

A high point in the development of ancient Chinese pattern looms: the multiple heddle pattern device

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Abstract

Based on the evidence of archaeological excavations, the multi-heddle loom appears to be the first pattern loom invented by humankind. Its core technology stores and controls the pattern on multiple heddles and can be called a 'multiple heddle pattern device' or 'multi-heddle patterning system'. In this article we explore multi-heddle looms from historical texts and ethnographic field investigations. First, we review the development of multi-heddle looms and put them in the context of the remarkable examples discovered in the Han Dynasty tomb at Laoguanshan. Finally, we summarize their historical status and significance. Within the historical of development of Chinese looms, the multi-heddle loom has a unique patterning device that integrates the advantages of several kinds of looms and is capable of producing many kinds of exquisite fabric. We conclude that the multiple heddle pattern loom was a necessary first step for the large scale production of patterned fabrics. Such looms established a technical foundation for the later technology of patterned silks that were traded along the Silk Road, as well as a gorgeous cultural heritage.

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Introduction

The loom is a great—arguably one of the greatest—inventions of mankind. Ancient Chinese looms can be divided into three categories: simple backstrap looms, efficient treadle looms and ingenious pattern looms. The pattern loom is the most complicated of these: it stores information on a pattern device, controls the pattern program during the weaving process and preserves it for repeated use.

The research on ancient pattern looms has a long history: according to scholars such as Joseph Needham¹ and Jean M. James² the pattern loom is the invention of Chinese people. In early studies of looms, due to lack of direct tangible evidence of actual looms, scholars have argued over the possible constructions of ancient

pattern looms. Most scholars believed that the earliest form was a multi-heddle and multi-treadle loom,^{3,4} but others have proposed fully-fledged drawlooms.^{5,6} The excavation of four pattern loom models in Laoguanshan Han tomb of Chengdu provided a direct answer to the forms of early ancient pattern looms.⁷ Although this loom has an unprecedented 'hook-and-shaft' design in terms of its mechanical transmission principle and heddle lifting method, the core principle of pattern weaving is the multi-heddle pattern device. This article attempts to generalize and classify multi-heddle pattern devices in various places, sort out their development context, analyze the core principles of multi-heddle looms, and summarize their status and function in the history of loom development.

Origins and categories of multiple heddle looms

A pattern loom permits richer and more complex shed openings when forming a pattern, in a reproducible manner. It can be realized by adding a set of pattern devices on the 'primitive' loom or treadle loom. Pattern devices can be divided into two types: multi-heddle types, in which each weft insertion is controlled by a separate heddle, and compound pattern leash designs in which sticks or cords placed in a single set of leashes controls the patterning. This article is concerned with the former type: the latter type is found amongst some Tai-Kadai speaking minority groups (Dong, Maonan, Dai) in southern China and also appears to have a long history.

Patterning first appeared in highly developed form on silk fabrics. Along the Silk Road, the development of looms can be summarized briefly as follows: firstly, the multi-heddle pattern device appeared in the East, secondly looms with pick-up patterning systems (producing design repeats in the weft direction) appeared in Central Asia and West Asia, and finally the fully-realized drawloom (with pattern leashes) appeared, perhaps as a combination of these inventions.

Multi-heddle frame looms are a development from the treadle loom. This loom uses a treadle to lift up or depress a heddle to control shedding, which frees up the hands of the weaver for weft insertion and greatly improves the efficiency of weaving. Since the original

treadle looms can only weave plain weaves or simple twills using the basic treadle mechanism, they rely on hand-picking when patterning is needed, which limits production efficiency and reproducibility. The multi-heddle loom was developed to overcome these limitations. Multi-heddle pattern looms fall into two main types, one uses a pattern-shed saving device lifted by hand, and the other is the multi-shaft loom controlled by treadles.

