

MECHANICAL ENGINEERING IN ANCIENT EGYPT, PART 55: ROPE INDUSTRY

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ABSTRACT

The objective of this paper is to investigate the development of mechanical engineering in ancient Egypt through the use and production of rope during their daily life. This study covers the applications of ropes in the daily life of the ancient Egyptians, samples and production of ropes in the ancient Egyptian society. The innovations in use and production of the analyzed ropes are highlighted.

KEYWORDS: Mechanical engineering history, ancient Egypt, rope applications, rope samples, rope production.

INTRODUCTION

This is the 55th part in a series aiming at investigating the mechanical engineering technology in ancient Egypt. It focuses on the application of ropes in the daily life of the ancient Egyptians and presenting scenes authorising this important industry with actual samples of their ropes living for thousands of years.

Ryan, 1985 outlined that the fibres of plants were used to produce artefacts such as cordage, basketry, brushed, etc. Which were discovered in Egypt and found in museum collections throughout the world.^[1] Ryan and Hansen, 1987 studied the ancient Egyptian cordage in display in the British Museum. They presented a complete data for specimens of the ancient Egyptian cordage.^[2] Charlton, 1996 in his thesis about rope and the art of knot tying outlined

that dozens of uses for rope existed on the sailing vessels of the ancient Egyptian fleets and presented a scene for an ancient Egyptian sailing ship dated to 1500 BC (during the 18th Dynasty). He displayed a scene for rope making from the tombs of Ptahhetep (5th Dynasty), Kahif, Nefer (5th Dynasty) Tehuti-hetep (Middle Kingdom), Rekhmire (18th Dynasty) and Khaemwaset (20th Dynasty).^[3] Fronzaglia, 2006 quoted that the ancient Egyptians used the spinning technique in making their ropes. He presented a 3500 years old Egyptian rope and two scenes for rope application from an ancient Egyptian tomb.^[4]

Veldmeijer and Zazzaro, 2008 investigated the rope cave at Mersa of Wadi Gawasis (25 km south of Saqqara of Egypt) which was identified as the Pharaonic harpor during the Middle Kingdom. They presented the analysis and offered suggestions for the function of the ropes found in the rope cave.^[5] Veldmeijer, 2009 outlined that cordage refers to rope, string and products obtained from them. He handled techniques used by ancient Egyptians to produce ropes and the materials used by them for this industry.^[6] Bohr and Olsen, described a geometrical property of helical structures and how it accounted for the early art of rope making. They presented scene for rope making from the tomb of Akhethotep and Ptahhotep about 2300 BC.^[7] Borojevic and Mountain, 2013 designed a simple and accurate method of identifying archaeological plant fibre sources. They examined 22 fibre samples from ancient Egyptian artefacts. They presented a papyrus rope from Deir el-Bersha in display in the Museum of Fine Arts of Boston and other ropes from the rope cave of Mersa/Wadi Gawasis of the Middle Kingdom.^[8] Slingenberg, 2016 in her master thesis about bird trapping with hexagonal net in the daily life scenes in the Old Kingdom elite tombs of the Memphite area presented different types of nets used in bird trapping with the help of ropes and pegs.^[9] Wikipedia, 2017 wrote an article about rope and outlined that ancient Egyptians were probably the first civilization to develop special tools to make rope and the Egyptian rope dates to 4000-3500 BC made of water reed fibre.^[10]

Rope Applications in Ancient Egypt

Ropes in ancient Egypt had extensive applications in different aspects of their daily life. The following presentations proof this fact through various eras of their ancient life.

The first example is a floating shelf application presented as a scene in an unidentified ancient Egyptian tomb !! and shown in Fig.1.^[11] This is a genius application where tools or vessels required to be stored in an elevated position away from handles of children or just for storing similar components such as the U-shaped units hanged in the top part of the shelf or

the vessels located on the bottom part of the shelf. The rope is wrapped around a pole emerging from the wall and then going down from both sides to be secured to the ground. Of course, the rope is under tension due to the weight of the shelf, By this mechanism, they can control the height of the shelf from ground through the length of the rope.



