

Mechanical Engineering in Ancient Egypt, Part XXV: Models Industry (Boats, Ploughing, Grain Grinding, Bakery and Brewery)

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Abstract:

The paper investigates the evolution of mechanical engineering in ancient Egypt through the study of models industry during the Predynastic and Pharaonic Periods. It covers models for boats, ploughing, grain grinding, bakery and brewery. The time span of each model application is assigned through the different dynasties or time periods for the Predynastic era. The gender of the labors participated in each activity is assigned.

Keywords — Mechanical engineering history, Ancient Egypt, model industry, boat models, ploughing models, grinding models, bakery models, brewery models.

I. INTRODUCTION

Modelling is one of the features extensively applied in recent civilization. However, ancient Egyptians may be the first nation to adopt physical modelling of activities, humans, animals, birds, houses, tools and human accessories thousands of years ago. They authorized their daily life activities through models manufactured from wood and other materials and kept them inside their Tombs. Those models were a store of a lot of technical information about science and technology in ancient Egypt.

Reisner (1913) stated that during the early part of the 6th Dynasty, statuettes of servants performing their usual functions were placed in the serdab (statue chamber) along with the statues of the owner and his family. Models of boats of various sorts were found in the serdab were usually of wood [1]. Vinson (1987) presented some of the boat models from Badary, Naqada, 1st Dynasty and Old Kingdom. He studied how the ancient Egyptians represented boats in their Tomba and Temples. He examined also what is called 'boat burial' and 'funerary boats' [2]. Tooley (1989) traced the

Old Kingdom. She studied in details model granaries, funerary and pilgrimage model boats and model offering-bearers [3].

Teeter (2003) in her book about ancient Egypt through the treasures collected in the Oriental Institute of the University of Chicago presented some useful information about models in ancient Egypt. She presented a very clear photo for a wooden model for a workshop from the 1st Intermediate Period (9th and 10th Dynasties before 2025 BC). The workshop was for baking, brewing and slaughtering. She presented a bronze model for a composite deity from the Late Period (26th to 31st Dynasties before 332 BC) with front face of Abunis and its back for a falcon [4]. Allen (2004) strengthened the statement of Swain (1995) that the use of models and miniature vessels and models of all sorts was common throughout pharaonic history from the earliest periods onward [5]. She presented samples of miniature vessel models from the 4th Dynasty and from the Middle Kingdom [6].

Bard (2007) wrote a wonderful book about the archaeology of ancient Egypt with too many illustrations. Among her illustrations a wooden model of a bakery/brewery workshop from the 12th Dynasty [7]. Brooker (2009) in his Master of Philosophy thesis presented ancient Egyptian model for houses constructed using pottery during the 9th

and 12th Dynasties of the 1st Intermediate Period and Middle Kingdom [8]. Kroenke (2010) stated in her Ph.D. Thesis that the collection of tomb models from Naga ed-Deir was significant because it was extensive and spanned the major phases of model production from Late Old Kingdom to Late Middle Kingdom. She presented a detailed analysis of tomb models in each phase of production represented at Naga ed-Deir. She presented a complete chapter in her thesis about tomb models from Naga ed-Deir with corpus of tomb models and locations of the collection [9].

Vinson (2013) indicated that ancient Egyptians used boats for general transportation, travel, military use, religious/ceremonial use and fishing. He presented scenes for boats from different eras starting from Late Predynastic Period to New Kingdom [10]. Smith (2014) outlined that ushabti was an ancient Egyptian practice from the Middle Kingdom to end of the Pharaonic Period. He synthesized data from Leiden Museum's catalog of ushabtis to explore some trends about material, time period, provenience and inscription [11]. Hagseth (2015) outlined that cattle boats of the Pharaonic Period appeared in the reliefs of the elite Tombs during the Middle and New Kingdoms. In her Master of Arts thesis, she presented a boat model from the 12th Dynasty [12]. Wikipedia (2016) stated that wooden tomb models were in Egyptian funerary custom throughout the Middle Kingdom and the models represented the work of servants, farmers and other skilled craftsmen, armies and religious rituals. According to Wikipedia, the best known models came from the Tomb of the Chancellor Meketre [13].

