Dragon-bone Water Lifts in the East of China (Jiangnan) and Their Tribological Aspects

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1. Introduction

The author lived first in the northeastern region and later in the middle part of China on business and sometimes visited river and lake districts around Changjiang (Yangtze) River and the east of China (hereinafter referred to as "Jiangnan", the south of Yangtze River) on holidays. Information that there would exist dragon-bone water lifts in the southern part of Yangtze River or Jiangnan was brought to the author when he had been interested little by little in this districts. This motivated the author to investigate on the subject.

Jiangnan is the richest farming area in China and various developments there may have led the way for state-of-the-art technology in agriculture particularly rice crop. The author's investigation started with the question, "What is a dragon-bone water lift?" because nothing was known at the beginning. Through the investigation, it was found that since 500-1800 years ago, a systematized technology of agricultural machines was already developed based on the dragon-bone water lifts, which utilizes human power, cattle power and natural energy (water/wind wheels). This report presents a part of these mechanisms together with the supporting tribological and elemental technology.

2. Search of Dragon-bone Water Lifts

Based on the information that there could be an explanation on the dragon-bone water lifts in some historical documents of agricultural machine technology, the author visited Wuxi City Museum and was introduced there to Mr. Feng Puren, a researcher at Wuxi Wu Culture Institute. By his indication that there could be a clue in Wu Culture Park, the author went to the park.

Also the author was introduced to Mr. Jin Xu of Association of Folklore Studies of Jiangsu Province and Association of Folklore Studies of Suzhou. Mr. Jin has been writing the report, "History of Traditional Agriculture of Wu District" and was kind enough to give the manuscript before its publication[1]. Further, Mr. Jin introduced the author to his friend Mr. Lu Zhiming, a painter. The ancestors of Mr. Lu had been making dragon-bone water lifts, but no lift remains now in the region. They have been replaced by electric pumps. Mr. Lu was grieving to see the agricultural technology of ancient China once well-advanced in the world now vanishing. He was enthusiastic to draw a picture of dragon-bone water lifts that his ancestors had made and he himself was observing. He was kind enough to give the pictures he drew to the author[2].

The passion of these people and kind permission to use those references received motivated the author to write this article.

3. Construction of Dragon-bone Water Lifts

One of the dragon-bone water lifts (water wheel) exhibited at Wu Culture Park is shown in **Fig. 1** while details are shown in **Figs. 2** and **3**[3]. This water wheel is manually operated and is supposed to be used for pumping from river where the difference in water level is relatively small.

Fig. 1 A whole picture of dragon-bone water lift[3]

Fig. 2 Drive and gear section[3]

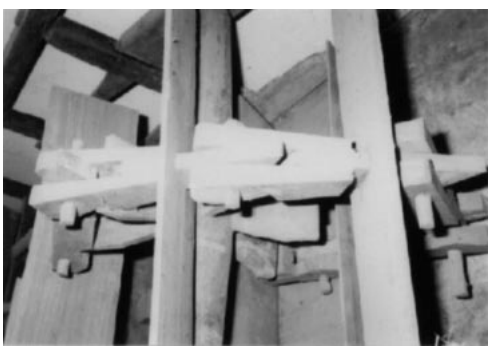

Fig. 3 Lian Tou and Dou Ban[3]

A dragon-bone water lift consists of a framework of a body (called Hu Dou in Chinese), keels (paddles made of pieces of wooden board) and "Bo" (Chinese word meaning gear section). The part to connect keels is called "Lian Tou" and carpenters who make these parts are called "He Xi" in Chinese. A piece of wooden board is attached to each one of Lian Tou, which is called "Dou Ban". These are the same as present-day chains and these movements resemble that of vertebra movement of dragons, which pump up river water to paddy field.

Figure 4 shows the whole drawing of dragon-bone water lift and "Bo" (the gear section) received from the painter Mr. Lu Zhiming[2]. The driving gear is called Bo in Chinese which means to splash or move. The wooden gear moves the Lian Tou (the connecting parts of keel) and Bo attached to dragon-bone water lift draws water and is thus called Shui Bo. The Bo placed at river side is called Xiao Shui Bo (small water gear) to which six teeth are attached. The bearing sections on both sides of those six teeth are called Nu Mi Jian. The Bo attached to the upper side, the paddy field side, is called Da Shui Bo (large water gear). Eighteen teeth are attached to the raceway shaft. There is no detailed description on bearing lubrication but water itself was supposed to be a lubricant.

