

# Analysis of the Reasons Why the Ancient Chinese Water-propelled Large Spinning Wheel Could Not Give Birth to the “Chinese-style Industrial Revolution”

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## Abstract

China had already invented the water-propelled large spinning wheel as early as the Yuan Dynasty, but it is not until 16th century that Arkwright had invented water-propelled spinning frame in the United Kingdom. The difference between the two is that Chinese water-propelled large spinning wheel is more than 300 years ahead of Britain's invention, but Chinese water-propelled large spinning wheel didn't trigger an industrial revolution like Britain. Through inspection of Chinese water rights system and cotton yarn production system, this article believed that among the factors that influenced the development of the water-propelled large wheel in ancient Chinese society, not only the technical factors played an important role, but also the water rights system for heavy shipping, irrigation and the cotton yarn production system based on rural sideline industries seriously obstructed the use of the water-propelled large wheel and emergence the industrial revolution in China.

**Keywords:** the water-propelled large spinning wheels, Arkwright's spinning frame, cotton, Industrial Revolution, the Yuan Dynasty

As early as the Yuan Dynasty, China had invented the water-propelled large spinning wheel, which was widely used in the spinning of silk and bast fiber. In Europe, the Arkwright's water-propelled spinning frame didn't appear in Britain until 1769. These two types of water-propelled spinning machines had many similarities in shape, but had different destinies. The water-propelled large spinning wheel was drowned in the birth of hand-cranked cotton spinning wheel when the cottage cotton manufacturing became popular, and did not transform into water-propelled cotton spinning machine. However, the Arkwright's water-propelled spinning frame spread to the whole of Britain at a rapid rate, creating a factory production system and detonating the industrial revolution. We believes that the water-propelled large spinning wheel in Yuan Dynasty of China could not ignite the industrial revolution. Although spinning technology factors were important, the obstacles to the development of the water-propelled large spinning wheel in social systems seemed to be more important.

## 1. Structure and Principle of the Ancient Chinese Water-propelled Large Spinning Wheel and Arkwright's Water-propelled Spinning Frame

There were many similarities in the structure between the water-propelled large spinning wheel and Arkwright's spinning frame. They both used water to drive the rotation of the spindle and draw and twist the fibers. However, it was real different in the structure of the spindle and the winding of the yarn.

### 1.1 The Water-propelled Large Spinning Wheel Based on the Structure Restoration of the Large Spinning Wheel

Some researchers had reconstructed the water-propelled large spinning wheel (Figure 1), and the model is now preserved in National Museum of China. It can be known from Figure. 1 that the power of the water-propelled large spinning wheel is generated by the water current hitting the blades in the water wheel, and the water wheel drives the bearing to transmit the rotation force to the left guide wheel of the spinning wheel frame. The rotation of the left guide wheel is connected to the right guide wheel through a leather string, and the left and right guide wheels form a circular motion. The lower leather string is directly pressed on the spindles, and the spindles are driven by friction, so that the spindles are rotated. The upper leather string is driven by friction to rotate the

rotating drums (a pair of intersecting wooden wheels) on the iron shaft of the yarn frame, and then the yarn frame is rotated. The rotation of the yarn frame relies on the action of rotating drums and rope strings. Therefore, the direction of rotation of the yarn frame and the rotating drum pressed in the upper bearing is opposite. Obviously, the power transmission device in the recovery picture is consistent with the description in Wang Zhen's "Nongshu".

