The Mystery of Chinese Ancient Ship

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中國 古代船의 神秘

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〈 Contents 〉

요 약

중국 고대선의 신비스러움은 다음 여덟 가지의 점에서 두드러지게 나타난다. 즉 격벽의 고안, 물새를 닮은 수선면, 바텐을 댄 돛의 발명, 타의 발명, 다수의 돛과 돛대를 장비하는 방법, 외륜의 발명, 그리고 역풍 항해 기술의 개발이다.

이 글에서는 중국 고대선의 신비스러움을 서양 고대선과 비교하여 설명하였다.

1. Introduction

Dr. Joseph Needham, the distinguished historian on science and civilization, Cambridge, UK, brought the Chinese contributions up a proper position of the world history since very few Chinese scholars studies on their own maritime civilization. Quoted from his celebrated book 'Science and Civilization in China' Vol. Ⅳ, part 3, he is saying that "From 3rd century to 13th century, China maintains a level of scientific knowledge which was much higher than that of the Western world". The technology and scale of shipbuilding during the period of Zheng He's(鄭和) expedition reached its climax in the history of shipbuilding, and "During the Yong-Le(永樂) period, his fleet consisted of some 3,800 ships in all, including 1,350 patrol vessels and 1,350 combat ships attached to guard stations or island bases, a main fleet of 400 large warships stationed at Hsin-chiang-khon(新江) near Nanking(南京), and 400 grain

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transport freighters." and "In the heyday around 1420 AD, the Ming navy probably outclassed that of any other Asian nation at any time in history, and would have been more than a match for that of any contemporary European state or even a combination of them." [1]

At that time it is obvious that China was the utmost shipbuilding country and had the most powerful navy in the world. During the International Sailing Ships History Conference which was held in Shanghai from 4th to 8th Dec.1991, Dr. Needham, as the Honorary President, declared that "After all, the rudder was a Chinese invention, and so also were watertight compartments in the hold, while the mat-and-batten sails permitted the sailing close to the wind." The inventions in the shipbuilding civilization confirmed by Dr. Needham are listed in Table 1.

Table 1. Chinese Inventions as Related to Maritime Civilization

Item	Number of Centuries which the Western Nations Lag behind China (approximately)
Principles of Naval Architecture and Nautical Science	12 centuries
Watertight Compartment	16 centuries
Rudder	10 centuries
Nautical Magnetic Compass	4 centuries
Technique of Sailing Close to the Wind	4 centuries

Being a foreigner, Dr. Needham not only gave a very high esteem to the Chinese ancient maritime civilization, but also propagated his studies through his great work, 《Science and Civilization in China》 to the world. I, As a Chinese researcher in the maritime civilization, one has the responsibility to undertake seriously the task of studying in the mysteries of Chinese ancient ships. It is hoped that this paper may serve as a first step in a long march with a view to attract jade by casting a brick.

2. Eight Mysteries

2.1 First Mystery: Nodal Septa of Bamboo and Watertight Bulkhead

Watertight transverse bulkheads were found in ancient Chinese boats for compartment. Apart being served as partitions for holds, such transverse bulkheads would keep the hold dry even if the neighboring hold being damaged and water rushing through the hole, so they are named "Watertight Bulkhead." By textual research, it is found that watertight bulkheads were installed in boats since East Han (61-220 AD) and period of Three Kingdom (220-280 AD). The oldest vessel being unearthed in China was built in Tang Dynasty (618-907 AD), which had normally 13 compartments partitioned with solid bulkheads. There were plugged drain holes underneath the bulkhead. When the plug is removed, any remaining water would be drained out, and when it is in, the bulkhead would be watertight. Ancient Western ships did not provide such watertight bulkheads, until modern naval architecture emerged. To prevent water from flooding into the whole ship, watertight bulkheads were then commonly installed.

