

Mechanical Engineering in Ancient Egypt, Part XIX: Textile Industry

Galal Ali Hassaan

Emeritus Professor, Department of Mechanical design & Production,
Faculty of Engineering, Cairo University, Egypt
galalhassaan@ymail.com

Abstract— The textile industry in ancient Egypt is one of the oldest industries transferred through the generations from the Predynastic era to present days. This paper discusses all aspects related to linen production from material selection to the final weaving process. It presents samples of ancient Egypt linen and use and focuses on technologies used for yarn preparation, spinning and weaving. It handles also the features of the ancient Egyptian linen and compares its fineness of its texture with a modern linen.

Index Terms— Mechanical engineering in ancient Egypt, textile industry.

I. INTRODUCTION

This is the 19th paper in a scientific research aiming at presenting a deep insight into the history of mechanical engineering during one of the greatest civilizations in the world, the ancient Egyptians civilization. The papers handles wide range of various industries in ancient Egypt to explore the materials, techniques and technologies used by those great people in times without computers or internet.

Roth (1913) studied the ancient Egyptian looms in a separate chapter of his book published in 1913. He discussed the horizontal looms presenting wall scenes from a Beni Hasan tomb of vizier Daga (11th Dynasty), physical model from Bani Hasan, scene from the tomb of Tehuti-hoteb (12th Dynasty). He also presented scene of a vertical loom from the tomb of Nefer-hotep at Thebes (18th Dynasty) [1]. Crowfoot (1931) displayed spinning techniques in ancient Egypt through scenes from the tombs of Baqt (6th Dynasty) and Khety son of Baqt at Bani Hasan and grasped spindle from tomb 104 at Thebes (18th Dynasty). He also presented a weaving model tomb 575 at Bani Hasan (11th – 12th Dynasties) displayed in Liverpool Museum and another model for spinning and waving from tomb of Mehenkwetre (11th Dynasty) at Thebes plus images from tombs of Daga (11th Dynasty) and Tehuti-hoteb (12th Dynasty).

Nicholson and Shaw (2000) edited an extensive work for the study of materials and technology in ancient Egypt. Their work included a complete chapter about 'textiles' written by Mr. G. Eastwood. He presented a model of a spinning and weaving workshop from the Middle Kingdom and scenes from Middle and New Kingdoms [3]. Anderson (2011) announced that excavations since 1995 at the Predynastic settlement of el-Mahasna produced tools associated with textile production. He presented data on the discovered objects together with the assemblage of awls and needles

manufactured from bone and copper [4]. Abdel-Kareem (2012) presented a brief historical information about natural dyes in different historical periods in Egypt. He presented the dye according their alphabetical names in his research paper [5].

Pritchard (2014) stated that at least 16 woven patterned textiles of the polymita type were recovered during the excavations of the Egypt Exploration Fund at Anticoupolis in 1913-1914. He described the fragments and placed them within a dated framework and elaborated on their use [6]. Strand (2015) stated that the horizontal loom was considered to be the oldest loop type came from Badari (Predynastic of Egypt) and the earlier representation of the two-beam loom occurred in Egypt during the final part of the 2nd millennium BC (i.e. during the Middle Kingdom) [7]. Gromer (2016) wrote a book about the art of prehistoric textile making. He included sections about: raw materials (plant and animal fibers), flax and wool preparation, tools found for fiber preparation, yarn spinning, weaving techniques, dying, pattern designs, fabric finishing, sewing and tailoring [8].

II. THE ANCIENT EGYPTIAN LINEN

The ancient Egyptians knew linen for more than 6500 years because simply fragments of ancient Egyptian cloth were dated 4500 BC such that Egypt was known as the 'land of linen' [9]. They were brilliant in selecting proper material for a specific purpose as we have seen in their furniture industry [10], jewellery industry [11]. Pottery industry [12], stone vessels [13] and glass industry [14]. Their selection of flax as a raw material for their linen was because it has some outstanding characteristics:

- The flax produces a beautiful linen such that from over 5000 years ago they named it 'woven moonlight' [15]. This is a very scientific expression meaning that their yarns are similar to the moonlight rays, i.e. very thin and pure.
- The linen fibre is very absorbent and garments made of it are valued for their exceptional coolness and freshness in hot weather [16].
- They succeeded to produce high quality linen superior to any other and exported it to Arabia and India [17].
- They produced linen with a fine texture for pharaohs and noblemen [18].
- Having the ability to produce long-life linen capable of withstanding severe underground environments without air or light (Fig.1 shows linens from the 18th dynasty survived more than 3300 years) [19].



