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MECHANICAL ENGINEERING IN ANCIENT EGYPT, PART 51: METAL CASTING

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ABSTRACT

This is the 51st research paper exploring the evolution of Mechanical Engineering in Ancient Egypt. The paper investigates the development of the metal casting industry in ancient Egypt during the Predynastic and Dynastic Periods. The evolution of both solid and hollow casting techniques is studied with extensive examples on each type. The use of casting molds is studied with detailed procedure for the casting process as depicted in tomb scenes. The characteristics of each metal-casted artifact are presented.

KEYWORDS: History of mechanical engineering, ancient Egypt, metal casting, solid-casting, hollow-casting, Predynastic and Dynastic Periods.

Introduction

This is the 51st research paper in a series aiming at exploring the evolution of mechanical engineering in ancient Egypt through the different activities of their wonderful civilization. The ancient Egyptians had registered a good mechanical technology for metal work through casting, hammering and forming producing wonderful artefacts survived for thousands of years.

Davis, 1935 in his book about paintings from the tomb of Rekhmire presented a number of colored paintings from the tomb of Vizier Rekhmire of the 18th Dynasty in the form of plates with an explanation title of each plate.[1] The Saqqara Expedition, 1938 in their book about

the mastaba of Mereruka presented a number of tomb scenes in the form of plates with titles explaining the story of each plate according to their location in specific chambers of the mastaba. The scenes included plates 30 and 32 presenting some metalworking processes during he time of Mereruka (6th Dynasty).[2] Davis, 1944 in his book about the tomb of Rekhmire at Thebes presented a number of wall scenes in the tomb of Rekhmire, the Vizier of Pharaohs Thutmose III and Amenhotep II of the 18th Dynasty. The scenes included weighing gold, soldering, polishing, hammering, engraving and sheet heating processes.[3] James, 1972 in his paper about gold technology in ancient Egypt announced that in the tombs of the first Dynasty gold objects were found. He also declared that some of the objects found in the tomb of Tutankhamun were made of solid gold such as the 110 kg innermost coffin of the Pharaoh. He presented a scene for the melting, casting and working of gold from the tomb of Mereruka (2300 BC) at Saqqara and some products produced using the lost-wax technique.[4] Nunn and Andrews, 1977 in their paper about Egyptian antiquities at the Royal College of Sargeons of England presented a hollow cast bronze statue of Osiris from the 25th or 26th Dynasty, a brass statue of Osiris from Late Period and two miniature brass obelisks.[5] Schorsch, 1988 outlined that the lost wax casting of figural bronzes was rare in ancient Egypt before the first millennium BC and high quality hollow cast bronze statues were produced during the Third Intermediate Period. He presented examples of hollow cast products including ibises, cat sarcophagus and ibex sarcophagus.[6] Scheel, 1989 in his book about Egyptians metalworking and tools outlined that metal processing became more common in ancient Egypt during the Naqada I-III cultures from about 4000 to 3000 BC. He outlined also that copper casting was practiced as early as Late Naqada II and Naqada III Periods (3200-3000 BC) and copper tools and weapons were manufactured by open-mould casting. He presented a lot of illustrations about the metalworking processes as depicted from ancient Egyptian tombs.[7] Bianchi, 1990 in his paper about Egyptian metal statuary of the Third Intermediate Period presented a number of bronze artifacts such as hollow-cast bronze statuette of Osarkon I (21st Dynasty), bronze weapon handle inscribed for Seti I (19th Dynasty), hollow-cast bronze statue of Amun and Osiris and a hollow-cast bronze statuette of a Queen from the 25th Dynasty.[8]

Jones, 2007 in his Master of Arts thesis presented the copper ingots in Egyptian texts and tomb paintings from 15th to 12th century BC. He presented a scene for an ingot bearer from the tomb of Rekhmire and another porter carrying ingot as a part of Syrian's payment to Nebamun for his services. He presented also scenes for copper melting and casting from the

tomb of Rekhmire.[9] Ambers et. al., 2008 investigated the life-size cast-copper alloy statue of the Gayer-Anderson cat in display in the British Museum and dated to 600 BC during the Late Period of ancient Egypt. They presented full technical investigations of the cat and the original manufacturing techniques used in its production.[10] Ben-Yosef, 2009 presented scenes for oxhide ingots depicted on the walls of Ramses III temple at Madinet Habu (20th Dynasty) and a scene of Egyptian metal worker with copper ingot from the tomb of Nebamun.[11]