The sea-going wooden ships were getting

1) Needham, J., Science and Civilization in China, Vol. Ⅳ: 3, Cambridge University Press, 1978, p. 484

larger and larger, depend on the sound structural configuration in the joining of shell planks using internal nails or pegs and caulking technique at the joining seams for watertight, as well as the employment of iron brackets to connect bulkhead with shell planks. Whilst at the same period, ancient ships in Southeast Asia in 589-907 AD were quite large. However, the ship size of later period became smaller because of poor joint techniques i.e. sowing shell planks together, the structure was not strong enough for ocean going voyage. In the later period of Tang Dynasty and that of Five Dynasties(五代)and Ten States(十國)(907-979 AD), the Chinese large sea-going sailing ships(Junk) were the most important passenger and cargo carriers in the Indian Ocean, since they were roomy, robust, having multi-masts and sails to provide speed and sea worthiness. Many Arabs, famous for their seafaring ability, traveled across the Indian Ocean by Chinese sailing ships for safety. In the Tang period, many Japanese ships dispatched to China suffered from foundering or ship wreck on the way, whereas, very few Chinese vessels were lost on the China-Japan and China-Southern Islands routes. Because of the watertight bulkheads arranged in Chinese ships, the probability of disasters in flooding and sinking was much less than that of contemporary Western sailing ships. The invention of watertight bulkhead is one of the Chinese shipwright's contributions in the field of naval architecture and maritime safety.[2]

How comes such an important invention in ancient times? In the early days, Chinese people used bamboo rafts as floating materials. The Chinese word "筏" (raft), has a "竹" (bamboo) as its component, which provides an indirect evidence that the raft was made of bamboo. Bamboo is a strong longitudinal material with inside hollow, yet reinforced with septa for transverse strength. If a piece of bamboo is split into two halves, the nodal septa might serve as watertight bulkhead and the half piece of bamboo as a boat. Since many inventions are derived from simulation, it may be postulated that the ancient people invented the watertight bulkheads and compartment of ships through careful observation of the bamboo. Fig.1 derived from Dr. Needham's 'Science and Civilization in China', shows the typical Chinese watercraft similar to half piece of bamboo[3], and Fig.2 shows the arrangement of watertight bulkheads in the unearthed ship of Tang Dynasty.

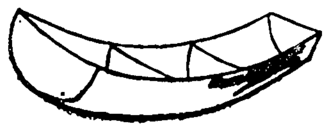


Fig. 1 The Half Piece of Bamboo Similar to Typical Junk

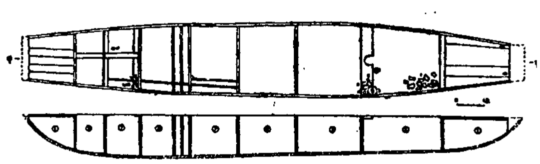


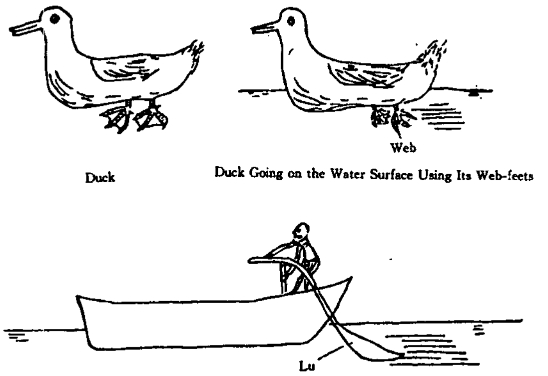
Fig. 2 Tang Dynasty Ancient Boat Unearthed from Yizhen(儀征), Jiangsu Province, with the Arrangement of Watertight Bulkheads

2) Xin, Yuanou, 'Types and Development of Chinese Ancient Ships' (in Chinese), Jiangnan Ship Design, Jiangnan Shipyard, No. 4, 1990, p. 9.

3) Needham, J., *op. cit.*, p. 391.

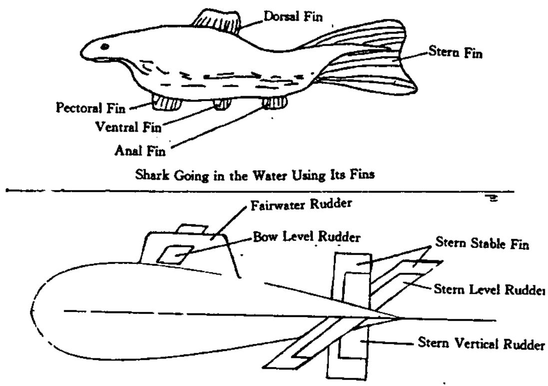
2.2 Second Mystery: Palmiped Waterbird and Waterline Shape of Chinese Ancient Ship