Fig. 1: Floating shelf in an ancient Egyptian kitchen.^[11]

The second example is a sealing application for Pharaoh Tutankhamun shrine (18th Dynasty, 1332-1323 BC) in display in the Egyptian Museum at Cairo and shown in Fig.2.^[12] The genius ancient Egyptians used a rope to construct a firm seal for the wealthy Pharaoh Tutankhamun that could survive for more than 3300 years without deterioration. The design of the seals is innovative since it used a human hand simulator holding a U-shaped fixture and a rope rapped around the hand and holding another U-shaped fixture in the other side of the shrine. Multi knots on the right side of the seal secured the whole process.



Fig. 2: Shrine sealing from the 18th Dynasty.^[12]

The third example is a sling from El-Lahun of Fayyum of Egypt during the 12th Dynasty of the Middle Kingdom (1900 BC) shown in Fig.3.^[13] The triangular body of the sling was

woven from the rope and two long rope parts emerged from its tip to be hold by the user. Unfortunately, I could not trace the location of this sling.

The fourth example is a harvest basket from tomb of Nakht, the high official of the 18th Dynasty (1400 BC) shown in Fig.4.^[14] The basket was designed to be carried by two men either using a pole or a rope from one of the sides. The rope helps the porter to maneuver the basket during the loading process and to pull the basket if it is very heavy to be carried by two porters.



Fig. 3: Sling from the 12th Dynasty^[13]



Fig. 4: Harvester basket from the 18th Dynasty.^[14]

The fifth example is a basket from the tomb of the Architect Kha during the reigns of Amenhotep II and Thutmose IV of the 18th Dynasty (1425-1350 BC) in display in the Egyptian Museum at Turin and shown in Fig.5.^[15] This is a heavy duty basket carried by two strong looped-ropes from two sides facing each other.

The sixth example is a toy in the shape of a milling mechanism found in one of the ancient Egyptian tombs and shown in Fig.6.^[16] The toy is driven by a rope connected to the moving body of the toy moving the milling stone upward. On releasing the rope, the milling stone moves downward under the effect of its gravitational force.



Fig. 5: Basket from tomb of Kha, 18th Dynasty.^[15]



Fig. 6: Milling mechanism toy.^[16]

The seventh example is the first positive displacement pump applied by a human being, the 'shaduf'. It is a colored scene in the tomb of Ipyu from the 19th Dynasty during the reign of Pharaoh Ramses II (1279-1213 BC) shown in Fig.7.^[17] The bucket is connected to a counter-weighted first-class lever through a rope with suitable length allowing the bucket to reach the water in the canal or well.

The eighth example is a plough scene in the tomb of Sennedjem from the 19th Dynasty (1200 BC) shown in Fig.8.^[18] As a planar mechanism, it consists of two links connected by a revolute joint between the ploughing tool and the driving stem. The designer used a rope to limit the maximum angle between the two links during operation. This design allows this angle to increase or decrease during operation but not to exceed the maximum value set by the ropes. The rope size and number of turns depend on the force exerted on the tool during ploughing.



Fig. 7: Shaduf from 19th Dynasty.^[17]



Fig. 8: Plough from 19th Dynasty.^[18]

The ninth example is an application for moving a huge stuff using ropes from the tomb of Nefer at Saqqara during the reign of Niuserre, the 6th King of the 5th Dynasty (2494-2345 BC) shown in Fig.9^[19]. In this application a huge stuff was put in a net secured to a heavy rope and pulled by four men under the supervision of an overseer giving them his instructions.



Fig. 9: Moving a huge stuff in the 5th Dynasty.^[19]

The tenth example is an application for moving heavy structures using sledge and ropes from the tomb of Djedhutyhotep at El-Bersha from the 12th Dynasty (1900 BC) shown in Fig.10.^[20] Here, the heavy structure is statue which was set on a sledge, tied firmly using a rope and then pulled by four rows of men using long ropes with labors on the sledge pouring water under it to act as a lubricant to reduce the pulling forces of the labors. The process , because of its importance was performed under complete supervision of a staff of overseers striding behind the statue.