Hand-lifted multiple heddle pattern looms

This type of pattern loom is based on a 'primitive' loom. The multiple heddle pattern device is installed near to the warp beam. There are two main types: one is temporary pattern-shed saving device or temporary warp-rod system, which is just an auxiliary device to assist the patterning process that can only be used in one time; the other is permanent pattern-shed saving device or permanent heddle-rod system, that is a permanent patterning device interlaced with the warps.

Temporary warp-rod systems: Lahu loom in Yunnan and East Sumba loom

A temporary pattern-shed saving technique can be seen on the primitive loom still in use by the Lahu ethnic group in Yunnan Province and the weavers of East Sumba in Indonesia⁸ (fig. 1). The warp rods are placed directly into pattern shed openings in the warp. The warp-rod system is a temporary pattern-shed saving device: each rod must be removed after use so that the next one can be used.



Fig 1. (left) Lahu backstrap loom with warp-rod system in Menglian, Yunnan; (right) Backstrap loom with warp-rod system in East Sumba, Indonesia (photo courtesy of Serena Lee).



Fig 2. Li weaver using a backstrap loom with heddle-rod system, Hainan.

Permanent pattern-shed saving device (permanent heddle-rod system): the Hainan Li loom

The pattern rod commonly used on the Hainan Li nationality simple body-tensioned loom is made by bending bamboo rods (fig 2). The form is similar to a horizontal U-shape. The upper rod is used as a handle, and the lower rod is wound with a heddle. The warp yarns are threaded through the heddle loops. Since the heddle 'eye' is actually the upper opening of each loop and has a certain height, the warp can move freely up and down in each 4~5 cm heddle loop, so the heddle loops of the front and rear heddle rods do not affect each other. The heddle rods are interlaced with the warps indirectly by separate strings. Each heddle is thus independent from the others, so the weaver can use the heddle-rods repeatedly and in any order.



The Palembang songket loom

The city of Palembang, in Sumatra, Indonesia, is famous for the production of *songket*, supplementary weft weaving with gilded threads. *Songket* is woven on a backstrap loom with two string heddles for the plain weave ground and multiple pattern heddles. Elaborate patterns may require over a hundred heddles. The principle of the *songket* loom (fig. 3) is the same as that of the Hainan Li nationality loom. The pattern information is stored in a set of heddle rods. Most of the pattern heddle rods, grouped furthest away from the weaver, are not used directly. First, the weaver 'transfers' the sheds of the heddle rods onto temporary warp rods. These warp rods are then used to open the sheds for the weft insertions.



Fig 3. Songket loom of Palembang, Indonesia.





Fig 4. (left) Zhuang brocade loom from Jingxi in Guangxi Province; (right) Its multiple heddle pattern device.

Zhuang loom in Jingxi, Southwest China

This loom is characteristic of Zhuang weavers in Jingxi county in northwestern Guangxi Zhuang autonomous region. It is used to make distinctive bedcovers that are decorated with silk supplementary weft. The Zhuang are a Tai group, related to other Tai peoples in Southwest China and Southeast Asia, including the Dong (Kam), Maonan, Shui, Dai and Buyi in China. They use a variety of different frame looms for this purpose, many of which include complex patterning systems, as noted. In this loom both the warp beam and cloth beam are fixed in the frame. The ground-weave sheds are opened with a pair of treadles and heddles. Pattern weft insertions are stored on individual heddles on a rack above the warp, arranged in sequence and lifted by hand. The weaver selects each heddle and lifts it, inserting a bamboo tube into the warp to hold the shed open (fig. 4). The weaver lifts up the heddle rods one by one or as the pattern unit requires. The principle is similar to that of the looms described above.

Treadle-operated, multiple heddle pattern looms

These looms, as their name suggests, have pattern heddles that are raised by treadles, in other words they have true shafts. As with the hand-operated kind, there are several varieties.

