

An Innovative Design for Drawlooms with an Open-Type Heald [†]

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Abstract: An innovative and simple design for a weaving loom was proposed to simplify the pattern design and the decoding process of weaving. Using the structural analysis of the existing looms and based on the concepts of weaving, a creative open-type rigid heald was developed to replace the traditional one and generate warp shedding. Corresponding to the raster graphics of the designed pattern, the heald shape had convex–concave features to control warping in shedding. The pattern design was integrated into the heald design using mechanical coding.

Keywords: open-type rigid heald; loom; raster graphic

1. Introduction

Textile is essential in culture with weaving being an ancient technique. Bone needles were found at the cave site of the Paleolithic period in China showing the earliest known origin of weaving, far before the time of pottery making [1]. The oldest textiles found in Peru date back to between 10,100 and 9080 BC [2]. Textiles were found in the birthplaces of civilizations around the world, including manual rope weaving, handmade instruments, and the design and application of textile machinery. The existing textile teaching focuses on knitting as knitting tools are cheap and easy to use and carry. For weaving, a mechanical device is necessary but expensive. A simple loom for plain weaving costs several thousand NTD, and a loom used for pattern weaving (Figure 1) costs more than ten thousand NTD. The device is heavy to carry, the procedure is cumbersome, and the pre-operation is time-consuming. The above problems make it difficult to promote the weaving science popularization activities.



Figure 1. Modern manual loom.

Therefore, there is a need to develop an innovative drawloom with creative flat healding to increase the popularity of learning weaving. The new device has a simple structure, low cost, and simplified pre-operation procedures. In addition, the bitmap of the



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woven pattern is used to design the flat healding to control the warps. The relationship between the weaving pattern and warp motions are coded by weaving program. By integrating the pattern design and the healding design, the popularization of weaving education is achieved.

2. Basic Concepts of Weaving and Drawlooms

The procedure for the typical weaving process includes three steps: shedding, picking, and beating up. In shedding, the operator controls the up–down motions of heddles to pull or press the warps and then divides them into upper and lower layers to create a shed for the warp layer. Picking is passing the beater with a weft through the shed from one side to the other side. The last stage of beating up involves pushing the new weft to the cloth using a reed or beater to evenly arrange the wefts. By repeating the motion of beating up, the horizontal wefts are arranged tightly to generate a tight cloth. When continuous weaving is carried out in traditional weaving, two synchronous actions of “warp control” and “cloth control” are necessary and generated by scrolling two beams as shown in Figure 2. The warp beam delivers the warps and the piece beam receives the cloth. The warps between these two shafts can maintain the required tensions.

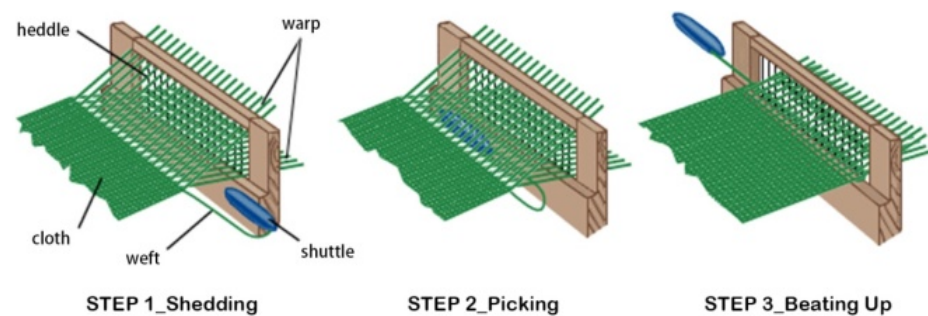


Figure 2. Manual procedure of a common drawloom.

