

Design and Construction of a Broadloom Capable of Weaving Compound Weaves

Isaac Kofi Awuyah Robert Ahiabor* Bennet Nyante
Department of Fashion Design and Modelling, Wa Polytechnic, P.O. Box 553, Wa, U/W, Ghana

Abstract

Handloom weaving in Ghana is relevant to the growth and development of the textile industry as well as the economy of the country. Handloom weaving in Ghana has taken a new dimension due to the dawn of modern techniques and equipment. Students, lecturers and researchers are making substantial efforts to improve efficiency and to solve problems associated with handlooms in Ghana. This research was carried out to address the problem of weaving compound structures on the broadloom, which is normally produced on the indigenous handloom in narrow width. The aim of the research is to design and construct an “improved broadloom” capable of weaving compound weave structures. The processes and methods used to achieve the compound structures have been vividly expatiated with highly detailed diagrams. The testing of the loom and results are clearly stated for easy analysis and criticisms. However, the proper use of this loom, without any controversy would go a long way in improving on the weave structures produced on handlooms in Ghana and beyond.

Keywords: *Design, Broadloom, Weaving, Weave structures, Compound weaves*

1. Introduction

Textiles, as a basic necessity of life have played myriad roles in the lives of mankind. It is also considered as one of the indispensable needs of humanity. Textiles have been used since prehistoric time with the prior aim of covering the nakedness of man. With the dawn of civilization, textiles production techniques have gone through several modifications. Thanks to advancement in technology, various textiles products were produced by methods of weaving, crocheting, printing, dyeing, bonding, felting, laminating and embroidery, among others. Weaving as one of the techniques employed in the formation of fabric consists of the interlacing of two sets of yarns normally at right angle. Weaving is considered to be one of the oldest methods of fabric manufacturing processes which have developed in technology through the ages to date. Loom is a device for manufacturing fabrics, and they vary in structure but operate with basic weaving principle/motions (shedding, picking, and beat-up). The indigenous loom, table loom, broadloom, power looms are examples of looms available. Weave structures produced from these looms basically are simple weaves and compound weaves. Compound weave structures consist of two or more series warp yarns or weft yarns. In this kind of fabric formation, a supplementary warp beam which is heddled on selected shafts lie in-between the ground warp yarns, forming two warp sheds (top and bottom shed) during the shedding process. Two or more different colours of weft yarns are woven alternatively as a way of embellishing the fabric. Due to the smaller width of fabric usually produced by the indigenous loom, it requires joining of several pieces together to form a full fabric, hence a tedious task especially when producing in large quantities. This is a limitation to the traditional handloom. Weaving on the conventional broadloom used by small and medium scale industries and educational institutions produces variations of plain weave structures, twill weaves and design weaves requires one set of warp and weft in the formation of the fabric. On the other hand, the use of two or more sets of warp and weft yarns made it possible for compound weave structures to be produced on the indigenous handloom. In view of this, the research aimed at redesigning and constructing of an improved broadloom capable of weaving compound weave structures.

2. Review of literature

Weaving cannot be separated from the loom, this is so because the purpose of the loom is to weave a fabric, and thus, the development of the loom and weaving are intertwined. The Macmillan English Dictionary (for Advance Learners) defines weaving as a process of making cloth by crossing long threads over and under each other on a machine called a loom. The interlacing of two sets of yarns (warp and weft yarns) to form a fabric (Adu-Akwaboa, 1989). Microsoft Encarta Encyclopaedia (Standard, 2006) consider weaving as a method of creating a fabric by interlacing two sets of yarn threads called the warp and the weft. Leslie J. Clarke (1968) defines weaving as ‘an art by which threads of any substances are crossed and interlaced to be arranged into a perfectly expanded form, and thus be adopted for covering others bodies. One of the most important and widely used methods of fabric formation by mechanical means is weaving. This consists of the interlacing of two sets of yarns at right angles by the use of the loom. The yarns in the lengthwise direction of the cloth (fabric) are the warp (ends) and the crosswise yarns are fillings or picks (Labarthe, 1969). Weaving can be dated as far back as the prehistoric era. The need for physical protection and body enhancement led to the development of spinning and weaving. In the late Stone Age the men were noticed for hunting and the women spinning as well as weaving. According to Ellacott (1956), the first attempt of loom construction, “Was an upright frame, two sides

and a crossbar, with a close row of long threads hanging from the crossbar. The threads were parted into groups at lower end and on each group hung a stone weight". The weaving was done by the insertion of a ball of thread passing to and fro the hanging threads with a under- and over sequence, this is done by raising every other thread by the fingers. The crosses were done by the use of wood stuff fixed along the crossbar. History has it that the principles of weaving were probably based on the wattle-work and basketry of previous era. Actual weaving would have been dated from 5,000 BC; this so because evidence of weaving structures was seen. Vegetable fibres (including flax, plant bast of various types and the stingless ramie or China grass) were mostly used.

