Chapter 3

EXPERIMENTAL WORK

3.1 Aim of work

Seamless 3D shapes woven directly on loom offer distinct advantages over those produced by making up or thermal moulding. For producing 3D shapes directly on loom, initial development consisted of weaving 3D shape in folded form on a shuttle loom with progressive elimination of ends. However cutting of eliminated ends becomes necessary in this method. Some irregularity is produced in structure where ends are eliminated.

Subsequently a rapier weaving machine was developed that can produce desired seamless 3D shape directly without any need for elimination of ends. This technology of weaving is quite different from 2D weaving and asks for radical changes in many elements of loom. This would also demand higher capital cost of equipment. Rapier method of weft insertion does not lay weft continuously like shuttle weaving. Therefore seamless uniform tubular structure cannot be woven.

Keeping this in mind the present work was initiated. The main aim was to bring about ***modifications on a power loom to weave some shapes so that basic concept of 3D shape weaving on shuttle loom is established.*** Attempt would be made to enable weaving of 3D shapes at reduced equipment cost.

The work would principally involve the following:

i. *Study of geometry* of some basic 3D shapes.
ii. Focus attention on how ***individual ends and picks would lie*** in shaped regions.
iii. ***Work out necessary modifications/ changes*** in weaving elements so that desired 3D shape can be woven.
iv. *Implement these modifications* first on handloom.
v. Based on handloom weaving experience, ***evolve feasible technique of 3D shape weaving*** for power loom.
vi. ***Procurement of suitable power loom*** with necessary accessories.
vii. ***Design various modifications/ changes*** in various elements/ mechanisms on power loom for 3D shape weaving.
viii. ***Fabrication*** of above mentioned elements/ mechanisms.
ix. ***Weaving 3D woven shapes*** with these modified elements/ mechanisms.

The total work has progressed witnessing several stages of development.

3.1.2 Progress of the work towards aim:

Various stages of development towards achieving aim are as follows.

(a) Producing woven hemispherical shape ***manually***.

(b) ***Study*** of this shape woven fabric and ***work out possible methods of weaving*** this on a hand loom.

(c) ***Producing*** 3D shapes on ***hand loom***. Various stages of development were as follows:

   i. Produce a hemisphere on handloom using ***shaped rods***. 3D shape could not be woven with this method but it inspired subsequent development.

   ii. Weave ***pyramidal*** and ***hemispherical*** shapes successfully using ***shaped slotted fins***. This was first success in weaving 3D shapes. However this method is not suitable for adopting on a power loom. Study of this method and 3D woven shapes gave an impetus for further development. The technique of 3D shape weaving using ***reed with shaped dent wires*** was evolved.

   iii. Weaving pyramidal and hemispherical shapes using ***reed with shaped dent wires***. 3D shape is woven in ***folded form*** in this technique. Reed is required to be displaced vertically on successive picks during weaving of shape. A pyramidal shape was woven with ***assistance of weave*** in shape development. This method was found suitable for application on a power loom.

Thus weaving on hand loom evolved technique of ***weaving 3D shapes in folded form using reed with shaped dent wires and weave assistance*** which was to be applied for power loom.

(d) A ***mathematical tool*** was developed for designing curve shapes for reed dent wires for weaving pyramidal and hemispherical shapes of given dimensions. It became possible to obtain print outs on computer for reed dent curve shapes from which helped in fabricating reeds.

(e) To ***implement*** technique of weaving 3D shapes using ***reed with shaped dent wires*** and ***weave assistance,*** it was necessary to work out details with regard to selection of a suitable power loom as well as selection/ designing and fabrication of various accessories, attachments, and modifications required. After giving a detailed thinking on various aspects, actual implementation was begun.

(f) A ***20 inch reed width power loom*** was procured and subsequent developmental stages were as follows.

i. A ***warp feeding creel*** of 800 ends capacity was designed and fabricated.

ii. Method of ***fabricating reed*** with shaped dent wires was developed. ***Brackets for mounting and supporting reed*** on sley, were designed, developed and fabricated.

iii. As an initial trial, a ***pyramidal shape was woven on power loom*** with dobby shedding and a mechanical arrangement for reed position control. ***Fell control mechanism with combs*** was designed, developed and fabricated. This trial revealed that method of weaving 3D shapes using reed with shaped dent wires works on a power loom. Subsequently a better mechanism for reed position control was to be developed and jacquard shedding was to be employed for getting assistance of weave in generating shape.

iv. A ***double lift double cylinder jacquard*** was procured for shedding. As conditions of weaving are quite different in 3D shape weaving, some hurdles were to be overcome in employing jacquard shedding.

v. A ***PLC stepper motor drive*** was designed and developed for reed position control. Suitable mechanical means was developed to transmit drive from stepper motor to reed. Subsequently a ***man machine interface*** that enabled reed position control through a ***computer*** was designed and developed.

vi. ***Weaving of a pyramidal*** shape was begun.

vii. A fell ***control mechanism with spiked rollers*** was designed and developed for better fabric control at fell.

viii. A ***jacquard design*** that would assist in developing 3D shape was ***developed.***

ix. Suitable solutions were sought for various problems faced during weaving and some modifications were employed wherever necessary.

x. ***A pyramidal shape*** was woven.

3.2 Producing 3D woven shape manually:

At preliminary level it was necessary to understand basic structure of a 3D shape woven fabric. So firstly it was thought to weave a 3D shape by manual means. For this purpose, a half cut rubber ball was taken which shaped a hemisphere. This was fixed on a board. Series of warp threads were laid manually over this ball and their position was maintained using pins. Weft threads were laid manually through this warp (Figure – 3.1). Thus a 3D hemisphere was woven manually.

3.2.1 Outcome of weaving 3D shape manually:

i A 3D hemispherical woven shape was produced.

ii Careful observation and analysis of the same inspired further work.

In next phase suitable method of producing 3D woven shapes on a handloom were to be evolved.

3.3. Producing 3D shape on handloom:

3.3.1 Producing 3D shape using shaped rods:

In first method, several specially **shaped rods** were taken. These rods were fixed on a wooden frame of handloom at front end (Figure – 3.2). The shaped portions of these rods together formed a hemisphere. These rods were passed through reed dents. Shed was formed by heald shafts. It was thought that on continuing weaving with this set up, the fabric would follow the shape of rod and hemisphere would be woven.

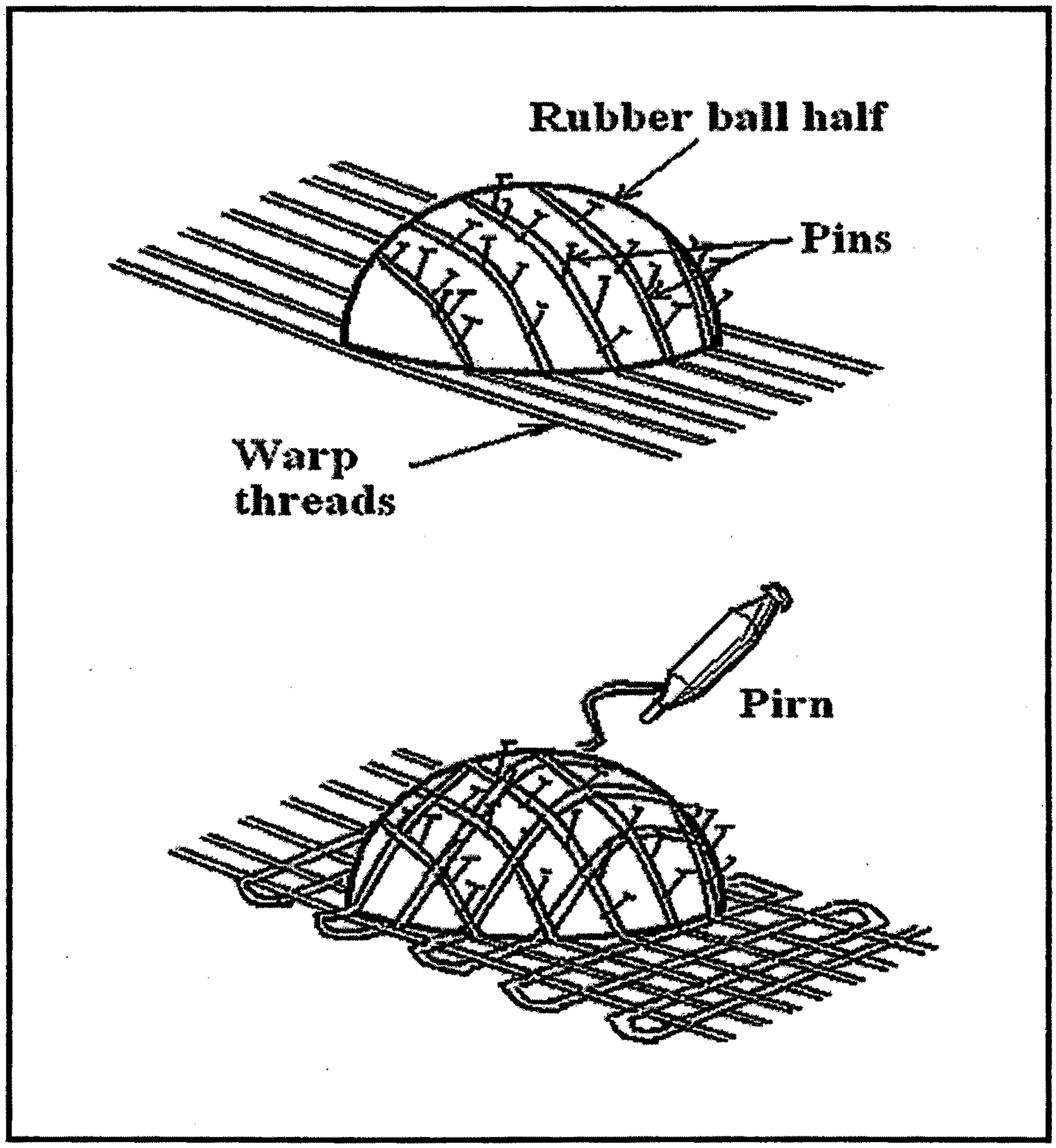


Figure 3.1

Weaving a hemisphere manually

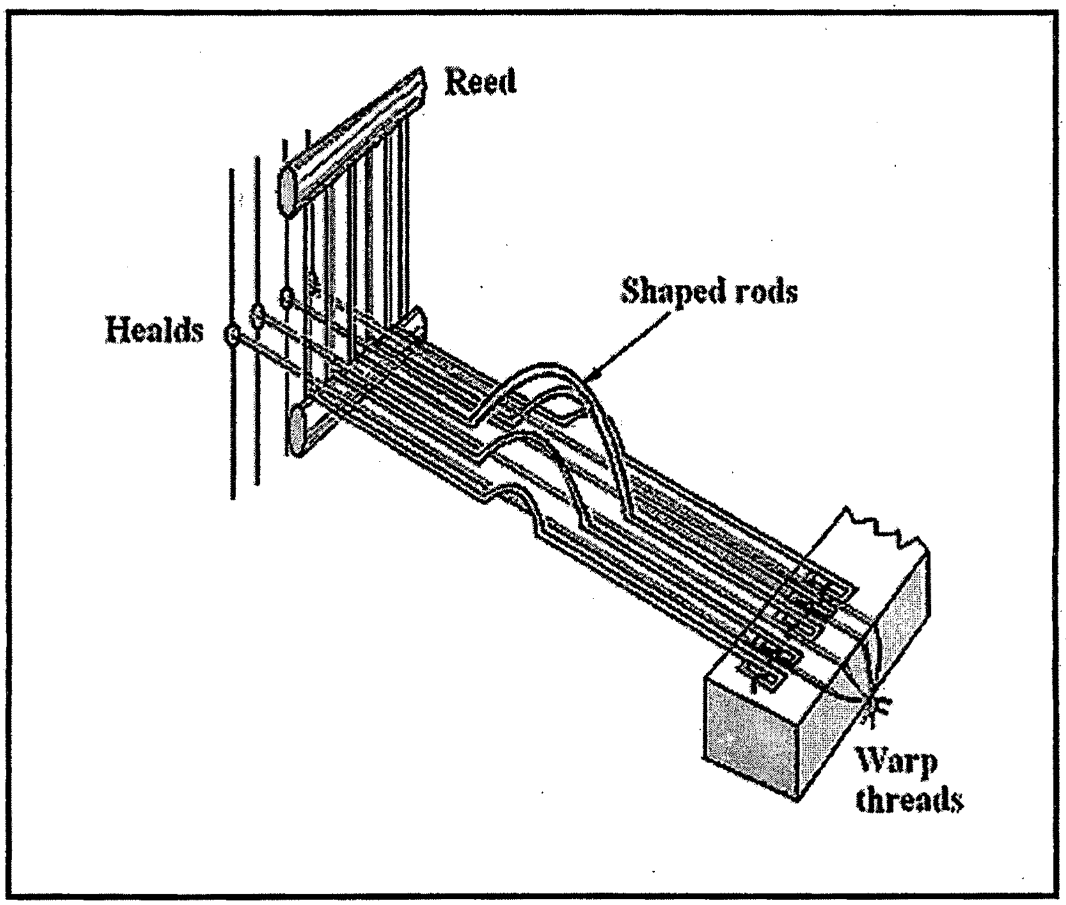


Figure 3.2

Weaving a hemisphere on handloom with shaped rods

3.3.1.2 Outcome of weaving with shaped rods:

i. It did not become possible to make fabric adhere to rods as weaving progressed due to warp tension. So 3D shape could not be woven.

ii. Although it was not possible to produce a 3D woven shape using this method, it was realized that this principle could produce desired 3D shape with further modification.

iii. It **inspired subsequent method** of producing 3D shapes using shaped fins.

3.3.2 Producing 3D shapes using shaped fins:

In next method, instead of rods specially slotted fins were used. The slots in fins together formed a sort of ***'mould'*** in which fabric was confined to weave. Shapes of slots were like vertical sections of 3D shape taken along warp direction (Figure 3.3). Length of each warp in shape portion is not same. So long warp length was taken and dead weight was put on each warp at rear end. So uniform warp tension was maintained and required warp length was delivered for weaving. Pyramidal and hemispherical shapes were woven on handloom with this technique (Photo 3.1).

