

## **EXPANDING THE LIMITS OF SILK WEAVING: TECHNOLOGICAL ADVANCEMENTS WITH THE FRENCH JACQUARD LOOM IN THE 19TH CENTURY**

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**Abstract:** The French silk weaving industry in the 19th century experienced significant technological innovations through changes made in the jacquard silk weaving loom. This paper explores the design of different types of jacquard looms and pattern cards used in France during the 19th century. The study highlights the changes in the shape, direction, and thickness of crochet and the shape and material of pattern cards. The research shows that improvements were made to the jacquard loom by adding harness cord and shaft monture to increase pattern width, reduce the weight of the pattern card, and expand the pattern template while maintaining the warp density and number of crochets. This resulted in the steady progress of the silk weaving industry. Through a literature review, data on the technical principles and pattern card specifications of different types of French jacquard looms in the 19th century were analyzed. The study shows that the French silk weaving industry continually optimized and improved the jacquard loom and pattern card design, resulting in significant advancements and allowing for more diverse designs of silk jacquard products in the industry. This new theoretical system of silk jacquard, which was independent from the East, influenced changes in silk fabric patterns at the time and had far-reaching effects on the reform and modernization of equipment and talent training methods in Japan, China, and other countries.

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**Keywords:** French silk, jacquard loom, pattern card, harness cord, shaft monture, warp density, and number of crochets.

### **Technical Principle of the Halter of Jacquard Loom**

The modern jacquard looms share common principles of construction. No matter jacquard looms, or subsequent Vincenzi looms, Olivier looms or Verdol looms, the jacquard halter crochet worked with the pattern card, to achieve the lifting of warp threads. The schematic is shown in Figure 1.

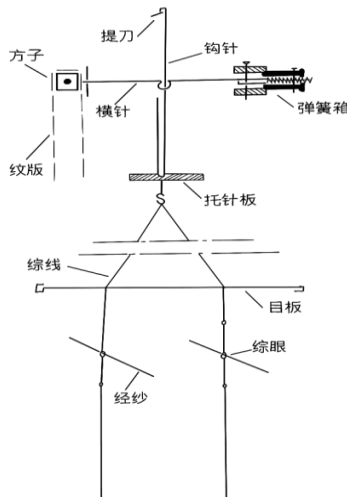


Figure 1. Schematic of the Principle of Warp Lifting Controlled by Loom Crochet

As shown in the above figure, the crochets in the jacquard halter (jacquard machine) were vertically arranged on the needle support. There was a hook at the tip of crochet and there was a griffe under each hook. There was a heddle beneath the crochet, which passed through the mesh plate. There was a heddle hole on the heddle, which was used to thread the warp. Each vertical crochet corresponded to a transverse needle. The hole on the transverse needle was bulged, in order to associate the crochet with it. The transverse needle was uniformly placed in the transverse needle plate, and in front of the transverse needle plate, there was a square block that can be rotated. The pattern cards strung together were placed on top of the block. Every time the block rotated by 90 degrees, a pattern card can be overturned (the pattern cards used by Verdol loom were consecutive, so the block was cylindrical).

Every time a pattern card was overturned, a flapping device would cause the block to press the pattern card against the transverse needle once. The small holes in the pattern card corresponded to the transverse needles one by one. If a small hole was punched in the pattern card, the transverse needle would go through the hole without moving when being pressed against it, and the associated crochet would remain still. The griffe would then lift, causing the crochet to rise, and the warp would pass through the corresponding heddle. Conversely, if a small hole was not punched in the pattern card, the transverse needle would be propped by the pattern card, causing it to push towards the spring end. The associated crochet would also be pushed out of the upper end of the griffe. In this case, if the griffe rose, the crochet hook would not be able to hold the griffe, and the crochet would not be lifted, which means the heddle and warp would not be lifted either. Therefore, whether the corresponding warp was lifted or not could be controlled by whether the pattern card was punched or not each time it was overturned.

