kwame Nkrumah University of Science and Technology, Kumasi, has two important electric centrifugal casting machines (which is non-operational at that time of this report) and a locally-made hand pulled device.

METHOD

Fabrication Process

The Authors opted for manual centrifugal casting device because of its inherent simplicity, durability and non-dependence on electrical power. A major component of centrifugal casting device is the means by which the spin is initiated. Manual devices use some wind –up mechanisms. The authors in this study decided to utilise a coil spring for this purpose. The device was fabricated following the engineering methodology of Dieter et al., (2000).

This manual centrifugal casting device prototype is design to:

1) Be cheaply and easily fabricated by simple (wayside) welding workshop operators
2) Be easily operated
3) Be capable of generating enough force to shoot the molten metal effectively and safely into mould cavity.
4) Lend itself easily to repairs when required;
5) Be fabricated with materials readily available locally
6) Be durable requiring virtually no maintenance or replacement

Table 1: List of the major components of the device and the fabrication processes employed in the fabrication.

Component	Materials	Fabrication process
Top cover	Sheet brass	Shearing, soldering
Body	Mild steel pipe	Sawing, are welded to base plate
Base plate	Mild steel pulley	Use as is and welded to body
Rotary Arm	Mild steel pipe	Sawing, are welded to bearing on main shaft
Crucible adjuster Arm	Mild steel rod	Shearing, are welded to
Crucible carriage	Mild steel	Shearing, arc welding, slides on crucible arm
Counterweight	Mild steel round bar	Drilling: internal threading to fit threaded arm.
Counterweight arm	Mild steel rod	External threading to hold counter weight

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Coil spring	Tool steel	Purchased and used as is, fitted around crucible adjusted arm
Mould flask cradle	Mild steel plate	Shearing electric arc welding
Main shaft	Mild steel rod	Lather turning
Ratchet post	Mild steel rod	Sawing, grinding, drilling reverting
Trigger bar	Mild steel bar	Grinding, drilling

Description of the centrifugal casting device prototype

The device (Fig.3) consists of coil spring actuated shaft that rotates in the vertical plane. The shaft carries a mould flask cradle for holding the mould flask. The main body, consist of a vertical square steel pipe welded to a base house, a coil spring and supports two bearings which rotates the shaft. There is a trigger arm arrowed that locks the spring and the shaft in tension until it is pull up to release the tension to cause the rotation of the rotary arm.