2.1 Brief history of early looms

The loom, as defined by the Macmillan English Dictionary (for advance learners) is a machine used for weaving cloth. The Longman dictionary of English language also defines it as a frame or machine for weaving together yarns or threads into cloth. The Microsoft Encarta Encyclopaedia (Standard 2006) does not hold any contrary view on this definition and also defines it as a machine used for weaving fabrics from yarn or other fibres. Adu-Akwaboa (1989) however, added that even though the loom is a device used for weaving cloth, it can be operated manually or by electric power. It is however, ambiguous to identify which form of loom was first developed – the vertical or the horizontal ground-loom. Ellacott (1956) explained that the vertical loom was used early in the history of weaving but there is a great deal of evidence to show that the horizontal ground-loom was developed first. This was a single apparatus the warp being stretched between pegs on the ground, or between the weaver's waist and a handy tree. This form of loom is still in use in the near east. The modus operandi of these looms was similar, but the problem of shedding was their greatest challenge. In both looms a means of shedding was developed; this was to insert a device that would part the warp threads in the sequence of one up and one down, to allow the weft to be inserted. As stated earlier, the weft on a spool is passed through the parting (opening) of the shed and this reduced the trouble of shedding and picking. The device used for the parting was the heddle (a rod placed diagonally on the warp). When lifted, the heddle raises the loop on the warp threads, and a shed is created between the warp sheets. The heddle is then removed (drops) after the pick has been inserted. Warp threads that were not attached to the heddle were pulled down out of line with the fingers and a thick rod shed was threaded through them, this forced the thread below the level of others, creating a counter-shed through which the return pick was made and subsequent beat-up with the hand. To prevent the warp threads from crossing each other, lease-rod was used.

Many improvement of the loom immersed both in the artistic enhancement and technological advancement. The basics of these looms led to the development of the horizontal loom of the A-Fipa people, north of Lake Tanganyika, the early Greek loom, the Mystery Loom, The 15th century wide-web loom, the square loom (developed in 1560), the broadloom, the development of John kay's flying shuttle, Cartwright's Power Loom, The Dobby loom, the Jacquard loom, shuttleless Looms, computer looms and a host of others.

2.2 Some types of looms and their modus operandi

The mystery loom was developed in order to weave tubular structures without joining at a seam, thus, seamless garment, now employed in modern knitting manufacturing. The tubular structure (weave) was supposed to have been arranged by using two sheds and counter-shed through which the shuttle was passed in turn. The weaver walks around the loom during the weaving process. It was noticed that this was a double loom for weaving two separate weave structures from one warp beam. After weaving the cloth hangs free in the middle of the loom. The beat-up was done in the upward direction. In the 1450s (15th century) there was a growth in mechanization of the loom this led to the development of the horizontal loom. But the main aim of this type of loom was to weave wider-web (cloths with wider widths). Two persons usually worked on one loom, throwing the shuttle through the shed from one end to the other end of the loom. And this produced fabrics of greater width. The square framed loom developed in the 1560s consisted of a side post and beams connected directly at right angles therefore depicting a squared structure. There were no lams but a cord is connected directly to the shafts and this made it different from other looms. The main frame work of the Broad loom (also known as the foot-power loom) is made up of four upright post which are held firmly by cross beams. There are two types of the broadloom; the first is made up of two sets of lams and the other is with one set of lams connecting the treadles in the shafts. In 1733, John Kay noticed the problem of wide-web looms – the width of the loom longer than the weavers' arm for throwing the shuttle. The invention of the flying shuttle mechanism(s) led to the weaving of greater width and at a faster rate hence increasing productivity. The movement of the shuttle was mechanized and this made it possible for the shuttle to move across the width of the fabrics without human effort as in hand driven looms.

Rev. Dr. Edward Cartwright contributed greatly to the development of mechanization in weaving. His effort in improving the hand driven loom(s) invented a loom that could be power driven. This loom which is electrically powered has the same primary motions (shedding, picking and beat-up) as other looms. There was the introduction of revolving cranks, and the use of cams which in essence were a means of converting a rotating motion into a push-pull action, Adu-Akwaboa (1989).

In the early 19th century French inventor Joseph- Marie Jacquard devised a specialized type of computer which was commonly called the silk loom. Jacquard's loom used punched cards to program patterns that helped the looms to create woven fabrics. In this type of loom each individual end can be lifted separately for the insertion of the weft picks. Although Jacquard was rewarded and admired by French emperor Napoleon 1 for his work, he fled for his life from the city of Lyon being pursued by weavers who feared their jobs were in jeopardy due to Jacquard's invention. The loom prevailed, however, when Jacquard died, more than 30,000 of his looms existed in Lyon. The looms are still used today, especially in the manufacture of fine furniture fabrics, Microsoft Encarta (14th December, 2006).