Fig.1 Linen from the 18th dynasty [19].

- The linen had the ability to be dyed using different colors.

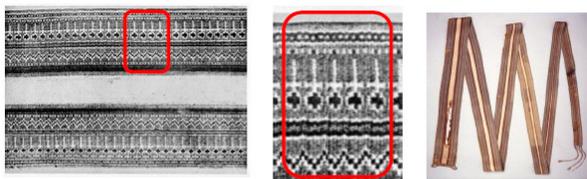
The ancient Egyptians succeeded to dye the linen since the 1st dynasty [19]. Fig.2 shows a wall scene of Pharaoh

Ramses III, the 2nd Pharaoh of the 20th dynasty in the tomb of Amenherkhepshef wearing a wonderful multi-colors dress [20].



Fig.2 Ramses III in a multi-color dress [20].

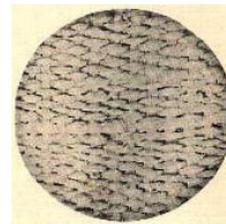
- Some of the linen designs had an outstanding characteristics from point of view of pattern and shape. For example, Fig.3 shows the 5 m long linen sash of Pharaoh Ramses III of the 20th dynasty displayed in the World Museum at Liverpool [21], [22]. The width decreases gradually from 127 to 48 mm over the five m length. This decrease is not observable in Fig.3 (a) because the rate of decrease is about 16 mm per m length. A section of the sash is zoomed in Fig.3 (b) to highlight the decoration of the sash. It has a very complex pattern that one cannot imagine how they woven it 3100 years ago ?. The sash is colored as shown in Fig.3 (c) [22].



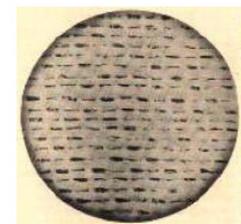
(a) Ramses III sash [21]. (b) Zoomed section (c) Coloured sash [22]

Fig.3 Ramses III sash [21], [22].

- Fine and accurate texture from about 5000 years. There is an existing evidence of a mummy linen from the 1st dynasty existing in the British Museum. To assess its fineness, they make microscopic investigation of its linen and compared with a modern linen recently woven. The result is shown in Fig.4 [15]. The top sector in the 1st dynasty and modern linen is zoomed and shown in Fig.4 (c). Having a deep insight into both we find the ancient Egyptian texture is much coherent than the modern one and it is similar to a beehive. This may give an answer of a question: how could the Egyptian lined survive for thousands of years in a difficult environment ?.



(a) Linen from the 1st dynasty



(b) Modern linen.



(c) Zoomed top sector of both linens.

Fig.4 First dynasty and modern linens [15].

III. ANCIENT EGYPTIAN LINEN USE

Because linen was manufactured from the flax plant available in Egypt, they used it in too many applications required for their daily life. Some of those applications are:

- Bag manufacturing: Fig.5 shows a bag manufactured from linen during the Middle Kingdom-Early New Kingdom and displayed in the Egyptian Textile Museum at Cairo [23]. It seems that the bag is

relatively large and there is no dimension scale beside it to help the researcher to assign its dimensions. On the other hand, I don't know what are the other objects set on the bag. It is possible that those objects were inside the bag when it was extracted from Tomb MMA 812 at Thebes.



Fig.5 Linen bag [23].

- Bed cover manufacturing: Because they are modernized people, they produced beds and heavy linen cover such as that shown in Fig.6, produced during the 4th Dynasty and displayed in the Metropolitan Museum of Art [24]. It has fringes at the ends and not dyed.



Fig.6 Linen bed cover from the 4th Dynasty [24].

- Sling manufacturing: They produced linen sling for purpose of hunting of birds and small animals. Fig.7 shows a model of a sling produced during the 3rd Intermediate Period and displayed in the Petrie Museum [25]. Its main part has a diamond shape connected at two of its terminals on the main centreline to two cords. The diamond is zoomed in Fig.7 (b). The zoomed section shows how it is accurately woven and the sides are trimmed without any defects and how it was survived for more than 2800 years in a severe environment.