II. BOAT MODELS

Egypt has a specific geographic characteristics. The River Nile crosses the country from its upper boundaries with Sudan to its lower boundaries with the Mediterranean Sea. Also it has the Red Sea in the East and the Mediterranean at the North. This made the ancient Egyptian keen to build boats and ships suitable for both Nile and Sea for civilian, military and religious purposes. We are going to trace the design of the ancient Egyptian boats through the different dynasties. .

- The 1st boat model is from Naqada II, one of the Predynastic Periods of ancient Egypt (3300 BC). It takes the shape of a crocodile and carries 3 mumiform figures as shown in Fig.1 [14]. The ancient Egyptian designer was a mechanical engineering expert. First, the crocodiles lives with him in the water resources of Egypt. Second he learned from the swimming characteristics of the crocodile that the surfaces have to be smoothly profiled. This what we see in the model body profile of Fig.1 more that 5300 years ago. How great was those people.



Fig.1 Crocodile boat model from Naqada II [14].

- The 2nd boat model from the Predynastic Period is from Naqada II/Naqada III (3500-3000 BC) shown in Fig.2 [15]. The boat is manufactured from pottery and has streamlined surfaces and sharp front to reduce water resistance to the motion of the boat.



Fig.2 Boat model from Naqada II/III [15].

- The 3rd boat model is from the End of the Old Kingdom, from the 6th Dynasty. It is a rowing boat with crew and two steering

posts as shown in Fig.3 [16]. The model has a unique design. It has a big ratio of height/length. It has an extremely long front pole. What does this mean from navigation point of view ?. An answer from specialists is required.



Fig.3 Boat model from the 6th Dynasty [16].

- The 4th boat model is from the Tomb of Herishefhotep in Abusir during the 9th /10th Dynasties and shown in Fig.4 [17]. This boat model was for sailing in the River Nile and probable manufactured from papyrus. It has a pilot in the front of the boat and a crew at both sides of the boat. There is a cabinet at the end. The body takes the shape of an ovoid with extended cylindrical ends from both sides.



Fig.4 Boat model from the 9th/10th Dynasties [17].

- The 5th boat model is from the 11th Dynasty. It is a transport boat shown in Fig.5 [18]. It has a decorated cabinet near its end, a pilot, a crew and a steering oar at its end. The travellers set inside the cabin and goods on the boat deck.



Fig.5 Transport boat from the 11th Dynasty [18].

- A 6th example is again from the 11th Dynasty. It is wooden fishing boats models found in Meketre Tomb and in display in the Egyptian Museum of Cairo and shown in Fig.6 [19]. They are a set of four boat models. The fishing net is between the first two boats and the boats are equipped with a full crew driving the boats and fishing. Each boat has an ovoid duck and the surfaces are filleted to smooth the sailing of the boat and provide high degree of safety during operation.



Fig.6 Fishing boats from Meketre Tomb [19].

- The 7th boat model is from the 12th Dynasty of the Middle Kingdom. It is a wooden funerary boat model in display in the Metropolitan Museum of NY and shown in Fig.7 [20]. The boat is painted and has a cabinet centred on the deck and carries the dead person. The boat has five figures representing the pilot, 3 persons looking after

the dead and one steering sailor. There is a large steering oar at the end of the boat and the surfaces are ideal for sailing purposes.



Fig.7 Wooden boat from Dynasty 12 [20].

- The 8th boat model is a river boat from the reign of King Amenemhat I of the 12th Dynasty. It is a model of a transportation boat driven by ten rowing oars, 5 from each side and one steering oar at the end. The pilot is in the front and the rowing and steering staff are all in working positions. A coloured cabinet is set near the end of the boat to balance with the driving crew.



Fig.8 Boat model from Amenemhat I reign [21].