Adu-Akwaboa, (1989), stated that the dobby loom was made by the English. There was an attachment that was fixed to the plain harness loom to create shedding for more than eight shafts which was beyond the capability of the plain harness loom. While the plain harness loom could control between 2 and 8 shafts, the dobby controlled as many as 32 shafts. So, when weave of more than 8 shafts were needed, the dobby attachment was usually employed. It is used shed pegs or punch plastic tapes to raise the shafts to create a shed and it produced more complicated designs than the tappet loom. Typical fabrics produced by the dobby are huckaback, towelling, pique, waffle cloth and shirting madras. This loom usually uses a shuttle in inserting the weft through the shed. The shuttle is basically made of wood, very slender and weighs about half a pound. Like other devices, the shuttle has its merit and demerits. Various attempts have been made to overcome some of the weakness of the shuttle. Clarke (1986) explained that, "the greatest drawback to the shuttle is its limited capacity since, it must, because of the size of the shed, be slender, and because it is thrown like a projectile it must be as light as possible". This however, led to the development of the shuttleless looms. In supporting the above statement, he added that: the first attempt in developing this type of loom was the needle (rapier) loom. The shuttle is replaced by a long thin needle that has an edge in its point through which the weft is threaded. In this loom there is a 'giver' and a 'taker' of the weft yarn in the open shed. The second development was made in the mechanism of a machine-gun; it is loaded with small bullets of weft, which are fired across the shed leaving out a tail of yarn as they go – the projectile loom. The third and the latest development employed a device which resembles water pistol and consists of a powerful little pump which forces a fine jet of water across the open shed – water and air jet looms. These looms have helped in mechanization and rapid development of the textile industry.

2.3 The description of the conventional broadloom

Adu-Akwaboa (1989) described the broadloom as a foot-powered loom, in other words it is normally operated manually. In comparing the broadloom to the square frame loom, they have similar parts making up the structure of the loom but differ in mechanism. In describing the structure, he stated that, it consists of four upright and corner posts and these are held together by four cross beams. The two front corner posts are held together at the top by the breast beam which is horizontally placed in front of the weaver and at the bottom of the floor beam. In the front of the breast beam is a slate inserted to prevent the woven cloth from friction. He added that there are two types of the broadloom. There is one with two sets of lams and the other with one set of lams. The lams help to connect the treadle to the shaft or the heddle frame. A treadle helps to open the shed when it is depressed. The broadloom as compared to the indigenous handloom has a number of parts attached to it but the basic mechanism of operation, thus, the primary motions are basically the same. The additional function of the broadloom would probably be the weaving of wider width which the Indigenous or the Kente loom is not capable of weaving but weaves in strips or narrow widths. This research seeks to combine these good qualities of both the indigenous loom and broadloom.

2.4 Weave structures and their significance to the strength of fabrics

Adu-Akwaboa (1989) explained that there are many weaves and fabrics and many of these attained their names either through how it was interlaced or from the originator of the design or weave. According to Wynne (1997), a weave is defined as 'the order of interlacing of warp ends and weft picks', she added that the strength of most woven fabrics are influenced by the way and manner they are interlace. There are four basic weaves; plain, twill, satin and sateen weaves. There are many other weaves in addition to the basic weaves. The huckaback is based on a plain weave, with an introduction of long floats to give good moisture absorbency. The Mock Leno is a fabric produced with holes to imitate an open gauze or net. The Brighton Honey Comb has one textured side, whereas ordinary honey comb has a similar textured effect on both sides. Crepe weave give a textured surface in a similar way to the plain weave fabric produced with crepe yarns. Bedford cord gives a fabric with a raised longitudinal warp-way lines. Compound weaves are weave structures which consist of two or more warp sheets and weft threads. These weaves have varying floats from supplementary warp yarns. This makes it more decorative, absorbent, strong and quite heavy. Bowdich (1979) also outlined some design techniques employed by the Asante and Ewe weavers. According to him, the most commonly seen design in Asante Kente is produced by combining two distinct decorative techniques. First, the introduction of supplementary weft float into the

ground weaves. The addition of extra weft threads to the weave does not form part of the basic structure of the cloth instead they float across sections of the ground weave appearing on one face of the cloth over six or eight warps then crossing through the warp to the back, floating there, then returning again to the face. Rows of the weft float are arranged to form design such as triangles, wedge and hour glass shapes. The second technique is to create solid blocks of coloured threads across the cloth strip entirely concealing the warp whilst the main design feature of Ewe Kente is the symmetrically arranged blocks of weft float designs and weft-faced stripes across the strips.

3.The design process

The design process as cited by Badoe (2014) in Wikipedia the free Encyclopedia is the creation of a plan or convention for the construction of an object or a system. In formal terms, design has been defined as a specification of an object, manifested by an agent, intended to accomplish goals, in a particular environment, using a set of primitive components, satisfying a set of requirements, subject to constraints.