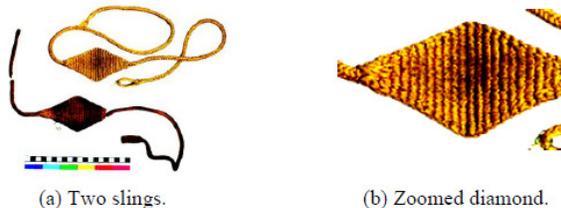


Fig.7 Linen sling from the 3rd Intermediate Period [25].

- Linen fishing net: Fig.8 shows an actual existing fishing net fragment found at Lahun manufactured during the Middle Kingdom and displayed in Petrie

Museum of the University College London [26]. The cords and knots are very fine, strong and homogeneous without any sign of degradation due to aging.

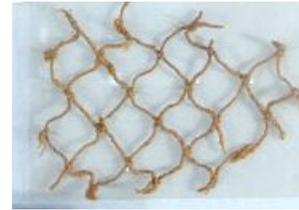


Fig.8 Fishing nets from Middle Kingdoms [26].

- Linen dresses: They used linen to produce different fashions of male and female dresses. Fig.9 shows two models of ladies dress: (a) is a long netted dress from the 4th Dynasty [27] and (b) is a short dress from the 6th Dynasty [28] both displayed in the Museum of Fine Arts at Boston. The first model is produced more than 4500 years in the time of King Khufu and has an impressive design. The pattern in the top is different than that in the bottom and it has a gradual very accurate profile around the body. Besides, it is still existing !!.



(a) Dress from the 4th Dynasty [27]. (b) Dress from the 6th Dynasty [28].

Fig.9 Ladies dress from 4th and 6th Dynasties.

- Mummy wrappings: The ancient Egyptians used linen in the mummification process of their dead. Two samples are presented here from the 11th Dynasty (Middle Kingdom) and the 18th Dynasty (New Kingdom). Both are produced from fine linen and have fringes. Both wrappings are displayed in the Metropolitan Museum of art at NY and labeled indicating the date of weaving [sample in (b)] as shown in Fig.10 [29], [30]. This is the top technology in authorizing production items known to the Egyptians from more than 4000 years..



(a) Wrapping of Henhenet's mummy from 11th Dynasty [29] (b) Wrapping of Pharaoh Tutankhamun from 18th Dynasty [30].

Fig.10 Mummy wrappings from 11th and 18th Dynasties.

- Body mummification: Mummification was practiced in Egypt from the 1st Dynasty (2920-2770 B.C)

where it required mountains of linen for bandage [31]. The mummification process consumes 100's of meters of linen strips around the dead body as shown in Fig.11 [32]. Fig.12 shows a

- linen bandage for Pharaoh Tutankhamun mummification in the 18th dynasty. It has a 1.65 m length and 60 mm width and displayed in the Metropolitan Museum of Art [33]



Fig.11 Mummification of a human body in ancient Egypt [31].



Fig.12 Linen bandage for Tutankhamun [33].

- Mummy shrouds: Beside mummification of high-rank people in ancient Egypt, they used a linen shroud to put the dead inside it. Fig.13 shows a linen shroud dated to 1000 BC (21st Dynasty) and displayed in the Vatican Museum of Rome [34].

Fig.13 Linen shroud from the 21st Dynasty [34].

- Linen sail: Because it was a great empire, they produced different types of boats and ships for their economical activities. They used course-linen sails to drive the ships using wind energy. Fig.14 shows a model of an Egyptian ship dated to 2500 BS (during the 4th Dynasty) and displayed in the Deutsches Museum of Germany [35].



Fig.14 Ship model from the 4th Dynasty [35].

IV. FLAX CULTIVATION

The genius ancient Egyptians knew that flax is the plant suitable for their linen production. Therefore, they planned for cultivating wide areas. Both men and women cooperated in harvesting the crop as illustrated in the coloured scene shown in Fig.15 from the Tomb of Sennedjem, the high official responsible for the excavation and decoration of the nearby [royal tombs](#) at Deir el-Medina of Thebes during the Pharaohs Seti I and Ramses II of the 19th Dynasty [36], [37]. The scene authorizes the harvesting process, the cooperation of the wife with her husband through both drawing and writing.



Fig.15 Flax harvesting in Sennedjem Tomb [37].