Gravett, 2011 analyzed a gilded bronze statuette for Osiris from the Middle Kingdom Period. She presented a survey of Egyptian bronzes in the National Cultural History Museum and material culture achievements of the 12th Dynasty. She presented a separate chapter about the ancient Egyptian metallurgy covering copper, copper alloys and gold. She studied the techniques used by ancient Egyptians to manufacture bronze statuary.[12] De Mieroop, 2014 in his paper about silver as a functional tool in ancient Egypt and Mesopotamia outlined that archaeologists found in El-Amarna, the capital of Pharaoh Akhenaten a buried jar containing 23 bars of gold (weighing 3.375 kg), silver fragments (weighing 1.085 kg) and silver figurine of a Hittite god. He also outlined that silver and copper/bronze were used primarily as measures of value in ancient Egypt in the 3rd and 2nd millennia BC.[13] Chirikure, 2015 in his book about metals in past societies outlined that over 7000 years of metal fabrication in Egypt and Nubia left residues and were on tomb walls preserving the evidence. He outlined also that because of their deep history of metallurgy, longer than anywhere else in Africa, Egypt and Nubia offered interesting perspectives on the evolution of metal manipulation and fabrication.[14] Ghoniem, 2016 in his study of a group of archaeological bronze Egyptian statues presented bronze statues for Sekhmet, Osiris, Amun, Horus, seated ram and feminine statue. He showed the bronze statues presented after cleaning and conservation.[15] Hassaan, 2017 in his investigation of the Mechanical Engineering in ancient Egypt presented a number of examples on copper, bronze, gold and silver human statues.[16] He presented a bronze figurine with gold inlay of a cat from the 21st to 26th Dynasties Period, a hollow-cast cat statue from the 22nd Dynasty, a casted bronze cat from the Late Period and a bronze dog statue from the 18th Dynasty.[17]

Solid-Casting Products

The ancient Egyptians new the solid-casting process as early as the time of Badari (4400-4000 BC). This continued through Naqada culture (4000-3000 BC) and the Dynastic Periods down to the Late Period as will be illustrated in details by the following examples:

The first example is copper pin excavated from the Badarian tomb number 5112 in display in Petrie Museum at London and shown in Fig.1.[18] It has a curved profile and sharp ends. It has a length of about 70 mm.

The second example is a gold wire from Naqada (4000-3000 BC) in display in the Petrie Museum and shown in Fig.2.[19] It may be designed to act as a necklace . Its diameter is less than one mm.

Fig 1: Copper pin from Badari.[18]

Fig 2: Gold wire from Naqada.[19]

The third example is a silver adze from the Early Dynastic Period (3100-2686 BC) in display in the Petrie Museum and shown in Fig.3 [20]. The adze length is about 180 mm and it has a decreasing width and thickness.

The fourth example is a copper shape from the 12th Dynasty (1890-1790 BC) found at Lahun of Faiyum in display in the Manchester Museum at UK and shown in Fig.4 [21]. Dimensions are not assigned and most probably it is a cutting axe with holding hand connected at its small neck.

Fig 3: Silver adze from Early Dynastic.[20]

Fig 4: Copper shape from 12th Dynasty.[21]

The fifth example is a golden uraeus (cobra) statue of Senusret II, the 3rd King of the 12th Dynasty (1897-1878 BC) in display in the Egyptian Museum at Cairo and shown in Fig.5.[22] The designer succeeded to inlay the golden uraeus in a fantastic engineering way using different types of semiprecious stones and used assembling techniques could sustain environmental effects for more than 3900 years.

The sixth example is a copper axe-head from the Middle Kingdom (2050-1800 BC) in display in the British Museum and shown in Fig.6.[23] The axe had a unique design with blade from its two terminals for dual use with uniform symmetric dimensions about its vertical axis.