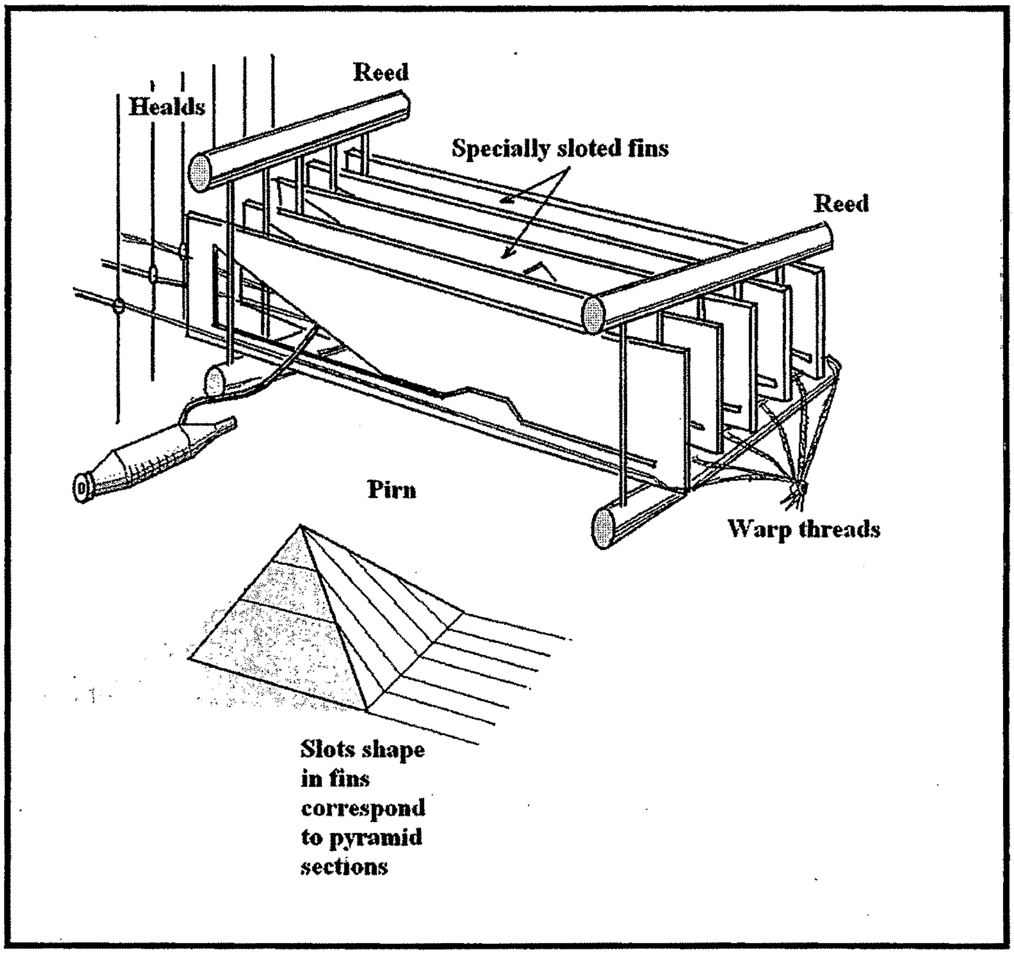
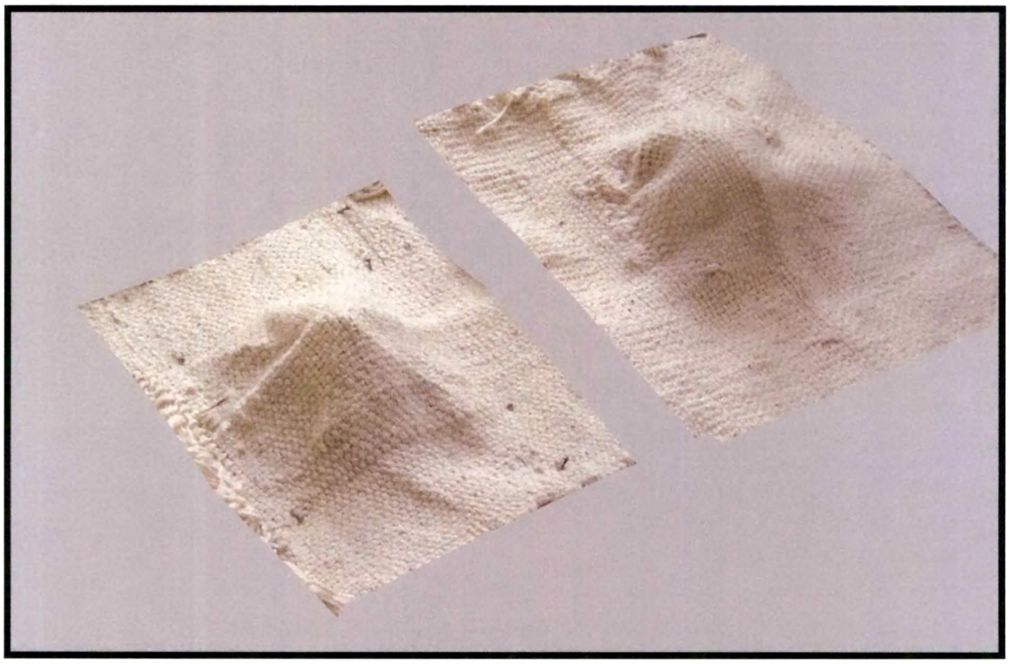


Figure 3.3

Weaving a pyramidal shape using shaped slotted fins



Photograph – 3.1

Photograph of pyramidal and hemispherical shapes woven using shaped slotted fins

3.3.2.1 Outcome of weaving with shaped slotted fins:

i. This was the ***first successful attempt*** of weaving 3D shapes on handloom that produced pyramidal and hemispherical shapes.

ii. This method was not suitable for a power loom because presence of fins would obstruct insertion of shuttle. Also beating of weft becomes difficult.

iii. Although this method is not suitable for adopting on a power loom, it became possible to understand 3D shape weaving further and enabled thinking in diverse directions for further progress.

3.3.3 Observations from weaving 3D shapes on handloom:

Weaving of 3D shapes on hand loom revealed the following:

i. Woven fabric is formed by interlacement between warp and weft. In a 2D fabric, the distance between consecutive ands and picks mostly remains the same. If we define a 'unit cell' as area between consecutive ends and picks, it is found to be more or less the same through out 2D fabric [Figure 3.4(a)]. Total number of cells in a fabric equals to $(E1-1)\times(P2-1)$, where E1 and P2 are respectively total ends and picks in the fabric.

ii. In a 3D fabric, the size of cells throughout shape portion does not remain same but varies depending upon shape [Figure 3.4(b)]. The space between consecutive ends and picks vary in shape portion, depending upon shape profile.

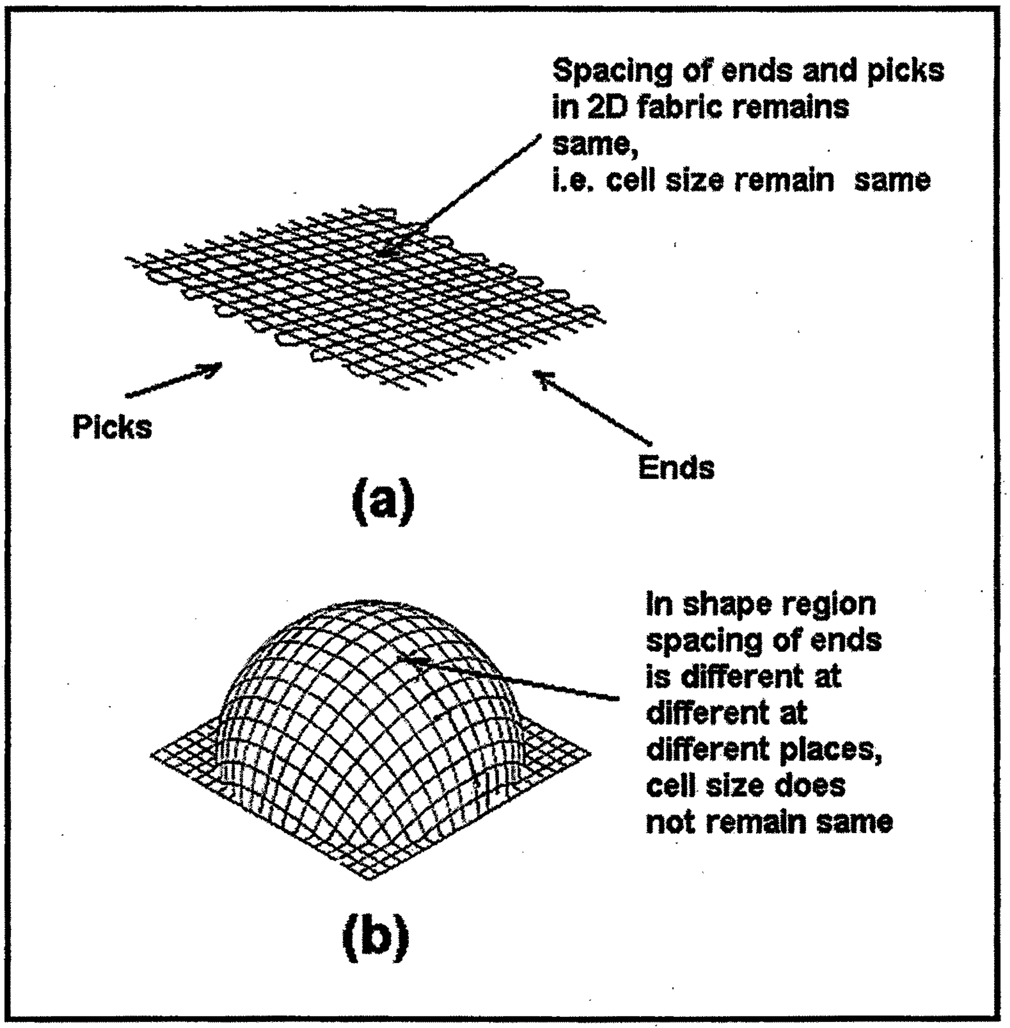

Spacing of ends and picks
in 2D fabric remains
same,
i.e. cell size remain same
Picks
Ends
(a)
In shape region
spacing of ends
is different at
different at
different places,
cell size does
not remain same
(b)

Figure 3. 4

iii. Therefore, to weave a required 3D shape, situation should be created in weaving in such a way that space between successive ends and picks is made to vary during weaving so that required shape is formed.

iv. So, in 3D weaving, the weaving process should be modified in such a way that space between successive ends and picks is varied depending upon shape to be produced.

v. Looking from other angle, it can be seen that in a 2D fabric all cross over points practically lie in same plane where as in 3D shape the cross over points lie in different planes depending upon shape profile. So desired 3D shape can be produced by modifying weaving process in such a way that the plane of cross over points is shifted across the width fabric as well as along the length, depending upon shape profile.

vi. However, method of weaving 3D shape by modifying weaving process that brings about change in spaces between successive ends and picks appeared to be more adoptable. Hence, subsequent job was to concentrate on all factors that influence space between successive ends and picks.

3.3.4 Factors influencing space between successive ends and picks:

Following factors influence the space between successive ends and picks:

(a) Space between successive ends is influenced by:

i. Space between successive wires of reed.

ii. Interlacement between ends and picks

iii. Weft contraction

(b) Space between successive picks is influenced by:

i. Rate of take up
ii. Interlacement between ends and picks
iii. Warp contraction

Therefore to weave a desired seamless 3D shape, the weaving process should be modified in such a way that it employs some or all of above mentioned factors listed above to bring about change in spacing between successive ends and picks during weaving of shape.

3.3.4.1 Changing end spacing by reed:

In 2D weaving reed used has parallel dent wires with same pitch throughout. Pitch of reed decides space between successive dent wires. Therefore space between successive ends in 2D weaving remains constant in 2D weaving. In 3D shape woven fabric, space between successive ends changes on successive picks. So during shape weaving, reed should be designed in such a way that the space between successive wires of reed can be varied from pick to pick depending upon shape profile.

This can be principally done in following ways.

3.3.4.1.1 Reed with sliding dent wires:

In this method reed wires should not be fixed at both ends but should be capable of sliding so that distance between any two successive dent wires can be varied by displacing them side ways (Figure 3.5).

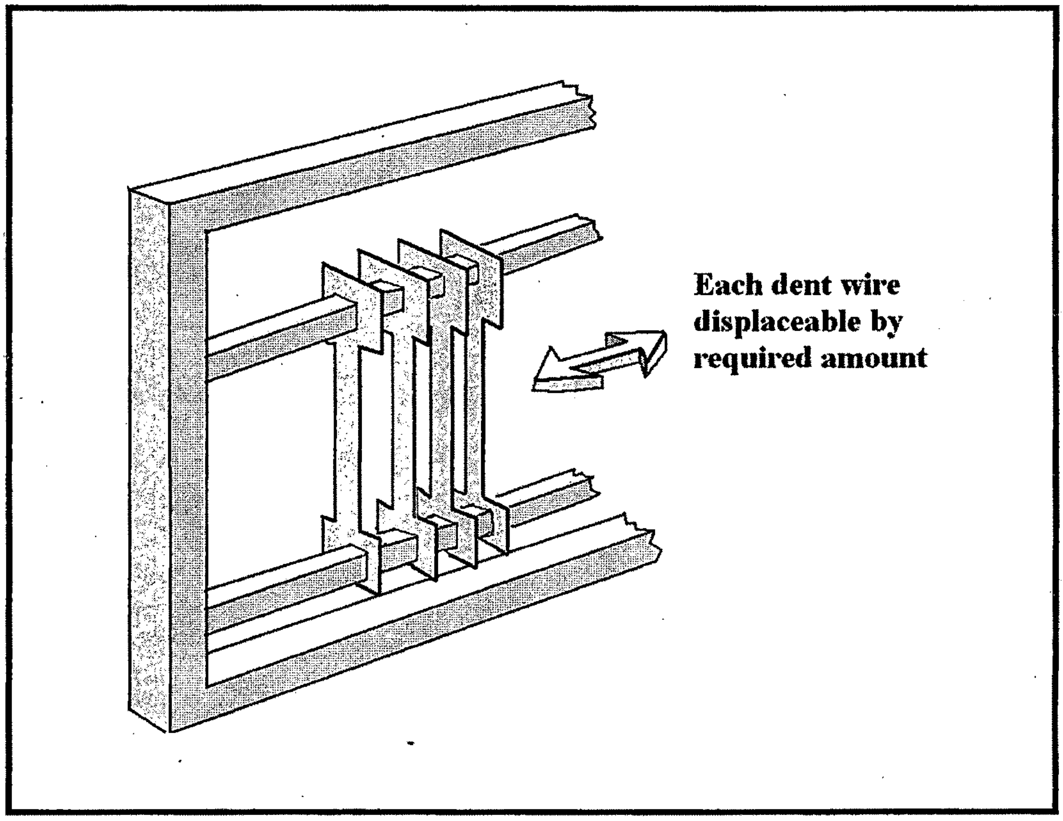


Figure 3.5

Reed with displaceable dent wires

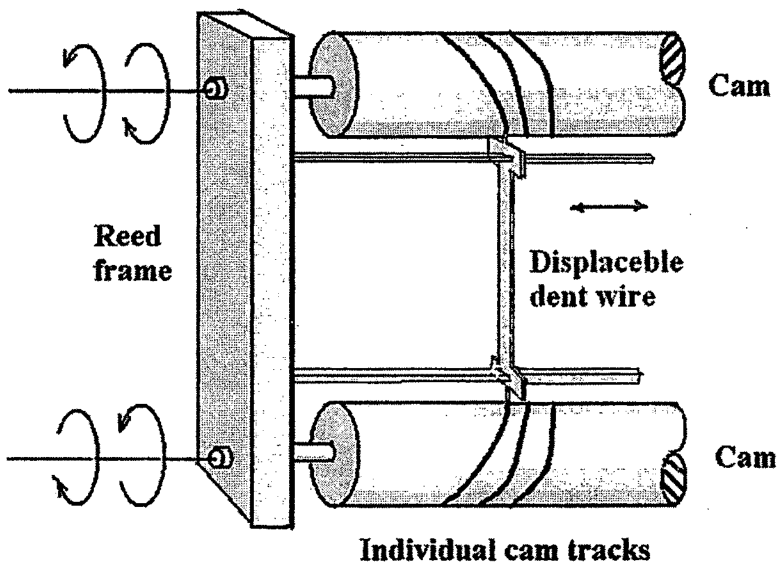


Figure 3.6

Reed with dent wires displaced by cam

Each dent wire of cam follow its individual track on a grooved cam. These cams should be designed and rotated during weaving to change their radial position in such a way that space between successive dent wires can be varied (Figure 3. 6). Design for such reed was prepared and was studied critically.

3.3.4.1.1.1 Outcome of effort of working on concept of developing reed with sliding dent wires:

i. This method seems ***less suitable*** as it would be difficult to maintain firmness of dent wires during beat up.
ii. Designing and fabricating cam with ***finer pitch*** would also be ***difficult***.
iii. Estimated fabrication ***cost was also exorbitant***.
iv. Due to reasons mentioned above, further work was not done on this concept.

3.3.4.1.2 Reed with shaped dent wires

Reed dent wires can be fixed at both ends, but each dent be shaped in such a way that the space between successive dent wires vary along reed height (Figure 3.7). If reed position were changed vertically on successive picks, line of beat would change which in turn would change the space between successive dent wires on successive picks. Designing and fabricating this reed is simpler compared to first method.

If an illustrative example of a pyramid is taken, it can be seen (Figure 3.8) that space between successive ends changes in shape portion. It should be noted that in 2D weaving, practically, all ends and picks are coplanar.