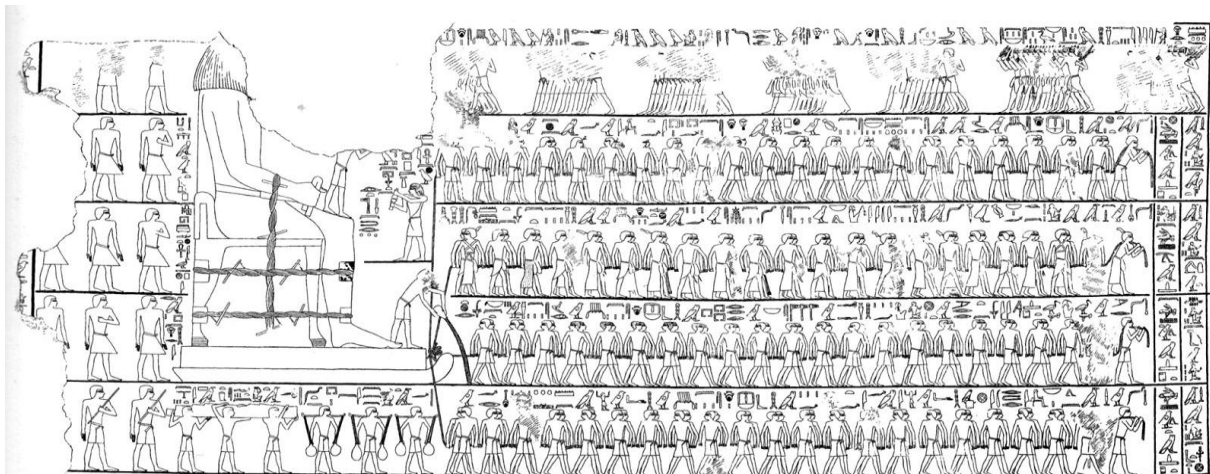


Fig. 10: Moving heavy structures from 12th Dynasty.^[20]

The eleventh example is a vehicle pulling by men and oxen from the tomb of Rekhmire at Sheikh Abdel-Qurna of Thebes from the 18th Dynasty (1479-1398 BC) shown in Fig.11^[21]. The vehicle is carrying four persons, three inside the cabinet and two on the sledge before and after the cabinet. The sledge was pulled by an oxen and helped by two men. Other men are supporting them with spare oxen and five overseers behind the vehicle.



Fig. 11: Moving a vehicle from 18th Dynasty.^[21]

The twelfth example is a model axe from the 12th Dynasty (1981-1802 BC) in display in the Metropolitan Museum of Art at NY and shown in Fig.12.^[22] The mechanical designer used a thin rope (cord) to secure the axe blade with its hand using a number of turns ending by a knot.

The thirteenth example is a ceremonial axe of Ahmose I, the founder of the 18th Dynasty (1549-1524 BC) in display in the Egyptian Museum at Cairo and shown in Fig.13.^[23] It used the same technique of the 12th Dynasty of using thin strong rope to secure its blade with the hand. Except from mechanical design of view, the designer of the 18th Dynasty was much experienced through the use of concave surfaces for the blade helping in forming very strong and stable fixture through using the rope.



Fig. 12: Model axe from 12th Dynasty.^[22] **Fig. 13: Ceremonial axe from 18th Dynasty.**^[23]

The fourteenth example is a land surveying application of ropes from the tomb of Rekhmire, vizier of the 18th Dynasty during the reign of Pharaohs Thutmose III and Amenhotep II (1479-1398 BC) shown in Fig.14^[21]. The colored scene depicts three surveyors holding a rope and measuring the boundaries of a field to assign its taxes. An important application to support the resources of the government from more than 3400 years ago.

Another example of land surveying (fifteenth example) comes from tomb of Menna, the scribe of the fields of the Lord of the two lands during the reign of Thutmose IV, the 8th Pharaoh of the 18th Dynasty (1398-1388 BC) shown in Fig.15^[24]. The surveyors are carrying their rope and receiving offerings from the people of the owner in a very wonderful meaning of sympathy and appreciation of their job.



Fig. 14: Land surveying in Rekhmire tomb, 18th Dynasty.^[21]



Fig. 15: Land surveying in Menna tomb, 18th Dynasty.^[21]

The sixteenth example is a ship model from the 5th Dynasty (2494-2345 BC) displayed somewhere and shown in Fig.16.^[25] The sail is attached to a large number of strong ropes used for its setting and orientation during seagoing.

The seventeenth example is an 1.3 m length boat model from the Middle Kingdom (2050-1800 BC) sold by Bonhams on November 2016 for 217,285 US\$ and shown in Fig.17.^[26] The model shows a complete crew for setting the sail under the supervision of one overseer.