3.1 Design and construction of the loom

The design of the loom has the same basic structure as the conventional broadloom. The redesigning and construction of the improved broadloom considered the following areas:

- i. The cloth take- up (cloth roller)
- ii. The dual warp let- off
- iii. The auxiliary heddle shaft
- iv. A spring- based race board

The main structure of the loom composed of four (4) upright (corner) posts which measures 3cm x 8cm x 88cm each. These posts form the main frame on which other components are connected. Tenon and mortise joints (Fig.1), were used to fix these beams to the four upright posts.

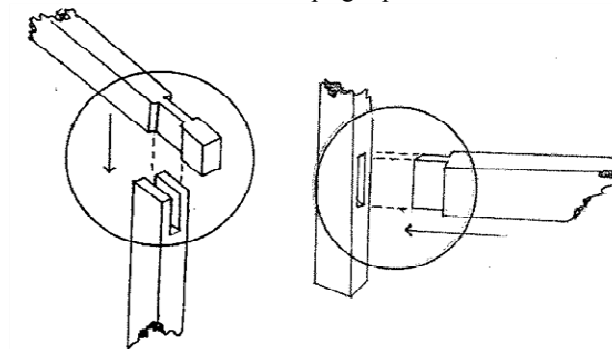
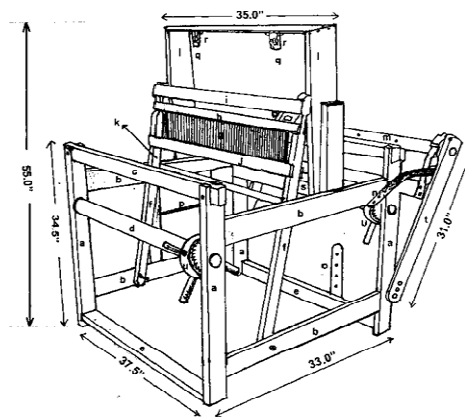


Fig. 1: Tenon and mortise joints

Built on the upper part of these cross-beams (Fig. 2(b)) is “the box” (Fig. 2(i)) into which the horses (Fig. 2(q)) and the spring (Fig. 2(r)) for both the main and the supporting shaft are housed respectively. There is also a breast beam (Fig. 2(c)) fixed onto the front corner post, and both front and back corner posts are held together by a floor beam (Fig. 2(e)).



- | | |
|---------------------------|--|
| a. Upright (corner) posts | l. Vertical beam |
| b. Side (cross) beams | m. Supplementary warp beam |
| c. Breast beam | n. Angular bracket (arc) |
| d. Cloth roller | o. Position of treadles |
| e. Floor beams | p. Position of lams |
| f. Sley | q. Horses |
| g. Reed | r. Spring for supplementary |
| h. Reed cap | snatt |
| i. Reed handle | s. Main warp beam |
| j. Race-board | t. Slanted post |
| k. Position of spring | u. Wooden handle - with ratchet & pawl |

Fig. 2: A three dimensional view of the loom and names of the various parts

The main frame of the loom consists of four (4) strong front and back corner upright post, Fig. 3. Both the cloth roller and the main warp roller are housed in these posts. Connective view of the main structure is shown below:

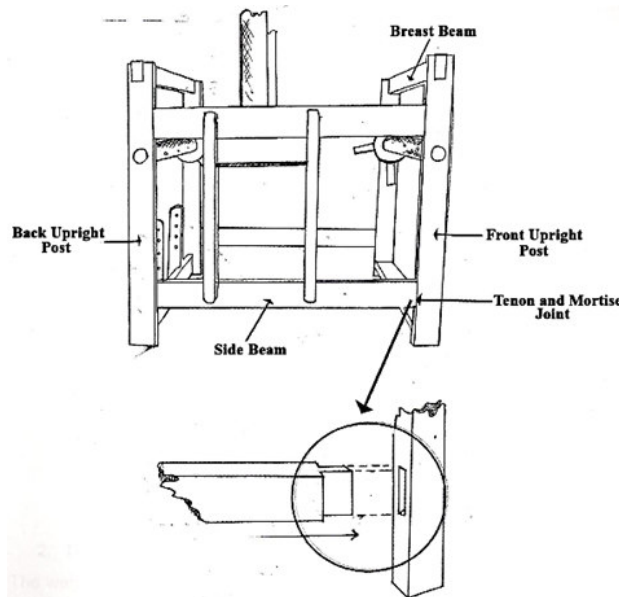


Fig. 3: A perspective view of the main frame of the loom

3.1.1 The cloth take-up (cloth roller)

The cloth take-up roller measures 33 inches in length and 8.5 inches as the circumference. At the right side of the roller is attached a ratchet wheel and pawl (Fig. 4) made of metal and a wooden handle. The cloth roller is positioned at a distance of 24 inches between the two upright pots.