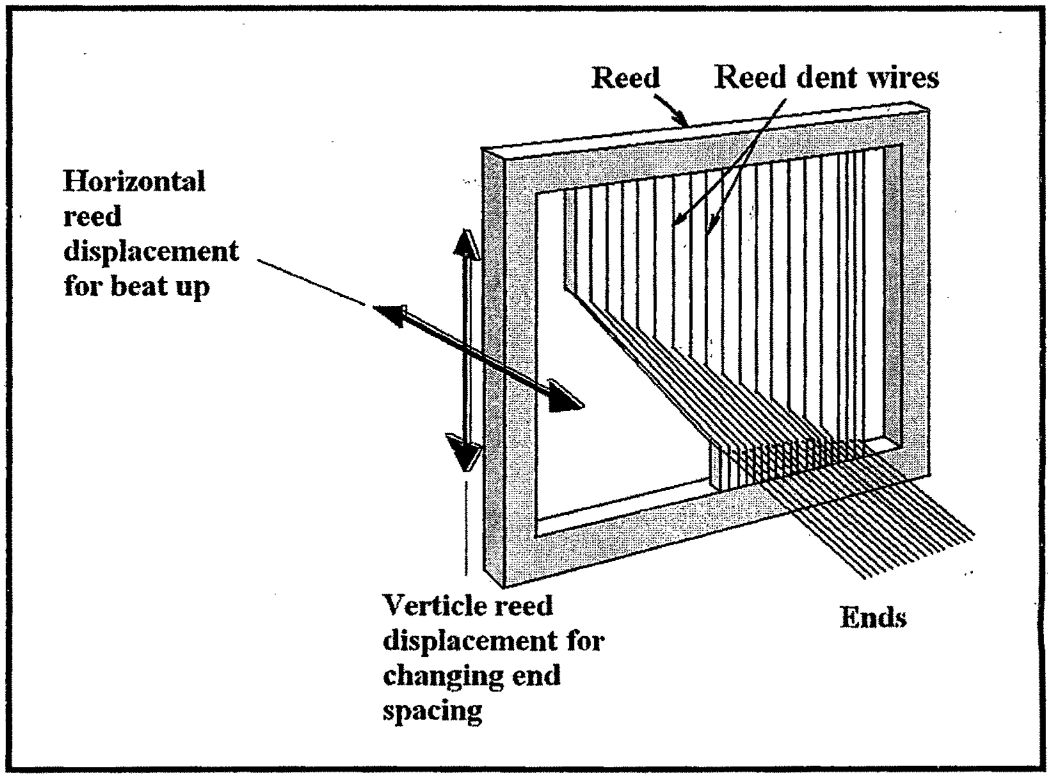


Figure 3.7

Reed with varying space between successive dent wires

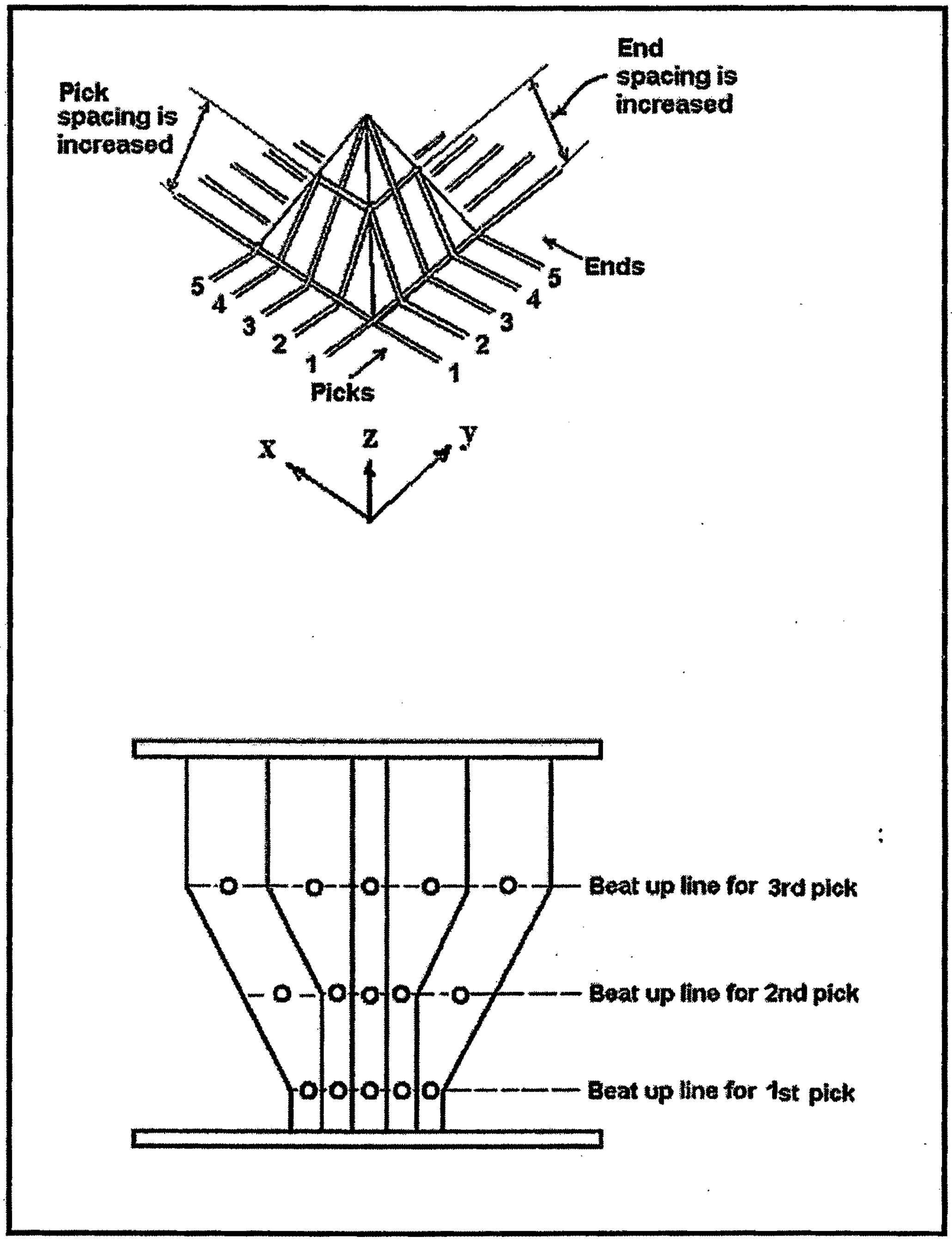

Pick
spacing is
increased
End
spacing is
increased
Ends
5
4
3
2
1
5
4
3
2
1
Picks
X
Z
Y
Beat up line for 3rd pick
Beat up line for 2nd pick
Beat up line for 1st pick

Figure – 3.8

A thread is not elevated in Z direction. But In 3D weaving, threads are elevated in Z direction. To elevate a thread in Z direction, it necessitates an increase in length of end and pick (Figure 3.8). So it can be said that in 3D shape weaving the contribution of length of each end and pick for a given length and width of fabric is not same. Widening of space between consecutive ends necessitates increase in pick length and vice versa.

As shown in Figure 3.8, a reed with shaped dent wires can be designed that would enable change in the space between successive ends as required for given pyramid. But it is very important to note that while weaving a 3D shape, e.g. a pyramid, cloth fell would not lie in straight line as it is in 2D weaving. Therefore controlling and maintaining fell position, with stresses during weaving, would be very difficult. So it would be more convenient to weave 3D shape in ***'folded'*** position (Figure 3.9). Thus weaving pyramid in folded fashion, i.e. in form of double cloth open at one end, seem more advantageous. On opening this pyramid would be formed.

3.3.4.1.2.1 Determining dent shapes for reed to produce a pyramidal shape:

A reed was designed for weaving a pyramid. Let 'a' be the base of the pyramid and 'h' be the height (Figure 3.10). This pyramid is symmetrical along warp as well as weft directions. Let n_1 and n_2 be ends/inch and picks/inch in ground (non-shape forming) region respectively. Therefore $1/n_1$ and $1/n_2$ become distance in inches between consecutive ends and picks respectively.

As this pyramid is symmetrical and is to be woven in folded fashion, reed needs to be designed for a quarter pyramid only.

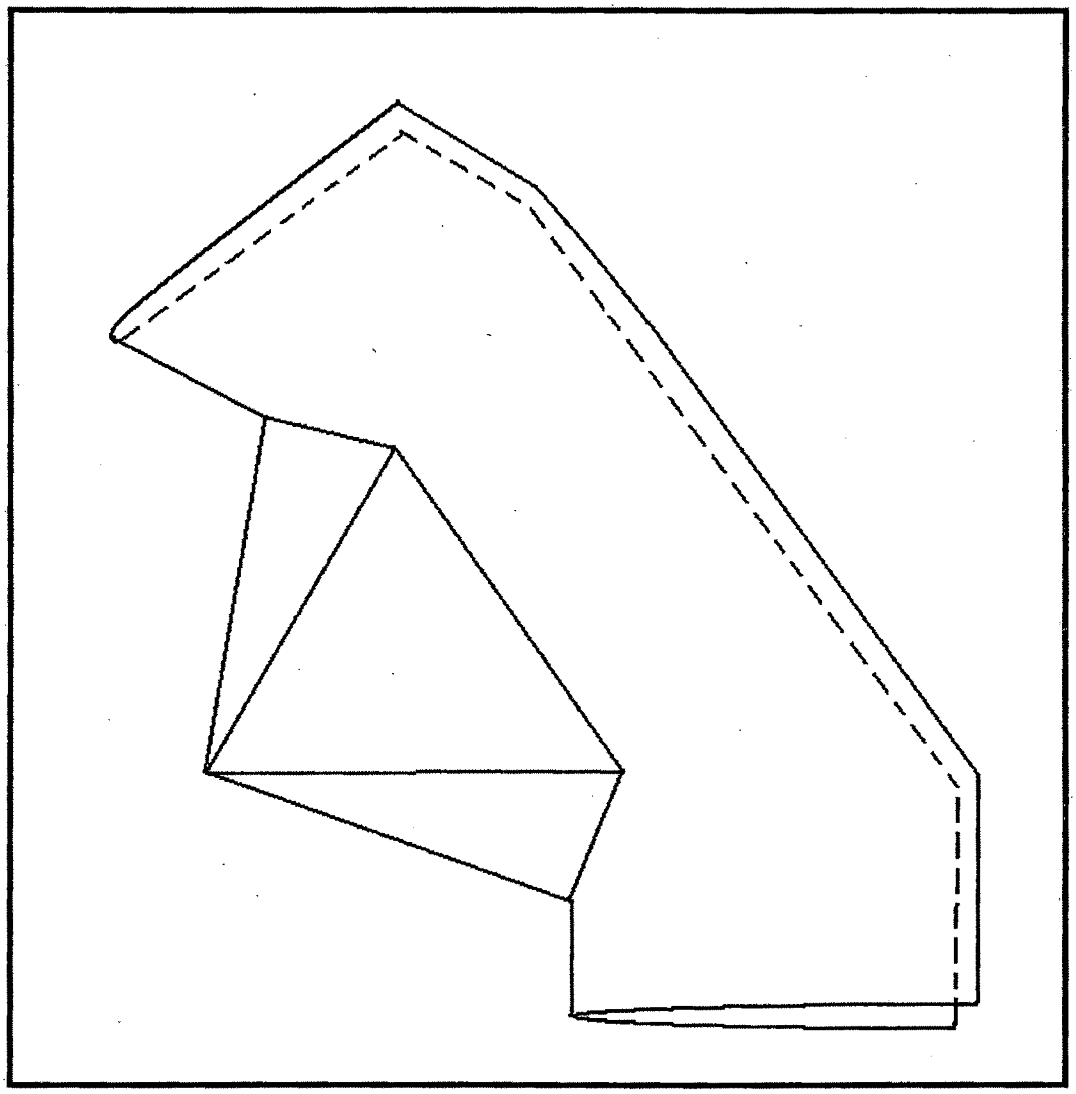


Figure 3.9

Weaving a 3D shape in folded form

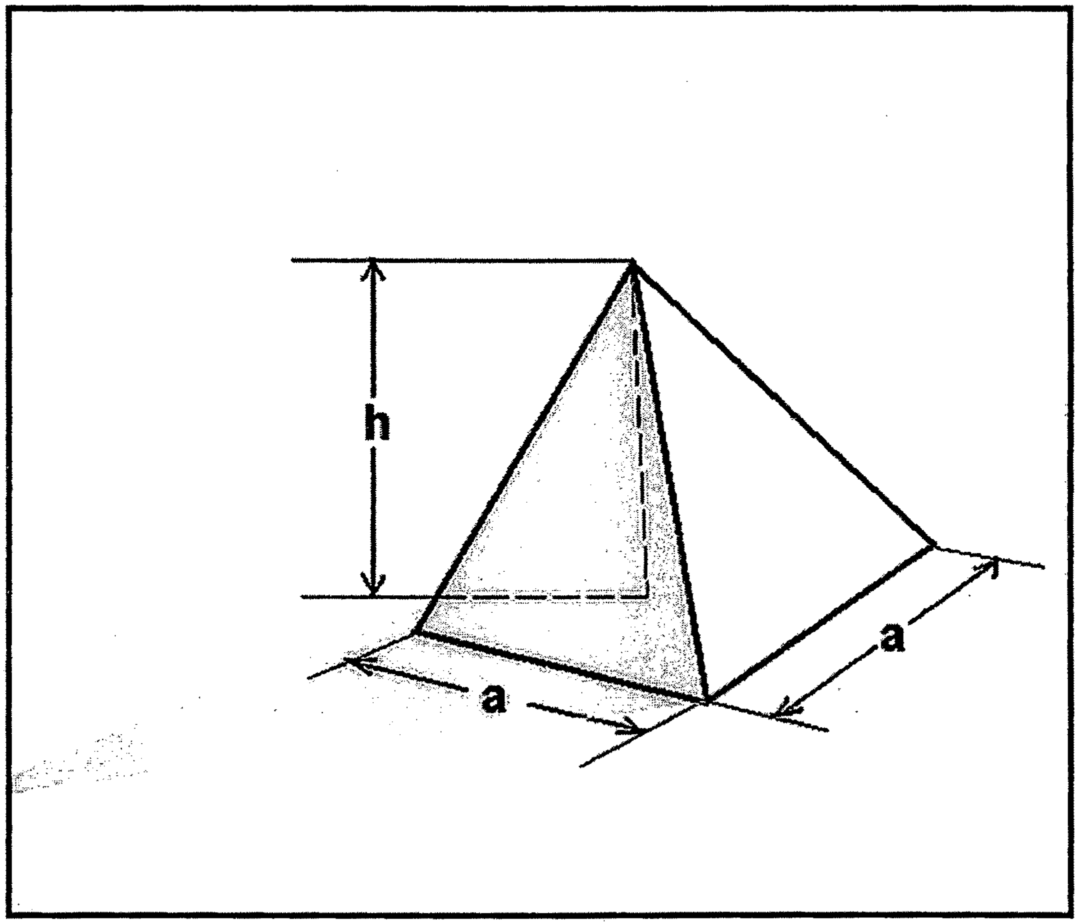


Figure 3.10

It can be seen in Figure 3.11 (a) and (b) that spacing of ends remains unchanged on face ABC. Beyond line AC, the ends space apart. Spacing between ends 1 and 2 remain unchanged till pick 1, whereas that of ends2 and 3 remain unchanged up to pick 2 and that of ends 3 and 4 up to pick 3 and so on.

Therefore reed design becomes as shown in Figure 3.11(c).

3.3.4.1.2.1.1 Weaving pyramidal shape using reed with shaped dent wires:

During weaving ground non-shape portion, beat up line should be at the bottom of reed where spacing is not widened. While weaving picks 2,3,4 …., the beat up line should be changed as indicated in Figure 3.11(c). Thus reed has to be lowered while weaving first half of the pyramid and is to be raised while weaving the other half. In other words, beat up line for picks 10,11,12 … is same as that of picks 8,7,6 … respectively. Thus, change in warp spacing can be brought about by reed.