From the working principle of jacquard halter, it can be seen that when the density was constant, the pattern width of fabric pattern depended on the number of crochets corresponding to the holes in the pattern card, while the pattern repeat depended on the length of pattern card. After Jean Antoine Breton improved the jacquard loom and made it truly adapted to large-scale industrial production, the improvement of jacquard loom kept going, and the focus of the technicians' improvement began to shift to how to make the halter accommodate as many crochets as possible and how to cut down the weight of pattern card, so as to increase the number of pattern cards, and enlarge the pattern template.

## 2. Changes in the Number of Crochets and Pattern Card

### 2.1 Change in the Number of Crochets

According to literature, the number of stitches in the early pattern card was 80 (stitches), which gradually grew to 1344 for common use (Lamb, 2005). Vincenzi, Olivier and Verdol emerged in succession. A series of improvements were made in terms of the form and material of crochet and pattern card, so that the halter of jacquard can accommodate more crochets, and the pattern card can punch more holes into a fixed area or lower the weight and area of paperboard with the number of holes being constant.

The biggest improvement of Vincenzi loom was to change the shape of crochet (see Figure 2b). The crochet was thinned to minimize the space occupied by it. In addition, the pressure on pattern card was greatly reduced, so that the pattern card can be cut smaller and thinner, and the cost can be reduced. As shown in Figure 2a, there was a loop on the transverse needle of jacquard loom. The crochet passed through the loop and was associated with the transverse needle. When the transverse needle was moved, the crochet was dragged off the hook. There was a short while when the crochet was in a “bow”-shaped state, and can break easily. So the crochet on the jacquard loom was made thick to prevent breaking. Accordingly, the hole in the pattern card was big. The crochet of Vincenzi loom was designed to be V-shaped and have a little elasticity, and the transverse needle was associated with the crochet with a small bulge. In the static state, the A1 side of crochet rested on the device, and the A2 side pressed against the bulge of transverse needle. When the transverse needle was moved towards the spring end, the force against the bulge of the transverse needle on the A2 side was diverted. When the crochet was V-shaped and had certain elasticity in itself, the crochet hook detached from the griffe area. In this way, the crochet didn't need to be very thick to achieve good usability. With the improvement of Vincenzi loom, the number of crochets of jacquard loom grew from 480-648 to 1320 (Charlin, 2003), and the hole on the pattern card became smaller accordingly.

Olivier changed the direction of crochets on Vincenzi loom (see Figure 2c). The original spring setting at the end of transverse needle B was cancelled and two ends of the transverse needle B were connected into a whole. When the block was pressed against the transverse needle, if there was no hole in the pattern card, the front and rear ends would drive the transverse needle to move at the same time. The crochet on the A1 side left the griffe. When the griffe was lifted, the crochet wouldn't be lifted, nor would the warp. This improvement further reduced the pressure of the transverse needle on the end spring and cut down the loss of spring (Cu, 1950).

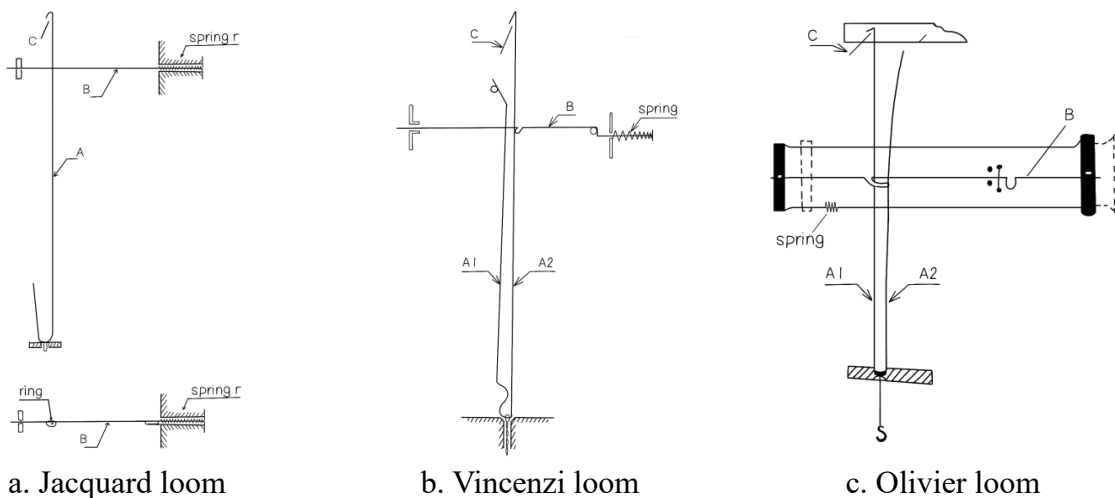


Figure 2. Schematic of the Match of Crochet and Transverse Needle of Different Looms