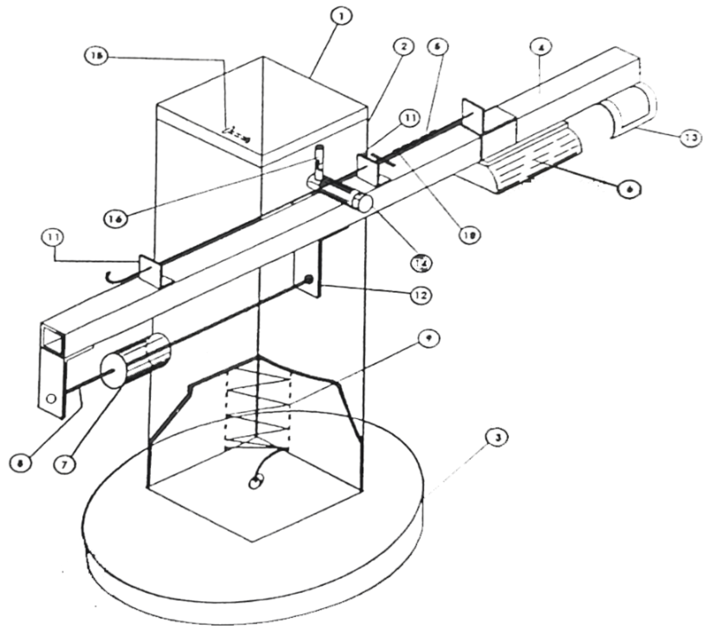
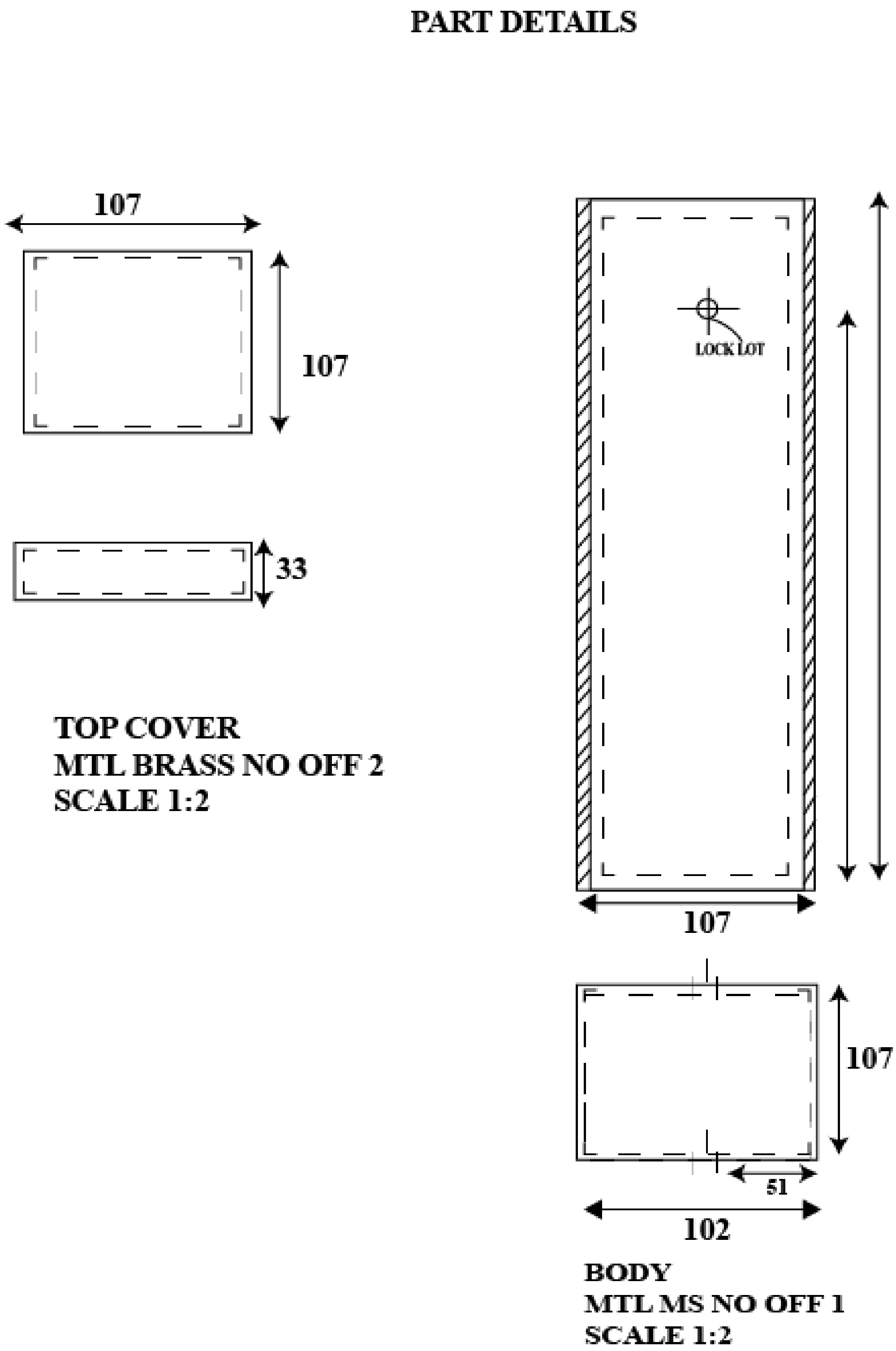


Fig.3: Schematic diagram of the casting device (with crucible arm down) and its detail parts diagrams.