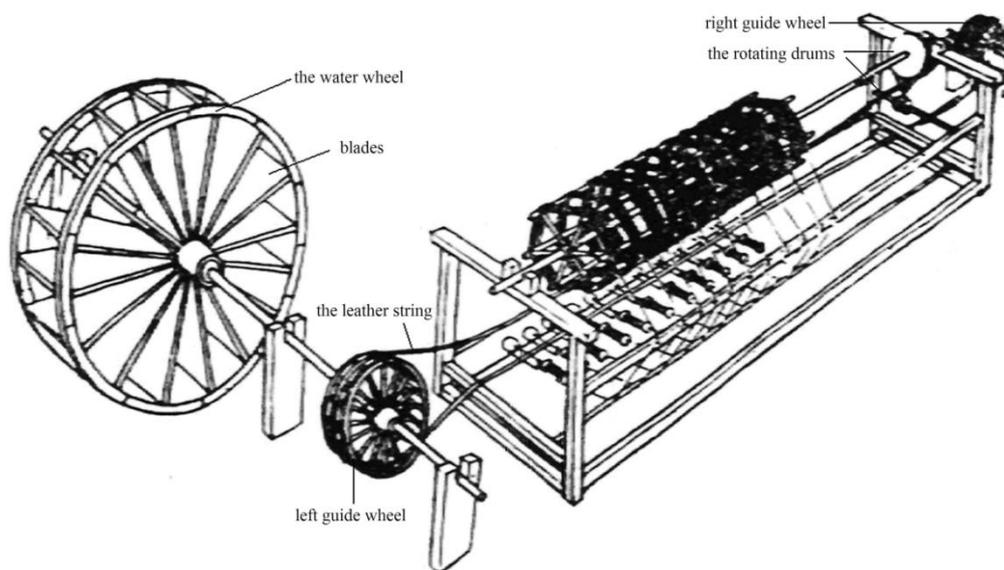


Figure 1. A reconstruction of the water-propelled large spinning wheel based on the data provided by Wang Zhen in his "Nong Shu"

### 1.2 Structure and Principle of the Arkwright's Spinning Frame

In order to figure out the Arkwright's water-propelled spinning frame, let's take a look at Spinning Jenny predated the Arkwright's water-propelled spinning frame. Spinning Jenny had been invented by the Englishman J. Hargreaves in 1764. The biggest feature of Spinning Jenny (Figure 2) is that 8 spindles stand upright on a wooden frame, and the fibers are fed through rollers. It can suitably spin for cotton, wool and hemp fibers. Later, Hargreaves continued to improve Spinning Jenny, increasing its spindles to 16, 30, and 100, which increased the spinning efficiency by dozens of times. The improved Spinning Jenny (Figure 3) is much more reasonable than the original prototype. Firstly, the power wheel is erected to make the spinning workers more convenient and labor-saving. Second, the roller device is designed more scientifically. Roller feeding of fiber strips is more convenient. Finally, the frame is modified to a rectangular shape to make it more stable. It can be seen that just by spinning the spindles upright and using roller, Western spinning technology could rapidly develop from a single spindle to a multi-spindle.



Figure 2. The Spinning Jenny

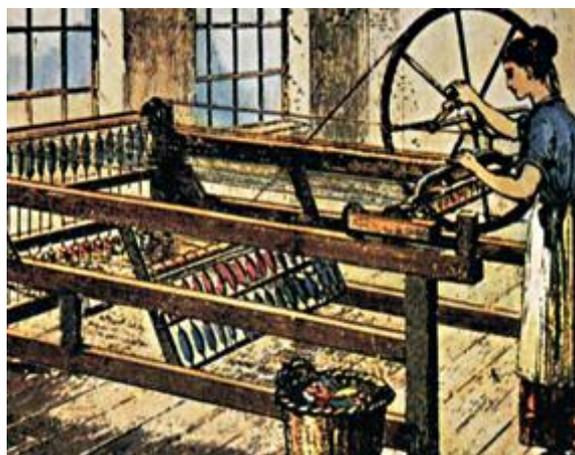


Figure 3. The improved Spinning Jenny

The Arkwright’s water-propelled spinning frame (Figure 4) and the Spinning Jenny both use the vertical spindle and roller to feed the fiber, but the structure of the spindle is very different. The spindle of the Arkwright’s water-propelled spinning frame uses a combination of flyer twisting and bobbin (Figure 5), so that twisting and winding can be performed continuously at the same time, increasing the spinning efficiency.