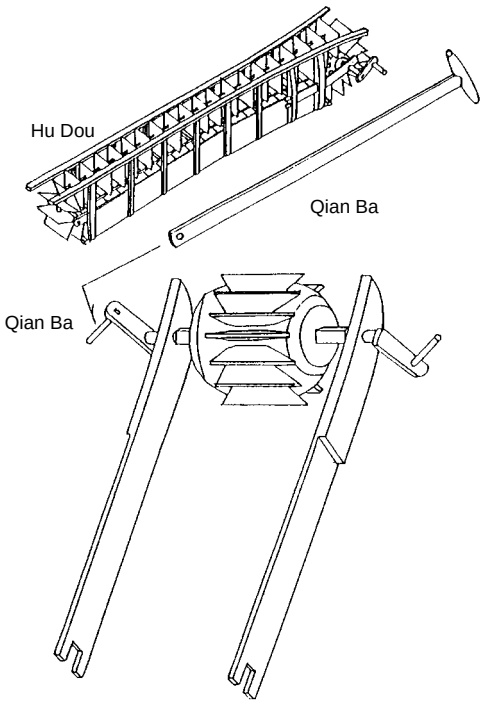

Fig. 4 Drawings of dragon-bone water lift[2]

Dragon-bone water lifts are made of wood and their technical level is high. For example, Bo (wooden gear) was a root of a machined gear, which was hand made by cutting each tooth one by one equally around the log. Shui Bo (water gear) was fan-shaped and very thin. There were supposedly various shapes and sizes depending on each load condition. Furthermore, the one attached to the horizontal shaft of cattle lifts or wind lifts was called Han Bo (dry gear). The tooth was rectangular and thick to support high load.

Technical requirements for Bo (gear) are said to be solidity, stability, low friction, low noise and wear resistance.

4. From Human Power to the Use of Cattle and Wind Power

4. 1 Manual Operated, Pedal Operated

According to Huang Zhen Nong Shu (Book on Agriculture by Wang Zhen) published in 1313 in China, Fan Che (water wheel) is described as a dragon-bone water lift. The water wheel having history of more than 1700 years is reportedly introduced to Japan in Tang era (618-907 A.D.). It is thought the wind wheel was, at first, manually operated as shown in **Fig. 5**, "Ba Che"[4]. Furthermore, when the difference in pumping water-level became larger, a pedal type as shown in **Fig. 6** must have been invented.

Fig. 5 Ba Che (hand-rocked lift)[4]

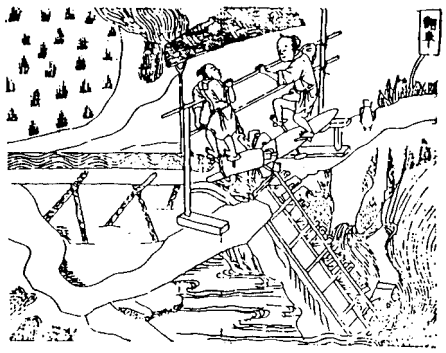

Fig. 6 Pedal lift[4]

4. 2 Cattle Power Type

As an example of cow-powered lift using cattle power, the pumping structure of actual dragon-bone water lift was exhibited at Wuxi Wu Culture Institute. On the other hand, **Fig. 7** shows a cow-powered lift included in Tian Gong Kai Wu[4] (Encyclopedia of Science and Technology). It is noted that the length of a dragon-bone water lift is longer compared to the hand-rocked one. It is thought to be a development in response to longer water-level difference for pumping.

A sample of this actual mechanism is shown in **Fig. 8** and its shaft end and bearing section are shown in **Fig. 9**. Supporting section of bearings is not round but oval. The shape of oval is formed toward the direction of the reaction force by engagement of wooden gears.

As for the pivot bearing section, the end edge of the core supports the whole load to the major diameter gear and aligns the whole drive core to the center. **Figure 10** shows the pivot bearing[3].