Diagram key:

1. Top
2. Body
3. Base plate
4. Rotary arm
5. Crucible adjusted arm
6. Crucible carriage
7. Counter weight
8. Counter weight arm
9. Coil spring
10. Crucible arm coil spring
11. Crucible arm brackets 2 No.
12. Counter weight arm brackets 2 No.
13. Mould flask cradle.
14. Main shaft


PART DETAILS
107
107
33
TOP COVER
MTL BRASS NO OFF 2
SCALE 1:2
LOCK LOT
107
107
51
102
BODY
MTL MS NO OFF 1
SCALE 1:2

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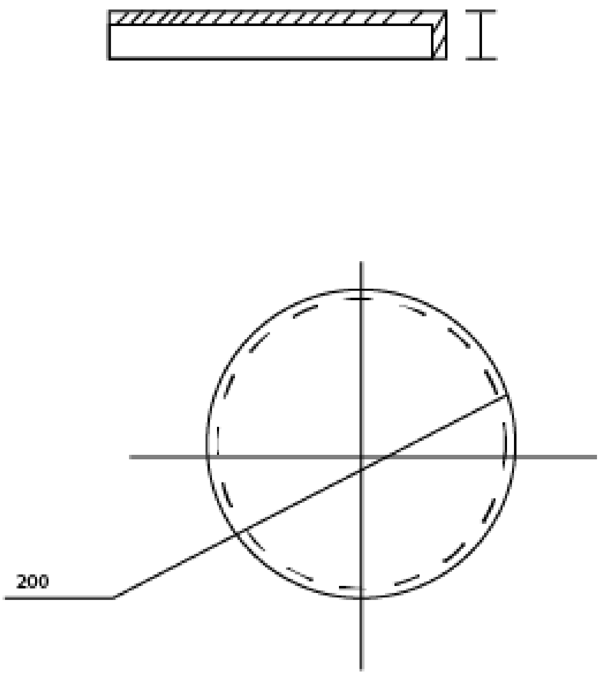
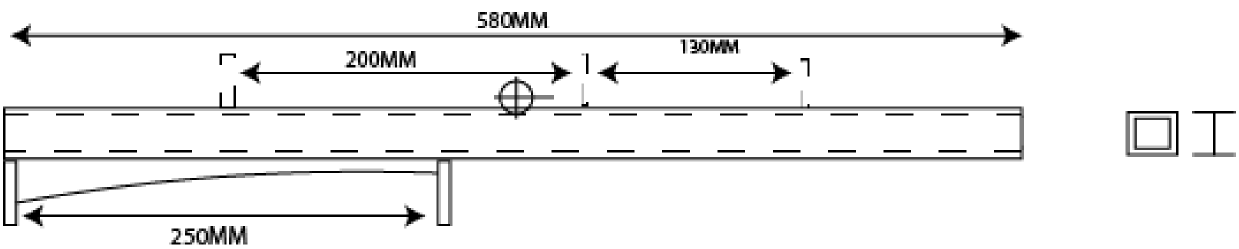
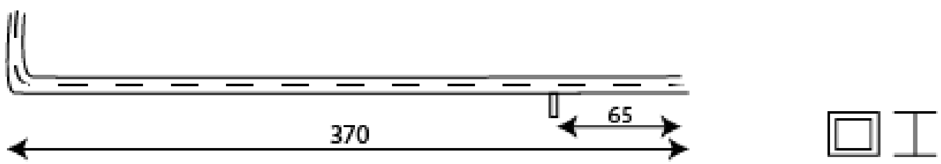
PART DETAILS (Cont.)