Multiple heddles and treadles loom in Dehong, Yunnan, Southwest China

In ethnic minority areas such as Yunnan and Guizhou there is a type of multiple heddles and treadles loom, in which the heddles are lifted by treadles connected to a set of levers (figs. 5a and 5b). A cross beam is mounted at the back of the loom, at the top. Several pairs of levers pivot on the cross beam. Each pair of levers is connected to a heddle, and a heavy wooden rod is hung under each heddle, which returns the heddles to their original positions after they are lifted. There are six pairs of levers on the loom surveyed in the Manghe Village of Dehong, but only five of them were in use on the loom shown in figure 5, corresponding to five treadles.



Fig 5a. Multiple heddles and treadles loom in the Dehong region, Yunnan Province.



Fig 5b. Multiple heddles and treadles loom in the Dehong region, Yunnan Province.

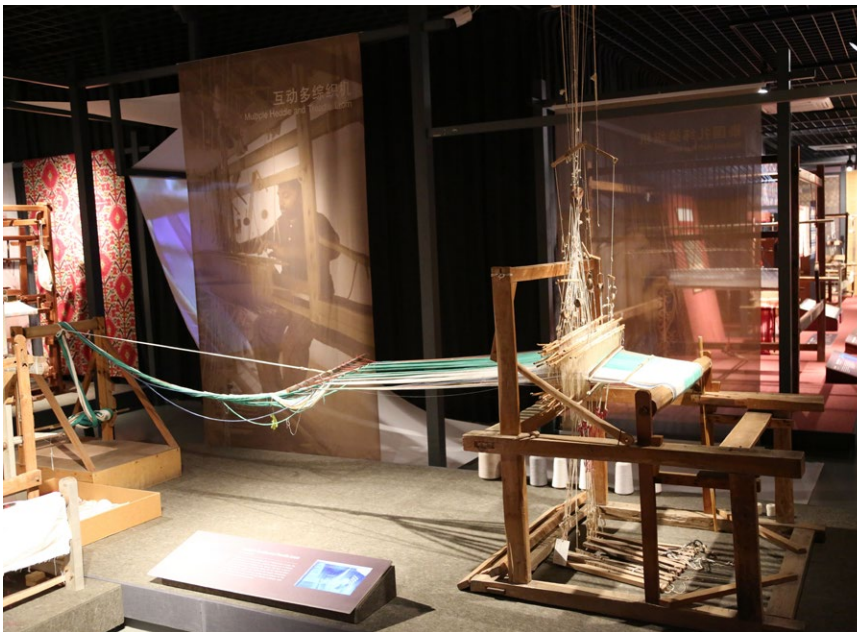


Fig 6. (left) Balanced multiple heddles and treadles loom of Bhujodi, Gujarat, India, on display at the China National Silk Museum, Hangzhou; (right) Weaver using the loom in Bhujodi.

Balanced multiple heddles and treadles loom in Gujarat, India

This loom is also known as the *Ghoda Shal* or 'Border Loom' in India⁹ (fig. 6). The loom in figure 6 is a special loom using 21 heddles and 11 treadles, from Bhujodi, Bhuj, in Gujarat. This loom is used to weave kachchhi mashru, a mixed-fiber textile with silk warp and cotton weft. Traditionally, mashru was woven for the Muslim communities. This *Ghoda Shal* is mainly used for making small repeating patterns on the middle section of the weave or on the side borders. In recent decades, many weavers have switched to using a dobby patterning device, so the use of this traditional method is declining.

Dingqiao multi-treadle loom, China

The *dingqiao* or 'stepping stone' loom is a multi-shaft and multi-treadle pattern loom. It gets its name from the small blocks on the treadles that look like stepping stones for crossing a river. It is used to weave ribbons in the villages near Chengdu, Sichuan Province, and it was formerly used to weave wider lengths of silk with short pattern repeats. The loom usually has 2–8 depression shafts for the ground weave and 40–60 lifting shafts for the pattern.¹⁰ Each shaft is controlled by a single treadle; therefore, the number of shafts equals the number of treadles. This type of pattern loom has a long history that goes back to the 3rd century, attested by historical documents from that period^{11,12} (figs. 7–10).