The second mystery is that the ancient Chinese sailing ship since Tang and Song Dynasties, either flat-bottomed or with deadrise, had a waterline shape simulating to that of palmiped waterbird. The broadest beam was situated after of amidships, contracting to the shape of Western sailing ships, which had the broadest beam forward amidships, or "a cod's head and a mackerel tail". Since fishes are totally submerged in water, their shape is more suitable for submarine with speed corresponding to low Froude's number. On the other hand, aquatic birds swim half submerged at the interface of water and air, see Fig.3, thus the shape of ancient Chinese ship are more suitable for surface sailing. Many ancient Chinese sailing ships had "鷁" (Chinese character, meaning a kind of aquatic bird) painted at their bows and quite a number ships named after birds. Not until the later decade of the 19th century, the Western naval architects understood that the features of Chinese sailing ships were more suitable for the sailing requirements and began to pay attention to the Chinese shipwright's inventions thousands years ago. Quoted from Needham, Admiral Paris in 1840 was perhaps the first observer to note this great difference in waterline shapes. He wrote, "For our best hulls we have taken the fishes as models, always larger at the cephalic end, but the Chinese, who also copied Nature, imitated the palmipeds, which float with the greatest breadth behind, for somewhat obscure reasons. In this they were acute, for aquatic birds, like boats, float between two media of air and water, while fish swim only in the latter. These strange people seem to



Ship Navigating on the Watersurface Using Lu by Shipman

a) Palmiped's Web-feets and Lu



b) Shark's Fin and Submarine's Manoeuvring Surface in Bow and Stern

Fig. 3 The Analogizing about Lu(櫓) and Palmiped's Web-feets, Fish and Submarine's Manoeuvring Surface

have done everything in the opposite way to which it is done at the other end of the continent, and they copied Nature still further in seeking to exert the greatest possible propulsion on the stern, instead of applying, as it were, a towing force to the prow. This led them to the use of those strong paddles (the Yulohs) which imitate in position the web-feet of the palmipeds-a position which much have been very important for swimming, since it deprived such birds of the facility of walking easily on land, and even, in the case of best swimmers, prevented this altogether. These very simple observations (which the Chinese have utilized) will find on day, perhaps, a happy application to the steam-boat, which, set in motion as it is by an internal force not coming like the wind from without, finds itself in exactly the same situation as the swimming bird, and might gain from a closer approximation to the latter's form" .[4]

In the above quotations, "a towing force to the prow" means the wind force transmitted from the Western type of sails, and the 'Yulohs ' inserted by Dr. Needham, means the paddle invented by Chinese in the West Han Dynasty (206BC-8 AD). In fact the two web-feet of aquatic bird, just like two paddles at port and starboard of stern, dipping into water, continuously change the angle of the palms and act as propulsion devices.

Quoted From Needham's book, "The widest beam of a good sailing-ship should be located between 3 and 8% after the center of the flotation. The racing yacht "America" demonstrated this figure in the end of the 19th century" .

The famous junk "Hai-Peng" (海鵬) constructed by Lo Pi(羅壁), superintendent of shipbuilding in Shanghai in the Yuan period (1271-1368 AD), as well as river junks "Ma-yang-zi" (麻穰子), "Ma-yang-hu-zi" (麻穰壺子), "Jin-yin-ding(金銀錠), "Hong-xiu-xie" (紅繡鞋), "Ya-shao" (鴨梢)(Fig.4) had the same waterplane shape. "Hai-Peng" referred in '庄子', was a kind of gigantic aquatic bird which could take off from the water surface by very fast speed. The reason for Lo Pi to name the junk as "Hai-Peng" might to be the hope of making the fastest speed for a ship. Lo Pi 's motto was "tortoise body and snake head" which was derived from the study of waterplane shape of boats of previous Dynasties. [5]

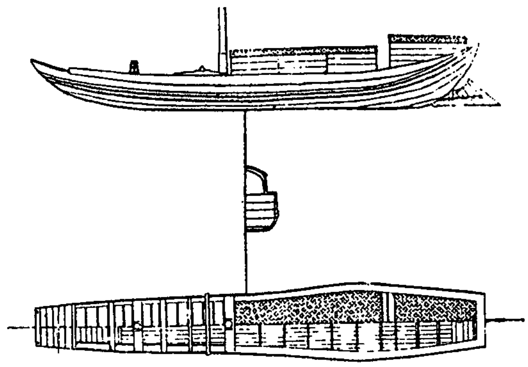


Fig. 4 Typical Junk "Ya-shao" (鴨梢) in Hubei District of China

It may be seen from the previous paragraph, the philosophy of Chinese shipwright's design was how to make the fastest speed on the water surface by imitating aquatic birds, which is proved to be more scientific than that of Western shipwright's imitating fish. Emphasizing the stern propulsive device, most likely such a design philosophy eventually paved the way of technical revolution featured in using screw propellers in lieu of paddle wheel.