Under the same conditions, a larger number of crochets requires more holes. A thicker transverse needle also requires a larger hole. Therefore, in the improvement of the structures of the crochet and transverse needle of

the Vincenzi loom and Olivier loom, the crochet and transverse needle were made thinner while ensuring their strength. Consequently, the holes in the pattern cards became smaller, and with the same number of crochets, the area of the pattern card could be reduced. Additionally, more holes could be arranged for pattern cards, and pattern cards of the same area could be assigned more holes.

## 2.2 Change in Pattern Card

A pattern card was also known as texture paper. It was a long cardboard strip. According to the number of crochets in jacquard halter, it can be divided into two or three sections, and the distribution of small holes also differed. As shown in Figure 3, there was a big hole at each end of pattern card, which were pegholes. When the pattern card used for stringing was placed on top of the block (i.e., the cylinder of modern jacquard), the position of pattern card was fixed. There were two small holes outside the punched hole, which were laceholes and used for threading ropes when connecting a single pattern card (Qu, 1950).

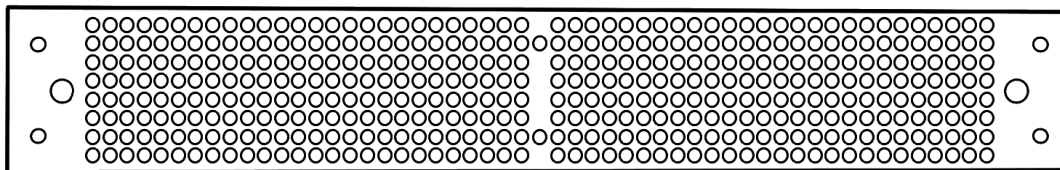


Figure 3. Schematic of Pattern Card

The improvement of Verdol loom was to meliorate the original pattern cards that were strung separately into a consecutive paper pattern card, and change the arrangement of holes from the original regular horizontal and vertical arrangement to staggered quincuncial piles.

In addition, by taking 1344 crochets and 1000 weft of pattern card 1000 as an example, the data of the length, width and weight of pattern card of three types of looms, i.e., jacquard loom, Vincenzi loom and Vedor loom, are shown in Table 1. Through visual comparison, it can be concluded that the length, width and weight of pattern card of jacquard loom were the largest among the three, provided that the number of crochets and pattern cards were the same. Compared with the jacquard loom, Vincenzi loom greatly diminished the width of pattern card from 80cm to 37cm and the weight from 53kg to 15kg, while the length of the pattern card of Vedor loom was only 27cm and the weight was only 2.15 kg.

Table 1. Comparison of Pattern Cards of Different Types of Jacquard Looms

Serial No.	Loom Type	Length of Pattern Card (m)	Width of Pattern Card (cm)	Weight of Pattern Card (kg)
1	Jacquard loom	88	80	53
2	Vincenzi loom	70	37	15
3	Vedor loom	27	47.7	2.15

Combined with the real pattern card in Figure 4, it can also be visually found that among pattern cards of three types of looms, compared with the jacquard loom, the height and width of the pattern card of Vincenzi loom were slightly smaller, while the number of crochets was more than twice as many. Compared with Vincenzi loom, the width of the pattern card of Vedor loom was slightly larger, but the height was visibly much smaller. From the perspective of material, the pattern cards of jacquard loom and Vincenzi loom were single cardboards, and needed to be strung together in turn with a thread when used, while the pattern card of Vedor loom was consecutive, and the material was plastic-like, making it more handy and durable.