Fig 5: Golden Uraeus from 12th Dynasty.[22]

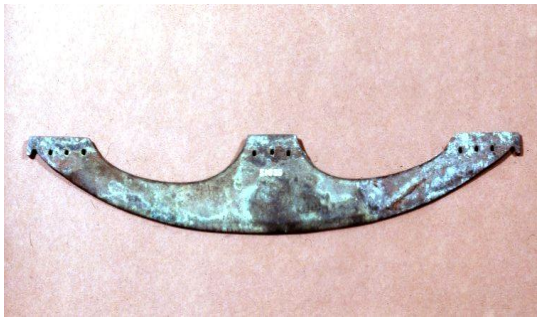

Fig 6: Copper axe-head from Middle Kingdom.[23]

The seventh example is a copper-blade axe of Ahmose I, the 1st Pharaoh of the 18th Dynasty (1549-1522 BC) in display in the Egyptian Museum at Cairo and shown in Fig.7.[24] It has a cedar hand with extensive decoration using gold sheets and semi-precious stones. The blade length is 163 mm and its width is 67 mm.

The eighth example is a golden sandals for Tutankhamun, the 13th Pharaoh of the 18th Dynasty (1332-1323 BC) in display in the Egyptian Museum at Cairo and shown in Fig.8.[25] The bottom part of the sandal is sold-casted while the top pars may be shaped by cutting from gold-sheet and welded to the bottom part through specific poles or through revolute joints.

Fig 7: Copper axe from 18th Dynasty.[24] **Fig 8: Gold sandals from 18th Dynasty.[25]**

The ninth example is a solid gold statuette of Amenhotep III, the 9th Pharaoh of the 18th Dynasty (1388-1350 BC) found in the tomb of Pharaoh Tutankhamun in display in the Egyptian Museum at Cairo and shown in Fig.9.[26] The Pharaoh was shown setting, wearing the Blue Crown of ancient Egypt with Cobra on his forehead and holding the Crook and Flail in his right hand. The point is that why not a statuette for Pharaoh Tutankhamun?. He was wealthy enough and had wonderful funerary products and not in need to take a statuette for one of his former Pharaohs.

The tenth example is the golden innermost coffin of Pharaoh Tutankhamun in display in the Egyptian Museum and shown in Fig.10.[27]

Fig 9: Golden statuette from 18th Dynasty.[26] **Fig 10: Gold coffin from 18th Dynasty.[27]**

The coffin consisted of two parts and took the shape of the Pharaoh with extensive inlay using semiprecious stones and glass. The coffin weight is 110 kg of gold and has a 1.875 m length and 0.51 m width and height.

The eleventh example is a 31 mm diameter golden finger-ring from the 18th Dynasty (1370 BC) in display in the British Museum and shown in Fig.11.[28] The ring shank was produced using solid cast of gold while its bezel was carved from lapis lazuli and hold in position by two gold bearings.

The twelfth example is a bronze finger-ring of Seti I, the 2nd Pharaoh of the 19th Dynasty (1290-1279 BC) in display in the Metropolitan Museum of Art and shown in Fig.12.[29] The ring bezel was inscribed by the Pharaoh name and had a height of 32 mm and a width of 29 mm. All the surfaces were perfectly rounded not to harm the user as the tradition of ancient Egyptian Mechanical Engineering.

Fig 11: Golden ring from 18th Dynasty.[28]

Fig.12 Bronze ring from 19th Dynasty.[29]

The thirteenth and last example is a 140 mm height solid-cast bronze kneeling statuette for Necho II, the 2nd Pharaoh of the 26th Dynasty (610-595 BC) in display in the Brooklyn Museum at New York and shown in Fig.13.[30] The designer showed the Pharaoh wearing a short Schenti and a Nemes Headdress with Cobra on its forehead part and having a long thin beard. The statue was well finished and showed the details of the Pharaoh head very clearly as depicted in the zoomed image in Fig.13. With the hands of the Pharaoh extending away from his body and in a kneeling position with setting over the feet, this is really a difficult design and reflects the high casting technology attained in ancient Egypt during the Late Period.