2.3 The Third Mystery: The Mat-and-batten Sails

Among the various types of sails, the Chinese mat-and-batten sail was unique (Fig.5). It had straight fore edge with an inclined yard, being a four-cornered balanced stiffened lugsail. The sail

4) Ibid., p. 419.

5) Liang, Menglong, *New Investigation of Sea Transport*, 1579.

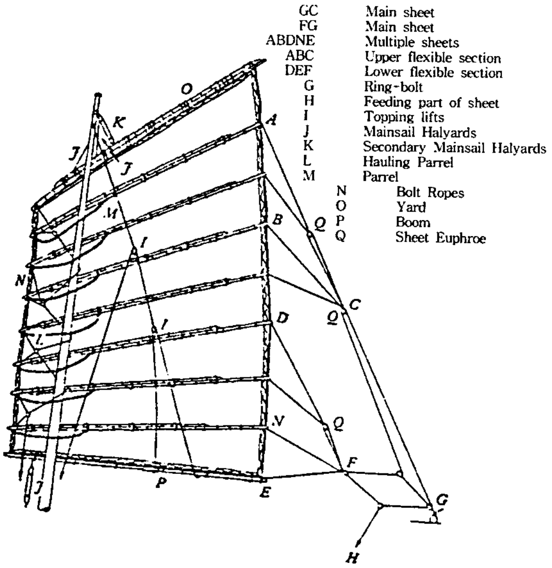


Fig. 5 Chinese Mat-and-Batten Longitudinal Sail

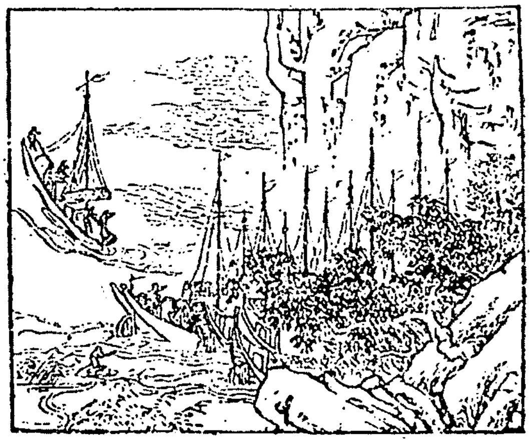


Fig. 6 Chinese Batten Sail in the Zheng Qian's(鄭虔) Picture

area forward of the mast (the balancing portion) was about 1/6 to 1/3 of the total sail area. It had a system of complicated sheets of bights, leads and pulleys, with which the sail was capable to rotate around a vertical mast axis freely and handy to control, thus named as longitudinal sail. The most outstanding characteristic is the batten that is attached on the mat. Such Fore-and-aft battened sail could meet the wind better. An example is shown in the picture drawn by Zheng Qian (鄭虔)of Tang period (Fig.6). It is estimated that such sails were used long before his time.[6)]

There are five unique features of the Chinese mat-and-batten sails.

1. Many battens are used to keep the sail flat vertically. The more the battens, the flatter the sail. This kind of sail design enables the ship gain the greatest propulsive force when sailing against the wind.
2. When meeting a squall and furling the sail, it falls neatly down by gravity to the lowest batten without jamming by controlling the halyard lift meeting a squall. It saves much manual labour as compared with Western type of sails which in case of flap, as mentioned by Audemard, "One has to send sailors aloft to take the reefs, always a dangerous operation in bad weather".
3. With the battens as stiffeners, the cloth, canvas or even mats may be used as material of sails, which is not as strong as that of the Western type of sails. The reason is that the stresses are well distributed by the system of bights, leads and pulleys and battens.
4. Battens may be used as ladder steps or ratlings for sailors to climb from deck up to the top of mast and to access to any part of the sail. The merit of such arrangement can only be appreciated if one has ever climbed up a triangular topsail of the Arab

6) Xin, Yuanou & Yuan Suishan, 'The Blue Ribon Holder in the Medieval Age-Chinese Junks', Proceedings of International Sailing Ships History Conference Held in December 4-8th, CMHRA, 1991, p. 69.

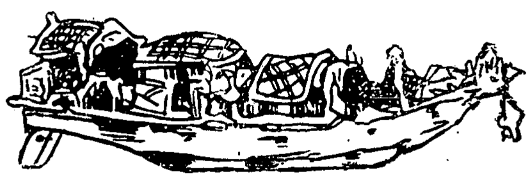


Fig. 7 East Han(AD25-220) Pottery Ship Model with Rudder Unearthed in Guangzhou

invention.