After the flax is cut, it is tied into bundles and carried away to the store as shown in the Tomb scene of Fig.16 [38].



Fig.16 Tying flax into bundles and moving to stores [38].

V. FLAX RIPPLING

As a preparation process for the flax, it is rippled in a specially designed device to clear the seeds away from the plant as shown in the wall scene shown in Fig.17 [39]. The scene shows a young worker carrying bundle of flax and an old worker using the rippling device to perform the rippling process. The writing on the wall registers an interesting dialogue between the old and young worker. The old worker is saying: 'Even if you bring me 11009 (sheaves), I shall ripple them all'. The young worker is replying: 'Hurry up and stop talking' [39].

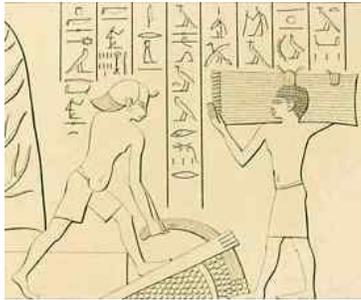


Fig.17 Process of flax rippling [39].

VI. FLAX BEATING

Next to the rippling process comes the beating process to extract the flax fibers through beating the rippled plant using a hand-bat. Fig.18 shows a typical bat displayed in the Petrie Museum [40].



Fig.18 Bat for flax beating [40].

Another beating technique stated by Nicholson and Shaw was by using two sticks hold by hand and practiced in the Middle and New Kingdoms [41]. Fig.19 shows a lady using this technique as registered in the Tomb of Dagi from the Middle Kingdom [41]. The lady is holding the sticks by her left hand and pulling the flax-stems by her right hand.



Fig.19 Flax beating using two sticks [41].

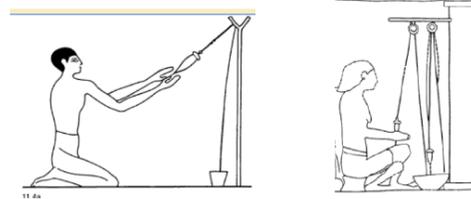
VII. YARN SPINNING

The next process after releasing the flax fibres is preparing the yarn through spinning. Most often, the ancient Egyptian women and men were responsible for this process as authorized by tomb scenes and weaving models as follows:

- Fig.20 (a) shows a spinning worker from Tomb of Khety, a nomarch during the 11th dynasty of the

Middle Kingdom [42]. The worker is standing and spinning the spindle using his both hands.

- Fig.20 (b) shows a spinning women from Tomb of Thutnefer, overseer of the treasury in the mid-Dynasty 18 of the New Kingdom [43].



(a) Spinning man from Dynasty 11 [42]. (b) Spinning woman from Dynasty 18 [43].

Fig.20 The spinning process in ancient Egypt.

- They practice spinning in the Middle Kingdom while standing as depicted in the scenes of the Tomb of Thutotep from the 12th Dynasty at Deir el-Bersha as shown in Fig.21 [44]. Two women are performing spinning while standing. The front woman is using her right hand to spin the spindle while holing the yarn with her left hand. The back women is spinning with her right hand and her right leg while holding the yarn with her left hand.

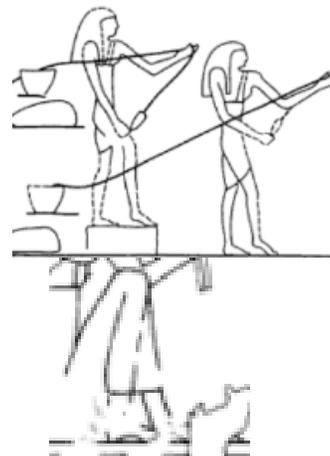


Fig.21 Spinning process during the 12th Dynasty [44].

- They authorized the spinning process using workshop models for linen production. One of those models of spinning and weaving was found in Meketre Tomb, [chancellor](#) and [high steward](#) during the reign of [Mentuhotep II](#), [Mentuhotep III](#) and perhaps [Amenemhat I](#), during the 11th Dynasty of the Middle Kingdom [45,46]. The model is displayed in the Egyptian Museum at Cairo and shown in Fig.22 [47]. The workers are all ladies, some of them spinning and the some others are

weaving using horizontal looms. One of them is moving the linen for storage. Wonderful administration technology from ancient Egypt to authorize industrial activities using wooden models.