Fig 13: Bronze statuette from 26th Dynasty.[30]

Hollow-Casting Products

Hollow-cast or lost wax casting technique is an advanced technique used to produce lighter metallic products and hence reduction of product costing. Presented evidences show that ancient Egyptians knew this technique since the Predynastic era and continued to use it down to the time of the Late Period. This will be illustrated by the following examples presented chronically:

The first example is a golden cylindrical bead from Naqada (4000-3000 BC) in display in the Petrie Museum and shown in Fig.14.[20] There may be an argument that this product was reduced by sheet forming and then soldering the ends. This depends on a sophisticated analysis of the structure of the bead to define if there is any sign of soldering or adhesion. If not then most probably those genius people applied hollow-casting more than 5000 years ago!.

The second example is a golden dish for Queen Hetepheres, wife of King Senefru, the founder of the 4th Dynasty (2613-2566 BC) in display in the Egyptian Museum at Cairo and shown in Fig.15.[31] Again this product may generate a large debate about its production technique. Is it produced by sheet hammering?. Is it produced by hollow-casting?. The answer is in the hands of the Archaeologists who have to investigate and analyze the surface of the dish looking for marks for soldering or adhesive application. Without any marks realized, then most probably they produced it using the hollow-cast process.

Fig 14: Golden bead from Naqada.[20]

Fig 15: Golden dish from 4th Dynasty.[31]

The third example is copper statue of Prince Merenre, the son of Pepi I, the 3rd King of the 6th Dynasty (2331-2287 BC) in display in the British Museum at Cairo and shown in Fig.16.[32] The designer showed the prince striding with complete strong body and inlaid eyes as depicted in the zoomed image, wearing a Khat Headdress and having a serious pose with very clear face parts indicating the high profession of the casting process used in producing the statue.

The fourth example is a golden hollow cylindrical 48 mm length and 8 mm diameter amulet from the 12th Dynasty (1938-1759 BC) in display in the Brooklyn Museum and shown in Fig.17.[33] The cylindrical body of the amulet was covered from both ends using a conical plug while the top plug had a ring in its top to hang the amulet. .The cylindrical body wad decorated by prominent shapes including too many miniature ball of diameter less than 0.5 mm as depicted in the zoomed image of Fig.17.

Fig 16: Bronze statue from 6th Dynasty.[32]

Fig 17: Golden amulet from 12th Dynasty.[33]

The fifth example is a 292 mm height bronze bust of a falcon headed Horus from the 21st-22nd Dynasties (1070-730 BC) sold by Christies on 8 June 2014 at New York for US$ 38,240

and shown in Fig.18.[34] The Horus was shown wearing the Double Crown of Egypt while the hands were shown missing indicating the hollow nature of the statue.

The sixth example is a female bronze statue from the 22nd Dynasty (845-730 BC) in display in the British Museum and shown in Fig.19.[35] The lady was shown wearing a Khat Headdress and raising both hands in different levels which complicates the mold design but nothing is difficult for the ancient Egyptians.

Fig 18: Bronze statue from 21st-22nd Dynasties.[34]

Fig 19: Bronze statue from 22nd Dynasty.[35]

The seventh example is an 108 mm height bronze Royal head from the 22nd Dynasty (945-715 BC) in display in the Rijks Museum at Amsterdam and shown in Fig.20.[36] The eyes were inlaid by another material (may be semiprecious stones) while the eyebrows were clearly market and may be inlaid with destroyed stone due to bad excavations by criminal tomb robberies or unprofessional archaeological organizations.

The eights example is a bronze 111 mm height cat from the Third Intermediate Period (1069-664 BC) sold by Christies on 6 October 2011 at London for US$ 21,189 and shown in Fig.21.[37] The designer showed the cat wearing a wedjet eye necklace around its neck. It was produced by the hollow-cast technique.

Fig 20: Bronze Royal head from 22nd Dynasty.[36]

Fig 21: Bronze cat from 3rd IP.[37]

The ninth example is a bronze 440 mm height statue for Isis and Horus from the 25th Dynasty (747-656 BC) sold in London by Christies on 6 December 2016 for 1.39 million US$ and shown in Fig.22.[38] The designer showed Isis wearing a Horns-sun disc Crown on her headdress and feeding her son Horus with inlaid eyes with two different semiprecious stones giving the white and black colors of the eyes. The design is really complex and requires very high profession and accuracy. This is why it was sold by more than 1.3 million US$.