5. Even if there are many holes in the sail's cloth, the sail will be still operable. Whereas a sail without batten, it has to be renewed once being torn. As a matter of fact, the junks on the Huangpu River(黃浦江) often had only one quarter cloth, one quarter holes and the other half being patched with other materials. The sailors found that holed sail seemed easier for handy operation, because it might adjust itself in a gentle breeze. The western type of sail could not adjust itself when the wind force is rather weak until the combined sail was invented.[7]

2.4 The Fourth Mystery: Invention of Rudder in China

Rudder is a device used for steering and maneuvering a vessel. Judged from unearthed relics (Fig.7), earliest rudder appeared in East Han period (25-220 AD), nearly 2000 years ago in China. Rudder is an indispensable device in modern ship, and it exhibits its longevity more than any other devices in the ship history. As mentioned above, the design philosophy of ancient Chinese shipwrights was to imitate

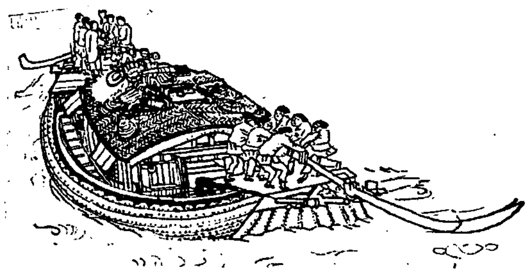


Fig. 8 Six Men Operating a Steering Sweep Picture in the "Qing Ming Shang He Tu"<清明上河圖> by Zhang Zeduan(張擇端) in North Song Dynasty

aquatic birds, and more attention was paid to the stern devices. One man controllable steering oar was eventually progressed to many men operated steering sweep (Fig.8). But in the Western ships, two steering oars were used, one at port and one at starboard side respectively. It was found that steering the stern oar was a tiresome job, and the efficiency was low because of the oar being inclined to the water surface. Only if the oar were perpendicular to the water surface the steering efficiency would be improved. The ship's watertight bulkheads provided proper condition to install vertical axial plate rudder, which may connect with the watertight bulkhead, so that the rudder stock may pierce through the ship bottom and unnecessary to be installed at the aftmost stern end. It was very difficult to install axial rudder matching the curvature of stern post for the Western shipwrights. But it was solved easily by the Chinese shipwrights using the method of piercing the ship bottom and the bulkhead construction. In Europe, the real practical adoption of axial rudder appeared in Hanse(1242 AD), which is found in "Cog" type

7) Worcester, G.R.G., 'The Junks and Sampans of Yangtze', *Order of the Inspector General of Customs*, Vol. 1, Shanghai China, 1947, p. 77.

of ship with straight stern.

The rudder in China developed from unbalanced rudder in Han period (206BC-220AD) to balanced rudder in Song period (960AD-1127AD), and to rudder with many holes in Ming period (1368-1644AD). In Europe, the balanced rudder emerged as a new type by the end of 18th century, and the multi-holed rudder did not appear until the era of steel ships. Based upon modern mechanics and hydrodynamics, both the balanced rudder and the multi-holed rudder are effective measure in reducing the turning torque of rudder. However, the ancient Chinese shipwrights adopted such principle and put into practice in 10-12 century. In the Tang and Song period, there were tackle-controlled that may be lift up when the ship sails into shallow water to avoid grounding.[8] From the above description, it may be seen that rudder is a remarkable invention by Chinese shipwrights in the history of shipbuilding.

2.5 The Fifth Mystery: Multi-masts and Sails Arrangement for Concentrating the Wind Force

The Chinese had used the multi-masts and sails for concentrating the wind force for a long time. In the Three Kingdom period (220-280AD), Wu Kingdom(孫吳) was famous in shipbuilding and navigation. Sun Quan(孫權) not only established a strong navy, but also sent officials to South East Asian countries for developing trade. The officials noticed that many ships in South East Asia had four masts and sails. Wan Zhen(萬震) described the multi-masts and sails technique in his book, 'Strange Things of the South'(南州異物志). He wrote, "The people beyond the boundary sometimes rigged their ships with four sails each along centerline from bow to stern. The four sails did not face directly forward, but were set obliquely to concentrate the wind force from one sail to another. Should gust be violent, the sailors reefed the sail. Because the oblique sails received from one another the breath of the wind, the ship could make good speed by using of wind pressure even encountering strong winds and dashing waves. " .