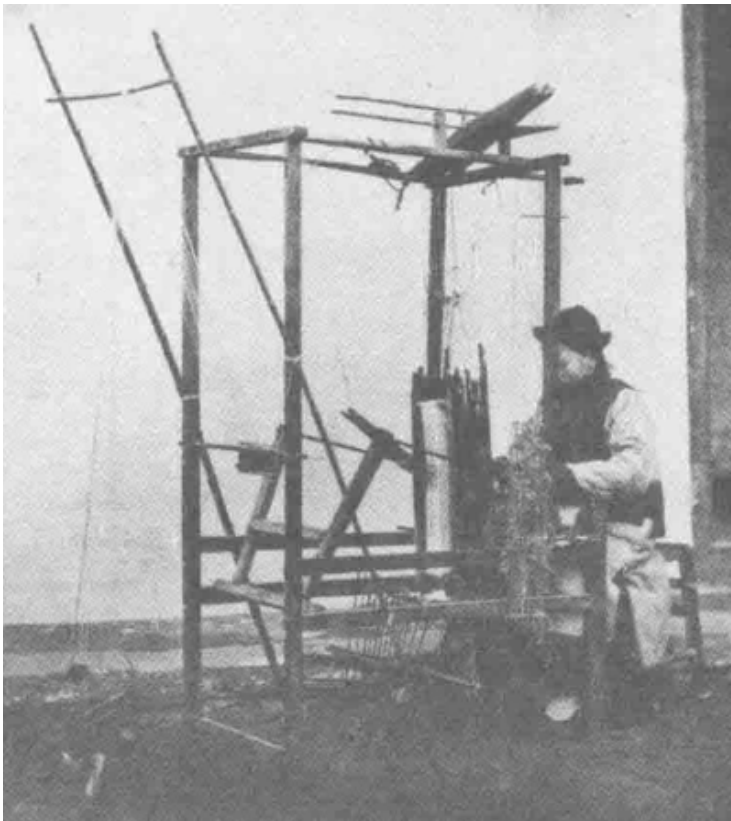


Fig 7. Multiple heddles and treadles loom of Jiangxi Province, in the late Qing Dynasty (after Thomson 2015, p. 385).



Fig 8. Multiple heddles and treadles loom in E. Rocher's report (after ZHAO 2005, p. 516).