As discussed earlier, change in pick spacing can be done either by selecting suitable interlacement order or take up. It can be observed that pick spacing in face ADC is closer than in face ACB. Therefore, rate of take up across width of pyramid should be differential. If t_1 ands t_2 are two rates of take up so that t_1 gives closer pick spacing as required in face (Figure 3.12).

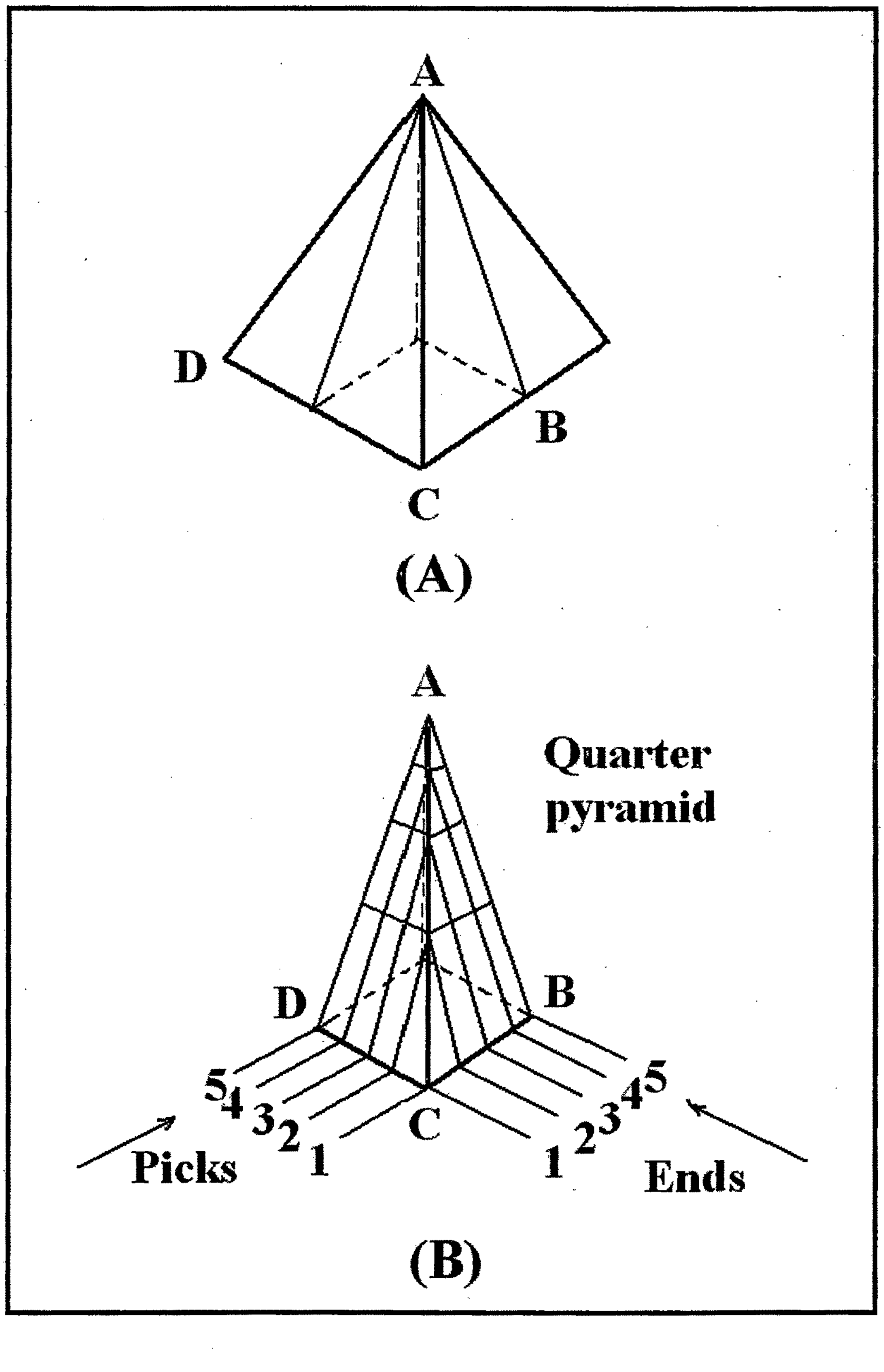


Figure 3.11 (a & b)

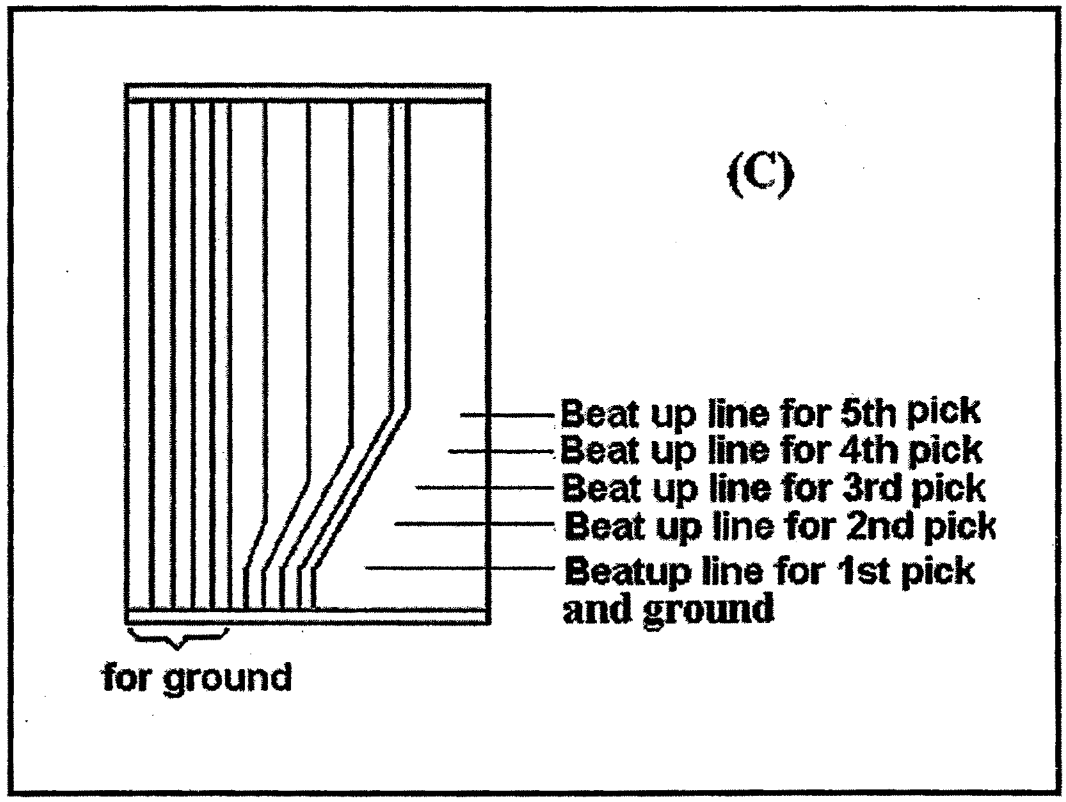


Figure 3.11 (c)

Curve shapes for reed dent wires for a pyramidal shape

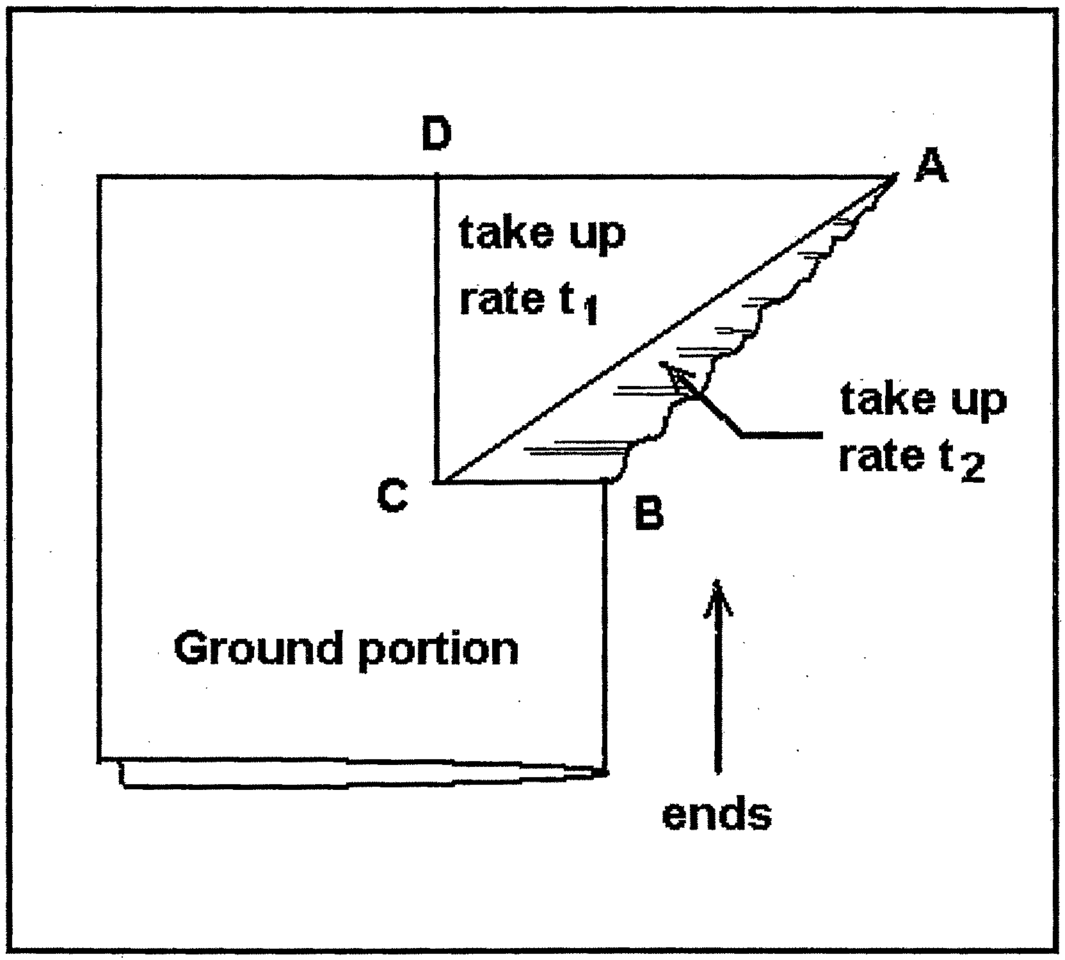


Figure 3.12

Other way of changing pick spacing is by interlacement. For example if 4/4 hopsack is selected in non-shape, i.e. ground portion, 4/4 weft rib in portion ACB and 4/4 warp rib in portion ADC then a situation would be created where ends and picks tend to move closer in ground portion, ends tend to move apart in portion ADC and picks tend to move apart in portion ACB. Of course this interlacement necessitates jacquard shedding.

3.3.4.1.2.2 Determining dent shapes of individual dent wires of reed to produce a hemispherical shape:

Shapes of individual reed dent wires can be determined for producing a hemispherical shape on the similar basis as that for a pyramid. Hemisphere is a symmetrical in shape. Therefore, reed is to be designed and fabricated only for quarter hemisphere.

Figure 3.13(a) shows a quarter hemisphere of radius ‘r’ to be woven.
ABC is the curved face of the hemisphere.

Figure 3.13(b) shows ends 1 to 9 for whom dent wires are to be designed. Let us take case of end number 5. For this end up to point D there is ground portion. So dent for this will lie straight for weaving up to point D. Later this dent is to be so shaped that it allows an increase in end spacing.

Same thing can be put or understood in other way also. If 2D fabric is woven throughout, the length of all picks between ends 1 and 5 remains almost same.

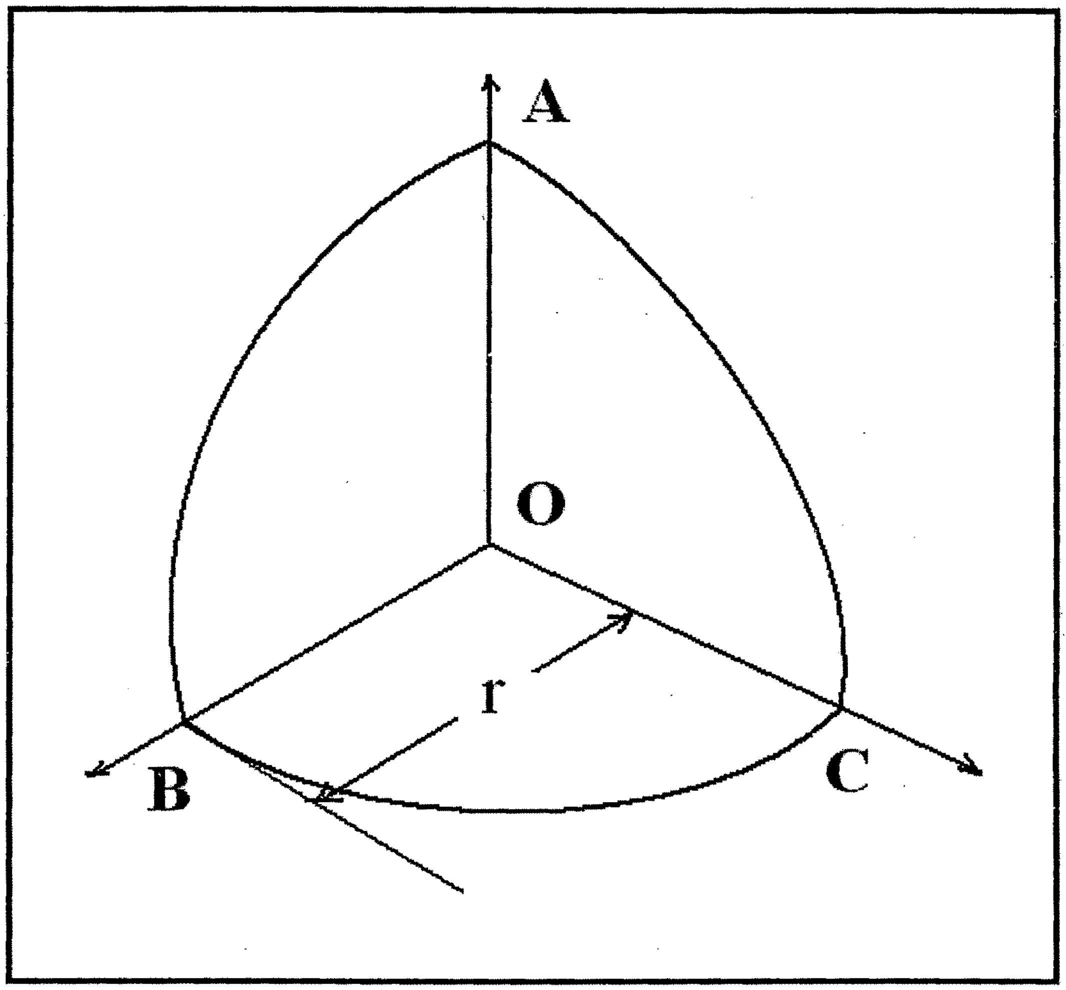


Figure 3.13 (a)