The watertight bulkhead construction of ancient Chinese ships provides convenience in the erection of mast shoes along fore-and-aft direction at any transverse position port or starboard, enables the sails set and controlled so as to concentrate the wind force without mutual interference. Learned from South East Asian people, the Chinese developed multi-masts and sails utilizing the traditional bulkhead construction. Henceforth, the majority of large sea going sailing ships were equipped four masts.

When Marco Polo was in charge of convoying the princess KuoKuo(闊闊公主) to Persia in 1292 AD for her wedding, Great khan(忽必烈) sent a fleet of 14 great four-masted sailing ships.[9]

The grand Zheng He's fleet consisted of various kind of ships, i.e. three-masted up to nine-masted ships(Fig.9). At that time, the largest European sailing ship had no more than three masts. Even up to the present, fishing boats named "Seven-fans" with seven masts may be seen in Tai-Lake and five-masted Sha-boat in the Chang-Jiang (Yangtse River). Quite a number of foreign maritime historians came to the Tai-Lake to see the diminishing

8) Xin, Yuanou, 'Notes on the Development of Manually-Operated Implements for Propulsion and Management of Ancient Chinese Crafts' (in Chinese), Marine History Research, CMHRA, No. 1, 1985, p. 54-6.

9) Xin, Yuanou & Yuan, Suishan, *op. cit.*, p.70.

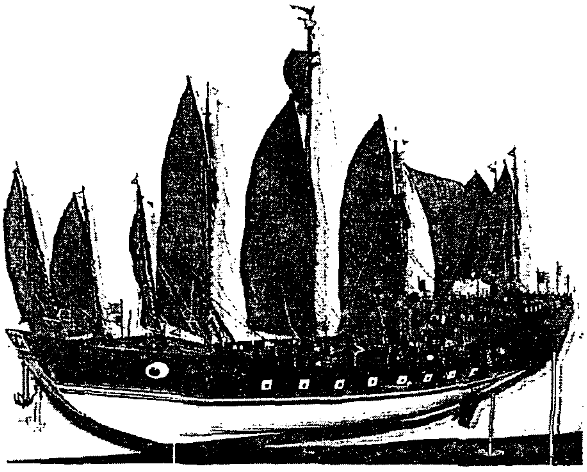


Fig. 9 Zheng He's Treasure Ship with Nine-masts and Twelve-Sails(Model)

Chinese ancient boats and investigating their wooden structures.

2.6 The Sixth Mystery: The Forerunner of Paddle Wheelers-Manual Paddlers or Che Chuan(車船)

As a transition from simple manual propulsion to manual paddlers, Che Chuan, which appeared in Tang and Song period (618-1127 AD), had partially submerged wheel-blades on both port and starboard side, connected with foot actuated crank-shaft. It is a significant progress to change from hand sculling to foot pedaling.

In the early period of South-Song(1127-1279AD), such type of Che Chuan was usually employed as naval ships for its higher speed and shallower draft. The Tai-Lake revolutionary leaders Yang Yao(楊么) used a large Che Chuan with 22 wheel-paddles (11 on each side), some with 24 and even more than 28(Fig.10). They successfully stroke against the government navy in Tai-Lake.[10] The government navy captured

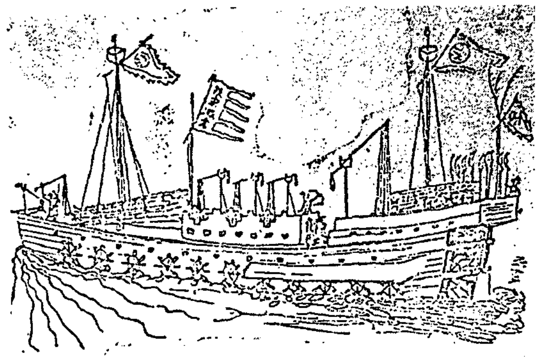


Fig. 10 The Style of Yang Yao(楊么) Che Chuan (車船)

Gao Xuan(高宣), the ship designer of the revolutionary army to confront Yang Yao's army. The famous government commander Yue Fei(岳飛) ordered his navy to pretend being defeated so as to allure Yang Yao's Che Chuan to very shallow water zone full of weeds. Because the wheel-paddles of Che Chuans were entangled by weeds and could not move, Yue Fei won the battle and smashed the Tai-Lake revolutionary forces. (Fig.10)