Fig.22 Weaving model from Meketre Tomb of the 11th Dynasty [47].

They used different types of spindles for yarn spinning as follows:

- Cylindrical wooden spindles: Fig.23 shows 7 wooden cylindrical spindles from the Middle Kingdom found at Lahun and displayed in Petrie Museum [48]. All the spindles have wide flange and short axles (the axles may be broken during excavations).



Fig.23 Wooden cylindrical spindles from the Middle Kingdom [48].

- Conical wooden spindles: Fig.24 shows two conical wooden spindles Top: New Kingdom type with conical whorl found at Gurob and dating to approximately 1450 BC (18th Dynasty). Bottom: from the Middle Kingdom site of Gurob and dating to approximately 1880 BC (12th Dynasty) [49].



Fig.24 Wooden conical spindles from 12th and 18th Dynasties [49].

- Pottery spinning bowl: They used pottery in producing spinning bowls of the form shown in Fig.25 from the Middle Kingdom, about 2025-1750 BC displayed in Petrie Museum [50].



Fig.25 Pottery spinning bowl from the Middle Kingdom [50].

- Bone spindles: They used bone to produce spindles capable to survive thousands of years. Fig.26 shows a set of Spindle whorl, Period: New Kingdom, Ramesside 19th – 20th Dynasties, from Memphite Region, Lisht North, Cemetery, MMA 1913-1914 and displayed in the Metropolitan Museum of Art [51].



Fig.26 Bone spindles from the New Kingdom [51].

- Double whorls spindle: They used double whorls spindles in the New Kingdom as that shown in Fig.27 from the 19th-20th Dynasties and displayed in the Metropolitan Museum of Art [52]. From dynamics point of view, this design will increase the inertia of the spindle and hence is capable of storing more mechanical energy required for the spinning process.



Fig.27 Double whorls spindle from the New Kingdom [52].

VIII. YARN WEAVING

Now, they have yarns ready for weaving to produce linen of varying qualities. To do this they used mechanical looms of various designs as illustrated below:

- Ground horizontal loom: They used horizontal looms from an early era as the time of Naqada I (4400-3500 BC) as authorized through a scene in a dish found in 1924 in Badari and located in the Petrie Museum. The dish is manufactured from pottery and shown in Fig.28 [53]. It has an elliptic shape, shining surface and scene on its interior surface.



Fig.28 Dish from Naqada I with waving scene [53].

- The horizontal loop continued to produced lines through the dynastic periods. Here a weaving workshop model from Meketre Tomb of the 11th Dynasty displayed in the Egyptian Museum and shown in Fig.29 [54]. The model presents a complete weaving workshops with two horizontal looms with all the operating and supporting staff.



Fig.29 Weaving workshop from the 11th Dynasty [54].

- Also, from the 12th Dynasty we have weaving scenes in the Tomb of Chnem-hotep, presenting linen weaving using a ground horizontal loom as shown in Fig.30 [55]. Two setting ladies operate the loom.

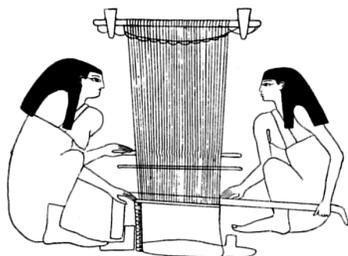


Fig.30 Ground horizontal loom from the 12th dynasty [55].

- During the 19th Dynasty of the New Kingdom, scenes from the Tomb of Nefer-Ronpet, the superintendent of weavers at Thebes depicted the use of raised horizontal loom as shown in Fig.31 [56]. This is the

second type of ancient Egypt looms where its level is above the knees of the operator. The scene shows two horizontal looms with each operator preparing the yarns before starting waving. The setting man at the left most probably is the superintendent supervising the work and recording the weaving process output. This is one of the shining features of the ancient Egyptian civilization and the top administration activity in the total management process of their industrial works.



Fig.31 Raised horizontal loom from the 19th Dynasty [56].

- They started using vertical looms in 1700 BC (during the 13th Dynasty) [57] for the production of large cloths and tapestry [58]. Fig.32 shows a weaving workshop as a scene in the Tomb of Nefer-Ronpet, the superintendent of weavers at Thebes [59]. This is the third type of the ancient Egypt looms. The workshop consists of three vertical looms with the operator settling and working. The setting man in the left may be the superintendent observing the work and giving his instructions to the three operators.