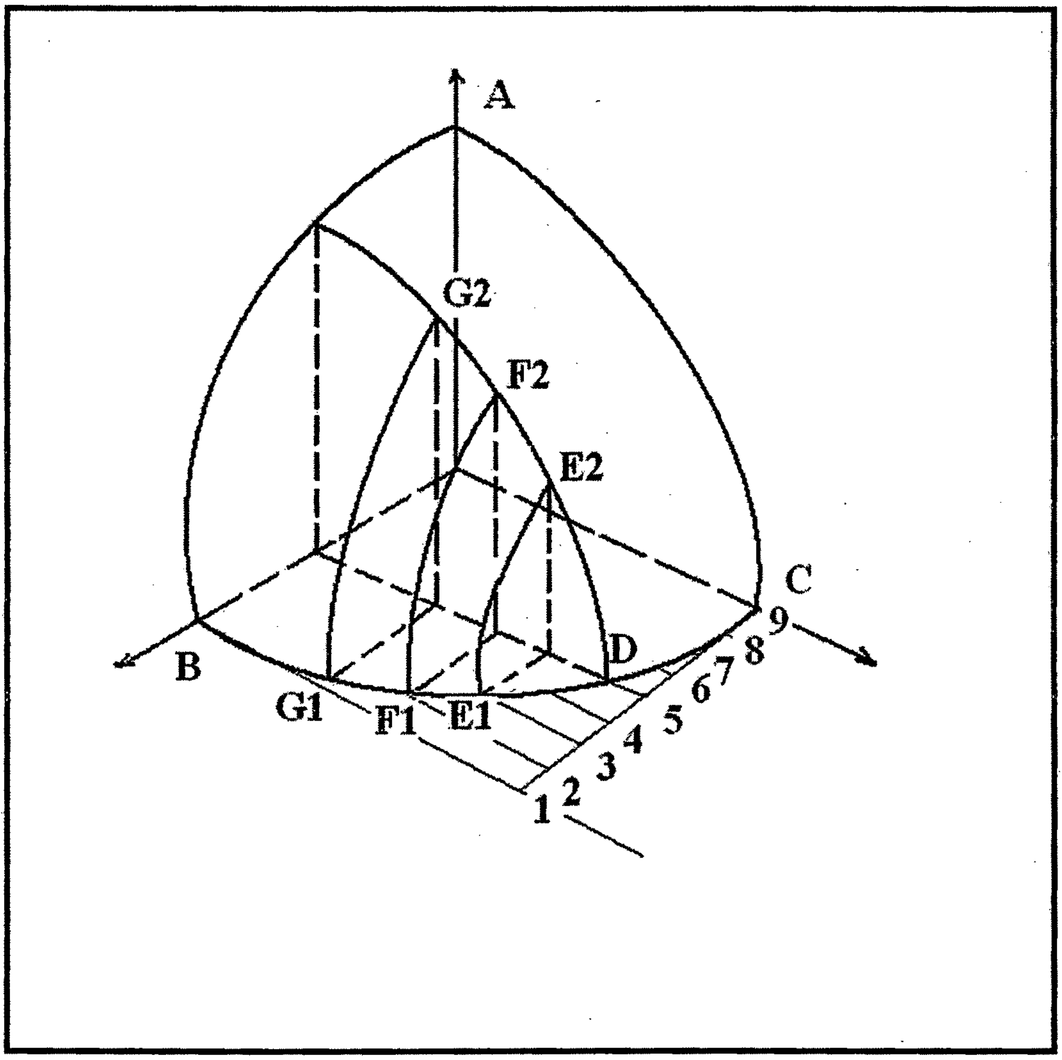


Figure 3.13 (b)

However, while weaving a 3D shape situation is not the same. It can be observed that when shape portion begins, the length of picks between ends 1 and 5 is not the same. Length of each pick is given by sum of length of pick in non-shape, i.e. ground portion, and that in shape portion. In other words, reed dent is to be so shaped that it will bring about increase length of picks depending upon shape. Hence dent shape can be derived like this. Arc lengths E_1E_2, F_1F_2, G_1G_2.... are to be straightened in plane OAB along lines E_1E, F_1F, G_1G ... respectively as shown in Figure 3.13(c). The curve for dent shape is obtained joining points E, F, G ... as shown in Figure 3.13(c). Therefore, during weaving this dent will bring about increased pick length as required.

If same procedure is followed for all other dent wires, the design for the whole reed would be as shown in Figure 3.13(d). This reed can be used to weave a hemispherical shape in similar way as a pyramid.

Taking this as the basis of reed design, a mathematical approach was developed and the shapes of curves of dent wires were obtained using computer. The approach is as follows.

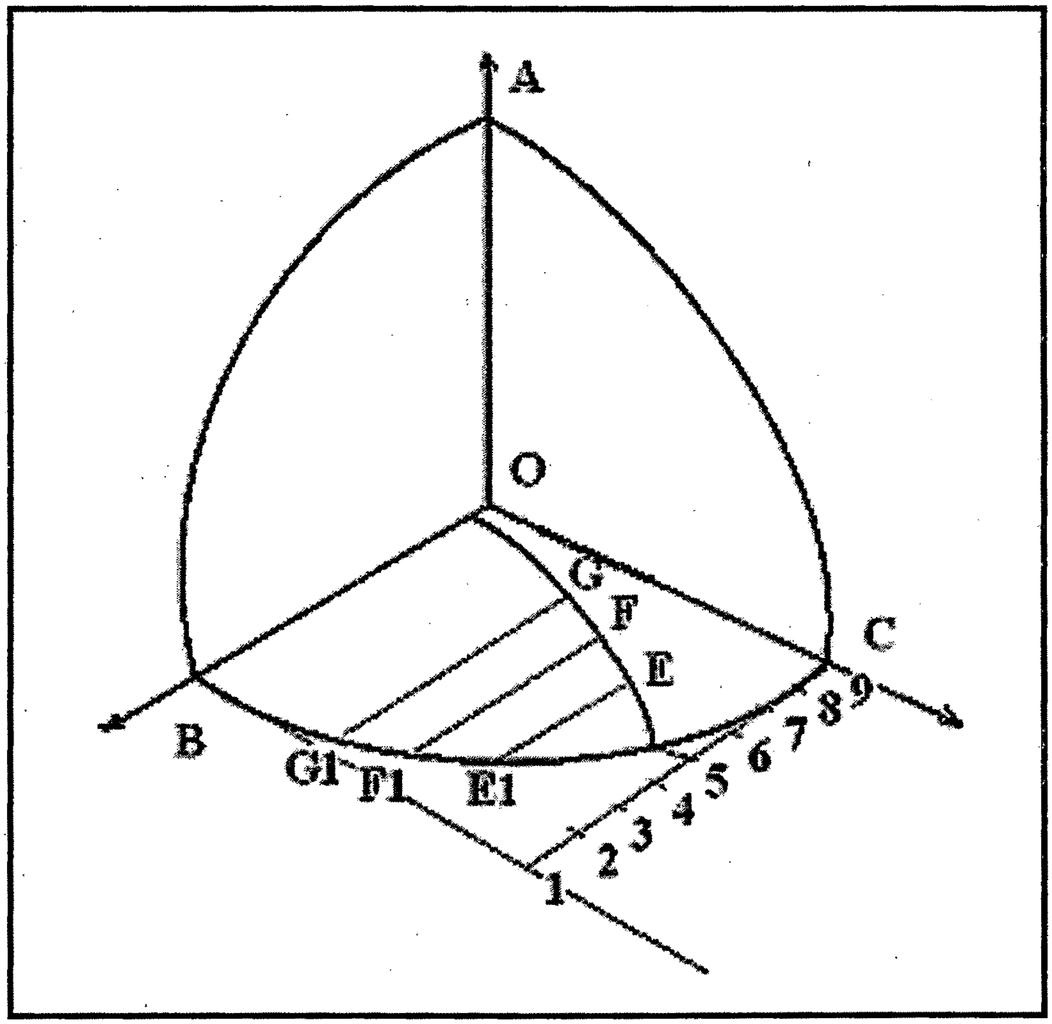


FIGURE 3.13 (c)

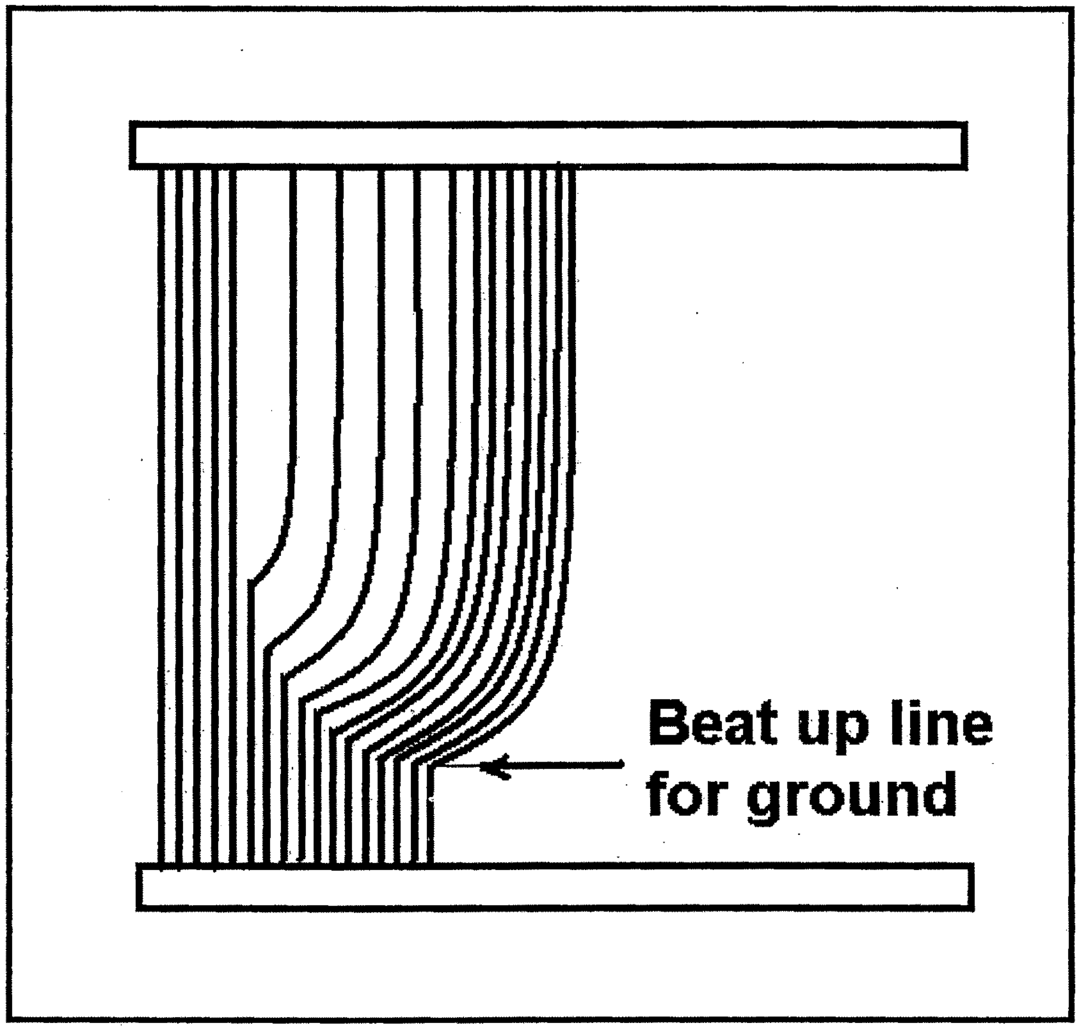


Figure 3.13 (d)

3.3.5 Mathematical tool for determining curve shapes of individual reed dent wires for weaving pyramidal and hemispherical shapes:

A ***mathematical tool*** was developed for determining curve shapes for reed dent wires for weaving pyramidal and hemispherical shapes of given dimensions. With mathematical treatment, equations are developed, which on feeding to computer, generate curve shapes for individual dent wires.

3.3.5.1 Generating curve shapes of individual reed dent wires mathematically for hemispherical shape:

As discussed earlier, reed will have to be designed only for a quarter hemisphere. As shown in Figure 3.14, r is the radius of the hemisphere. Therefore:

OA =OB = OC = r

If number of dent wires in reed to produce hemisphere portion are n, then pitch of reed

p = r/n .... (1)

The dent wires are numbered 1, 2, 3 ....

Let the dent number be denoted by 'd',

So d =1, 2, 3, 4 .....

Along line DC, distance between point D and d^{th} dent becomes $\frac{dr}{n}$

.... (2)

Let us consider designing of d^{th} dent.

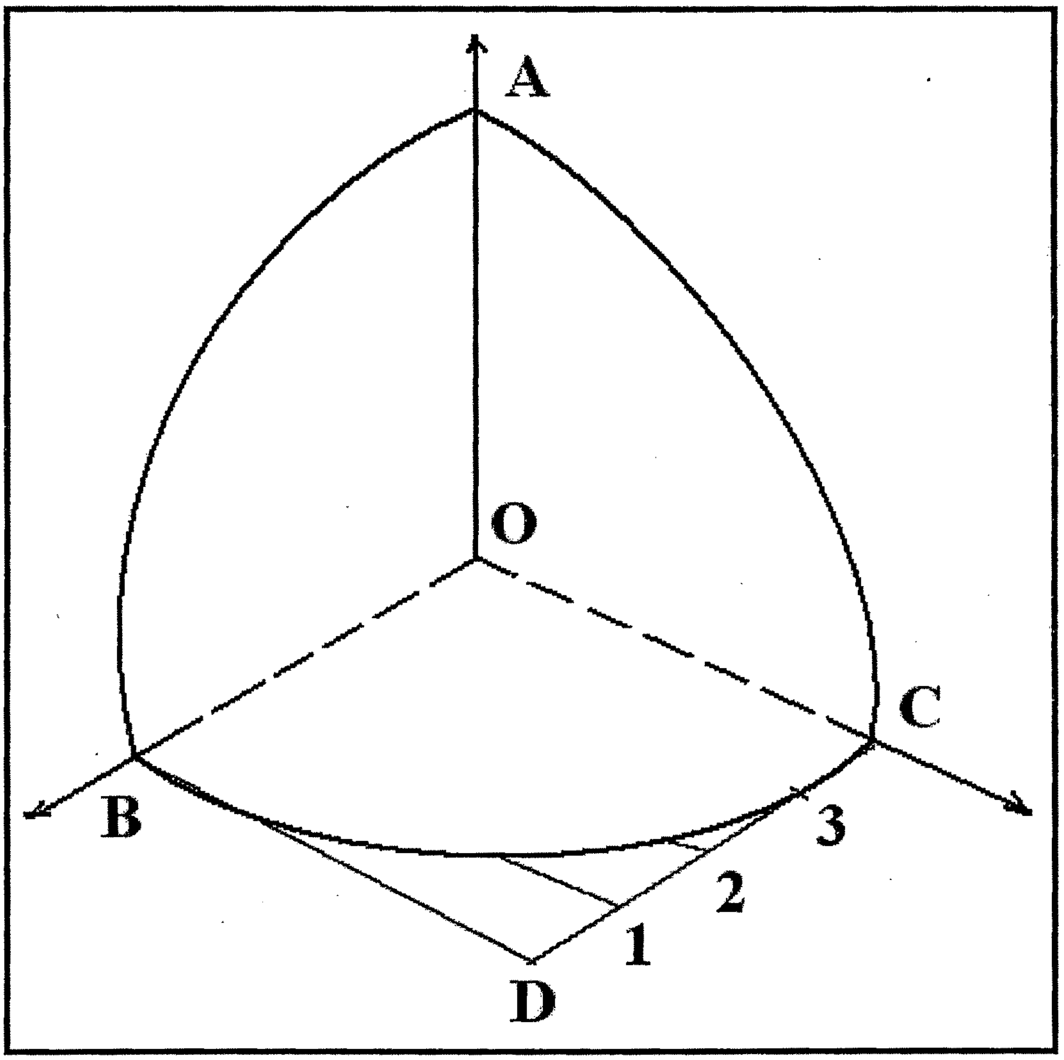


Figure 3.14

As shown in Figure 3.15, let dth dent be located on point E on line DC.