Since that time is long before the industrial revolution, there was no mechanical power to replace tiresome foot paddling. The wheel-paddle boats had seldom been built and at last died away during the following seven hundred years. Until the Industrial Revolution started with Watt's invention of steam engine, based upon the wheel-paddle principle, in 1807, American Fulton invented paddled steamer. The arrangement of facilitating wheel-paddle at both sides of ship were the same as Che Chuan, and the difference was that the paddle was much larger and was driven by steam engine. During the 1840 Opium war, some of the Chinese officials built similar

10) Tang, Zhiba, *History of Chinese Naval Crafts*, Naval Press, Beijing China, 1989, pp. 89-90.

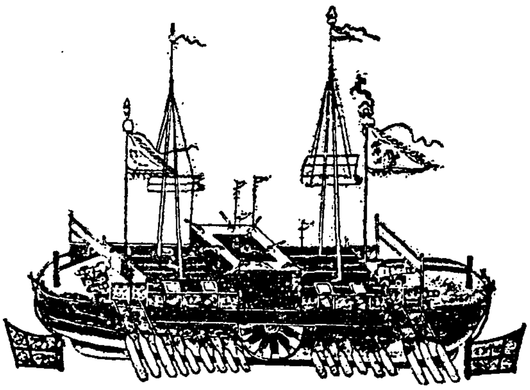


Fig. 11 The Che Chuan Made in Guangzhou by Wu Zhangqing(吳長慶) in 1840

ships, but because of lack of steam engine, they had to be foot-actuated (Fig.11).[11] Che Chuan and paddled ship may be considered as one step higher than oared boat, since it appeared seven hundred years before Fulton's paddle steamer, and the design philosophy will be acknowledged as pioneer no matter whether Fulton had been inspired by Chinese Che Chuan or not.

2.7 The Seventh Mystery: The Ancestor of Screw Propeller- Lu(櫓)

As it is known that the most original propulsive device is oar, started from short oar using both hands, then long oar with fork at shipside to support its weight and to serve as a lever fulcrum, thereby less human effort is needed. Both the short and long oar have a common draw back, i.e., the oar does virtual work when out of water. The oar man feels more force is required at the instant when the oar is entering into and departing from water surface. If the oar

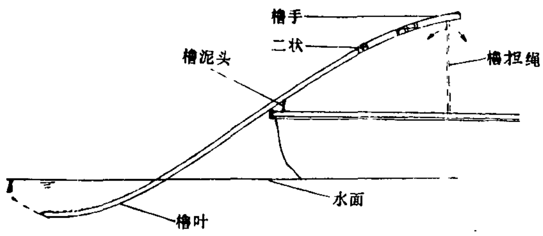


Fig. 12 Yulou System Brief Chart

is always immersed and sculling, then the efficiency will be increased significantly, consequently the intensity of manual labour will be decreased. However, in order to achieve such state, the blade angle of the immersed part should be ever changing while the oar is swinging transversely with a reciprocating motion.

The ancient Chinese shipwrights invented the "Lu" systems in West-Han period (206BC-8AD), as shown in Fig.12. "Lu" is a curved long oar with an inverted cup block attached under its middle point, rested on a thole-pin fitted at the stern. The cup-and-pin serves as a fulcrum with an universal joint. Its handle is attached with a length of heavy rope on a fixed ring at deck. By pulling and pushing the handle to and from, the immersed portion of "Lu" is moving in a reciprocating motion with varying angle of incidence to water through the action of human waist. At the end of each stroke, the rope exerts a jerk to change the direction of motion. A self-feathering effect is thus achieved to minimize water-drag to "Lu" . Since less manual efforts are used to operate "Lu" for ship propulsion, there is a saying "One Lu, equivalent to three oars" . Lu serves not only as

11) Ling, Qingyuan, 'An Introduction of Western Naval Construction Technology into China just before and after the First Opium War' (in Chinese), *Marine History Research*, CMHRA, No. 4-5, pp.38-9.