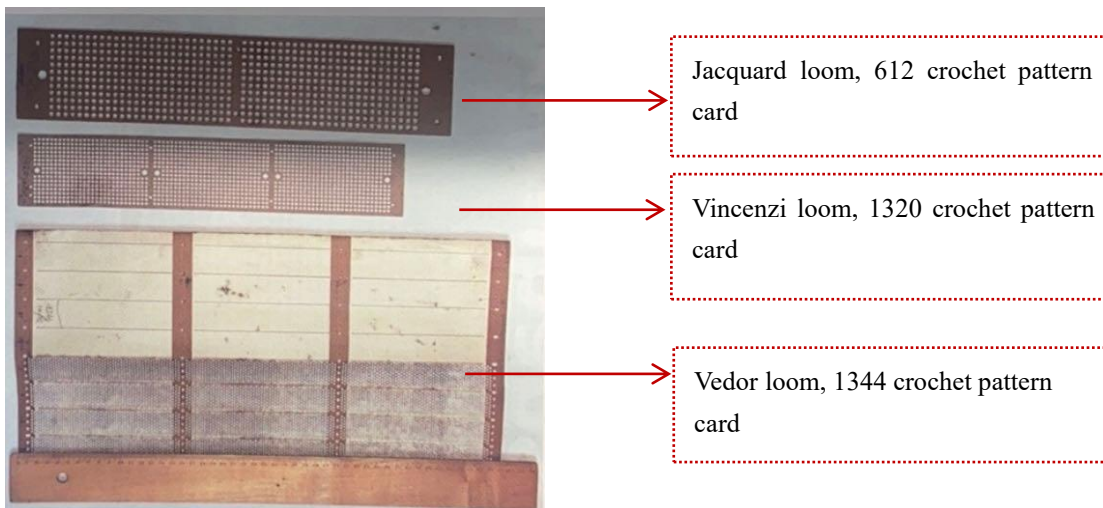


Figure 4. Comparison of Pattern Cards of Different Looms

### 3. **Invention of Harness Cord and Shaft Monture**

The width of jacquard fabric pattern was namely pattern width, and associated with warp density and number of jacquard crochets. When the number of crochets of jacquard halter was constant, the warp density was negatively correlated with pattern width, so when designing large-size patterns, the density of warp can be lowered or the number of crochets of jacquard can be increased. However, from the perspective of fabric, the fabric needed a certain warp density to ensure the necessary fastness of fabric, so the density can't be too small, and the number of crochets of jacquard was also limited. Although the pattern width can be doubled by means of symmetrical threading, this approach can only make symmetrical patterns, and with this, the harness cord came into being.

#### 3.1 *Harness Cord and Shaft Monture*

A harness cord refers to a device in which two or more warps are hung in a gait-over pattern with a crochet. For figured weaving with high requirement for pattern size, double harness cord or triple harness cord were frequently used. When some wider fabrics, such as curtain cloth and tablecloth, were adopted, greater harness cords can be employed, even up to octuplet harness cord. When a harness cord was used, it was easy to enlarge the pattern, on the premise of ensuring the fastness of fabric. The difficulty of artisanal drawing was not heightened, and it was also easy to punch the pattern card. But since it had several warps, the outline of pattern inevitably felt rough and stiff (Miller, 2014). Figure 5 shows French fabrics woven with a multiple harness cord in the 19th century, a marked serrated shape was observed at the edge of pattern, and the edge line can't be delicate and rounded. Not only was the edge of the pattern rough, but also similar problems occurred in the presentation of tissues. Taking double harness cord as an example, if two crochets made a regular plain weave and each crochet controlled two warps, then the tissues on the fabric actually formed a 2/2 weft rib effect.



Figure 5. Real French Fabric Woven by Multiple Harness Cord in the 19th Century



Figure 6. Shaft Monture of French Loom

In 1860, a textile worker in Lyon invented the solution to this problem, that is, to add a heddle frame to the vertical heddle for control. This device was known as shaft monture or splitor scale harness. A shaft monture was a thin and narrow wood chip (Figure 6), whose function was to separate warps in the harness cord, so that they can move alone and solve the drawback that multiple warps had the same law of motion for because the harness cord expanded the inner pattern width.