Fig.32 Vertical loom from the 19th Dynasty [59].

IX. WEAVING ACCESSORIES

The ancient Egyptians used some accessories facilitating the weaving process in a successful manner. From those accessories:

- Loom weight: Fig.33 shows a loom weight from the Middle Kingdom displayed in Petrie Museum [60].



Fig.33 Loom weight from Middle Kingdom [60].

- Warp spacer: Fig.34 shows a warp spacer from Gurob of ancient Egypt used to set a 6 mm space between yarns and displaced in Manchester Museum [61].

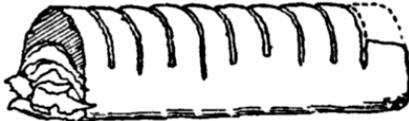


Fig.34 Warp spacer from Gurob [61].

- Heddle jack: Fig.35 shows a set of heddle jacks found at Lahun of Egypt belonging to the Middle Kingdom and displayed in Petrie Museum [62].



Fig.35 Heddle jacks from Middle Kingdom [62].

- Other components: Some other components were used with the horizontal loom as shown in Fig.36 from a model from the Middle Kingdom including: shuttle, heddle jack and lease rod [39].

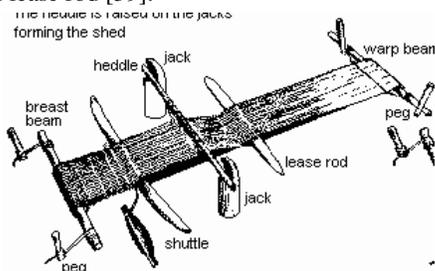


Fig.36 Loom model accessories from Middle Kingdom [39].

X. CONCLUSIONS

- The evolution of mechanical engineering in ancient Egypt through the study of the textile industry was investigated.
- The characteristics of the ancient Egyptian linen were presented giving an explanation of the reason for the ancient Egyptians to select flax as a raw material for their garments.
- Samples of the ancient Egypt linen were presented either as through wall scenes or as real samples survived for thousands of years in the world museums.
- They could produce linen with colored and very complex pattern during the 20th Dynasty.
- They had the technology to produce very fine and accurate texture from more than 5000 years which was comparable or even better than a modern linen.
- Their linen texture simulated a beehive of a very coherent nature.
- They produced linen for clothing, bags, bed covers, slings, fishing nets, mummy wrappings, body mummification, mummy shrouds and sails.
- They cultivated wide areas of lands by flax required for their linen and oil production and both man and woman cooperated in harvesting the crop.
- They set a procedure based on experience for preparing the flax for linen production including: harvesting, tying in bundles, transferring bundles to stores, rippling, beating, yarn spinning and yarn weaving.
- They used different types of spinning devices including: cylindrical wooden spindles, conical wooden spindles, pottery spinning bowls, bone spindles and double whorls spindles.
- They new the ground horizontal loom from the time of Naqada I (more than 6000 years ago).
- They authorized the weaving process through wooden models for weaving workshops during the 11th and 12th Dynasties.
- They used the raised horizontal loom in the 19th Dynasty through a scene from the Tomb of Nefer-Ronpet, the superintendent of weavers at Thebes.
- They new the vertical loom since the 13th Dynasty and its use was authorized in the 19th Dynasty.
 - Some accessories required to complete the weaving process were presented.

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BIOGRAPHY



Galal Ali Hassaan:

- Emeritus Professor of System Dynamics and Automatic Control.
- Has got his B.Sc. and M.Sc. from Cairo University in 1970 and 1974.
- Has got his Ph.D. in 1979 from Bradford University, UK under the supervision of Late Prof. John Parnaby.
- Now with the Faculty of Engineering, Cairo University, EGYPT.
- Research on Automatic Control, Mechanical Vibrations, Mechanism Synthesis and History of Mechanical Engineering.
- Published more than 200 research papers in international journals and conferences.
- Author of books on Experimental Systems Control, Experimental Vibrations and Evolution of Mechanical Engineering.
- Chief Justice of the International Journal of Computer Techniques.
- Member of the Editorial Board of a number of International Journals including IJARMATE.
- Reviewer in some international journals.
- Scholars interested in the author's publications can visit:

<http://scholar.cu.edu.eg/galal>