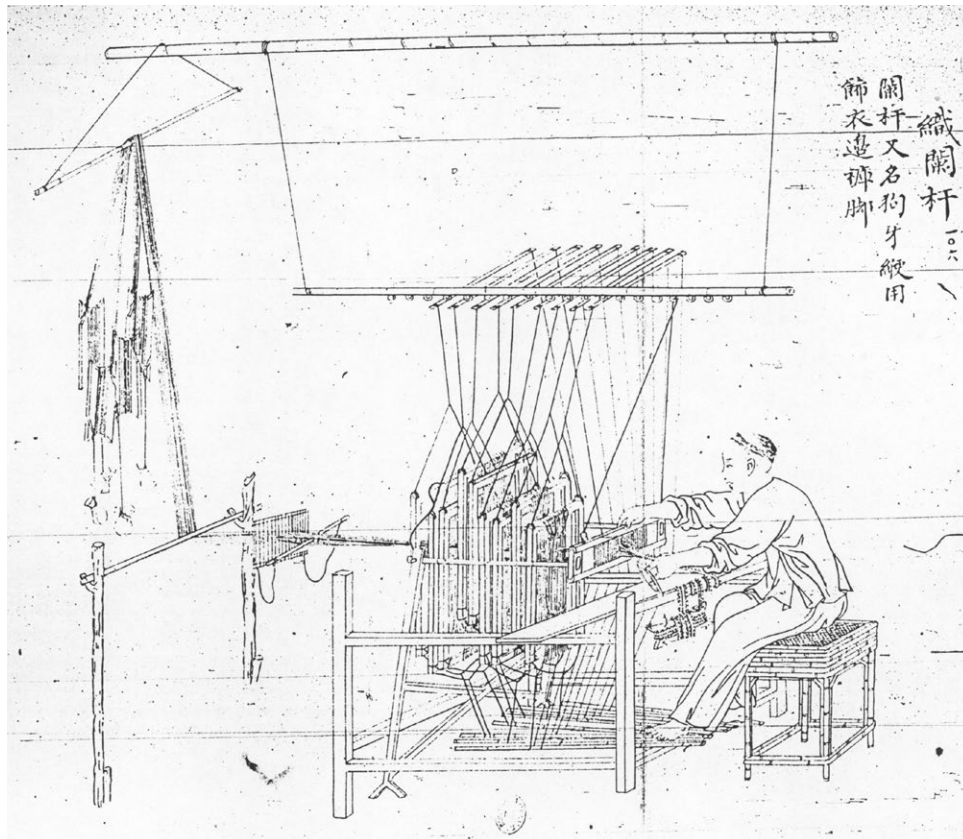


Fig 9. Multiple heddles and treadles loom in a painting from the Qing Dynasty (after ZHAO 2005, p. 516).



Fig 10. Model of the Multiple heddles and treadles loom from Shuangliu, Sichuan Province.

The Laoguanshan multiple shafts loom

In 2012 and 2013, the Chengdu Institute of Cultural Relics and Archaeology and the Jingzhou Cultural Relics Conservation Center made a remarkable discovery at Laoguanshan in Tianhui, Sichuan Province. While excavating four Han Dynasty tomb mounds containing wooden coffins, they found a total of 620 objects made of lacquered wood, pottery, bronze, and iron. At the bottom of one wooden coffin they discovered four loom models made of wood and bamboo,¹³ along with traces of silk threads and pigments (fig. 11). The largest of the four looms is 50 cm tall, 70 cm long, and 20 cm wide. The other three looms are smaller, measuring around 45 × 60 × 15 cm. Of equal interest were the 15 miniature painted wooden human figures that, judging from their postures and inscriptions, may be models of the workers at a workshop where Sichuan *jin* silk was produced. To date these are the only complete models of Han Dynasty looms with firm provenance.

These looms are quite different from the looms that have been discussed so far. They are large and complex and must have belonged to organized workshops producing high-quality silk textiles. In technical terms, the Laoguanshan model looms are ‘hook-and-shaft pattern looms,’ or ‘single hook and multi shaft pattern looms,’ which use two ground heddles and multiple patterning

heddles to create patterns. The closest modern loom corresponding to this type is the Dingqiao loom discussed above, though the pattern-heddle opening mechanisms on the Laoguanshan looms are different from those on the Dingqiao loom. The four looms fall into two types: the largest loom is of the ‘sliding frame’ type, and the other three are of the ‘linked shaft’ type.

The ground heddles are operated by a pair of foot treadles connected to a pair of pulleys in the upper part of the loom, and the pattern heddles are held in a cage-like frame, the position of which is fixed by a notched beam at the top of the loom. The heddles are selected by a pair of suspended wooden hooks, and then raised by either the sliding frame or the notched beam via the foot treadles. The patterning heddles in the miniature looms number from 10 to 20. However, judging from actual silk textiles found in Warring States and Han Dynasty sites (5th century BCE–3rd century CE), actual full-size looms had many more heddles than the models.

The Laoguanshan tomb models reveal a weaving technology of remarkable sophistication, and are the key to understanding how *jin* silks, which were important within China and also widely traded along the Silk Road, were manufactured at this period, around 2000 years ago.



Fig 11. Model looms in situ in the Laoguanshan tomb.

Thus far, we have summarized the main types of looms equipped with multiple heddle pattern devices. It can be seen that there is a range of forms, from simple devices adding pattern-shed saving heddles to a backstrap loom, up to one-to-one or one-to-many multi-heddle systems on treadle looms. Although the forms of these heddles are different their principles of operation are the same. Both simple and complex forms have survived, in different settings, up to the present day.

How does the multiple heddle pattern device work?