### 3.2 *Match of Shaft Monture and Crochet*

The shaft monture was placed in the coil of vertical heddle, one for each vertical heddle, which was hung beneath the crochet with a hemp thread. The crochet that controlled the shaft monture was called shaft monture needle, generally with one half at either end of the pattern card. For the shaft monture, typically a weft texture was selected and mainly used in the ground texture of fabric, for example, double weft damask. Thus, the function of shaft monture was not to press down the lifted yarn, but to work with the crochet to achieve the changes of texture, as shown in Figure 7. This was equivalent to the addition of a device to control warp lifting to the loom, after the addition of harness cord and shaft monture. This device didn't conflict with crochet control. It can control the warp alone or in combination with the crochet (Besse et al., 2004). Different from the yarn controlled by crochet, the warp controlled by crochet was a multiple harness cord. When a single crochet was lifted, multiple warps would be lifted, while the warp controlled by shaft monture was single. Therefore, if we wanted to express a texture of individual points on a fabric, we can resort to shaft monture,

as a means to solve the problems mentioned above, that is, the rough edges of pattern and texture with the lifting of multiple warps.

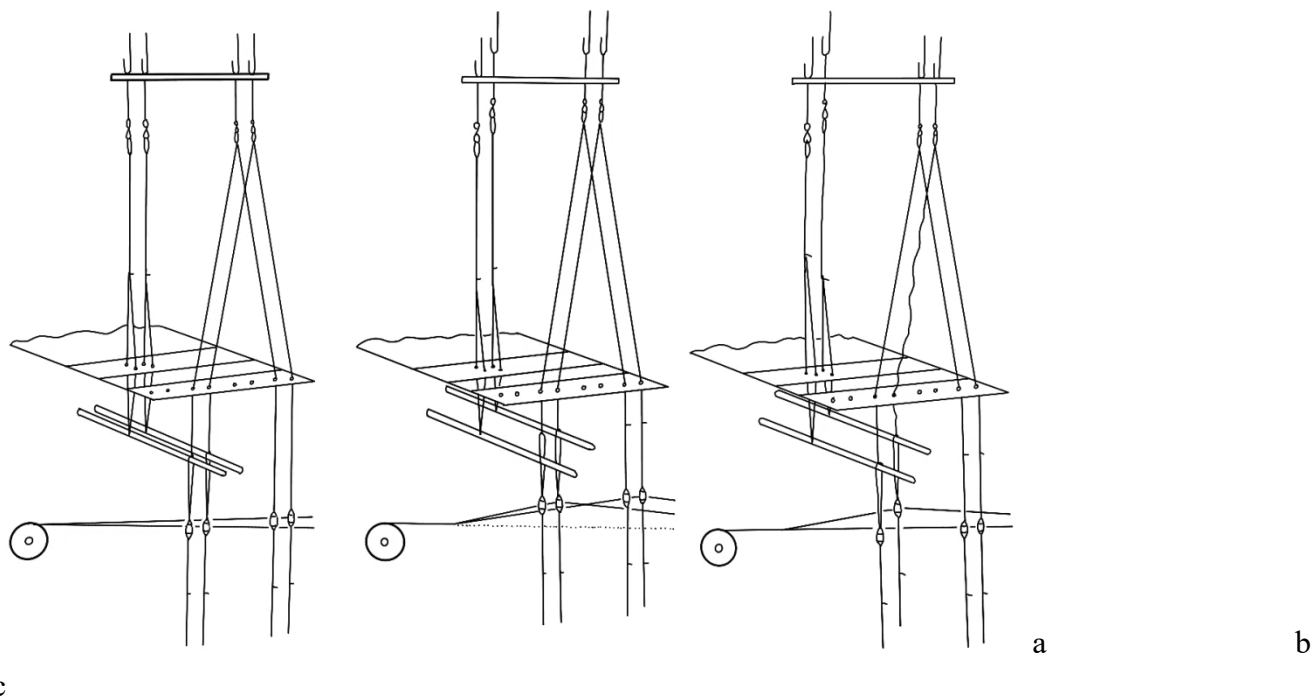


Figure 7. Schematic of the Match between Shaft Monture and Crochet

See Figure 8 for the schematic of the match between shaft monture and crochet. Panel I shows the texture of crochet, Panel II shows the texture of shaft monture needle, Panel III shows the motion texture of shaft monture needle. Area A is the texture of shaft monture needle at the front end of pattern card, and Area B is the texture of shaft monture needle at the rear end of pattern card. Panel IV shows the effect after the match between shaft monture and crochet. The red dots are the warp points lifted by the crochet, the green dots are the warp points formed by the lifting of both crochet and shaft monture needle, and the blue dots are the warp points formed by the lifting of shaft monture needle, whereas the crochet was not lifted. Panel V shows that a crochet controls two warps. By comparing Panels I and IV, we can see that there were 10 longitudinal grids in the crochet texture diagram, but 20 longitudinal grids after match, and every two warps moved in the same way.