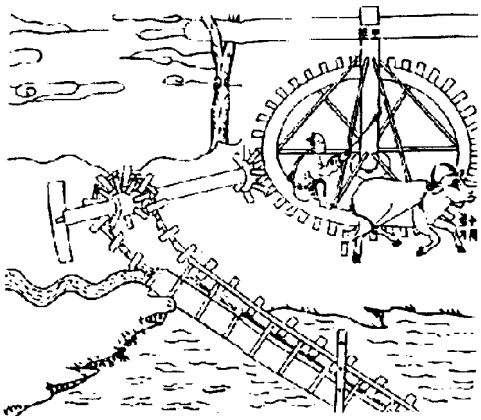

Fig. 7 Cow-powered lift[4]

Fig. 8 A picture of whole mechanism[3]

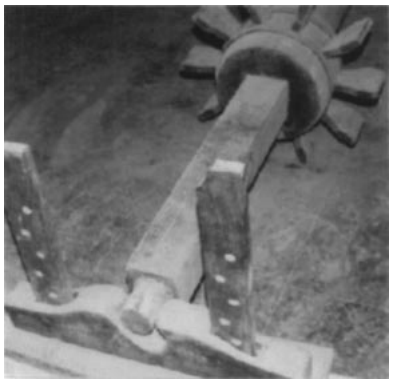

Fig. 9 Shaft end and bearing section[3]

Fig. 10 Pivot bearing section[3]

4. 3 Wind Powered Type

What impressed the author most during this investigation was the encounter with wind wheels (wind-powered dragon-bone water lift) (**Fig. 11**). These are figures of the horizontal shaft wind wheel and dragon-bone water lift[2] drawn by Mr. Lu Zhiming himself which were presented to the author. Power originates from horizontal wind collected at the six pieces of canvas wings. Power conveyed through mechanical section drives the dragon-bone water lift to pump up water. Comparison between the length of the dragon-bone water lift in **Fig. 11** and that of hand-rocked or pedal wind wheel shows that the length of the former is longer.

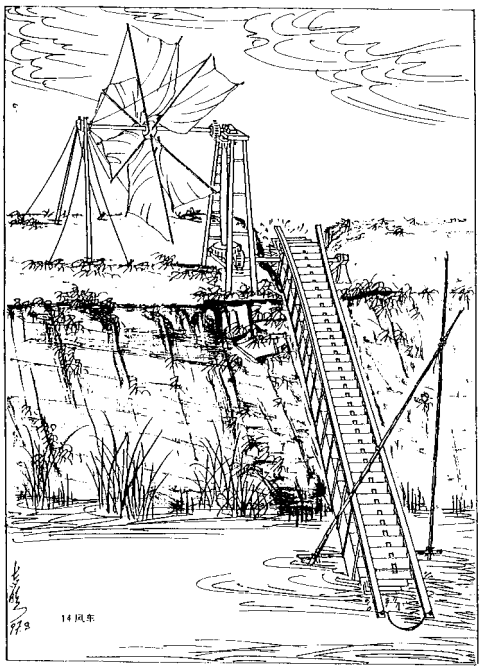

Fig. 11 Horizontal axis wind wheel and dragon-bone water lift[2]

This water lift was supposed to be invented from technical requirements as a result of more and more larger difference in height between paddy field level and water intake level, and perhaps from wind characteristics of Changjiang River and Lake Tai Hu, where ancestor's wisdom was gained through sails of sailboats floating in the Lake Tai Hu.

5. Acknowledgement

Many people assisted the author during this investigation. Special thanks to Mr. Wang Jianming, well known in Wuxi, who assisted the author, Mr. Yu Wei and Ms. Bai Yongxia who were such a great help for the author with poor Chinese language, Mr. Feng Puren of Wuxi City Museum, and Mr. Jin Xu, Vice Chairman of Association of Folklore Studies of Jiangsu Province and Chairman of Association of Folklore Studies of Suzhou who gave the author the unfinished/ unpublished manuscript of "History of Traditional Agriculture in Wu District".

Mr. Jin introduced the author to the painter Mr. Lu Zhiming. Mr. Lu who was well acquainted with the dragon-bone water lifts and was eager to convey them to the next generation as his ancestors by making them. He was kind enough to give figures of wind wheels and dragon-bone water lifts connected which were nearly precise designs for re-production purpose. Mr. Song Taotao helped the author to get the Chinese language edition of Tian Gong Kai Wu.

It was based on the warmful support and kindness of so many Chinese friends that made it possible for the author to complete this report. Wishing to express the sincerest appreciation.

References

1) Jin Xu: History of Traditional Agriculture of Wu District (1999)
2) Figures by Lu Zhiming
3) Collection exhibits in Wuxi Wu Culture Institute and Wu Culture Park
4) Song Yingxing: Tian Gong Kai Wu (Encyclopedia of Science and Technology), Min era (1637)
5) Nippon Tribology Gakkai, Kikai Gigyutu Shintenshi Kenkyuukai: Jiangnan Gigyutushi Chousa Kouryuu Kikou (2002)

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