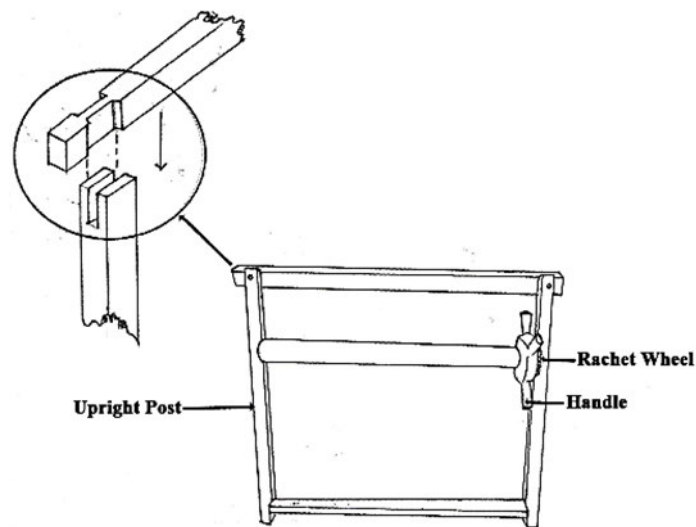


Fig. 4: The cloth beam fixed between the front upright posts

3.1.2 The dual purpose warp let-off motion

There are two warp beams; the main warp beam and a supplementary warp beam (Fig. 5 (A & B)). The exact position of the main roller is between the two back upright posts. The supplementary warp beam on the other hand is separated from the main frame of the loom with an adjustable angular bar. The supplementary warp beam is housed in a slot which allows easy removal and re-fixing when necessary (insert (Fig. 5)).

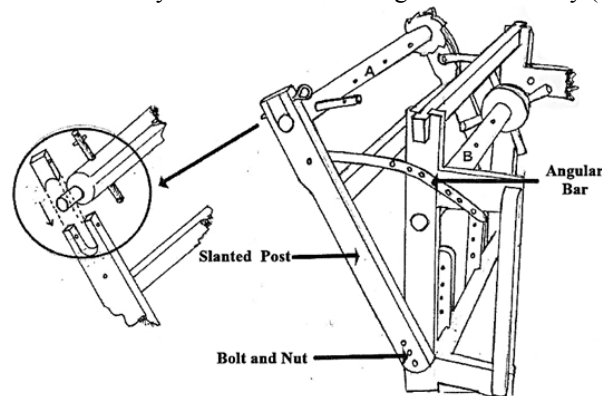


Fig. 5: The diagram shows the two warp beams (A and B)

A: Supplementary warp roller B: Main warp roller

3.1.3 The auxiliary shaft supported by spring mechanism

The supplementary shaft supported by a spring carries a large number of healds (650) which is made of metal. This supplementary shaft (Fig. 6) is important in order to accommodate the warp ends of the supplementary warp beam. When the appropriate treadle is depressed, the spring stretches and allows for creation of shed. On release, it comes back to its original position as quickly as possible.

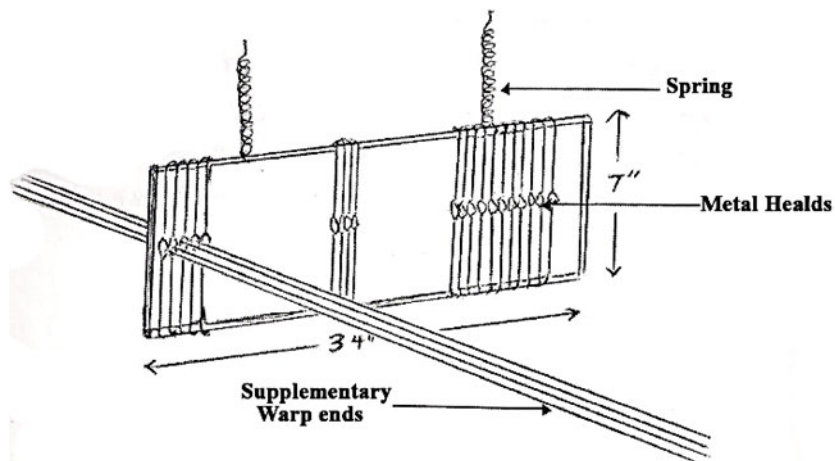


Fig. 6: The supplementary shaft with some warp ends

Fig. 7: shows a wooden frame in which the shafts are connected (or housed). "The Box" measures 35x 5x 29.5 inches.