BASE PLATE
MTL MS NO OFF 1
SCALE 1:2

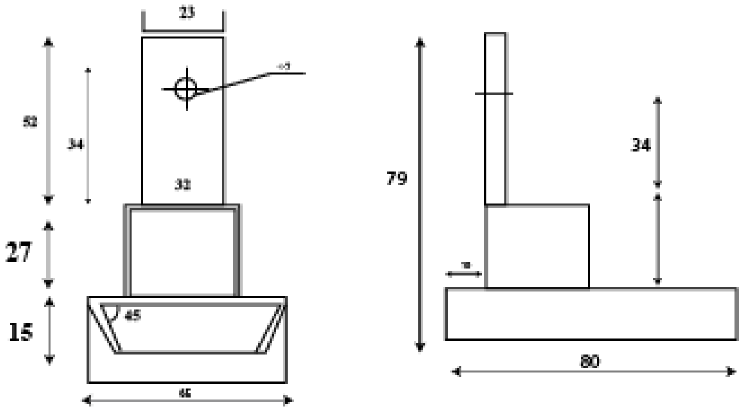


ROTARY ARM

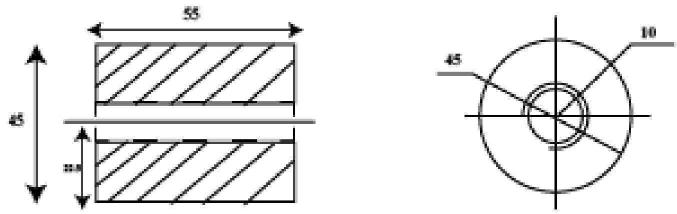


CRUCIBLE ADJUSTER ARM
MTL NO OFF 1
SCALE 1:2

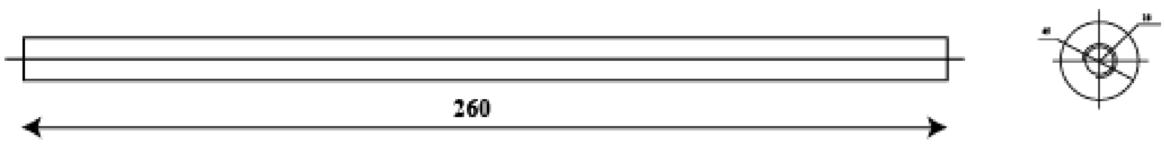
PART DETAILS (Cont.)



CRUSIBLE CARRAIGE
MTL MS NO OFF
SCALE 1:1

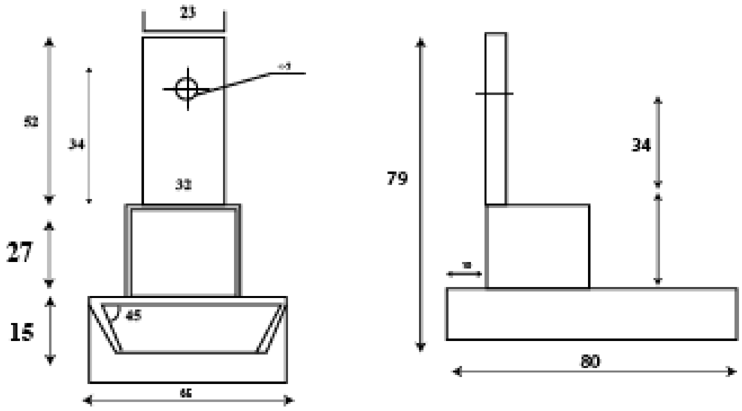


COUNTER WEIGHT ARM
MTL MS NO OFF 1
SCALE 1:1

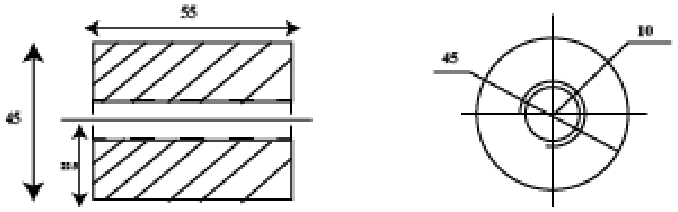


COUNTER WEIGHT ARM
MTL MS NO OFF 1
SCALE 1:1

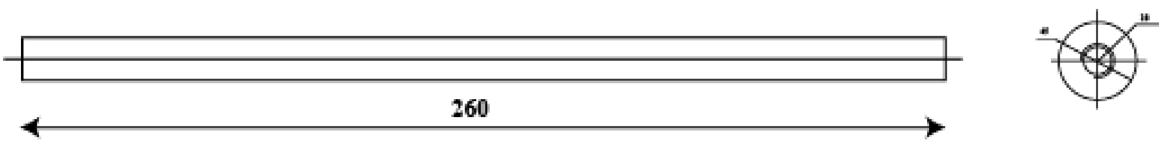
PART DETAILS (Cont.)