The eighteenth and last example is a Red Sea vessel of Hatshepsut, the 5th Pharaoh of the 18th Dynasty (1479-1438 BC) within the trading expedition to Punt lands during her reign as registered in her temple at Deirel Bahari and shown in Fig.18.^[27] The scene shows the ships ready to un-load and load the goods with the sails in their lowest position using the too many ropes controlling each sail.

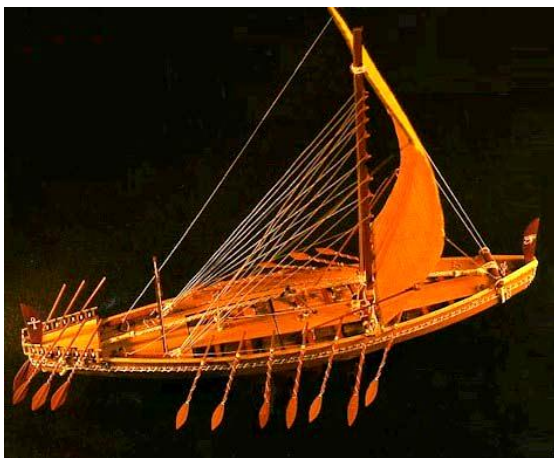


Fig. 16: Ship model from 5th Dynasty.^[25]



Fig. 17: Boat model from 12th Dynasty.^[26]

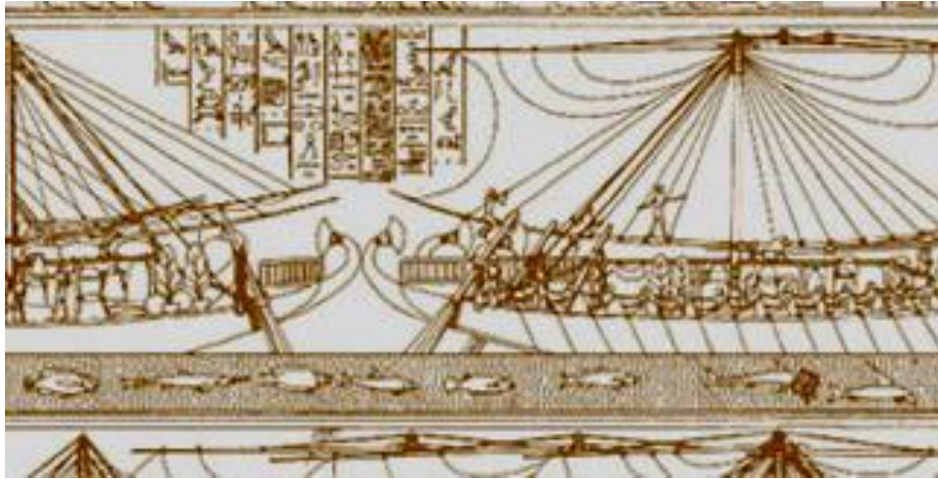


Fig. 18 Red Sea ship from 18th Dynasty.^[27]

Rope Samples

The ancient Egyptians produced ropes from a number of plant-materials such as papyrus, halfa, flax and palm fibers. Because they are genius, they thought to resister their rope production not only through scenes in their tombs and temples, but also through actual samples and rope-coils left in tombs and stores. Here are some of their rope samples produced during an era between Old Kingdom and Late Period

The first example is a rope for the solar ship of Khufu, the founder King of the 4th Dynasty (2589-2566 BC) produced from halfa in display in the Khufu Boat Museum at Giza and shown in Fig.19.^[28]

The second example is a three-strand rope from the 12th Dynasty of the Middle Kingdom during the reign of Senusret II, Senusret III and Amenemhat III (1926-1839 BC) found in a cave in Mersa/Wadi Gawasis on the Red Sea produced from papyrus and shown in Fig.20.^[29,30]



Fig. 19: Khufu solar ship halfa rope from 4th Dynasty.^[28]



Fig. 20: Papyrus rope from 12th Dynasty.^[29]

The third example is palm fiber rope from the reign of Pharaoh Hatshepsut of the 18th Dynasty (1503-1473 BC) in display in the Oriental Institute Museum of the University of Chicago and shown in Fig.21.^[31] It is obvious from Fig.21 that the rope was a two strand one perfectly twisted and had a homogeneous diameter through its length.

The fourth example is a halfa grass rope from the tomb of Seti I, the 2nd Pharaoh of the 19th Dynasty (1290-1279 BC) in display in the British Museum and shown in Fig.22.^[32] It has a less quality compared with the palm fiber rope shown in Fig.21. It has greater pitch and has relatively weak strand twisting.