In weaving process, creating warp openings for patterning is the most complicated step. The core principle of the multiple heddle pattern devices reviewed so far is to store the weaving structure and pattern design of the fabric in each corresponding heddle in strict accordance with the order, and to read and release the information sequentially during weaving. All the subtleties lie in the information storage principle in the heddles, which is equivalent to the concept of '1' and '0' in modern computer binary. It reflects the relationship between the heddle and the warp is 'passing through' or 'not passing through', which corresponds to the 'lifting' or 'non-lifting' of the warp in the weaving process (fig. 12).

Considering examples of warp-faced and weft-faced fabrics to illustrate the principle of pattern weaving (figs. 13, 14), generally speaking, patterned fabric is composed of a foundation weave (plain weave, twill, satin) and a pattern weave. The pattern of the fabric strictly follows the pattern heddles. In the weaving process, the foundation and pattern systems are employed alternately: the groundweave consolidates each pattern weft between foundation wefts.

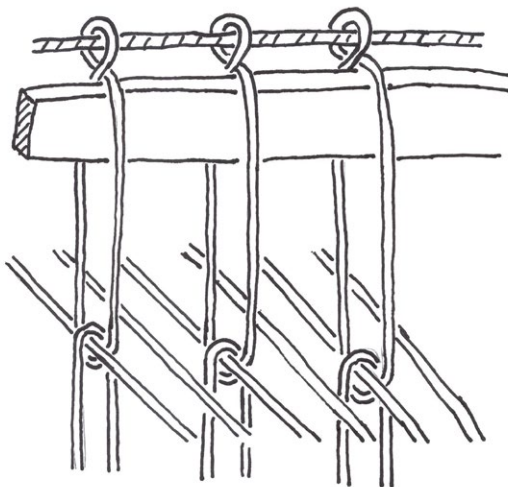


Fig 12. Diagram of the relation between warp and harness.

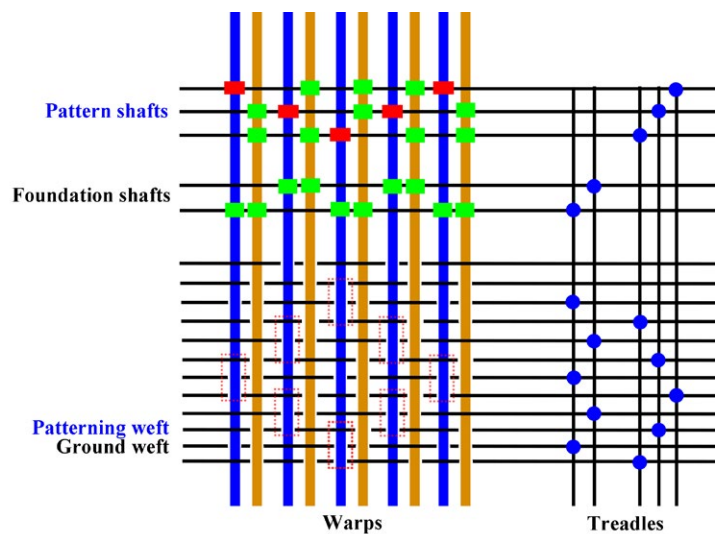
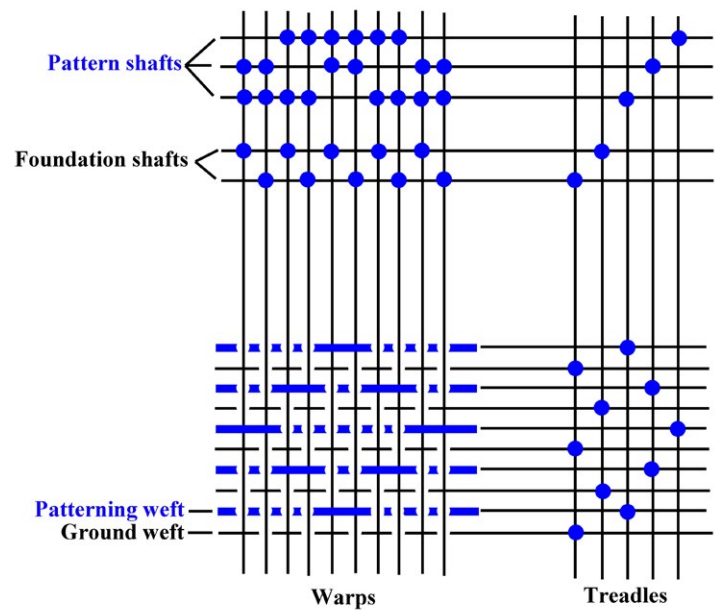