- The 9th model is for a funerary boat from the 12th Dynasty displayed in the Metropolitan Museum of art and shown in Fig.9 [22]. The boat model has 2 rowing oars and 2 steering oars, full crew, cabinet with a specially profiled roof and may be a sail (not clear in the picture).



Fig.9 Funerary boat model from Dynasty 12 [22].

- Now, we jump to the 18th Dynasty, one of the most wealthy Dynasties of the ancient Egyptian history. The model is from the Tomb of Pharaoh Amenhotep II, the 7th Pharaoh of the 18th Dynasty and shown in Fig.10 [23].



Fig.10 Boat model from Tomb of Amenhotep II of the 18th Dynasty [23].

- Another model from the 18th Dynasty belongs to the young Pharaoh Tutankhamun, the 13th Pharaoh of the 18th Dynasty. It is manufactured from alabaster and displayed in the Egyptian Museum of Cairo and shown in Fig.11 [24]. The front and back ends of the boat model take the form of an gazelle and there is a shrine of 4 pillars and a roof in the middle of the boat with 2 persons at both ends of the shrine. All cut from rock alabaster. The model is decorated by multi-colours could survive for more than 3300 years. This piece is an indication of the high mechanical technology practiced by the ancient Egyptians.



Fig.11 Boat model from Tomb of Tutankhamun of the 18th Dynasty [24].

- The last boat model is for a warship from the 20th Dynasty during the reign of Pharaoh Ramses III, the 2nd Pharaoh of the 20th Dynasty. The model is shown in Fig.12 [25]. The model was built without crew. It is powered by 24 rowing oars, one steering oar and a linen sail. The warship is multi-coloured, has smooth ovoid profile and a long pole from the front end.

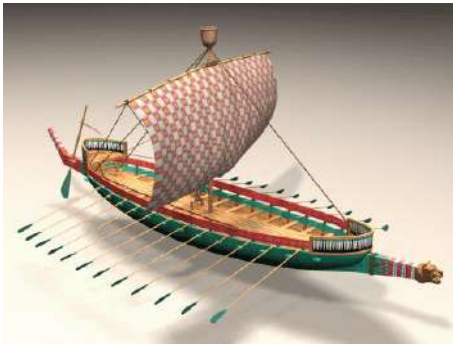


Fig.12 Warship model from the 20th Dynasty [25].

III. PLOUGHING MODELS

Ploughing is an agriculture process required to prepare the land for the new crop. Because the ancient Egyptian was a successful agricultural man he gave all his attention to all activities related to the agriculture process including ploughing.

- The 1st ploughing model is from Late 11th Dynasty of the Middle Kingdom displayed in the Museum of Fine Arts of Boston and shown in Fig.13 [26]. The farmer is using a wooden plougher powered by two oxen's under the supervision of an overseer.



Fig.13 Field ploughing from the 11th Dynasty [26].

- The 2nd ploughing model is from the 11th / 12th Dynasties displayed in the British Museum of UK as shown in Fig.14 [27]. The plough is powered by two oxen's and guided by the farmer. There is no overseer as in the model of Fig.13.



Fig.14 Field ploughing from the 11th/12th Dynasties [27].

- The 3rd ploughing model is from the 13th Dynasty of the Second Intermediate Period and shown in Fig.15 [28]. The design of the ploughing edge in this model is different than those in Figs.13 and 14. In the present design of the 13th Dynasty the plougher has two cutting edges and there are 4 labour pins, 2 from each side to suit the height of the farmer.



Fig.15 Field ploughing from the 13th Dynasty [28].

IV. GRANARY MODELS

As an agricultural country, the ancient Egyptians now have a huge amount of grains specially wheat which they need all-over the year to produce bread. Therefore, they need means for wheat storage. From here, came the

idea of designing and building different types of granary silos under the full control of the government as will be illustrated in the following models they left in their tombs:

- The first granary model is from the 1st Dynasty from Abydos and it is in display in the Petrie Museum of UK and shown in Fig.16 [29]. The silo is loaded from its top and discharged from its bottom through a door not shown in the Fig.16.