From equation 2,

$$DE = \frac{dr}{n} \quad ....(3)$$

This dent is to be kept straight up to F, as this is non-shape portion.

$$EC = FF'$$

$$\therefore EC = DC - DE$$

$$\therefore EC = r - \frac{dr}{n}$$

$$\therefore EC = r(1 - \frac{d}{n})$$

$$\therefore FF' = r(1 - \frac{d}{n}) \quad ....(4)$$

Δ OF′F is a right-angled triangle, where OF is hypotenuse.

$$\therefore OF' = \sqrt{OF^2 - FF'^2}$$

But, $OF' = r$, therefore from equation (4)

$$OF' = \sqrt{r^2 - r^2(1 - \frac{d}{n})^2}$$

$$\therefore OF = r\sqrt{1 - (1 - \frac{d}{n})^2} \quad ....(5)$$

Now, $OC - OF' = CF' = EF$

∴ From equation (5)

$$EF = [r - r\sqrt{1 - (1 - \frac{d}{n})^2}]$$

$$\therefore EF = r[1 - \sqrt{1 - (1 - \frac{d}{n})^2}] \quad ....(6)$$

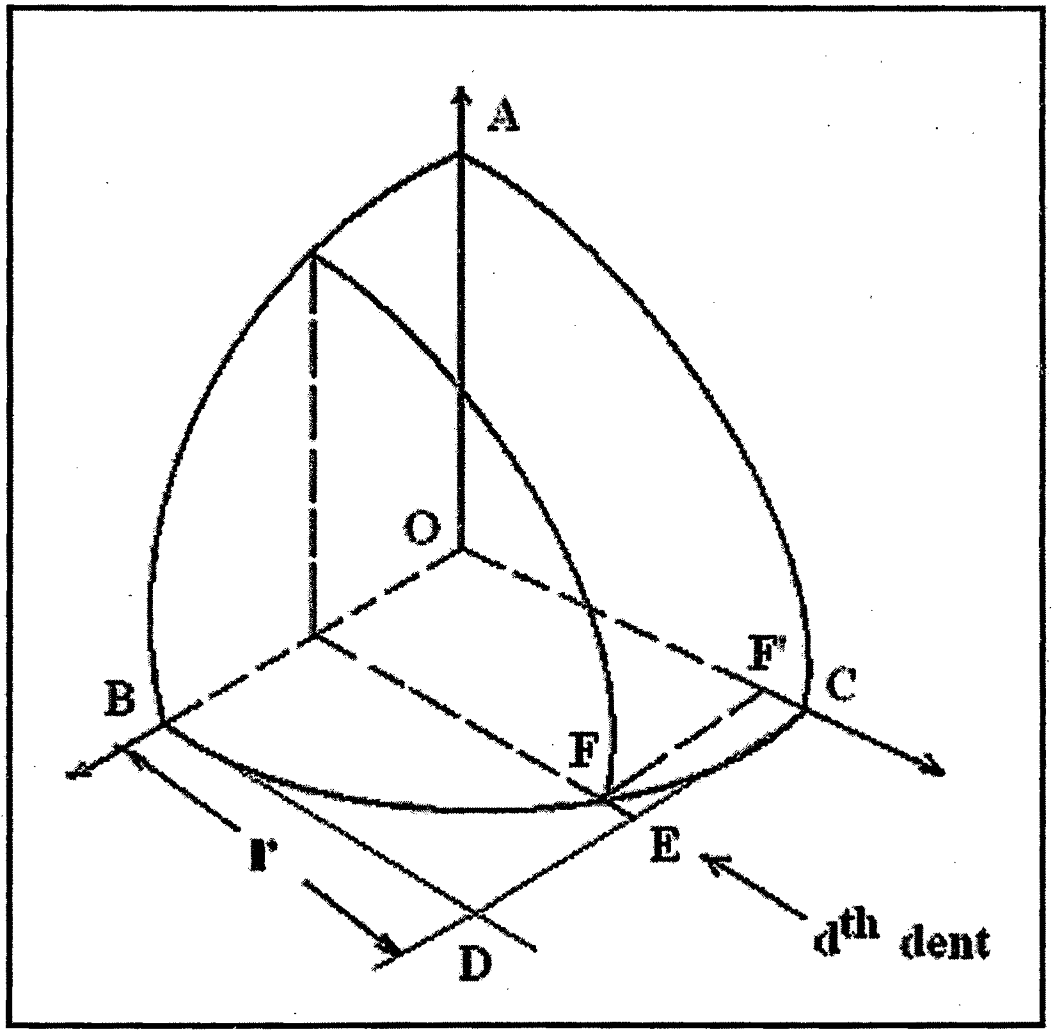


Figure 3.15

Hence, for a hemisphere of radius r having n dent wires in width r, d^{th} dent remains straight up to distance given by equation (6). Beyond this, it will assume a curve.

Consider two dimensional reference axis as follows.

Point D be considered as origin (FIGURE 3.16) and line BD be y-axis and line DC be x-axis.

To find dent design further, divide sphere portion between F to G by series of planes parallel to plane OAB equidistance from one another.

Let FG be divided by number of planes equidistance from one another. As shown in figure 3.17, FG is divided in m parts. For example, taking m=4, the curve beyond EF would lie in xy plane and curve points are obtained by straightening arcs 11′, 22′, 33′.... Along 1I, 2J, 3K .. lines respectively.

FI = IJ = JK = Distance between consecutive planes $= \frac{FG}{m}$.

Next job is to find arc lengths and curve points.

As number of dividing planes are m, they can be numbered from 1 to m. Let f be plane number so that,

1 = f = m,

So for f^{th} plane shown in FIGURE 3.18,

$$FQ = \frac{f.FG}{m} \quad ......(7)$$

$$\therefore QG = FG - FQ$$

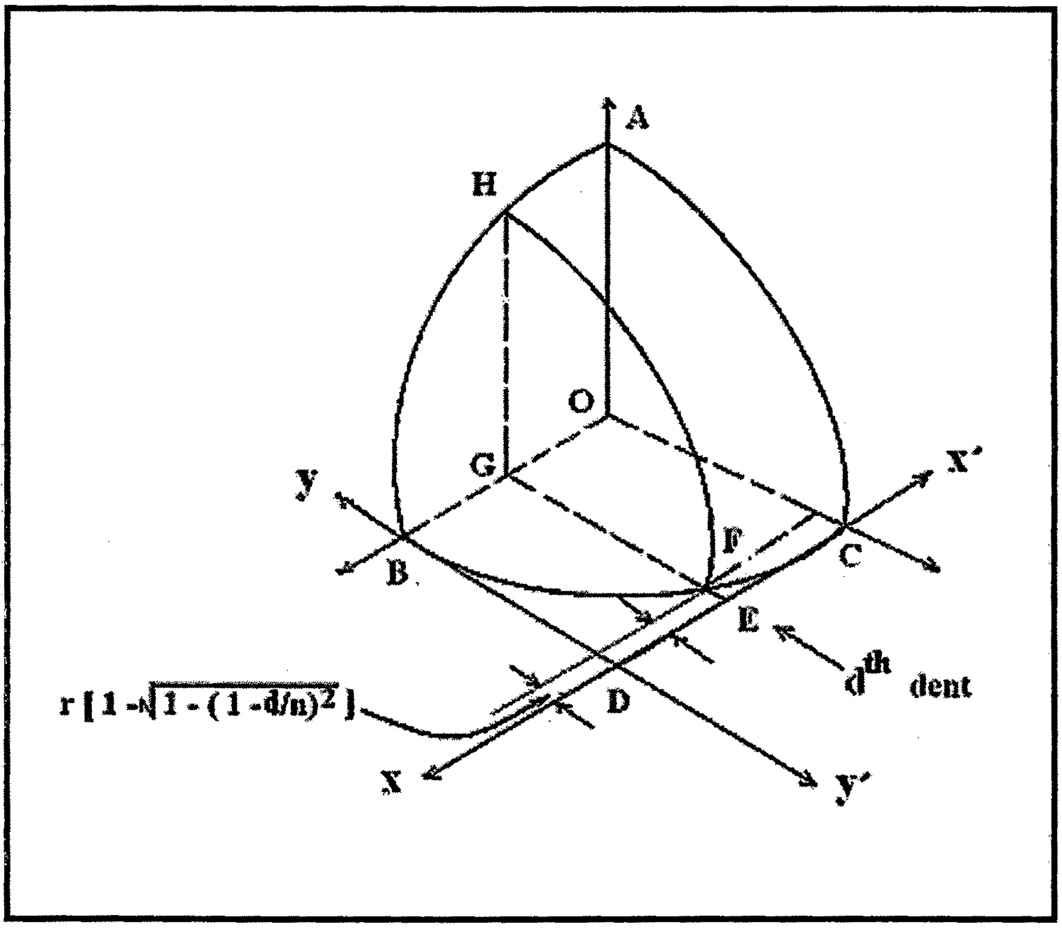


FIGURE 3.16

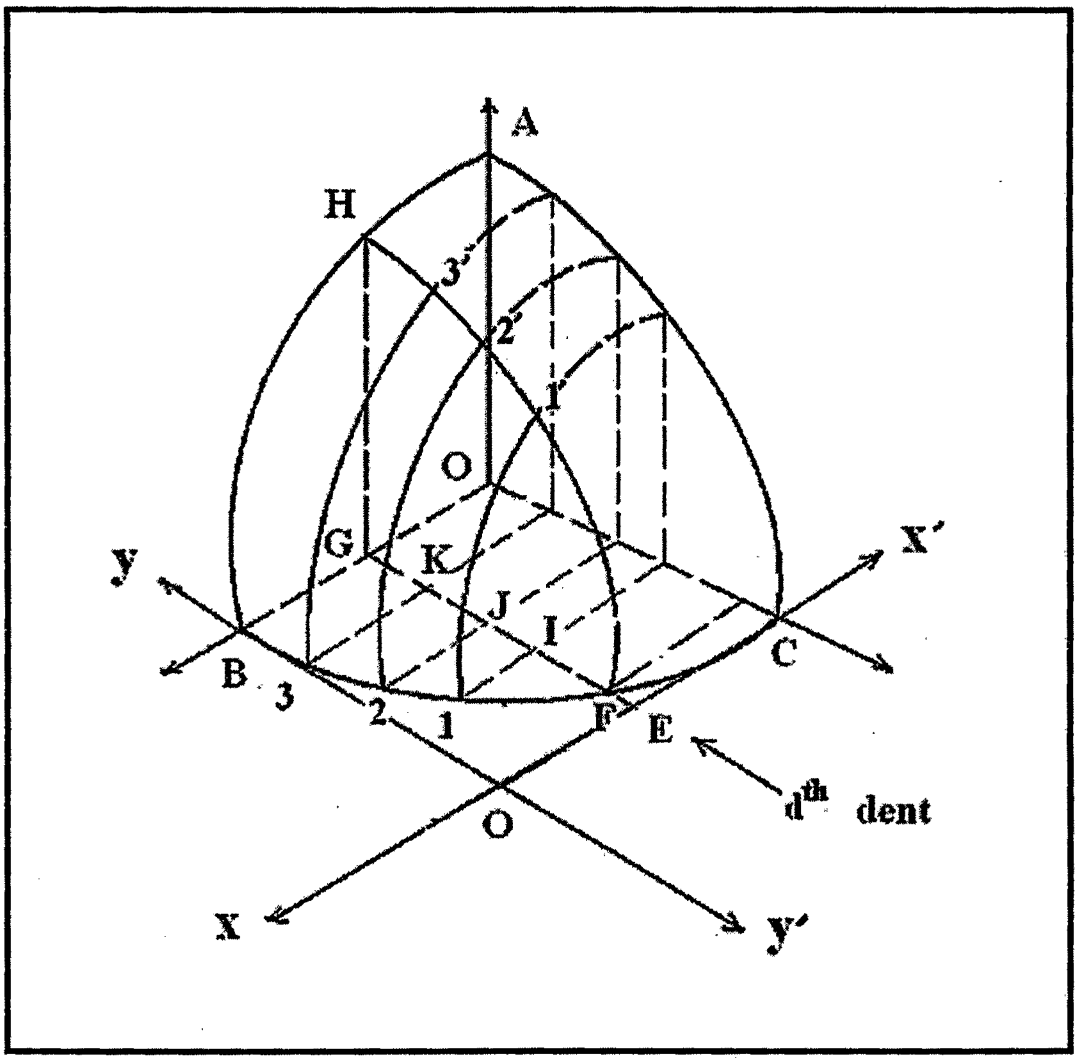


FIGURE 3.17

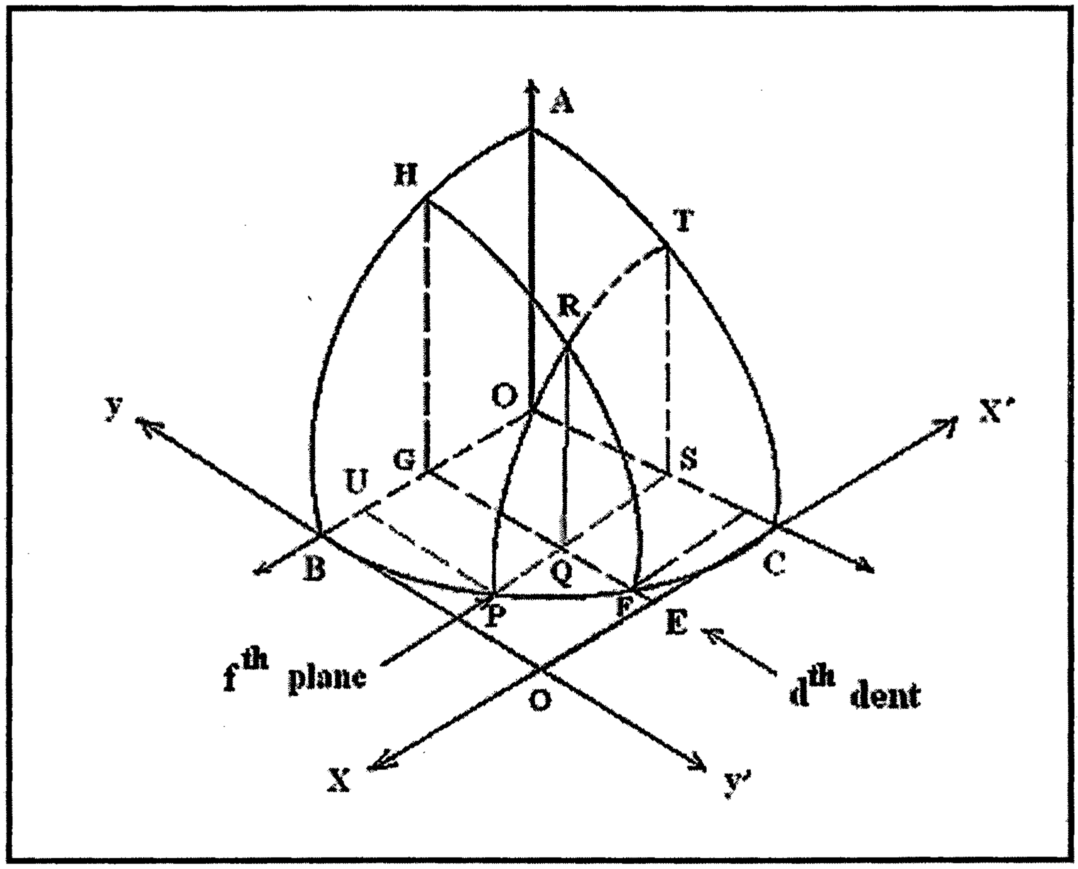


FIGURE 3.18

From equation (7),

$$QG = FG - \frac{f\,FG}{m}$$

$$\therefore QG = FG\ (1 - \frac{f}{m})$$

Now, $FG = r - EF$

$\therefore$ from equation (6)

$$QG = [r - r\{1 - \sqrt{1 - (1 - \frac{d}{n})^2}\}][1 - \frac{f}{m}]$$

Let $1 - \sqrt{1 - (1 - \frac{d}{n})^2} = q$

$$\therefore QG = (r - rq)(1 - \frac{f}{m})$$

$$\therefore QG = r\,(1 - q)(1 - \frac{f}{m})$$

$\therefore$ Radius of circle with radius SP - i.e. $SP = \sqrt{OP^2 - OS^2}$

$$\therefore SP = \sqrt{[r^2 - (r - rq)^2\ (1 - \frac{f}{m})^2]}$$

$$\therefore SP = r\sqrt{1 - (1 - q)^2\ (1 - \frac{f}{m})^2} \quad \text{.........(8)}$$

For finding length of arc PR (Figure 3.19),

$SP = SR = r'$, &

$$\theta = \cos^{-1} \frac{r(1 - \frac{d}{n})}{SP} \quad \text{... (9)}$$

$$arc\ PR = PR' = SP.\theta \quad \text{....... (10)}$$

Here SP is radius and θ is angle in radians.