Fig 13. (above) Example of a weaving plan for a weft-faced fabric.

Fig 14. (below) Example of a weaving plan for a warp-faced fabric. Red squares represent warps passing through pattern shafts. Green squares represent warps passing through ground shafts. Sections of warp enclosed in red dots indicate warps forming part of the pattern on the fabric surface.

The use of permanent pattern heddles represents an advance on the temporary warp-rod system, though as with the Palembang loom, the two systems can be used together. Palembang weavers are able to lift more than one heddle to create pattern elements, then save the lifts on one pattern rod before inserting a pattern weft. As noted, a weaver can (in principle) use any heddle in any order because each one is independent from the others (fig. 16). Unlike the temporary warp rods, the heddles are a permanent record of the pattern. Provided that a short section of unwoven warp is retained with the heddles attached, they can be saved for future use after weaving is complete.

The addition of mechanical systems of treadles and lifting levers (shafts), such as those found on the *Dingqiao* and Laoguanshan looms, increases weaving efficiency and frees up the weaver's hands for weft insertion, though the basic patterning principle remains unchanged.

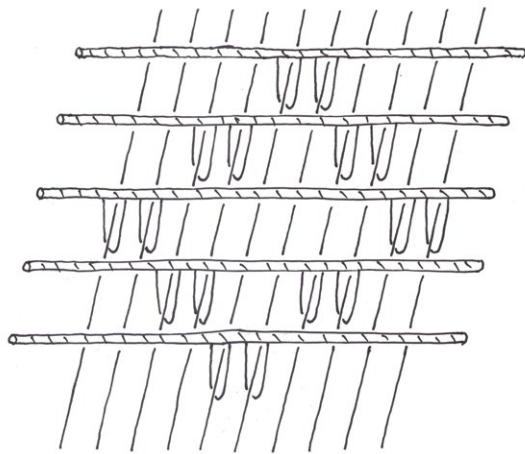


Fig 16. Permanent heddle-rod system.

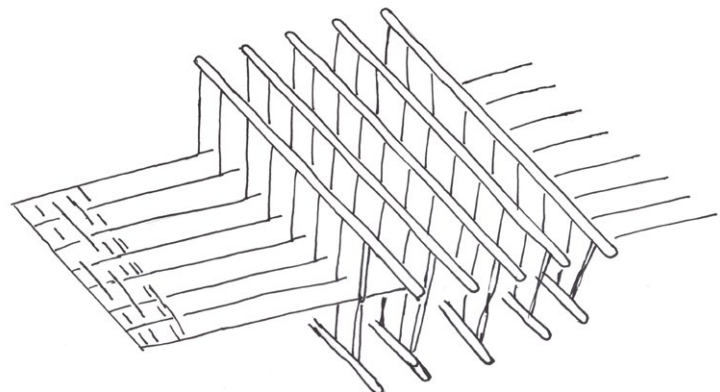
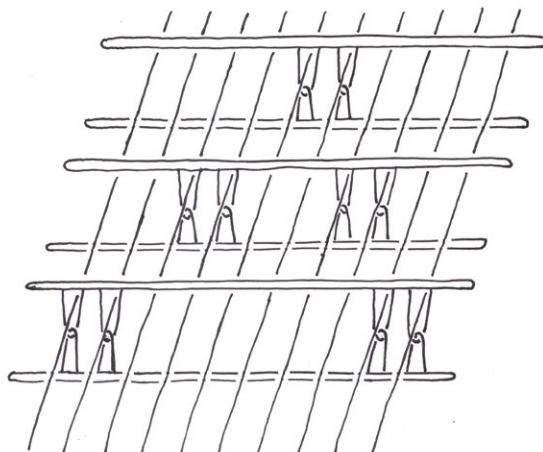


Fig 17. Multiple heddle pattern systems.