The repetitive patterns in weaving are essential in textile machinery. The pattern design corresponds to its weaving procedure, i.e., the pattern cards, jacquard design, or weaving plan. In ancient Chinese weaving, the pattern cards were called “Yi Jiang Tu (意匠圖)” or “Hua Ben (花本)” (Figure 3). The principle was to convert the pattern of the jacquard into the regular action program of each warp in the weaving process (that is, “moving up and down” or “not moving”), and the actions of the warps depended on whether the warp passes through the harness eyes or the cord eyes. This is called “sleying” or “healding.” Under the combination design of the healding arrangement and the number of harnesses, all of the warps’ actions in a specific sequence were controlled by operating certain harnesses to complete the function of shedding.



Figure 3. Pattern cards (Yi Jiang Tu).

The up-down action of the warps is called “lifting.” In the design of machinery, it is common to lift harnesses using a direct manual or mechanism linkage method. The simple looms are manually operated and usually found in the traditional culture. These ancient looms consisted of parts that were not mechanical devices. The looms that can weave fabrics with complicated patterns were operated by mechanisms, and floor-type looms were common.

For the jacquard machine, the structure of multiple treadles and harnesses is designed to be a pattern storage method for fabric production. The information of the pattern is stored in several healds. In the weaving process, the healds are lifted in sequence according to information on the fabric [3]. Aside from the complexity of its pattern, the relationship between warp and weft is described as “passing through” or “not passing through” depending on the “lifting” and “not lifting” of the warp in weaving. The concept is equivalent to the symbols “0 and 1” in computer coding [4]. If the color yarn and weave changes are added, the pattern is designed as a “color matching pattern” [5], so the weaving sequence of warps is a loom-specific program translated based on the textile patterns. Therefore, the “lifting” and “healding” processes realize the textile pattern, and the pattern card is a decoder.

However, it is difficult for beginners to learn weaving techniques and understand pattern design using pattern cards. Integrating pattern design with weaving in the teaching plan is difficult. If the pattern design is not taught in weaving lessons, learners cannot learn how to translate programming language into the drawloom. With logical thinking and image coding concepts, the most critical concept of weaving can be skipped in weaving teaching.

3. Structural Analysis of Looms

Weaving is an ancient technique of making clothes. The drawlooms have developed into several types in the development of the textile industry. In this article, three representative ancient looms and one common modern loom are introduced.

The slanting loom and the drawloom (Figures 4 and 5) were introduced in the ancient Chinese Book *Tian Gong Kai Wu* (天工開物) by Song Ying-Xing (宋應星). The slanting loom is more common than the drawloom, and the loom is divided into three types, including “Yao Ji (腰機),” “Bu Ji (布機),” and “Wo Ji (臥機)” according to the operating angles of the looms and the fixed method of warps. The warp motions of a slanting loom are usually operated by stepping on the treads. A treadle connects to one heald by a scale link and strings. Such a mechanism is called a heddle-raising device. Based on previous research [6,7], the slanting looms fall into four categories: two treadle, single heddle rack (TTSH); single treadle, single heddle rack (STSH); single treadle, half heddle rack (STHH); and two treadle, two heddle rack (TTTH). By analyzing the topological structure, the heddle-raising device was found to be a planar or a spatial mechanism with four, five, or six links. After operating the treadle to finish the shedding and picking, the loom with one heddle must be weighed on the scale link to make the heddle recover its initial weight. Mostly, a slanting loom has two healds to control the odd number of warps and the even number of warps for a plain weave.

The structure of the drawloom is more complex than the slanting loom to generate sophisticated patterns on clothes. It results in a diversity of weaving patterns and the elegance of clothes. In ancient China, the drawloom called “Da Hua Lou Ti Hua Ji (大花樓提花機)” (Figure 4) was used to weave the emperor’s court dress. The weaving work of a drawloom is time-consuming and complicated. Two people simultaneously operate a drawloom. One weaves and the other controls the warp weaving procedure, i.e., the program of the pattern design. Owing to the complicated weaving pattern and cloth structure, the drawloom needs several healds to control the sequential motion in each row weft of the pattern design. In the structure design and layout of the loom, it is hard to increase the number of essential healds. Therefore, the drawloom uses two mechanisms to control healds. One is the foot-raising heald mechanism, and the other is the