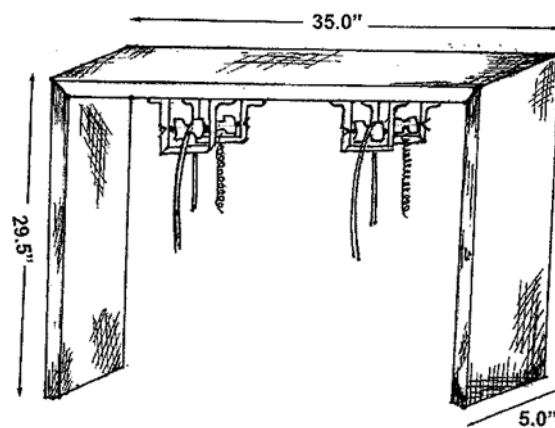


Fig. 7: "The Box"

3.1.4 A spring-based race board

The sley which contains the reed is located inside the loom and is fixed with bolt and nut at the base of the connecting side posts. The reed is housed in a groove in the race-board (Fig. 7). The race-board is spring loaded (see insert, Fig. 8) at the extreme ends along the side of the sley, this allows for free up and down movement of the race-board when a warp sheet is depressed during weaving.

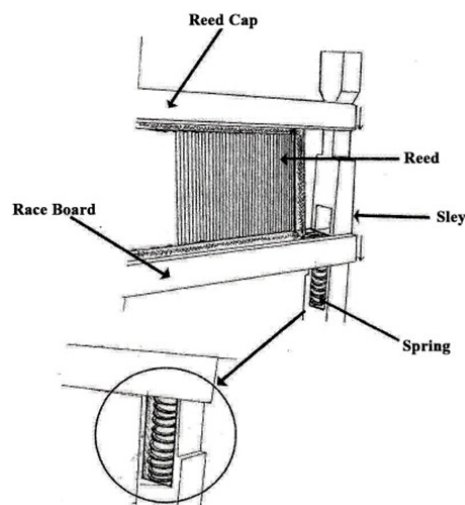


Fig. 8: The reed and the spring – based race board

The reed cap (Fig. 8) which is grooved to house the top of the reed; is not permanently fixed to the sley, but moves with the reed and the race-board when a warp sheet is depressed. The tension in the depressed warp sheet

causes the up and down movement of the reed cap, the reed and the race-board. In addition to all these is a reed handle, permanently fixed to the top of the sley. This helps to facilitate the beat up action of the reed and the efficiency of the sley. All these are called “the race case”.

4. Analysis and interpretation of results

To test the loom, two warp beams were prepared; the main (ground) warp (black 20ends, white 20ends) and the supplementary warp (white 20ends, black 20 ends) alternating in this order. The number of ends for both the main warp and the supplementary warp in a unit repeat is 80. The total repeat pattern across the width of the fabric is 11 and the total number of ends used is 880. The reed number used is 30s. The total number of warp yarns on the main shafts was 440 and the same number (440 ends) was on the supplementary shaft. The warp pattern was designed in order to obtain a giant plaid compound weave in black and white. The effect is achieved by healding the white warp yarns on the supplementary shaft warp sheet and the black ground warps on the main four shafts.

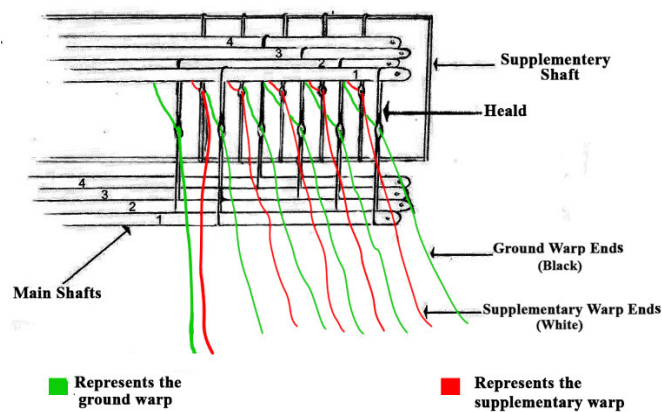


Fig. 9: shows the healding of the main warp alternated with the supplementary warp

It is important to note that healding order for the ground warp yarns is straight draft (1, 2, 3, 4), each end of the main warp is alternated by a supplementary warp end. During this process, the weaver must ensure to leave one heald of the supplementary shaft in between every end of the ground warp. The denting process was also accomplished by combining, one ground warp and one supplementary warp into the dents of the reed.