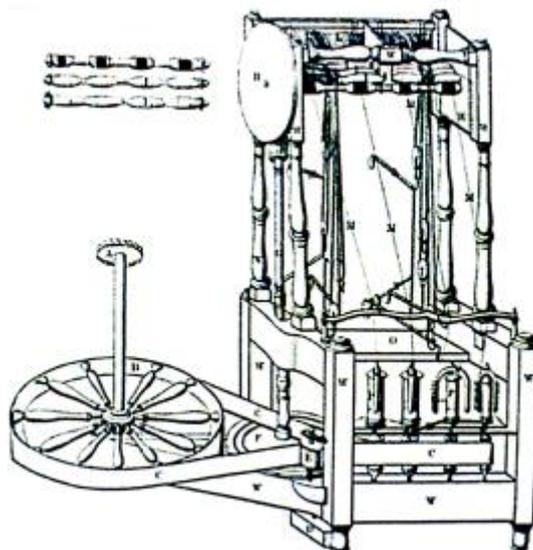


Figure 4. The Arkwright’s water-propelled spinning frame

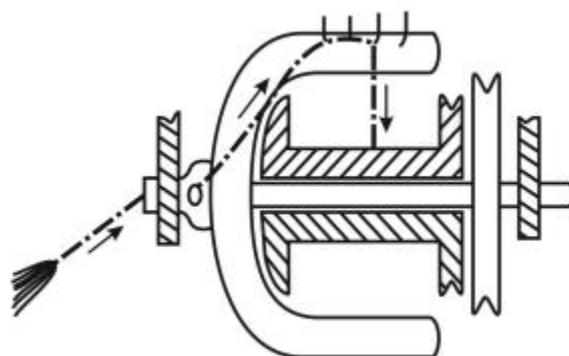


Figure 5. The construction of Saxony spinning wheel

By comparing the structure and the principle of the water-propelled large spinning wheel and the Arkwright’s water-propelled spinning frame, it could be found that there were many similarities between their dynamic

structure. The rotation of the belt on the working machine was driven by the rotation of the water wheel. The tight contact of the spindle and the belt caused the spindle to rotate and produced a twisting action. There were two aspects of the difference: First, the spindles of the water-propelled large spinning wheel were lying horizontally, while the spindles of the Arkwright's water-propelled spinning frame were standing. Secondly, the way of feeding the fiber and the way of spinning yarn were different. The water-propelled large spinning wheel adopted the unwinding and twisting method. That meant the good hemp was wound on the spindle first, and the spindle was unwound and twisted on the long bobbin. The Arkwright's water-propelled spinning frame was a type of flyer roving frame, which used rollers to feed fibers, draw, twist on the rotor, and finally wined it on the bobbin.

## 2. Main Obstacles to the Development of the Water-propelled Large Spinning Wheel

The water-propelled large spinning wheel must be used in places with abundant water flows. Throughout the history, the use of water resources was nothing more than the three major categories of shipping, irrigation, and water power. Since the ruling class of ancient China took Confucianism and the examination content of the Imperial Examination System after the Sui and Tang Dynasties was mainly literature and history knowledge. Most intellectuals were indifferent to technical books. Therefore, it was difficult for us to find the application of the water-propelled large spinning wheel among the few ancient technical books that existed. For this reason, we could only indirectly explain the actual application level of the water-propelled large spinning wheel from datas of some ancient water right system.

### 2.1 *The Use Order of Water-propelled Machines Causes Destruction of Water-propelled Large Spinning Wheel*

The order of using water resources in ancient China always followed the order of shipping-irrigation-milling (hydraulic machines) since the Han Dynasty. This hierarchical order of water resources use had deep social reasons. First of all, ancient China followed the feudal concept of "All lands under heaven belong to the emperor, and all people live in land are subject to the emperor" and formed a unified thought. In this way, the rule of the emperor must be maintained in the formulation of water resources use. Shipping was preceded over irrigation, mainly because major cities needed a lot of living materials, and only water transportation could maintain normal operation. At the same time, the ruling power of the emperor was mainly concentrated in major cities. Therefore, it was inevitable that shipping preceded over irrigation. That irrigation was preceded over milling because the vast majority of the population ruled by the emperor were farmers and the basis of rule. The insurgent forces that changed the dynasties in ancient China were all farmers. How to stabilize and comfort the farmers was also the focus of the emperors. Secondly, in ancient China, there is a rank order of "agriculture, commerce, industry". Emphasizing agriculture and suppressing business is almost a basic state policy of ancient China. The interests of privileged classes must be higher than those of farmers, and the interests of farmers are higher than those of businessmen. Therefore, the use of water resources must be allocated in this order.

This order of using water resources was, of course, not conducive to the development of the water-propelled large spinning wheel. The application fields of the water-propelled large spinning wheel belonged to the milling category. When all parties' interests of water using conflicted, the interests of those who used water to run machines were first sacrificed. Three large-scale destruction of mills occurred in the sixth year of Yonghui reign of Emperor Gaozong of Tang Dynasty (A.D. 655), the ninth year of Kaiyuan reign of Emperor Xuanzong of Tang Dynasty (A.D.721), and the second year of the Guangde reign Emperor Daizong of the Tang Dynasty (A.D.764). The reason is that the heavy use of watermill and water-powered roller seriously affected the water used in irrigation. In the Northern Song Dynasty (1078-1111), the dispute between the water-mill and tea, which essentially interweaves the contradiction between officials and businessmen, the contradiction between the water for irrigation and the water for motive force. As in "Records of Rivers and Canals" of "History of the Song Dynasty": "Suzhe(an official in the Song Dynasty) said: In recent years, many water mills were installed on rivers outside the capital, so the river course was shallow and blocked the official and private shipping. The water mills outside the east gate of the capital caused the flood. Fifty or one hundred square kilometers of farmlands were damaged, and the graves of the native ancestors were damaged a few times." The results were also conceivable that water mills and tea were both abolished.