Historical and textual evidence

Almost uniquely in world history, weaving devices are described (and in some cases, depicted) in early Chinese historical texts, a testament to their importance in Chinese culture. The multi-heddle pattern loom, for example, has a clear record in early texts. The Western Han Dynasty 'Xijing Zaji' (Miscellaneous Records of the Western capital) and the 'Annotations by Pei Songzhi for Wei Zhi' (Records of the Wei Kingdom), a commentary on the San Guo Zhi (Records of Three Kingdoms) describe looms with multiple heddles and multiple treadles.

Among extant domestic looms, the Dehong multi-heddle and multi-treadle loom and the *Dingqiao* loom have the closest similarities with the looms of Han period in weaving principles and mechanical structures. The first key point is that the warp entering process is similar: each warp end is threaded through the top part of a heddle loop of the multiple heddle patterning system. That is to say, in a complete pattern unit, a warp can be controlled by several heddles at the same time.

With this kind of entering process, no matter what type of textile, the number of pattern heddles and the number of pattern wefts are equal in a complete pattern unit (or half of one unit, in the case of symmetrical designs). The complexity of the pattern that can be woven is determined by the number of pattern heddles. The second key point is that the heddles are all lifted by treadles, and each heddle is connected to just one treadle, which explains why 'a loom that has 50 heddles will also have 50 treadles' as recorded in ancient texts.

Based on archaeological evidence, the multiple shafts loom excavated in Laoguanshan of Chengdu is undoubtedly the first shaft-operated pattern loom invented. It is tangible evidence of multiple heddle pattern device was in use 2000 years ago, able to produce *jin* silk in long rolls with precise repeats. Its core technology controls patterns with multiple heddles, which were a permanent record of the design on the finished textile. Each individual pattern heddle corresponded to the warp lifts for one weft insertion. Within the development of loom technology, this unique pattern device integrated the advantages of several kinds of looms present at that time and was able to produce exquisite silk in quantity, satisfying both the demands of the imperial court and the Silk Road trade. It has left a gorgeous heritage of silks, preserved in China, Central Asia and as far away as the shores of the Mediterranean Sea.

Conclusions

The multiple heddle pattern device or multi-heddle patterning system is the core technology of the earliest known ancient Chinese pattern loom. Multiple heddle pattern devices used both by small domestic looms and the more complex looms belonging to professional workshops is proof of the advanced level of weaving technology around 2000 years ago. The loom combined the advantages of several different looms present at that time. The hook-shaft pattern loom excavated in Laoguanshan seems to be the key loom that produced the famous and widely traded Shu *jin* silk during the Han Dynasty. It is important not only for Chinese history of textile making, but the world history of science and technology. Based on the foundation provided by the multiple shafts pattern loom, the drawloom was subsequently developed and introduced to the West, Persia, India and Europe, ultimately giving rise to the Jacquard loom and to binary programmed devices, computers and control systems more generally. The Chinese silk pattern loom thus represents a key link in the development of world textile culture and human civilization.

Photographs are by LONG Bo unless otherwise noted.

Notes

1. Needham 1954, 240.
2. James 1986, 64–65.
3. TU 1983.
4. HU 1980.
5. SUN 1963.
6. GAO and ZHANG 1997.
7. ZHAO, WANG, et al. 2017.
8. Sardjono 2019, 91.
9. Varadarajan and Amin-Patel 2008, 91.
10. HU, WANG, YU et al. 1980.
11. Thomson 2015, 385.
12. ZHAO 2005, 516.
13. XIE, WU, et al. 2014.

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