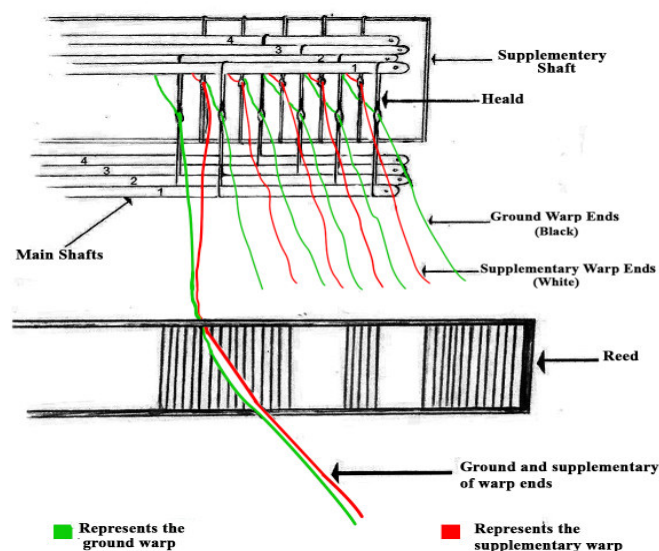


Fig. 10: The denting plan

Another interesting aspect of this loom is the tie-up of the shafts to the treadles which play a significant role in achieving the weave structure. The tie-up is as follows:

- Treadle 1 Shafts 1 and 3
- Treadle 2 Shafts 2 and 4
- Treadle 3 Shafts 1, 3 and 5

- Treadle 4 Shafts 2, 4 and 5

As indicated in the tie-up plan, the treadles 3 and 4 are used when the supplementary warp is to be lowered with the other two shafts of the main warp whilst treadles 1 and 2 are used for lowering and lifting of the ground warp sheet. In this case, the supplementary warp lies in the middle of the shed which enables the shuttle to traverse through the lower shed.

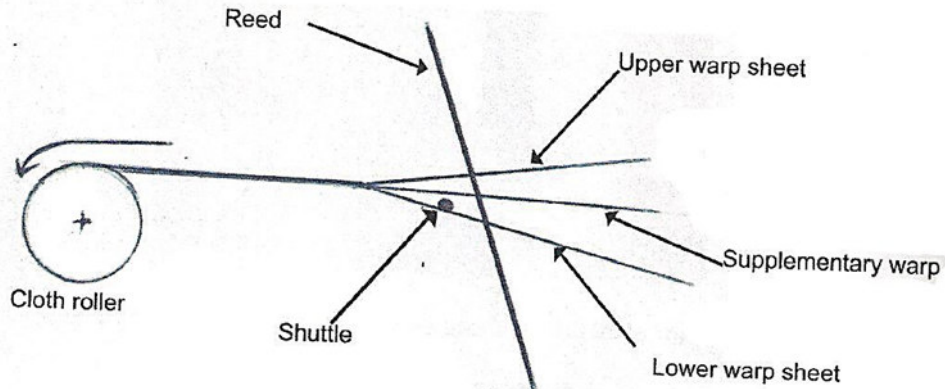


Fig. 11: A schematic drawing showing the traverse of the shuttle through the lower shed

It is also important to note that, treadles 1 and 2 are used for weft insertion at the lower shed whilst treadle 3 and 4 are used for weft insertion at the upper shed. In all, there are six treadles located beneath the loom. The first two is use for plain weaves (also for binding floats) and the remaining four for design weaves.



Plate 1: The main structure of the loom with 5 lams and 6 treadles
Size: 55" high x 67" wide

After the milling process, the warps were raddled in order to set it to the required width. The plate below shows the tensioned warp fixed to the beaming box after raddling. The warp is divided into two for easy handling during the beaming process.

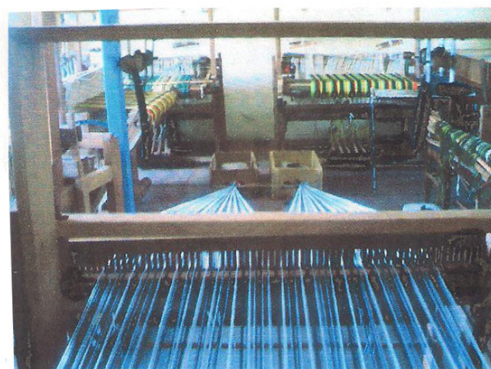


Plate 2: Tensioning and beaming after raddling

The heddling process was carried out after raddling. Heddling is passing the individual warp ends through

the eyes of the healds. The heddling was done according to the planned heddling order (1, 2, 3, 4).



Plate 3: Heddling of the supplementary warp ends

NB: the ground (main) warp is tensioned

The next process involves the passing of individual warp ends through the dents of the reed (reeding). Here, yarns from both the ground warp and the supplementary warp were 'rendered' together. The plate below indicates a reed hook receiving the yarns from both warps.



Plate 4: Reed hook receiving a warp end during reeding

The warp is then tensioned by tying them onto the apron stick in smaller units.



Plate 5: Tying up the warp ends (from both beams) to the apron stick

Overall tensioning of the tied warp yarns was then carried out. Plate 6 indicates a three-quarter view of the tensioned warp sheet.



Plate 6: Tensioning after tie-up

The back section of the loom indicating the position of the two warp beams. These beams have been tensioned separately for smooth weaving process. The supplementary shaft can also be seen just before the main shaft.