### 2.2 *Restrictions on the Use of Machines Run by Water Cannot Lead to the Formation of Hydraulic Workshops*

China's feudal society not only stipulated the order in which water resources are used, but also imposed some restrictions on the scale and time of the application of water mills. According to the "Shuibushi" of the Tang Dynasty, "Water mills could be used from August the 30th to January the first in next year. For the rest of the time, the government sealed water mills under the sluice gate. But when the seals were relieved, they were first to use for the irrigation." It could be seen that water mills were allowed for use in only four months each year in

Tang Dynasty. During the Ming and Qing Dynasties, according to the “Tongli Canal Book” excerpted from “Water Conservation in Hongli County”: “Water mills in the villages had been abandoned for a long time due to the impermanence of the canal water. And it won’t be restored. Offenders would be investigated.” It could be seen that during the Ming and Qing Dynasties, it was forbidden to rebuild machines that run by water. In addition, the “Tongli Canal Book” also limited the time of the use of water mills. “The use of the water mills in each canal were personal interests. Water conservancy was related to the lives of people. It was planned to stop the water mills from the beginning of March to the end of September every year. And during November to February, it was leisure time for farming. As were shown in advance every year. Violators would be punished severely.” It was not difficult to see that the feudal ruling class’s restrictions on the use of hydraulic machinery and the use of time undoubtedly caused the fate that hydraulic manual workshops couldn’t be generated normally.

Through a brief analysis of the water right system in China, we could see that under this water right system, the application of various hydraulic machines was too restrictive. Because of this, since the Yuan Dynasty, there were no manual industrial area powered by hydraulic machinery was formed. Although, water run machines could be found in some areas. For example, Piao Zhiyuan (1737-1805), a famous scholar of the Li Dynasty of Korean, witnessed these machines while traveling in North China in 1780. He wrote in his memoirs: “When I passed Sanhe County, Hebei, I saw that the hydraulic power was used in all aspects. Blowering, reeling, and grinding for furnaces, everything was done by turning the water wheel with the impact of water.” However, a single type of hydraulic machinery did not form a certain scale and concentrated in a certain area, so it could be concluded that it was impossible to form a dynamic mechanism for technological competition and innovation, and under the severely restricted feudal water rights system, hydraulic machinery, which including water-propelled large spinning wheel, was bound to the end.

### **3. Analysis on the Reasons Why Water-propelled Cotton Spinning Machine Is Unable to Generate in Ancient China**

Since the Yuan Dynasty, cotton has gradually been widely planted in the Changjiang River Basin of China, especially when Huang Daopo (?-?), whose hometown is Wu Nijing of Shanghai, brought back cotton textile technology from the Li ethnic group in Hainan, and improved and innovated the cotton textile technology, which promoted the development of the cotton textile handicraft industry and hemp fabrics were gradually replaced by cotton fabrics for clothing. Cotton fabrics become the raw material of clothes for ordinary people. However, in the period of great development of the cotton textile industry, why the water-propelled large spinning wheel was not applied to cotton spinning. We believed that it was necessary to discuss on not only the cotton spinning technology but also the cotton textile production system.

#### *3.1 Difficulty of Technological Innovation Is an Important Factor*

As a staple fiber, cotton spinning can not be directly applied to the spinning wheel for hemp or silk, because the speed of the power wheel and spindle in the spinning wheel is relatively high for cotton spinning. If the spinning wheel is directly applied to cotton spinning, yarn breakage will often occur. But in the Yuan Dynasty, Huang Daopo solved the phenomenon of yarn breakage during spinning by reducing the diameter of the power wheel. The three-spindle cotton spinning wheel is a major reform of Huang Daopo’s application of hemp spinning technology to cotton spinning.

The existence of four-spindle and five-spindle cotton spinning wheels was controversial in the academic field. It was never heard that cotton spinning wheels with more than five spindles. As we all know, the world’s first multispindle spinning machine is the Spinning Jenny invented by the British weaver and carpenter Hargreaves (1721-1778) in 1764. So, in ancient China, was it possible to produce a large spinning wheel dedicated to spinning cotton with the spindle lying horizontally? Zhao Gang pointed out in his book “History of Chinese Cotton Textiles” that it is completely possible, “We can imagine the big spinning wheel for cotton spinning according to the big spinning wheel painted in Wang Zhen’s “Nongshu” for silk or hemp spinning. The big spinning wheel for cotton spinning was 20 feet long, two drawbars must be installed, each of which is operated by one person, and another one is needed to shaking the wheel. Therefore, the large spinning wheel is operated by three workers.”