Fig. 21: Palm fiber rope from the 18th Dynasty.^[31]



Fig. 22: Halfa rope from the 19th Dynasty.^[32]

The fifth example is a linen rope from the 11th Dynasty, reign of Mentuhotep II, the 5th King of the 11th Dynasty (2061-2010 BC) in display in the Metropolitan Museum of Art at NY and shown in Fig.23.^[33] It is a multi-strand rope professionally twisted having uniform diameter all over its length.

The sixth and last example is a 90 mm diameter papyrus rope from the Late Period (664-332 BC) in display in the Petrie Museum at London shown in Fig.24.^[34] It was ended by a knot forming a firm loop may be for use with boats and ship operation.



Fig. 23: Linen rope from the 11th Dynasty.^[33]



Fig. 24: Papyrus rope from Late Period.^[34]

Rope Production

The ancient Egyptians used a twisting technique to produce multi-strands ropes as registered starting from the 5th Dynasty of the Old Kingdom. Here, are some of their registrations from the 6th Dynasty and from the Middle Kingdom.

The first example is a rope making scene from the tomb of Akhethotep from the 6th Dynasty (2300 BC) shown in Fig.25 ^[35]. The process was performed by two labors. The setting one to the right is holding and feeding the strands while the labor in the left twisting the strands. Ready produced rope were set in the form of coils tied by 3 loops arranged around the rope coil with 90 degrees angular span. A dead weight was hanged on each strand to increase the tensile stress in the strand during the twisting process.

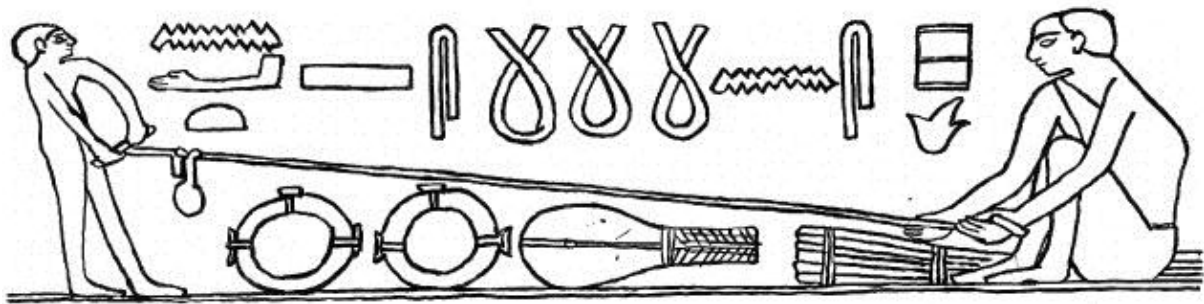


Fig. 25: Rope making in Akhethotep tomb, 6th Dynasty.^[35]

The second example is a scene from an ancient tomb for rope making shown in Fig.26.^[34]

The location and time are unknown. Here, the twisting labor is stressing the strands by tying a rope around his waist and pushing himself backward while twisting the strands. The finished ropes are prepared in the form of coils tied using one tie loop.

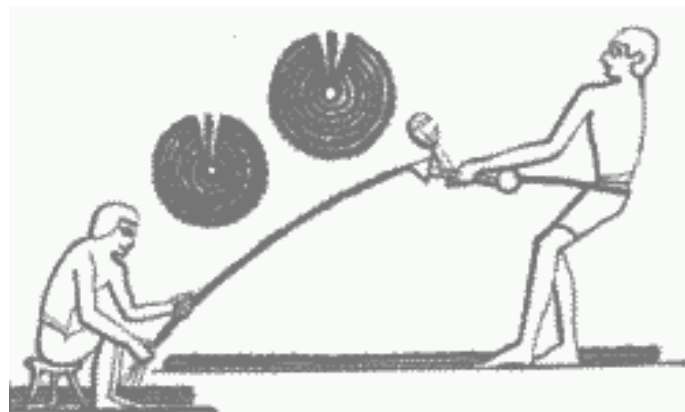


Fig. 26: Rope making from an ancient Egyptian tomb.^[34]

The third example of rope production in ancient Egypt is a scene in the tomb of Djehutyhotep from the 12th Dynasty (1900 BC) shown in Fig.27 ^[36]. This may be a part of a mechanism used for multi-strand rope production. Five strands are guided by a setting woman to go through five rollers and then to the twisting part of the machine which is not clear in the right half of the scene.