foot-falling heald mechanism. They are called “Wen Zong (紋綜)” and “Di Zong (地綜)” and are used to make repeated patterns in the ground-woven clothes. According to the reconstructions [6,8], the foot-raising heald mechanism can be a planar or spatial mechanism with five or seven links. The foot-falling device is a planar or spatial mechanism with four, five, or six links. However, this is not enough to fulfill the pattern weaving of the drawloom. The embossed pattern is arranged by the “Hua Ben (花本)”, i.e., the pattern cards. By applying the knots to mark the weaving sequence, a person operates the weaver and controls the warps for weaving the embossed patterns. Therefore, pattern weaving requires a special design for the textile machines in ancient China. According to the functions, the pattern weaving of the drawloom includes five subsystems: a foot-raising heald mechanism, foot-falling heald mechanism, hand-raising warp mechanism, weft pressing mechanism, and fabric reeling mechanism. Although the design of the loom is excellent, it needs to be operated by a human, not by an automated machine.

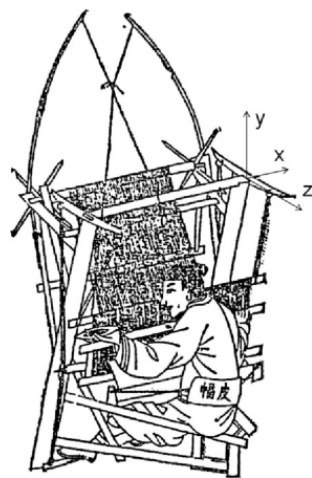


Figure 4. Slanting loom in ancient China.

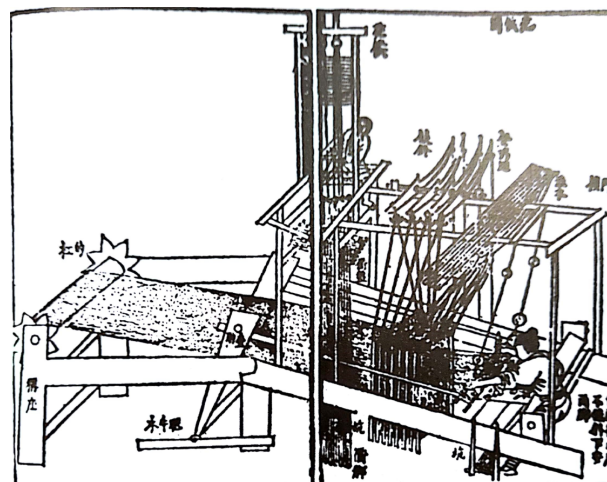


Figure 5. Drawlooms in ancient China.

In the West, a Jacquard loom with similar functions was invented by Joseph Marie Jacquard in 1807 (Figure 6). One weaver can operate the Jacquard loom. The healds are also used to control the warps' motions based on the repeated pattern design of the cloth. A punch card made of a piece of wood with several circle holes is used to represent a row of weft as shown in Figure 6b. A skilled worker transfers the pattern design into punched cards. These punch cards are stitched together in a continuous belt and fed into the loom. A pattern design must be generated by several pattern cards. The function of the holes on the pattern card is to move the iron stick with a circle and spring at its end. An iron

hook passes through the stick's circle and controls a warp. Therefore, for a punch card, the stick can pass through the hole without affecting the hook's position. Then, the hook can be pulled on to draw the warp. Otherwise, for a position on the punch card without a hole, the stick is pressed, and the hook is moved out of its original position. Then, the hook cannot be pulled on, and the corresponding warp is not drawn. With the punch card, the spring can recover the stick's position. Owing to such a design, the Jacquard loom does not need a person to draw the warps to operate the foot-raising heald mechanism, foot-falling heald mechanism, or hand-raising warp mechanism. This machine simplifies the process of manufacturing woven fabrics with complex patterns, such as brocade, damask, and matelassé [9].