Fig.16 Granary model from the 1st Dynasty [29].

- The 2nd model is from the 4th Dynasty of the Old Kingdom found in El-Kap Mastaba. It is in display in the Ashmolean Museum of UK and shown in Fig.17 [30]. It consists of 12 domed silos arranged in two rows with cover on each silo top opening. There is a little flange in the bottom to help getting better stability for each silo and the surfaces have different diameters fillets (wonderful mechanical engineering design).

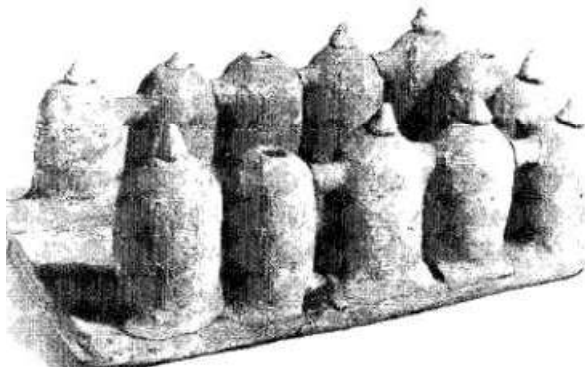


Fig.17 Granary model from the 4th Dynasty [30].

- The 3rd granary model is from the 6th Dynasty of the Old Kingdom. It is a wooden granary model in display in the Egyptian Museum at Cairo and shown in Fig.18 [31]. The mechanical engineer of the 6th Dynasty designed the discharge doors of those silos to be sliding doors in the bottom of the silos. Of course this gives excellent control on the flow rate of the grains out of the silos.

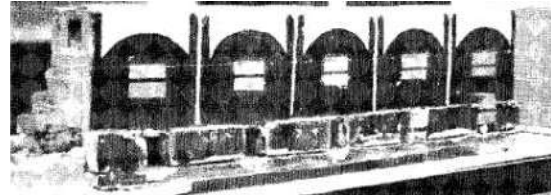


Fig.18 Five domed granary model from the 6th Dynasty [31].

- The 4th granary model is from the 11th/12th Dynasties of the Medium Kingdom. It is in display in the Metropolitan Museum of NY and shown in Fig.19 [32]. It has a parallelogram structure with main entry door from the front. It is of the closed-compartment design. There are two porters transferring the grain sacks to the granary through stairs, one scribe recording the input/output data of the granary, one overseer beside the scribe at the roof surface of the gallery. The discharge doors of the gallery are from the bottom in the open-air compartment.



Fig.19 Granary model from the 11th/12th Dynasties [32].

- The 5th granary model is from the 12th Dynasty. It is in display in the Metropolitan Museum of art and shown in Fig.20 [33]. It is of the open-compartment design. The porters go up using stairs and pour their grain-containers into the storage compartment. The main door of the granary opens to a scribes office where a good number of scribes record the input/output of the granary in a very successful administration system to reserve the wealth of the country and fight any corruption.



Fig.20 Granary model from the 12th Dynasty [33].

- The last granary model is from the reign of Pharaoh Tutankhamun of the 18th Dynasty. It is in display in the Egyptian Museum at Cairo and shown in Fig.21 [34]. Its door is in the left and internally it has more than 10 internal compartments, may be for storing different grains. The partitions height is almost half the outside walls of the model.

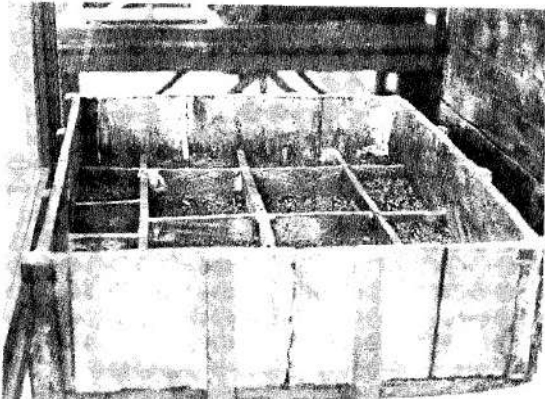


Fig.21 Granary model from the 18th Dynasty [34].