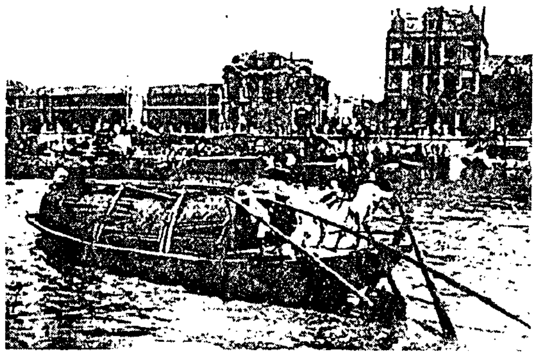


Fig. 13 Yulou by Shipmen Prospect

a propulsive device, but also as a steering device. When the frequency of swing (push and pull) is even, the ship will go ahead straightly, and when the frequency is not even and the angle of incidence of the "Lu" is increased only at one side, the ship will then change the direction(Fig.13). Such a unification of propulsion and steering functions is superb not only in the ancient ships but also in modern ships with fixed-pitch-propeller and ordinary shaft. As early as 15 BC., in the 'Fang Yen'('方言') written by Yang Xiung(楊雄) the terminology of "Lu" and its accessories were listed, a fact which shows that the appearance of "Lu" was long before Christ.[12)]

Though the Western multi-oar ships appeared much earlier than those of China, and the Greek galleys having three tiers of oars operated by more than hundred labour forces which looked grand in appearance, the invention of "Lu" was in the ancient China. It was not until 18th century, the naval constructors in the British navy found the miracles of "Lu", and inspired designers to search for a device that may continuously work in water and keep immersed, eventually invented screw propeller. Compared with paddle wheel and oar, the underlying principle of screw propeller marked a leap in shipbuilding technology. It is remarkable that the Chinese shipwright already knew such mystery about 2000 years ago.

2.8 The Eighth Mystery: Original Creation of Sail Against Wind by Tacking

In the history of sail navigation, the Chinese technique of tacking to sail against wind has a unique position. In the Western World, the use of sail was more than thousand years earlier than in China, however, the type of sail used was square sail which proved to be very effective only in following wind, no efficiency when the ship was meeting cross wind. When the Arabian invented jib-headed sail transferred to Europe, Western sailing ships were capable to sail in cross wind after 8th century, but the ability to sail against wind was poor until 15th century. The reason is that to sail against wind, the action of fore-and-aft sail by turning around a vertical mast is not enough, coordinate rudder steering is also necessary, and the introduction of axial plate-rudder in Europe was 1,000 years later than that in China.

Coordinated rudder and sail operation enables the sailing ship run against wind. From Fig.14, one may see that the sail angle swings port and starboard by slackening or tautening the sheets, as well as the rudder angle changes simultaneously, and the ship proceeds in a zigzag pattern to the wind. Such operation is called "tacking". If there is no rudder action, the sailing ship cannot really proceed against the wind. In order to

12) Xin, Yuanou, *op. cit.*, pp. 52-3.

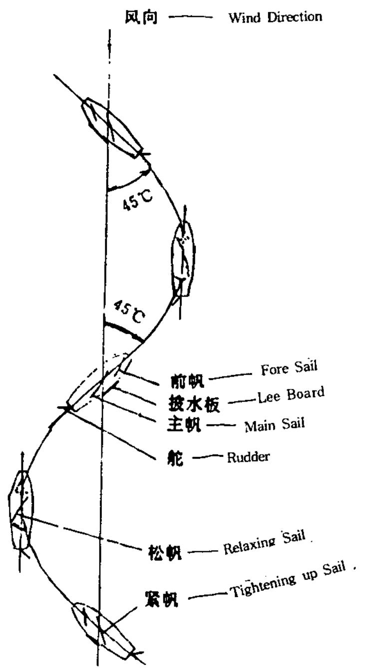


Fig. 14 Tacking Changing against Wind Coordinated Operation of Rudder, Sail and Leeboard

reduce the amount of sideway during tacking, leeboard at one side of ship should be lowered into water, while the leeboard at the other side being lifted up out of water. Such coordinated operation of rudder, sail and leeboards enables the sailing ship to tack handily or even nimbly at high speed going forward. The mystery of sailing against wind handily is thus revealed, and the coordinated leeboard operation might be seen as special feature of Chinese tacking technology.[13)]

Conclusion

This paper endeavors to make a first step in digging out of treasures that Chinese ancestors contributed to shipbuilding technology. Through comparing the Chinese ancient ships with the western's, the items revealed in the eight mysteries of Chinese ancient ships approved the Chinese outstanding shipbuilding technology which was applied to the western shipbuilding after some one thousand years. The author expects this paper will be a touchstone for changing the viewpoint of the shipbuilding history lead by the western civilization.

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13) Xin, Yuanou & Yuan, Suishan, *op. cit.*, pp. 71-2.

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