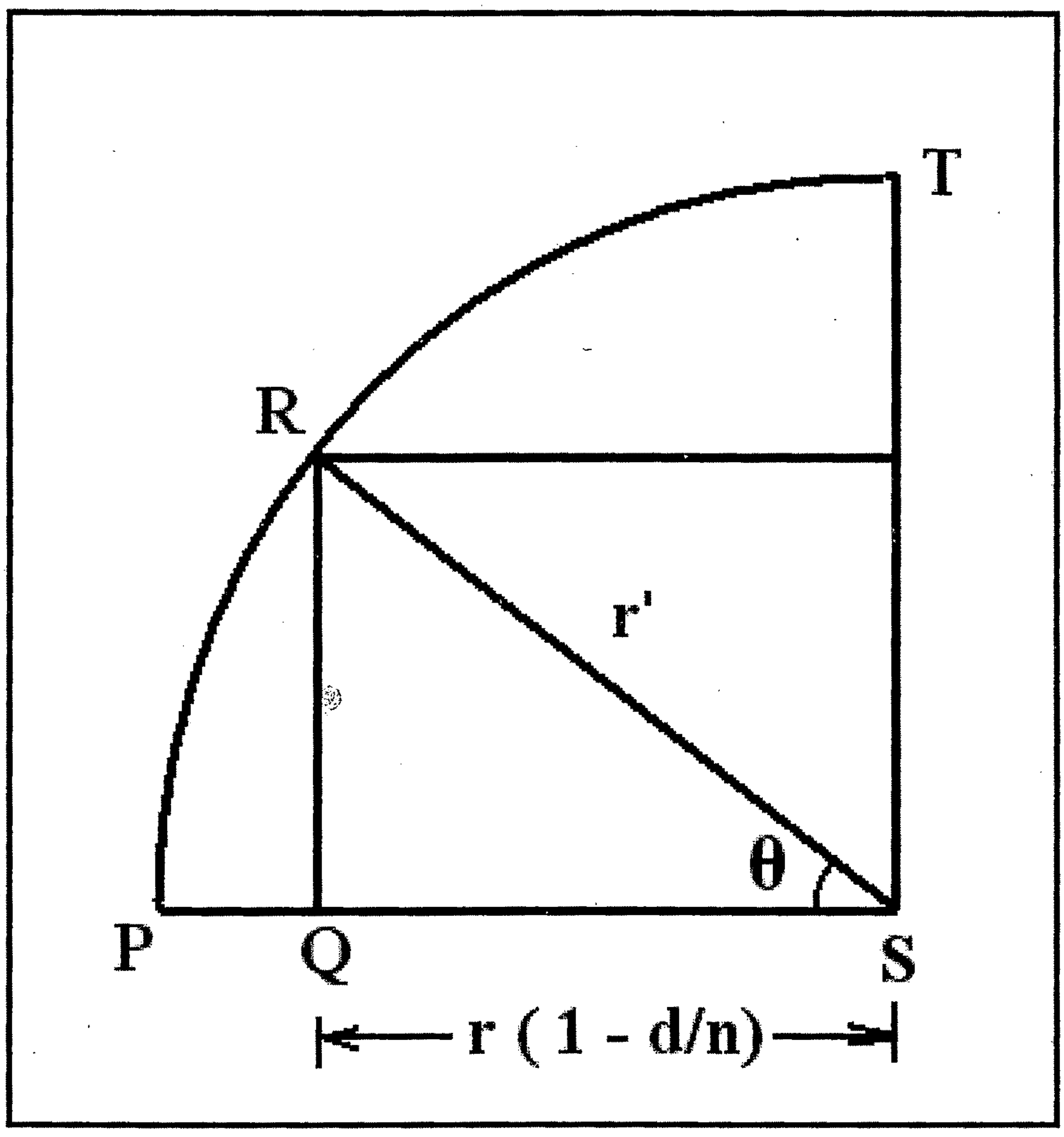


Figure 3.19

Values of SP and θ can be substituted from equations (8) and (9).

If this arc is straightened and projected along line PS, projection of point R beyond Q, as shown in Figure 3.20

$$QR' = QS - R'S$$

$$R'S = SP - PR'$$

$$\therefore QR' = QS - (SP - PR')$$

$$QS = r(1 - \frac{d}{n})$$

$$SP = r\sqrt{1-(1-q)^2 (1-\frac{f}{m})^2}$$

$$PR' = \left[r\sqrt{1-(1-q)^2 (1-\frac{f}{m})^2} \right] \left[\cos^{-1} \frac{r(1-\frac{d}{n})}{\left[r\sqrt{1-(1-q)^2 (1-\frac{f}{m})^2} \right]} \right]$$

Values of SP and PR are to be substituted from equations (8) and (10).

Therefore finally what we get is values of x co-ordinate for values of y

y = initial straight portion + curve portion

$$\therefore y = EF + \frac{f \cdot FG}{m}$$

is given by $\frac{d\,r}{n} + QR$

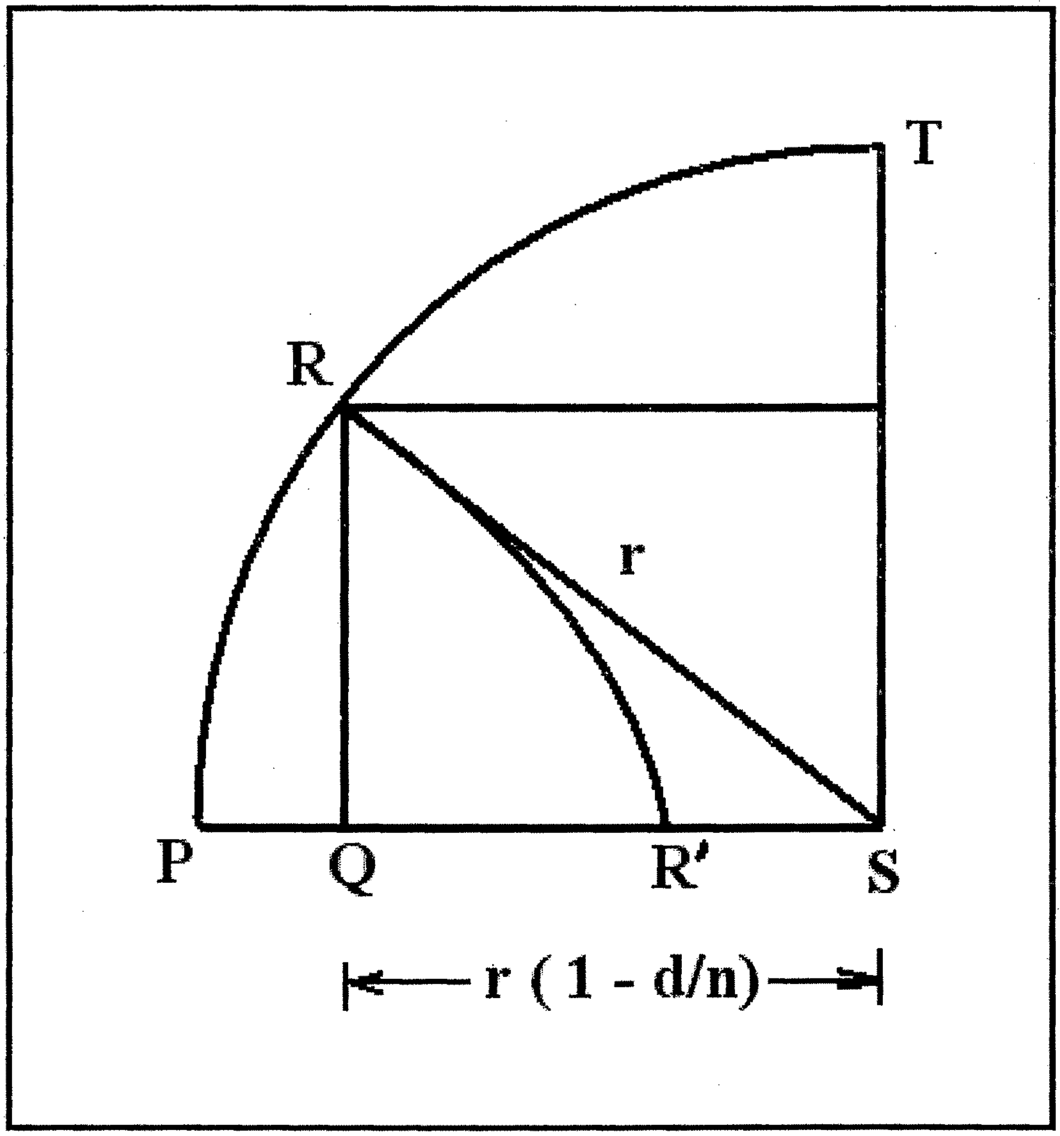


Figure 3.20

Finally it can be concluded that -

For,

r = sphere radius

d= dent number

n = number of dent wire in hemisphere quarter,

Up to $0 \le y \le rq$ where, $q = 1-\sqrt{1-(1-\frac{d}{n})^2}$

Value of x remains constant, i.e. $\frac{dr}{n}$

Beyond this, i.e. for,

$rq \prec y \le r$, when –

$y = q + r(1-q)(\frac{f}{m})$

Corresponding values of x are given by,

$$x = \frac{dr}{n} + r(1-\frac{d}{n}) - [r\sqrt{1-(1-q)^2(1-\frac{f}{m})^2}] + [r\sqrt{1-(1-q)^2(1-\frac{f}{m})^2}][\cos^{-1}\frac{(1-\frac{d}{n})}{r\sqrt{1-(1-q)^2(1-f/m)^2}}]$$

[$\therefore QR = QS-(SP-PR), x = \frac{ir}{n} + QR, i.e. QR = \frac{ir}{n} + QS - SP + PR$, values of QS, SP and PR are substituted]

Thus curve shapes for all dent wires for a hemisphere of given radius can be can be obtained. However, it should be noted that in this derivation, crimp in the yarn is ignored. Therefore, values of x will come out to be higher than this calculation. Suitable correction factor has to be employed to find correct values of x for range of values of y. Other alternative is selecting interlacement between warp and weft in such a way that it gives change in warp thread spacing as desired. The dent spacing in ground should be taken little wider so that on contraction desired warp spacing is obtained in ground.

3.3.5.1.2 Fabrication of a reed for weaving a hemispherical shape:

- By feeding these equations in MS Excel, curve shapes of all dent wires were obtained for a hemisphere of radius 9 cm.
- A reed for hemisphere was fabricated shaping dent wires as per curves obtained (Photograph 3.2).

3.3.5.2 Generating curve shapes of individual reed wires mathematically for pyramidal shape:

Let 'w' be the width of the base of the pyramid and l be its length (Figure 3.21). Let h be the height of the pyramid. As this pyramid is symmetrical about horizontal and vertical directions, reed is to be designed for its quarter portion.

Figure 3.22 shows a quarter pyramid.

Let d = dent wires/ inch

$\therefore$ 1/d becomes distance between successive dent wires

$\therefore$ Number of dent wires in half width $= \frac{wd}{2}$ ....(1)