V. GRAIN GRINDING MODELS

The ancient Egyptians didn't have mills to grind their grains, but they depended on the main-power to do this job using simple mechanism designed specially for this purpose as will be illustrated in the following models:

- Fig.22 shown a limestone model for a lady grinding grain from the 5th Dynasty of the Old Kingdom [35]. The grinder is a two-elements mechanism, one stationary (frame) and one movable by the two hands of the grinder in a reciprocating rectilinear motion. The position of the grinding lady applies the body weight on the moving element to ease grinding with minimum hand-effort.



Fig.22 Grinding woman from the 5th Dynasty [35].

- The second grinding model is from the 9th – 11th Dynasties Period and shown in Fig.23 [36]. In this model the woman applies more forces by her hands independent of her body weight and the stationary part of the grinder has stoppers at its end to increase the efficiency of the grinding process.



Fig.23 Grinding woman from the 9th/11th Dynasties [36].

- The 3rd grinding model is a wooden model from the 11th Dynasty in display at the Rosicrucian Egyptian Museum in San Jose, California and shown in Fig.24 [37]. In this model, the woman depends on her top part weight to apply the grinding force and the fixed element of the grinder has a roughened surface to increase the efficiency of the grinding process.



Fig.24 Grinding woman from the 11th Dynasty [37].

- The 4th grinding model is a wooden model from the 12th Dynasty in display in Haifa of Palestine and shown in Fig.25 [38]. The moving element is hemi-cylindrical and the body exerts the required grinding force.

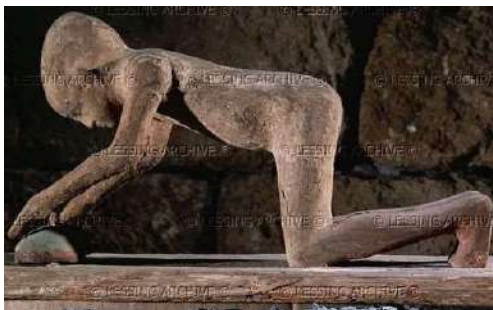


Fig.25 Grinding woman from the 12th Dynasty [38].

VI. BAKERY MODELS

Now, the ancient woman has prepared the flour required to produce the bread which was and still a gain food item for the Egyptians in all-over their history. Here, are some of the available bakery models:

- Making bread requires heat energy source. Fig.26 shows a woman from the 5th Dynasty tending fire as an important step in producing

bread. The model is in display at the Museum of Fine Arts of Boston [39].



Fig.26 Woman from the 5th Dynasty tending fire [39].

- The 2nd model is from the 10th Dynasty for a team working in producing bread. It is in display in the Egyptian Museum at Turin, Italy and shown in Fig.27 [40]. The team consists of four members dealing with all the activities of bread production.



Fig.27 Men making bread from the 10th Dynasty [40].

- The 3rd bakery model is a wooden models group from the 11th Dynasty for three groups of people producing bread and looking after two cows as displayed in the Museum of Fine Arts of Boston and shown in Fig.28 [41].
- The 4th bakery model is from Meketre Tomb of the 12th Dynasty for a group of two men and two women cooperating in producing the bread and shown in Fig.29 [42]. The two ladies are preparing the dough. One of the men is setting in front of the closed oven, while the other man is setting the final touch

on the dough and it seems that he is wearing gloves in both hands.



Fig.28 Bakery model from the 11th Dynasty [41].



Fig.29 Bakery model from the 12th Dynasty [42].

- The last bakery model is from the 21st Dynasty for a bakery and brewery team of four men and four ladies working in preparing food and beer as shown in Fig.30 [43].



Fig.30 Bakery and brewery model from the 21st Dynasty [43].