The eighth example is a bronzes statue for an ibis from the 26th Dynasty (664-525 BC) in display in the Los Angeles County Museum of Art and shown in Fig.23.[39] The designer showed the ibis striding over a parallelogram base presenting the details of its head and legs.

The ninth example is an 89 mm height copper alloy head for Osiris wearing the Atef Crown of ancient Egypt hollow-casted during the Late Period (664-332 BC) in display in the British Museum and shown in Fig.24.[40] It was inlaid by gold and Crown decorations are depicted in the zoomed image of Fig.24.

Fig 22: Bronze statue from 25th Dynasty.[38]

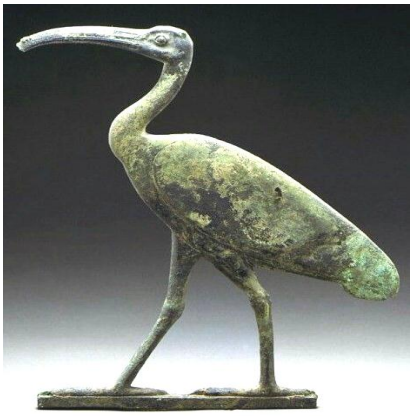

Fig 23: Bronze ibis from 26th Dynasty.[39]

Fig 24: Osiris copper alloy head from Late Period.[40]

The tenth example is a 197 mm height bronze statue for Ptah produced during the 26th Dynasty (664-525 BC) in display in the World Museum at Liverpool and shown in Fig.25 [41,42]. This unit represents the top Mechanical Technology regarding bronze casting. The designer shoed Ptah standing, wearing a Cap Headdress, full-robe, having a long thin beard, wearing a wide pectoral and bracelets and holding the was-scepter with the ankh sign behind his right hand. The bronze statue was inlaid by gold in different locations.

The eleventh example is a copper alloy coffin model of dimensions 174 x 132 x 43 mm casted during the Late Period (664-332 BC) in display in the British Museum at London and shown in Fig.26 [43]. The designer represented Horus standing on the top of the coffin and wearing the Double Crown of ancient Egypt. Horus was made as a solid part while the coffin itself was a hollow part. Therefore both techniques of solid and hollow casting were used in manufacturing this product as the museum claimed.[43]

Fig 25: Statue of Ptah from 26th Dynasty.[42]

Fig 26: Coffin model from Late Period.[43]

The twelfth and last example is a hollow cast bronze setting cat produced during the Late-Ptolemaic Periods (664-30 BC) in display in the World Museum at Liverpool and shown in Fig.27.[44] The cat had dimensions of 120 x 70 x 37 mm with inlaid eyes and holes in the ears.[44]

Fig 26: Bronze cat from Late-Ptolemaic Period.[44]

Solid Casting Molds

The ancient Egyptians used molds for the production of solid objects since the time of Maadi (4000-3500 BC) and continued to use this technique down to the end of the New Kingdom (1155 BC) where the hollow-cast technique took place and continued down to the end of the Dynastic Periods. Here, are some examples on the used of sold-cast molds in ancient Egypt:

The first example is an ingot-mold from the time of Maadi (4000-3500 BC). No data are available on its present location, material or dimensions!. It is shown in Fig.27.[45] Those clever ancient Egyptians produced copper ingots as an intermediate process between copper-ore and final copper product.

Fig 27: Ingot-molds from Maadi.[45]

The second example is a pottery mold for casting a copper chisel from the 12th Dynasty (1890 BC) in display in the Manchester Museum fornd at Kahun (ot Lahun of Faiyum) and shown in Fig.28.[46] The molded produced is a chisel of conical sides and round ends from both

sides. The mold cavity was generated with very high accuracy as if it was drawn using an AUTOCAD computer package.