CRUSIBLE CARRAIGE
MTL MS NO OFF
SCALE 1:1



COUNTER WEIGHT ARM
MTL MS NO OFF 1
SCALE 1:1



COUNTER WEIGHT ARM
MTL MS NO OFF 1
SCALE 1:1

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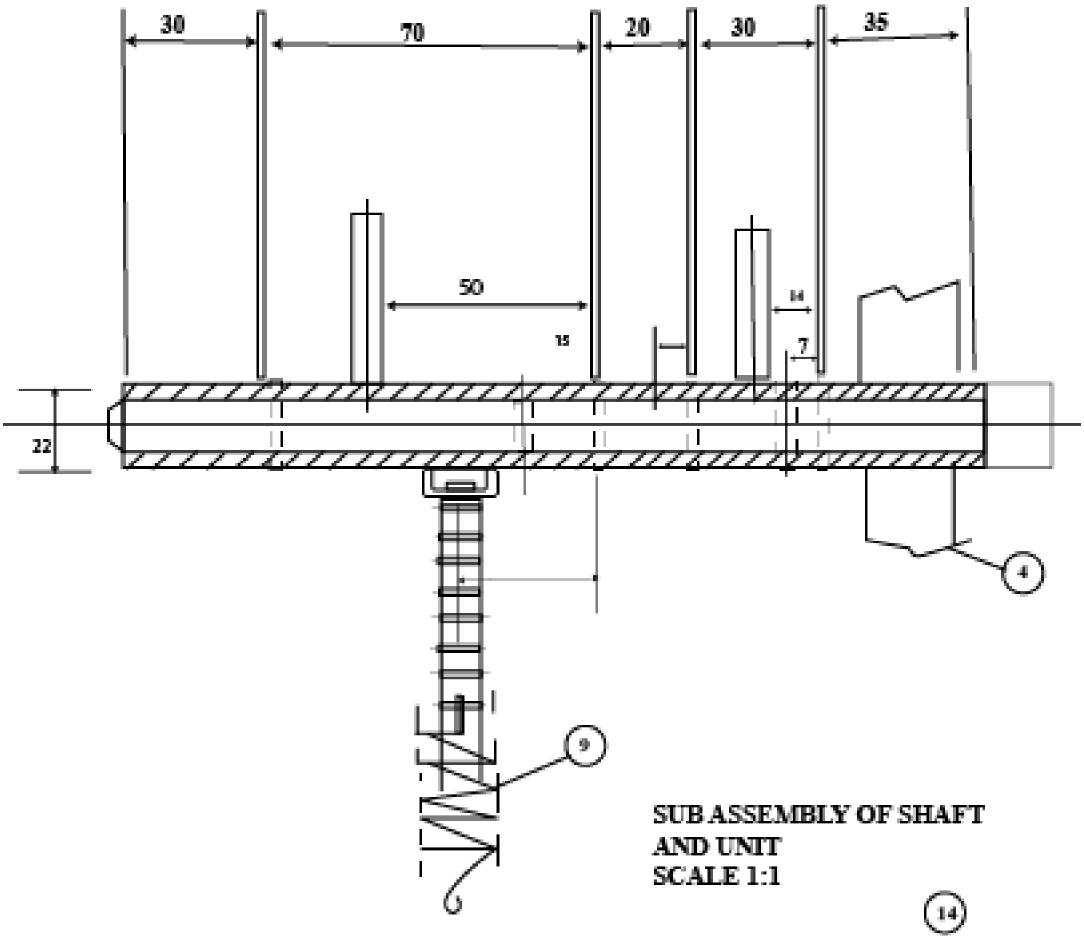
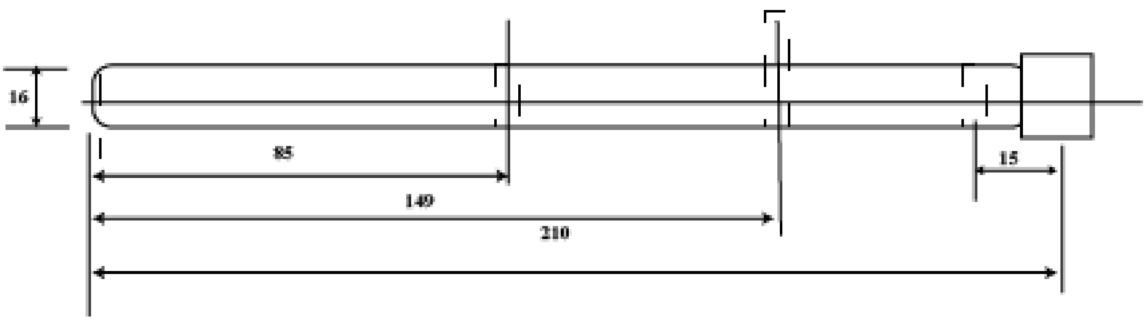
PART DETAILS (cont.)