VII. BREWERY MODELS

Ancient Egyptians manufactured beer and wine from early times of the dynastic periods for two purposes: drink by wealthy people in replacement of the contaminated River Nile water and for medical purposes [44]. Here are some models of brewery covering a historic era from the 6th Dynasty up to the 12th Dynasty:

- Fig.31 shows two men from the 6th Dynasty of the Old Kingdom preparing beer and storing it in specially designed jars [45]. The setting man is filling the jars with beer and sealing them. The model is coloured with at least four colours: black, white, light brown and dark brown. They used dark brown for the jars lids to differentiate it from the jar body and direct the user directly to the location of opening the jar. Such jars are labelled by the name of its owner are indicated by jars of King Aha I of the 1st Dynasty [44].



Fig.31 Brewery model from the 6th Dynasty [45].

- The 2nd brewery model is from the First Intermediate Period (7th – 9th Dynasties) from the Tomb of Wadjet-hotep (2150-2050 B.C.). The model is shown in Fig.32 [46]. This is a model for a complete team for bread and beer making with all the devices required to complete the two manufacturing processes.



Fig.32 Brewery model from the 1st Intermediate Period [46].

- The 3rd brewery model is for a lady from the 9th Dynasty of the First Intermediate Period brewing beer as shown in Fig.33 [47]. The model clarifies the role of the ancient Egyptian model in the society and her participation in the national economy of the state.



Fig.33 Brewery model from the 9th Dynasty [47].

- The 4th brewery model is for a big factory for producing beer in the 11th Dynasty of the Middle Kingdom. The model is in display in the British Museum and shown in Fig.34 [48]. The model is produced from wood and has two rows of working men, one standing row and one setting row, 3 men in the front in a 3rd row and an overseer to the extreme left of the model supervising the whole work. The model is coloured showing the dress of the operating crew.



Fig.34 Brewery model from the 11th Dynasty [48].

- The last brewery model is from the 12th Dynasty of the Middle Kingdom and in display in the Metropolitan Museum of NY and shown in Fig.35 [49]. The model is from Meketre Tomb and consists of three men workers preparing and storing beer in two jars of them is already sealed.



Fig.35 Brewery model from the 12th Dynasty [49].

VIII. CONCLUSIONS

- The mechanical engineering in ancient Egypt was investigated through the model industry representing some activities in the ancient Egyptian society.
- Boat models were investigated in a historical era from Naqada II to the 20th Dynasty.
- They manufactured models for civil and military boats and ships.
- The models reflected various design schools for different purposes such as transportation, fishing, amusement, funerary and war.
- Boat models with and without oars, with and without sails were produced.
- Ploughing models were manufactured during the 11th to 13th Dynasties.
- Great attention was paid to the granaries since Egypt was basically an agricultural state from the very old history.
- They designed and produced granary models starting from the 1st Dynasty and continued up to the 18th Dynasty.
- Both closed and open granary models were designed.
- The granary process was under complete and accurate accounting through scribes and supervision through overseers..
- They designed cylindrical silos and parallelogram-shaped granaries.
- They used covers for cylindrical silos to preserve the grains and reduce losses and bottom doors to discharge the grain.
- They invented sliding doors to control the discharge of the grain flow out of the granary.

- Work in the granaries was allocated only to men labors and overseers.
- Grain grinding to produce flour required for the bread industry was a job allocated the ancient Egyptian woman.
- Models for women grinding grains using two elements grinders (mechanisms) were authorized starting from the 5th up to the 12th Dynasties.
- Ancient Egyptian women took position during the grinding process helped them to exert grinding forces based only on their body weight (top part).
- Sample of bakery models appeared in the Tombs of the 5th Dynasty and continued up to the 21st Dynasty.
- Both men and women cooperated in producing bread for their society.
- Ancient Egyptians had a brewery industry for beer and wine production for drinking and medical purposes.
- They authorized the brewery industry through models found in the Tombs of the 6th to 12th Dynasties.
- Both men and women participated in the brewery industry.
- They stored they production of beer and wine in sealed and labeled jars.

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