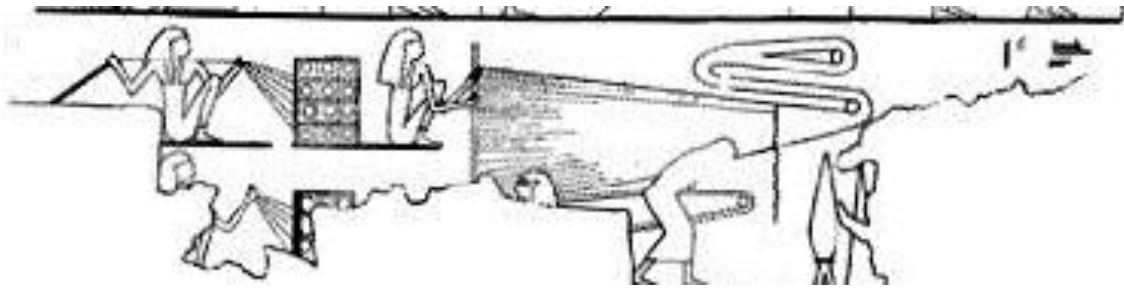


Fig. 27: Rope making from 12th Dynasty.^[36]

CONCLUSION

- This paper investigated the evolution of mechanical engineering in ancient Egypt through the production of ropes.
- The study covered a time span from Old Kingdom to Late Period.
- The ancient Egyptians authorized the rope production through tomb and temple scenes and actual rope samples and coils.
- They used papyrus, palm fibers, halfa grass and flax in producing ropes.
- They used ropes in some daily-life applications such as: floating shelves, shrine sealing, sling production, harvesting basket production, basket special handles, operating mechanism models, irrigation shaduf design, plough design, moving huge stuff and heavy structures, moving vehicles, axe design, land surveying and boat and ship sailing mechanisms.
- They left true samples of their ropes produced from papyrus, halfa, flax and palm fibers.
- Their ropes survived for more than 4500 years without deterioration.
- Actual rope coils were found in the site of the solar ship of King Khufu near his pyramid at Giza.
- The presented rope samples are from the 4th Dynasty, 11th Dynasty, 12th Dynasty, 18th Dynasty, 19th Dynasty and Late Period.
- Ropes with diameter up to 90 mm were excavated.
- The paper presented production techniques used in rope making in the ancient Egyptian society. All the techniques depended on rope twisting under the application of strand tensile stress.

REFERENCES

1. Rayan, D. "The misidentification of ancient Egyptian fibers", *Varia Aegyptiaca*, 1985; 1: 143-149.
2. Ryan, D. and Hansen, D., "A study of ancient Egyptian cordage in the British Museum", British Museum, 1987.
3. Charlton, W. "Rope and the art of knot tying in the seafaring of the ancient Eastern Mediterranean", Master of Arts Thesis, Texas A & M University, 1996.
4. Fronzaglia, B. "The history of rope", The Classic Yacht Symposium, 2006.
5. Veldeijer, A. and Zazzaro, C. "The rope cave at Mersa/Wadi Gawasis", *Journal of Research Center in Egypt*, 2008; 44: 9-39.
6. Veldmeijer, A. "Cordage production", *UCLA Encyclopedia of Egyptology*, March, 2009.
7. Bohr, J. and Olsen, K. "The ancient art of laying rope" *EPL (Europhysics Letters)*, 2011; 93(6): 5.
8. Borojevic, K. and Mountain, R. "Microscopic identification and sourcing of ancient Egyptian plant fibers using longitudinal thin sectioning", *Archaeometry*, 2013; 55(1): 81-112
9. Slingenberg, M. "Bird trapping with hexagonal net in the daily life scenes in the Old Kingdom elite tombs of the Memphite area", Master Thesis, Faculty of Humanities, Leiden University, 2016.
10. Wikipedia "Rope", <http://en.wikipedia.org/wiki/Rope>, 2017.
11. Hill, H. "The wonder book of knowledge", The J. Wilson Company Publisher, 1921; 122.
12. Dvorsky, G., "The actual seal that secured King Tutankhamun's tomb", <http://io9.gizmodo.com/this-is-the-actual-seal-that-secured-king-tutankhamuns-1663189358>.
13. McDougall, A. "The oldest known sling to survive to this day", <https://www.pinterest.com/pin/252483122836858270/>.
14. Taneter, "Nile valley: An early agrarian society", <http://www.taneter.org/nile.agriculture.html>.
15. Deir el-Medina, "The tomb of Kha", 2015. <http://www.deirelmedina.com/lenka/TurinKha.html>.
16. Quatr, "Egyptian games", <http://quatr.us/egypt/games/>
17. Primary Home Workshop, "Ancient Egyptian farming", <http://primaryhomeworkhelp.co.uk/egypt/farming.htm>.
18. Wikipedia, "Burial chamber of Sennedjem, Plowing farmer",