SHAFT

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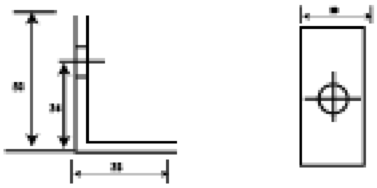
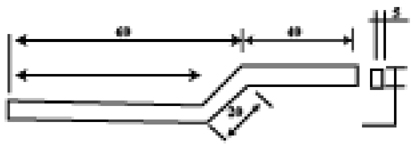
PART DETAILS (cont.)

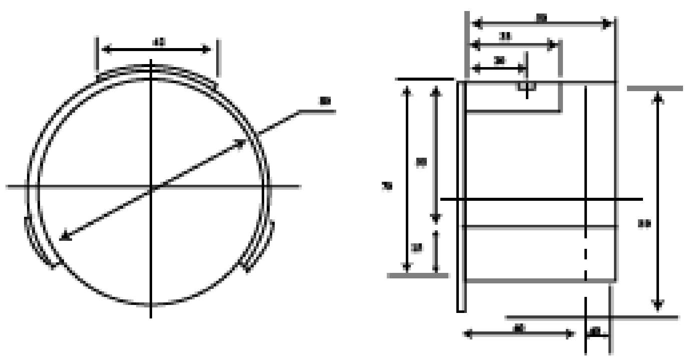


COUNTER WEIGHT ARM BRACKETS (12)
MTL. MS NO. OFF 2
SCALE 1:1

COUNTER WEIGHT ARM BRACKETS (11)
MTL. MS NO. OFF 2
SCALE 1:1



LOCK BAR (15)
MTL MS NO OFF
SCASLE 1:1



MOUL FLASK CRADLE (13)
MTL. NS NO OFF 1
SCALE 1:1

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Operation of the centrifugal casting device prototype

Operation of device is discussed in relationship to Figure 3 and Plate 2. The trigger bar is lifted and helds up. The rotary arm is positioned to engage the rachet post and is turned clockwise one revolution. The trigger bar is released to lock the coil spring (9) in tension. A mould is mounted in the cradle (13) and correct weight (up to 300 grams) of required casting metal is placed in the crucible. The counterweight (7) is screwed in or out to balance out the weight of the charged and the mould flask in such a way as to allow the rotary arm to barely rest on the Rachet post. The metal is melted appropriately using oxy- LPG or oxy-acetylene gas torch. When the metal is melted, the trigger bar is pulled up. Tension is instantaneously released in the coil spring thereby briskly rotating the rotary arm to cause the shooting of the molten metal into the mould cavity.

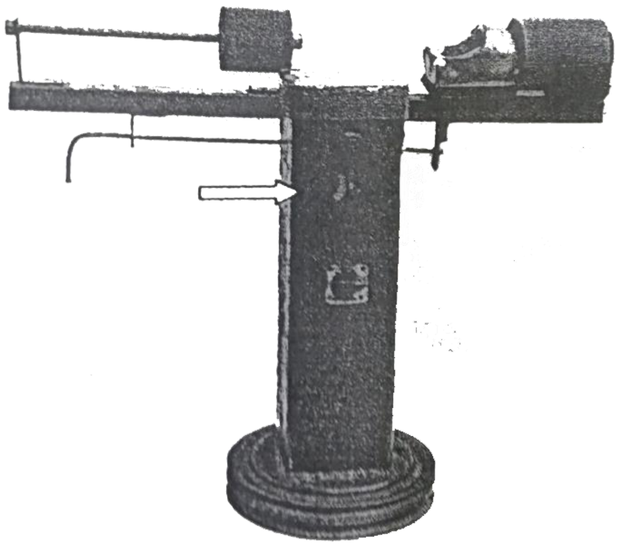

Plate 2: Photograph of the prototype casting device (trigger bar arrowed, crucible arm under tension)

EVALUATION

The device was tested under workshop and was utilised for lost was casting and sand casting (with modification). For sand casting and sand casting flask that could be accommodated in the cradle was used in place of the refractory flask used for lost wax casting. The test outcome showed the following: The device is suitable for jewellery-scale sand casting and lost wax casting.