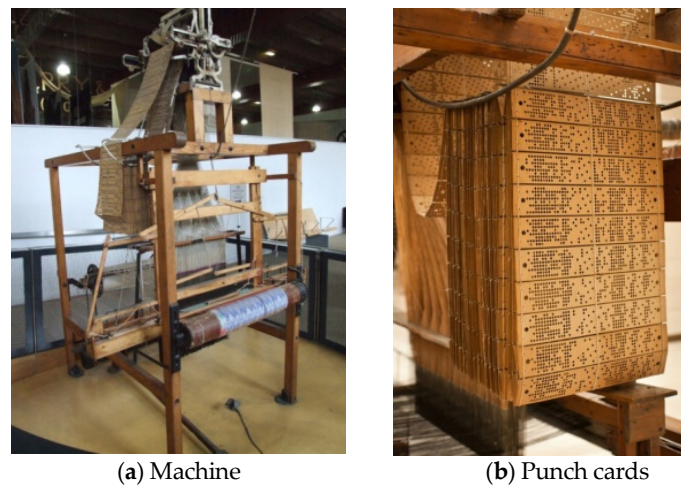


Figure 6. Jacquard machine.

4. Innovative Design of Drawlooms

Regardless of the ancient looms or modern desktop looms, the price of the devices is high. Therefore, an innovative drawloom was developed by using the simplest structure (the three-links mechanism). The loom has similar functions as basic weaving with convenient functions for fabricating quickly. Figure 7 shows the innovative and simple drawloom, which consists of a front plate, a rear plate, and two side plates with a slide. The maximum size of the existing design was about 32 cm in length and 15 cm in width. The device includes a flat heald to replace the traditional heald or reed but maintains the function of generating a shed. To control the motions of the warps, a V-shaped notch replaces the cord eyes. The concave and convex shape of the end plate allows the warp to be in the right position. The left and right side panels have a chute design to adjust the size of the machine and maintain the warp tension according to the user's hand length or fabric length.

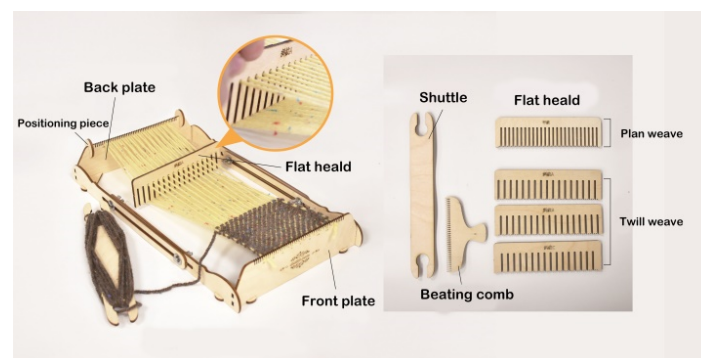


Figure 7. Innovative design of manual drawloom.

According to the description shown in the figures, the heald is lifted to control the movement of the warp, and the warp action in a lifting sequence is determined by the heald frame. The steel sheet is matched with the heald eye and the rigid-body heald frame; the rigid-body heald frame is presented as a closed one-piece flat plate with a chute and a steel sheet with a heald eye since the drawing is a process of connecting the pattern and lifting the heald. The innovative feature of the design of this teaching aid was to replace the heald frame of the traditional weaving machine with flat heddles. The shape of the heald determined the movement of the warp, and the “heddle” was transformed into the shape of the heald, which uses a binary code of 0 and 1 for bump sorting. The shape of the flat heald is a flat comb, and the concave and convex order controlled the up and down position of the warp according to the pattern design. The edge of the protruding part of the heald is in the shape of an inverted V, which is convenient for clamping and pressing the warp. The depth of the concave part determines the stroke of the warp that was displaced up and down. During the process of combing and combing the yarn by the heald, the starting position is confirmed through the positioning piece of the rear end plate to avoid the problem of jumping wires during the combing and combing process of the warp yarn and improve the accuracy of the yarn opening operation. The shuttle has the same function as the shuttle to wrap the weft yarn and guide the weft yarn during the weft insertion process. The beating-up comb is the same design as the beating-up knife of the ground loom and the reed of the typical drawloom to complete the beating-up process.