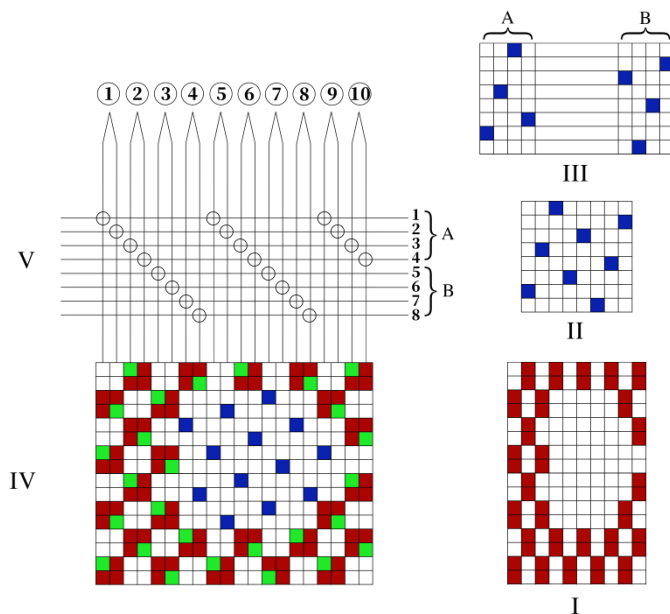


Figure 8. Schematic of the Match between Shaft Monture and Crochet Textures

The harness cord and shaft monture worked with each other, which expanded the pattern width, with the warp density and number of crochets being constant, and made the design of silk jacquard products partly go beyond the limitation of the number of crochets because of the repetition of textures of multiple warps induce by harness cord and deliver more flexibility and liberty. This was an important invention in silk weaving, which affected modern and contemporary silk weaving technology and product design and became an inherent device on the silk loom. Modern and contemporary brocades in China, such as Du Jinsheng brocade, have utilized harness cord and shaft monture. These two devices are still adopted on the traditional mechanical jacquard machine today. While only a single harness cord device is used on an electronic jacquard machine because of the adequate number of crochets (the number of stitches. At present, the maximum number of stitches in China is 40,000).

#### 4. Discussion

In the 19th century, after the emergence of the jacquard loom and pattern cards, the French silk weaving industry continued to explore ways to increase the number of warps controlled by the jacquard mechanism. This involved changes to the shape, direction, and thickness of the crochet, as well as modifications to the shape and material of the pattern cards, and adjustments to the size and arrangement of the holes. In addition, the fabrication theory of the jacquard loom was perfected, resulting in several technological advancements, including the addition of harness cords and shaft montures. These improvements expanded the pattern width while maintaining the warp density and number of crochets, allowing for more diverse designs of silk jacquard products and influencing changes in silk fabric patterns at the time. The new theoretical system of silk jacquard, which was completely independent from the East, had far-reaching effects on the reform and modernization of equipment and talent training methods in Japan, China, and other countries. It also stimulated the entire French silk weaving industry to advance together.

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