1) The crucible can conveniently gold and cat about 200 grams of 18k gold, far more than what is possible for cattle-fish bone casting;
2) Castings made on the device appeared denser than those made in the cattle- fish bone and sand under gravity;
3) The success rate of casting was higher on the device than in gravity lost wax or sand casting for instance, samples of KNUST security service crowns were successfully cast

in brass whereas gravity pouring into the sand-casting moulds could not reproduce the surface details of the insignia.

CONCLUSION

Ghana's history and traditional institutions have been associated with gold and gold jewellery for ages. Ghana is currently the largest producer of gold in Africa and the sixth in the world with gold production amounting to a total of 117.6 tons in 2021 (Garside, 2022). However, its jewellery industry, which is the value addition machinery accounts for a very little percentage of the world's production in total. In terms of quality, locally produced gold jewellery which is not even hallmarked, can barely compete on the international market. There is therefore the need to improve the quality of Ghana's gold jewellery to enable it compete successfully globally.

It is generally accepted that centrifugal and vacuum assisted casting offer product that are denser than the passive gravity method. Jewellers, goldsmiths and others who cast jewellery and miniature items in metal can improve their work rate and reduce rejects through the use of the device under discussion. This locally-made casting device can thus enhance productivity of jewellers and goldsmiths and thereby support the post Covid-19 recovery agenda.

REFERENCES

Asomaning, K.A (2002) Gold: The Link Between Ancient and Modern Ghana, Ghanaian Philosophical Studies II. Helen Lauer (ed) Legon, Ghana, Available at: http://www.cfvp.org/book/series02/11-5/chapter_xii.html

Bell E. (2001), Know the Disease Before Trying The cure. Quality casting: identify the defects, WGC Gold Technology No. 31 Spring, pp.2-9

Bovin, M. (1979) Centrifugal or lost wax casting for Schools, tradesmen, craftsmen: Murray Bovin Ltd, N.Y

Chamberlain, M. (1976), metal jewellery Techniques, Watson-Guptill, New York pp.96.

Dieter, G. E. and Linda Schmid, C. (2000). Engineering Design. New York

Faccenda V (2003) Handbook on investment Casting, World Gold Council, London pp.80-81.

Fening, P.A., Agyei, I. K., Bruce. (2023). The Impact of Covid-19 Pandemic on the Traditional Gold Jewellery Industry in Ghana: The Gold Price Factor. Neuroquantology |November 2022 | Volume 20 | Issue 17 | Page 131-141 | Doi: 10.14704/Nq.2022.20.17. Nq88019, T.

Ishak, A. ., & Safitri Maladeni, E. . (2022). Manajemen Keselamatan Kerja Pelaksanaan Konstruksi Infrastruktur Jembatan Bahteramas Kota Kendari. Sibatik Journal: Jurnal Ilmiah Bidang Sosial, Ekonomi, Budaya, Teknologi, Dan Pendidikan, 1(8), 1401–1410. https://doi.org/10.54443/sibatik.v1i8.182

Kallenberg, L. (1981) Modelling in Wax for jewellery and sculpture, pp.9

McCreight, T. (1991), the Complete Metalsmith, Davis Publications, Inc. Worcester, Massachusetts pp.90-98

GFMS, Gold Survey 2004, www.gfms.co.uk/market%20commentary/gold

GIPC, Ghana Investment Profile, www.gipc.org.gh/documents/jewellery .pdf

Government of India, (99-2000) Budget, http://pid.nic.in/archive/bud9920/99gbspsarta.html

Untracht, O. (1985), Jewellery Concepts and Technology, Doubleday, New York, pp.483-520