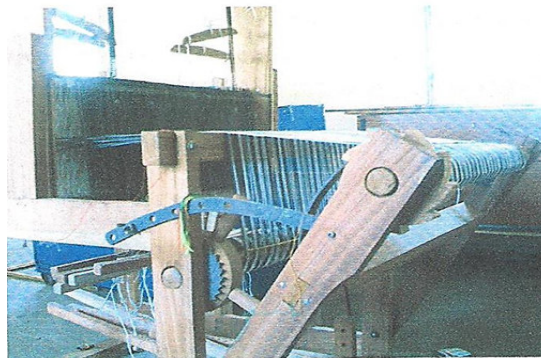


Plate 7: Side view of the loom showing the two warp beams after tensioning

NB: Main warp beneath, supplementary warp on top

One of the most important aspects of the weaving process during the test weave was the tie-up. The image in Plate 8 shows how the lams are connected to the treadles. Care was taken to do this connection, since most weave structures are highly influenced by the way the tie-up is done.

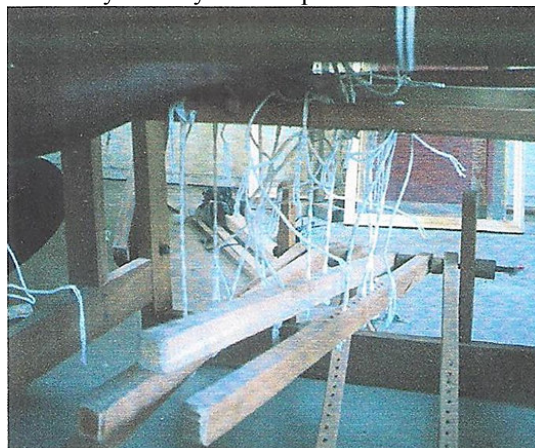


Plate 8: Tying the treadles to the appropriate lams and with the corresponding shaft.

After a critical examination of the necessary adjustments and other connections, the weaving was then carried out. Care was taken not to break any warp yarn since this impedes weaving.

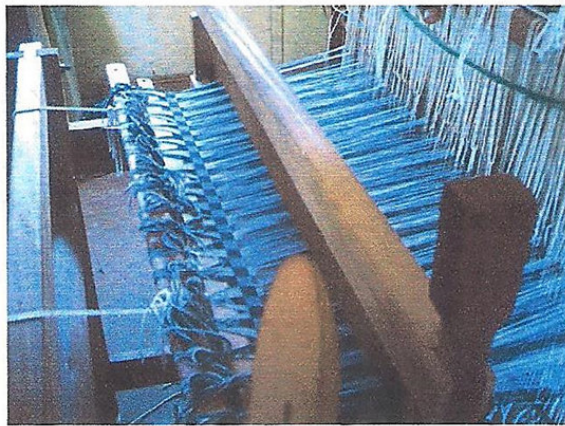


Plate 9: First phase of the weaving process

Plate 10 and 11 give vivid picture of how the test weave was carried out. The white areas seen in the structure are alternated by black yarns beneath. Viewing the weave at an angle can be seen in plate 10 whereas Plate 11 indicates the full structure of the weave.



Plate 10: Side view of the test weaves



Plate 11: The weave structure (compound weave)

5. Evaluation of the loom

The loom is made up of four sections; a dual warp let-off (two warp beams – main warp beam and a

supplementary warp beam), the fabric take-up (cloth roller), supplementary shaft connected with spring and a spring based race-board. Red wood (*Odum*) was used in construction of the loom. This is so because, research has shown that the species from which this wood comes from is strong and durable and can withstand stresses and strains impose on it. The other materials used were also appropriate looking at the functionality of the loom. Furthermore, it should be noted that strict adherence to the mode of operation of the loom is very essential for excellent results. Since this goes a long way to influence the type of weaves to be produced. What makes this loom special is the incorporation of the supplementary shaft connected with spring and the spring-based race board.

One important advantage that can be derived from the use of this loom is its versatility i.e. its ability to weave plain, twill, satin/sateen and other complicated (double-faced) weave structures. The test weave shows that the improved broadloom can conveniently weave compound structures with a wider width.

6. Conclusion and Recommendations

In conclusion it was noted that, the improved broadloom can serve dual purposes – weaving of compound structures (plain and twill) and other basic weaves i.e. plain weave, twill weaves and their variations. The use of supplementary shaft for additional warp ends makes it possible for weaving a heavier plain and twill weave fabrics. The important aspect of weaving compound weave structures on this loom is the double sheds so; the sheds must be created properly before picking. For satisfactory and effective weaving the researchers recommend the following:

- i. Healding and tie-up should be done carefully with the appropriate adjustments of the connections to obtain a correct weave structure.
- ii. Dual shedding is very necessary in compound weaving. Therefore, the upper/ lower sheds should open fully before the traverse of the shuttle.
- iii. Strong and durable cords should be used for both the healds and tie-up to avoid breakages during weaving.

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