The third example is a mold for casting a Royal sphinx for Amenhotep I, the 2nd Pharaoh of the 18th Dynasty (1524-1503 BC) in display in the Los Angles Country Museum of Art and shown in Fig.29.[47] The designer showed the Pharaoh wearing the Nemes Headdress and the Two Feathers Crown of ancient Egypt while his body in the shape of a lion raising both right hand and tail with Cobra in front of him wearing the Lower Egypt Crown with text in the back side of the sphinx.

Fig 28: Pottery-mold from 12th Dynasty.[46]

Fig 29: Sphinx mold from 18th Dynasty.[47]

The fourth example is a 33 mm diameter pottery mold for a ring from the 18th Dynasty (1390-1353 BC) found at Thebes in display in the Metropolitan Museum of Art and shown in Fig.30.[48] The mold was for the solid casting of a one piece metallic ring.

The fifth example is a mold for the Throne name of Seti I, the 2nd Pharaoh of the 19th Dynasty (1290-1279 BC) in display in the Los Angles Country Museum of Art and shown in Fig.31.[49] The designer gave the product the shape of a Cartouche of Seti I carrying his Throne name 'Menmaatre'.[50] The Cartouche had a rounded corner with large diameter with internal frame.

Fig 30: Pottery-mold from 18th Dynasty.[48]

Fig 31: Seti I mold from 19th Dynasty.[49]

The sixth example is a mold with Cartouche of Ramses III Throne name, the 2nd Pharaoh of the 20th Dynasty (1186-1155 BC) in display in the Los Angles Country Museum of Art and shown in Fig.32.[51] The cartouche had a rectangular shape with small fillet at the corners without any separate frame compared with that in Fig.31 of Pharaoh Seti I.

The seventh example is a twelve terracotta amulet molds from the New Kingdom (1570-1075 BC) with the largest mold dimensions: 40 x 30 mm presented by Live Auctioneers for sale with an estimated price of US$ 400-500 per mold and shown in Fig.33.[52] Some of the molds are as small as 25 mm diameter while others are of 40 mm length and the rest are in between. The objects casted by those molds had different shapes and characteristics.

Fig 32: Ramses III mold from 20th Dynasty.[51]

Fig 33: Molds from New Kingdom.[52]

Melting Furnaces

One of the main items in a metal casting process is the furnace. A furnace is required to melt the metal ore or ingots to be ready for the casting process to give the final shape of the metallic product through the mold. Each metal has its own meting temperature as depicted from Table 1.[53]

Table 1: Melting temperature of some metals.[53]

Metal	gold	silver	copper	lead	tin	bronze
Melting temperature (^oC)	1063	951	1083	327	232	913

The simple heat source in the ancient world was simply dried wood which was available everywhere. Using dry wood as a fuel source lets a furnace runs between 343.3 and 482.2 ^oC.[54] Referring to Table 1, wood heat source can cast only lead and tin. Other metals required another technique enhancing the efficiency of wood-fired furnaces to provide temperatures above 1083 ^oC to melt copper. Ancient Egyptians realized this fact and invented three techniques for this purpose:

Technique 1: Using blowing tubes

They used tubes with special front tip to create a stream of air inside the furnace by men mouths, thus providing more Oxygen to increase the fire temperature as depicted in Fig.34.[55] The worker in the left of the Plate is holding a tube by his left hand and blowing air stream into the furnace by his mouth and holding a metallic gripper by his right hand.

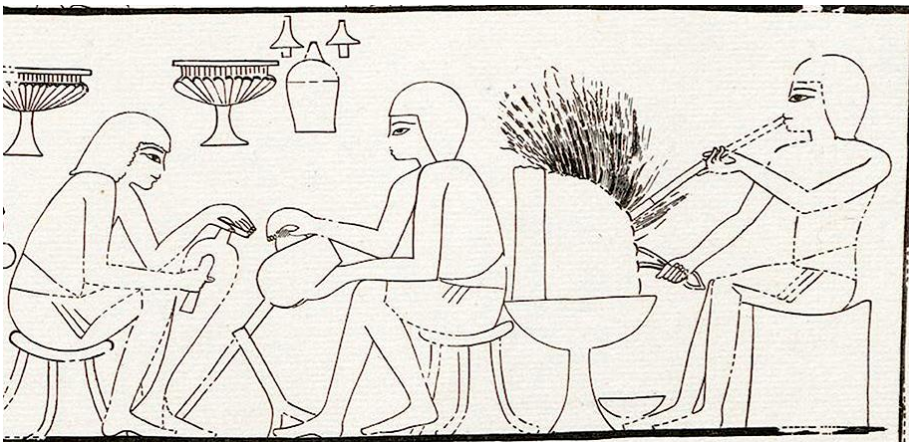

Fig 34: Metal workers from Thebes.[55]