- https://en.wikipedia.org/wiki/File:Maler_der_Grabkammer_des_Sennudem_001.jpg.
19. Dunn, J. (2017), "The tomb of Nefer at Saqqara in Egypt",
<http://www.touregypt.net/featurestories/nefert.htm>.
 20. Williams, M. "Djehutyhotep's statue and the wood beam", 2014.
<http://www.unexplained-mysteries.com/forum/topic/261560-djehutyhoteps-statue-and-the-wood-beam/>.
 21. Osirisnet, "Tombs of ancient Egypt: Rekhmire – TT 100",
https://osirisnet.net/tombes/nobles/rekhmire100/e_rekhmire100_07.htm.
 22. Metropolitan Museum, "Model ax", 2017.
<http://www.metmuseum.org/art/collection/search/544289>.
 23. Dunn, J. "Edged, close combat weapons of the ancient Egyptians", 2017.
<http://www.touregypt.net/featurestories/edgedweapons.htm>
 24. Osirisnet, "Tombs of ancient Egypt: Menna – TT69",
https://www.osirisnet.net/tombes/nobles/menna69/e_menna_02.htm .
 25. Art Sales, "Egyptian galleons in ancient Egypt and Egyptian art", 2010.
http://www.artsales.com/ARTistory/Ancient_Ships/06_egyptian_galleons.html .
 26. Bonhams "A large Egyptian gesso-painted wood model boat", 2017.
<http://www.bonhams.com/auctions/23365/lot/169/?category=list&length=10&page=17>
 27. Tyson, P. "The expedition to Punt", 2017.
<http://www.pbs.org/wgbh/nova/ancient/expedition-punt.html>.
 28. Butard, K. "Khufu ship at the Giza pyramids", <https://traveltoeat.com/khufu-ship-at-the-giza-pyramids/>, 2015.
 29. Linsley, A. "Three-clan confederations of the bible", 2015.
<http://jandyongenesi.blogspot.com/2015/07/three-clan-confederations-of-bible.html>.
 30. Borojevic, K. and Mountain, R. "The Ropes of Pharaohs: The Source of Cordage from "Rope Cave" at Mersa/Wadi Gawasis Revisited", Journal of the American Research Center, 2011; 47: 131-141.
 31. Common Wikipedia "Rope, Luxor, Deir el-Bahari, New Kingdom, Dynasty 18, reign of Hatshepsut", 2016. https://commons.wikimedia.org/wiki/File:Rope,_Luxor,_Deir_el-Bahari,_New_Kingdom,_Dynasty_18,_reign_of_Hatshepsut,_c._1503-1473_BC,_palm_fiber_-_Oriental_Institute_Museum,_University_of_Chicago_-_DSC07919.JPG.
 32. Window into the Bible "Construction and stone masonry", 2013.
<http://www.windowintothebible.com/construction-and-stone-masonry>

33. Metropolitan Museum "Rope", 2017.

<http://www.metmuseum.org/art/collection/search/572195?sortBy=Relevance&ao=on&ft=Rope&offset=0&rpp=20&pos=7>.

34. Reshafim "Making rope", <http://www.reshafim.org.il/ad/egypt/trades/rope.htm>, 2009.

35. Cleveland Art, "Palette in the form of a fish",

[http://www.clevelandart.org/art/1989.32?f\[0\]=object_location:Gallery%20107](http://www.clevelandart.org/art/1989.32?f[0]=object_location:Gallery%20107).

36. Osirisnet, "Tombs of ancient Egypt: Djehutyhotep",

https://osirisnet.net/tombes/el_bersheh/djehoutyhotep/e_djehoutyhotep_02.htm.

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