However, we believed that it was technically difficult for the ancient Chinese to apply the large spinning wheel into a cotton spinning industry. According to Zhao Gang, the problem of drawing of cotton sliver could be solved, but there were some problems in cotton winding. Comparing the spinning process between cotton spinning and hemp spinning in ancient China, we would find that cotton spinning and hemp spinning were different in winding. When spinning cotton, a spinning woman pressed a cotton sliver on the spindle, swung the handlebar

with the right hand, and raised the left hand gently, the symmetrical cotton thread was drawn out, then the twisted thread was wound around the bobbin. For hemp spinning, hemp yarns were wound around the bobbin, and the yarn was twisted and drawn by the “unwinding and twisting method”, such as the five-spindle spinning wheel of the Yuan Dynasty (Figure 6). It is shown that the hemp yarn is not wound back onto the bobbin. Therefore, in ancient China, the water-propelled large spinning wheel could not achieve the winding of cotton yarns.

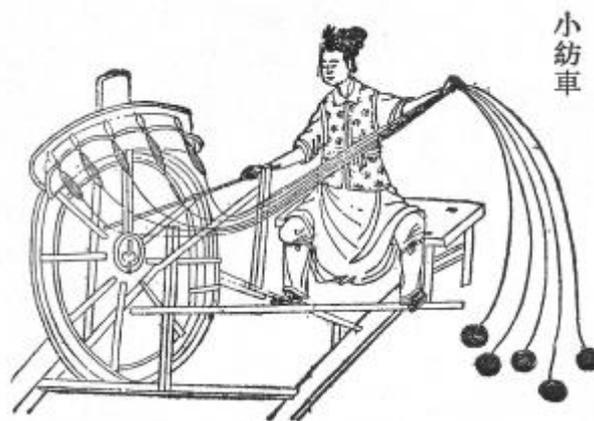


Figure 6. An illustration from “Nong Shu”, depicting the spinning wheel specially designed for twisting ramie strands

### 3.2 The Backwardness of the Cotton Textile Production System Is the Key Factor

As we all know, ancient Chinese countryside was a self-sufficient natural economy. When cotton was instead of hemp and used as the raw material for spinning and weaving, spinning and weaving were always existed as a sideline in rural areas. This kind of home-based production was for self-use or for simple household products, and the main labors in the home were still invested in agricultural production. As a sideline, cotton textiles strengthened the natural economy of self-sufficiency, and it was more difficult to spawn manual workshops for the production of silk fabrics. It was based on this system of manual production of households that cotton textile machinery had lost its motivation to evolve into a large spinning wheel. As a sideline industry, the cotton textile industry originally basically used the surplus labor in the family. There was no so-called opportunity cost, that was, the inherent requirements for commodities were not very high, and there was no lower limit on the cost of productivity. If the cotton spinning machinery developed in the direction of large spinning wheels, there must be workers who specialize in operating these machines, and the workshop would spend a lot of money to manufacture these machines and paid the workers basic wages. Under the family manual production system with no lower limit of labor costs at the time, the cost of such large-scale mechanical production was not lower than the cost of family production. Moreover, in the cotton-growing area, almost every household in the countryside was engaged in this kind of cotton textile production. It could be seen that the cotton fabric market of the locals was small. Therefore, the cotton textile industry could not appear as large-scale private workshops as the silk industry.

## 4. Conclusion

The water-propelled large spinning wheel and cotton revolution didn't ignite China's industrial revolution in Yuan Dynasty, and it had profound social system reasons. On the one hand, the limitation of the water rights system resulted in the inability of the water-propelled large spinning wheel to change to the workshop system. The lack of incentives for technological innovation has made it impossible for the water-propelled large spinning wheel applied to cotton spinning. On the other hand, the production of cotton yarn as a form of rural sideline had long existed in ancient China, resulting in no upper limit on the productivity cost of cotton yarn and no technological competition mechanism, which was unable to form a workshop system. The combination of these two reasons made it impossible for China to invent and create a cotton spinning machine like water-propelled large spinning wheel, which couldn't lead to China's industrial revolution.

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