Technique 2: Using positive displacement compressor

The first technique may be suitable for small applications, while for large applications mor air flow are required. They invented a dual-leg driven blowing bellows (compressor) registered as inscriptions in a number of ancient Egyptian tombs including the tomb of Rekhmire at Thebes (Vizier of Thutmose III and Amenhotep II of the 18th Dynasty). Fig.35 shows a four-bellows positive displacement compressor blowing air into a metal working furnace by two workers as depicted by a scene from the tomb of Rekhmire.[56] Because there is no spring action inside each bellow, a cord is fixed to the top plate of the bellow and pulled by the worker when raising his feet, while the other feet will be pressing the other bellow to deliver the flow into the furnace (positive displacement compressor). This means that each bellow must be equipped with two non-return valves to direct the flow to flow in one direction only. The question now is: had they got this technology in this earlier times (more than 3400 years ago) ??.

Fig 35: Compressor from the 18th Dynasty.[56]

Technique 3: Using a wind-powered furnace

In the Eastern Desert of Egypt and Sinai Peninsula where there were strong wind, the used a wind-powered furnace to get use of the wind to increase the fire temperature. One of such furnaces from the Eastern Desert is shown in Fig.36.[57] The authors expected that the U-shaped furnace of Fig.36 is one of those types where the front part of the furnace is missing.

Fig 36: Smelting furnace from Eastern Desert.[57]

Metal Casting Procedure

Ancient Egyptians were pioneers not only in the engineering sciences but also in the administration ones. Documentation is one of the important tools required for successful administration of engineering and non-engineering works. Following this approach, they registered too many aspects regarding engineering works in the tomb of Vizier Rekhmire of the 18th Dynasty. Among those is the procedure for casting bronze temple-doors. The procedure according to the wall paintings in the Rekhmire tomb is as follows:[58]

1. Moving the raw materials and copper ingots to the casting site: Fig.37. Here three porters are carrying the stuff required by the casting process in two baskets and one sack under complete supervision from a supervisor striding behind them.
2. Storing the charcoal in the furnace site: Fig.38. Here, the charcoal is transported in large black-white sacks by porters to the working site. The specific color system of the charcoal sacks is to identify it from other casting process stuff.

Fig 37: Moving casting raw materials.[58]

3. Firing the furnace: Fig.39. Here two workers are blowing air into the furnace using a positive displacement compressor while the third worker is disturbing the charcoal for proper heat generation.
4. Melting the copper-tin alloy (bronze): Fig.40. Here, either the copper and tin ingots or the bronze ingots are put in a ceramic pot with carrying poles by two workers is et in the fire for melting.
5. Raising the molten bronze out of the furnace: Fig.41. Based on experience the metal casters now when to raise the pot with the bronze completely molten.
6. Pouring molten bronze through funnels into the clay mold: Fig.42. This is the last stage of the casting process where the final product with require finishing to get rid of the different elements connected to the product such as: sprue, runner, riser and gas vent.

Fig 38: Storing the charcoal.[58]

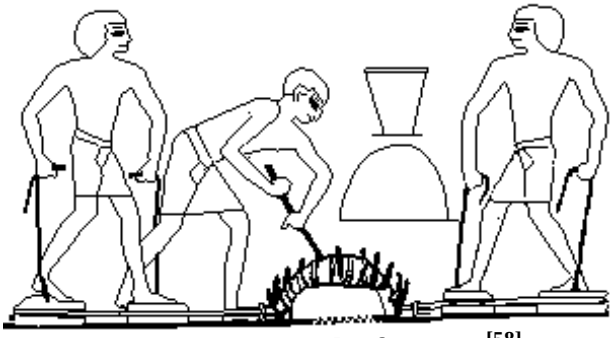

Fig 39: Firing the furnace.[58]