5. Bitmap Concept of Pattern Design

Learning Weaving for beginners requires considerable time. Thus, a method to simplify the complicated pre-work of weaving and the concept of pattern design is presented in this article. An innovative drawloom with a simple structure is presented under the concepts of three weaving procedures. This innovative loom is used on a desktop and without the warp control and cloth control. Hence, it weaves clothes of a limited size based on the length and weight of the device and cannot weave continuously. To simplify the patterns converted into warp action procedures, the image of the weaving pattern was created into a bitmap so that abecedarians could code the weaving procedure with intuitive concepts. They did not execute the healding process, the most complicated step in the weaving technique. The lifting action generated a shed based on the designed sequence of warps.

The pattern coding procedure for the simplified drawloom is as follows: (1) The number of rows and columns is determined to generate a grid; each column corresponds to each weft yarn and each row corresponds to each warp yarn. (2) The warp and weft are expressed in multiple selected colors. (3) By filling in the selected color of the warp and weft in the squares of the grid, the pattern is produced as a bitmap of a graph. (4) For a specific row, the color change of the row determines the upper and lower positions of each warp in the picking process, which correspond to pressing or not pressing the warp, and confirm whether the warp needs to be moved. If the field is the color of the weft yarn, the warp yarn is pressed down, and the inverted V shape must be filled. If it is displayed as the color of the warp yarn, the warp yarn does not move, and the horizontal line figure must be filled in. (5) The inverted V shapes and horizontal lines are connected to each column to generate the concave–convex sequence for the side of flat heald corresponding to the designed weft yarn. (6) The bitmap of the design pattern in turn is created to generate the heald geometry for each row (weft yarn). In the example shown in Figure 8, the warp is white, the weft is blue, and the warp is pressed down by the flat heald to generate a shed so that the weft is on the top after picking. According to the blue and white sequence of the bitmap, the side geometry of the flat heald in the red line corresponds to the action procedure of the warps as a code. Moreover, the combination of the flat healds is regarded as a program translating the pattern.

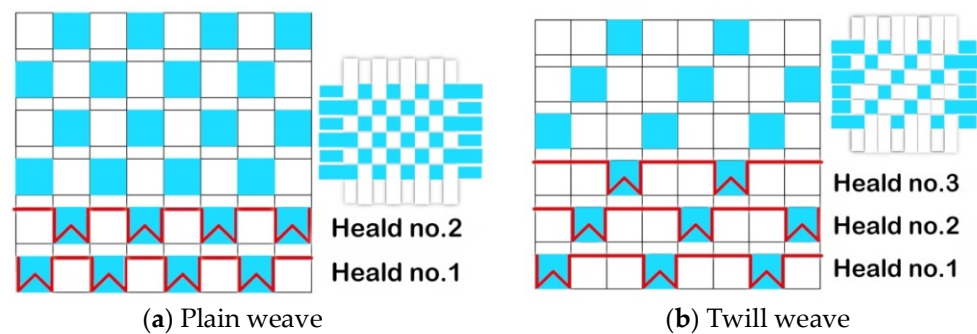


Figure 8. Bitmap concept of pattern design for new drawloom.

6. Conclusions

Textiles are an element of civilization, representing humanities, history, craftsmanship, and machinery. It is worthy of promotion as a popular science education project. In this study, the basic principle of weaving and the existing drawlooms were analyzed for the looms in ancient China and the ancient West. Considering the concept of simplified structure and weaving process and lower cost, an innovative simple drawloom with flat healds was developed. The weaving pattern was directly drawn in the form of a bitmap. The shape design of the heald was used to control the upper and lower sequence of the warp yarns so that the weaving pattern could be converted into the weaving coding more intuitively. Through the combination of the design method and the new drawloom, the complicated process of “sleying” or “healding” was simplified. In this way, the open-type flat heald was invented. The result was successful in creative weaving. Learning weaving techniques and design became much easier. With the integration of this innovative design, the popularization of science activities for textiles has proliferated. Also, the programming of weaving was improved.

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