Fig 40: Melting the bronze.[58]

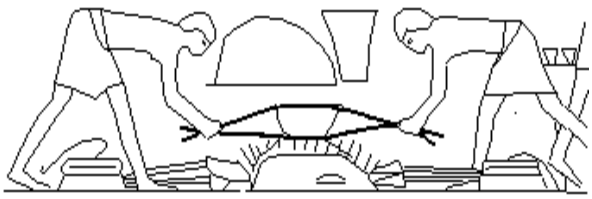

Fig 41: Moving the molten bronze.[58]

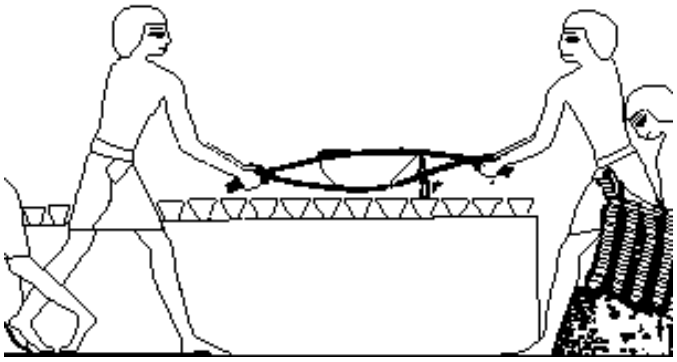

Fig 41: Pouring the molten bronze into the mold.[58]

CONCLUSION

1. The metal casting industry in ancient Egypt was investigated.
2. The ancient Egyptians practiced metal solid casting since the time of Badari (more than 5000 years ago).
3. They casted gold in the form of wire during Badari and Naqada Periods.
4. They solid-casted silver during the Early Dynastic Period.
5. Copper objects were casted during the 12th Dynasty of the Middle Kingdom found at Lahun of Faiyum.
6. Solid casted objects inlaid with semiprecious stones appeared during the 12th Dynasty.
7. They produced Royal axe using copper inlaid with gold and semiprecious stones during the 18th Dynasty of the New Kingdom.
8. The revolution of the sold-casting industry reached its peak during the 18th Dynasty specially in the reign of Pharaoh Tutankhamun.
9. They could produce a full golden statuette for Pharaoh Amenhotep III of the 18th Dynasty.
10. They casted a 110 kg golden innermost coffin for Pharaoh Tutankhamun..
11. They used the solid-casting process in producing some of the jewellery of the 18th Dynasty.
12. They used bronze in producing some of the jewellery of the 19th Dynasty.

13. They used the solid casting process in producing full statuettes during the 26th Dynasty of the Late Period.
14. It was expected that the ancient Egyptians new the hollow-casting technique since the time of Naqada where they produced golden cylindrical beads.
15. They produced golden dish for Queen Hetepheres from the 4th Dynasty of the Old Kingdom most probably using the holoow-cast process.
16. They produced a complete hollow-cast copper statuette for Prince Merenre from the 6th Dynasty of the Old Kingdom.
17. They produced hollow-cas amulets during the 12th Dynasty with professionally applied inlay.
18. Hollow-cast bronze statuettes of Human beings continued to appear during the 22nd and 25th Dynasties of the Third Intermediate Period.
19. Hollow-cast bronze statues of some animals appeared during the Third Intermediate and Late Periods.
20. Hollow-cast bronze deities were produced during the Late Period with gold inlay.
21. They used molds for the solid-casting process since the time of Maadi and continued to use solid-cast molds down to the time of the New Kingdom.
22. They designed ingot molds since the Maadi time , tool-molds during the 12th Dynasty, Royal sphinx and jewellery in the 18th Dynasty, Royal Cartouche and amulet molds in the 19th Dynasty.
23. They used three techniques to increase the temperature in the melting furnace required to complete the casting process: blowing tubes, positive displacement compressors and wind-powered furnaces.
24. The metal casting procedure as applied by the ancient Egyptians during the 18th Dynasty was presented as exactly registered by tomb scenes in the tomb of Vizier Rekhmire.

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