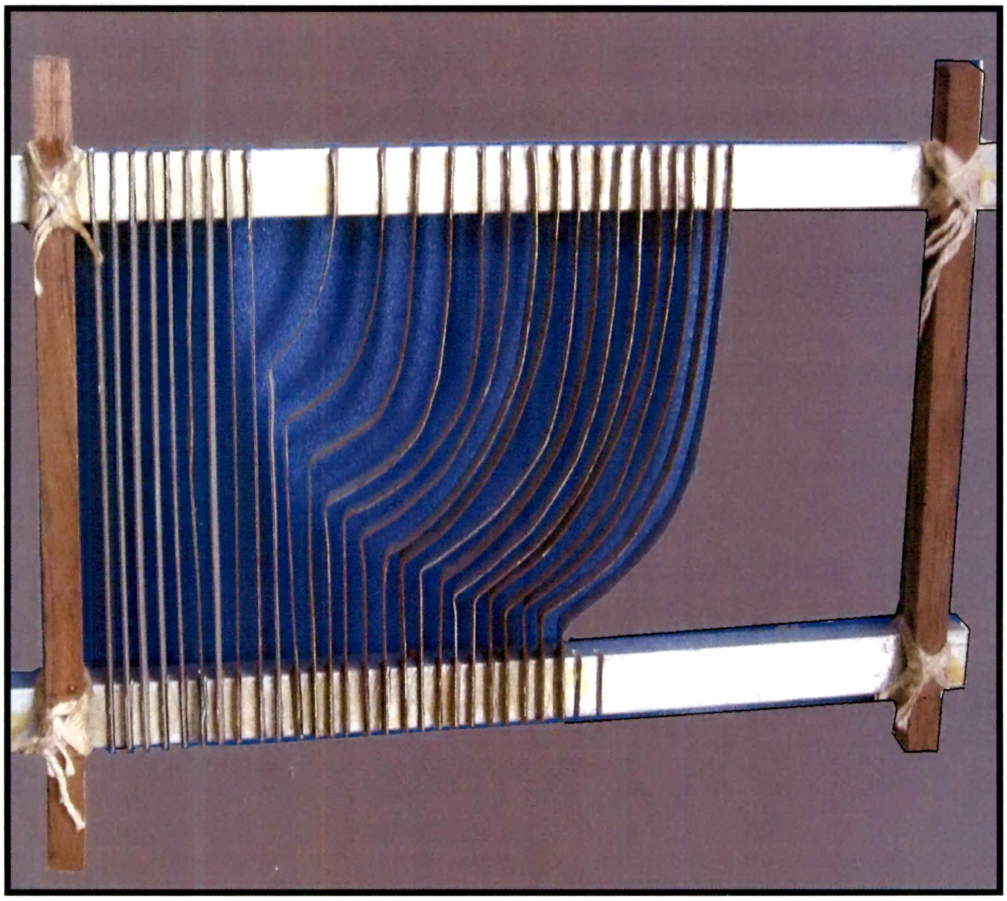


Photo 3.2

Reed for weaving hemispherical shape

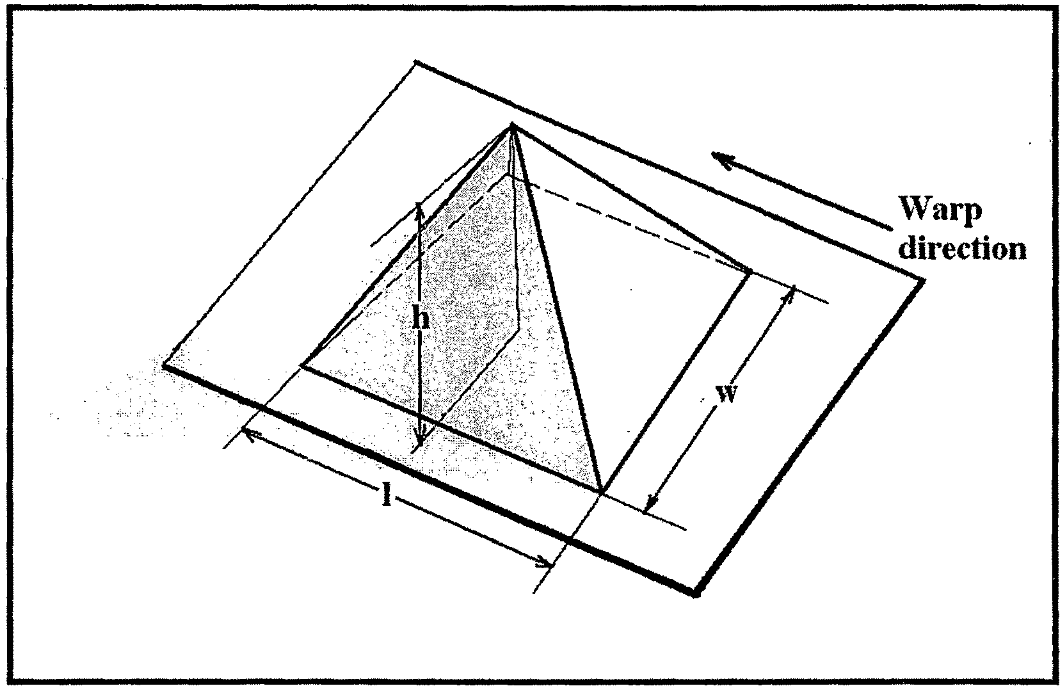


Figure 3.21

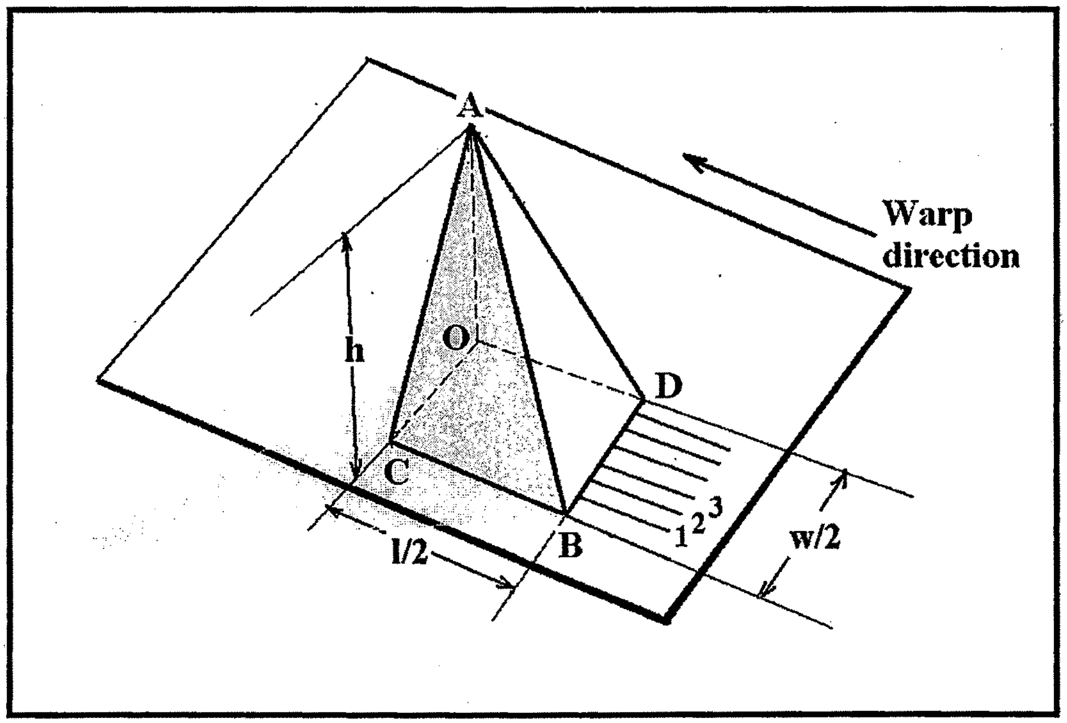


Figure 3.22

Let us consider designing shape of f^{th} dent.

It can be seen in figure 3.23 that f_{th} dent should be shaped in such a way it varies warp thread distance so that increased pick length, measured from line BC up to end, passing through f^{th} dent, is obtained. End passing through f^{th} dent intercepts line BD at M. Beyond M it passes over inclined plane ABD. Further, it meets line AB at N. Then it has a horizontal path over plane ABC.

Figure 3.24 shows a situation where situation is shown how end would lie if fabric is woven 2D. End passing through f^{th} dent is shown straight which meets line OC at R. Here lengths of all picks between BC and MR would be same. But while weaving a pyramid, pick lengths between BC and end path M-N-P is different. Therefore f^{th} dent should be shaped in such a way that it allows increased lengths of picks between BC and path M-N-P. The length of picks between lines BC and MN keeps on increasing where as that to NP remains constant, which equals to QN.

As shown in figure 3.25 dent shape is obtained by joining end points of paths x_1y_1-z_1, x_2-y_2-z_2, x_3-y_3-z_3 ..... straightened on plane OCBD, parallel to BD. On doing so dent shape is obtained as shown in figure 3.26.

Path M-T-U on plane OCBD shows dent shape.

Referring to figure 3.26(b),

$$BM = QM' = \frac{f}{d} \ \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

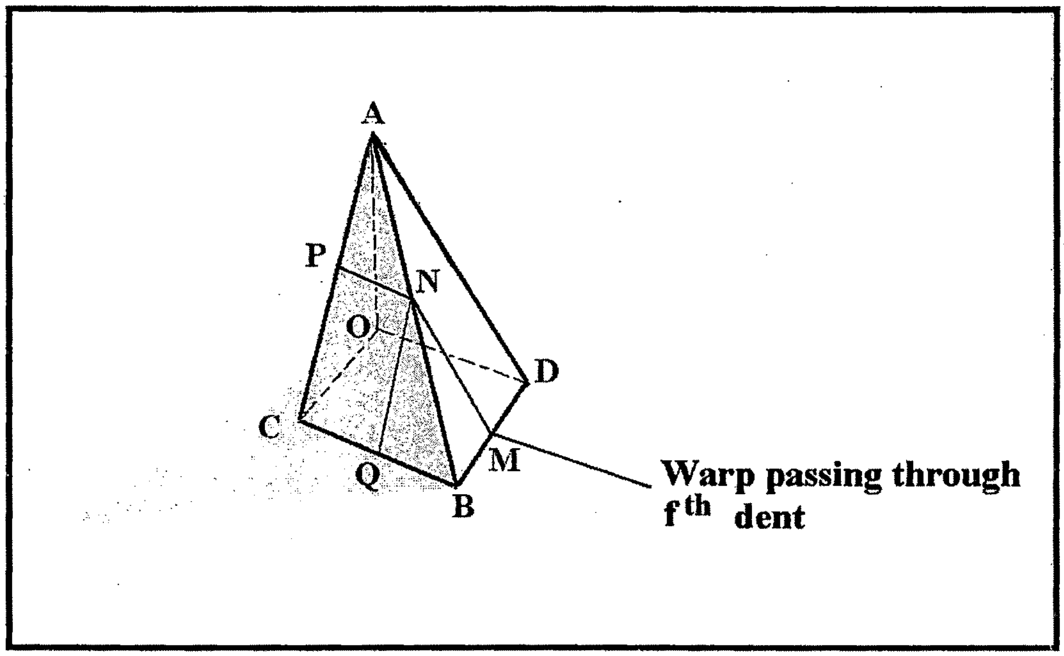


Figure 3.23

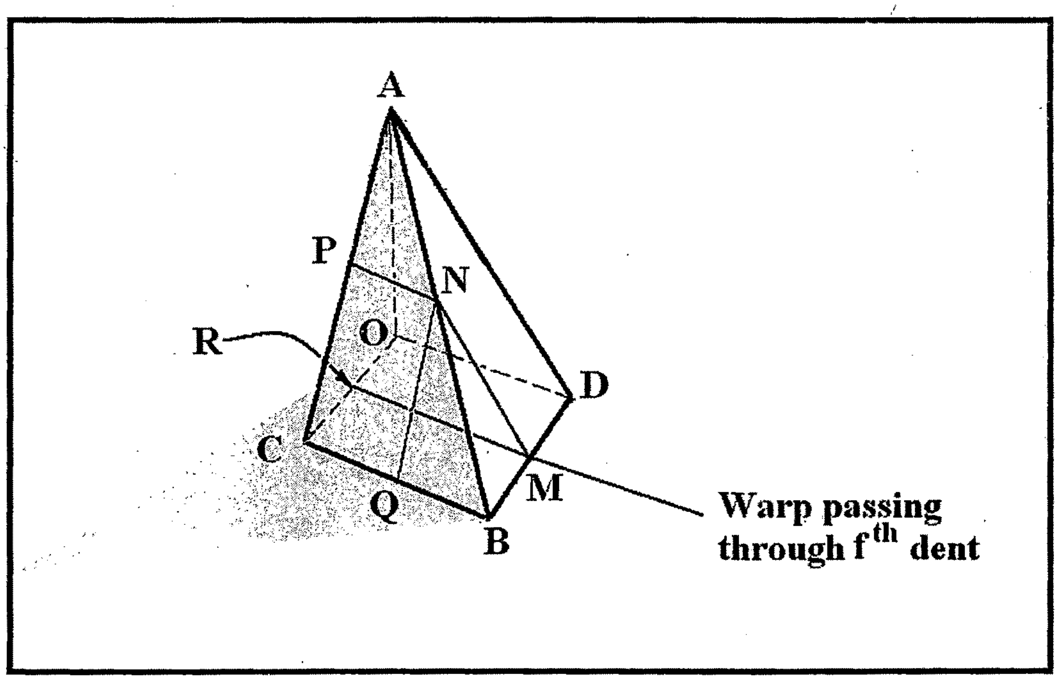


Figure 3.24

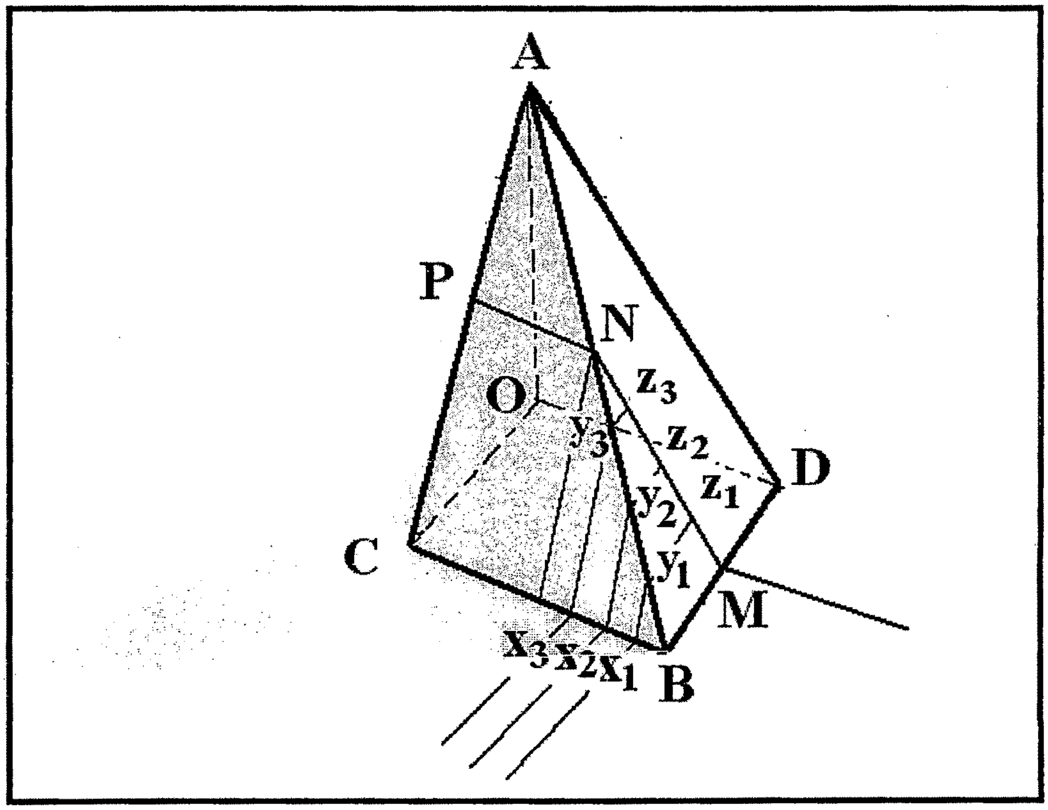


Figure 3.25

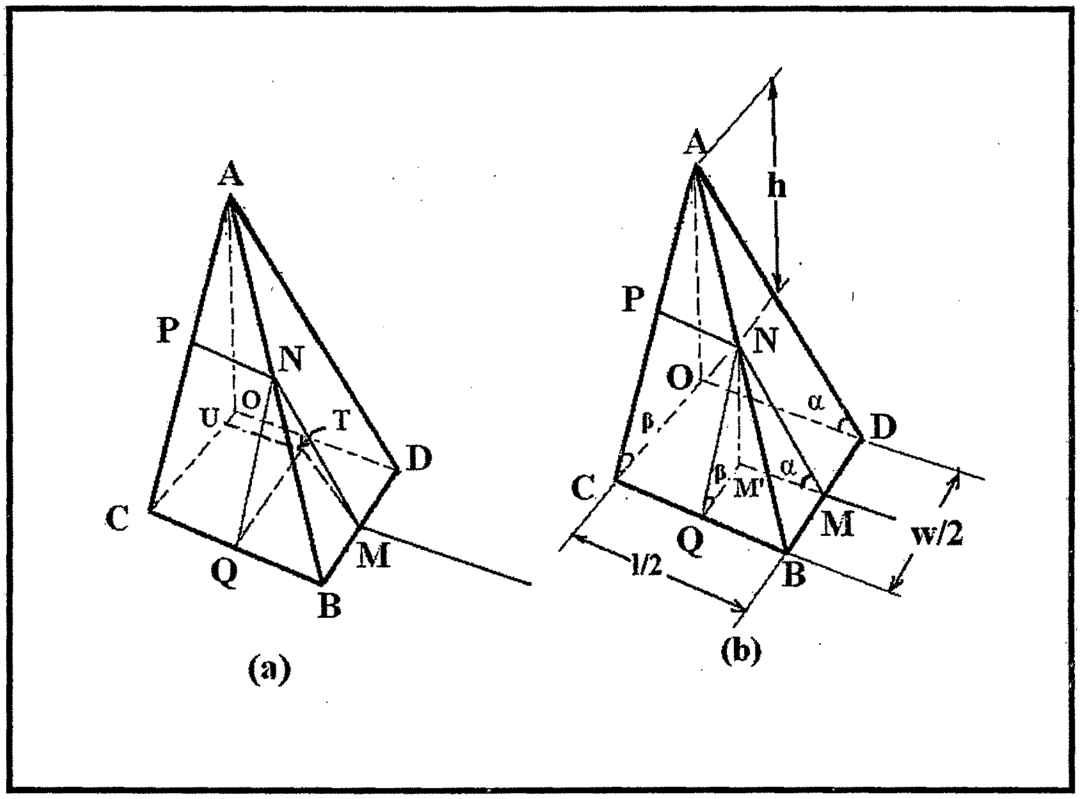


Figure 3.26

$$\beta = \tan^{-1}\frac{2h}{w} \quad \text{..............................(3)}$$

Now, $\frac{QM'}{QN} = \cos\beta$ ($\therefore$ angle ACO = angle NQM' = β)

Substituting values of QM' and β from equation (2),

$$\therefore QN = \frac{f}{d\cos\{\tan^{-1}(\frac{2h}{w})\}} \quad \text{..............(4)}$$

Thus pyramid dent is shaped with initial inclined portion followed by a portion parallel to reed height direction.

Angle ADO = angle NMM' = α

$$\alpha = \tan^{-1}\frac{2h}{l} \quad \text{..............(5)}$$

$$\frac{M'N}{MM'} = \tan\alpha$$

Now, $M'N = QM'\tan\beta$ .... (6)

But, $QM' = \frac{f}{d}$ and $\tan\beta = \frac{2h}{w}$

Substituting values in equation (6),

$$\therefore M'N = \frac{2fh}{wd}$$

Now $\frac{M'N}{MM'} = \tan\alpha$

$$\therefore MM' = \frac{M'N}{\tan\alpha}$$

$$\therefore MM' = \frac{(2fh)/(wd)}{(2h/l)}$$

$$\therefore MM' = \frac{fl}{wd} \quad \ldots\ldots\ldots\ldots(7)$$

Dent shape for f^{th} dent is as shown in figure 3.27.

Using this equation curve shapes for individual dent wires were obtained for pyramidal shape in similar way as that for hemispherical shape.

3.3.5.2.1 Application of geometric transform for designing reed for Shape Weaving:

As a part of modeling seminar of students of M.Sc. (Industrial Mathematics), Faculty of Technology and Engineering, M.S.University of Baroda, a tool is developed using application of geometric transform under guidance from M.V.Koranne, Reader, Textile Engineering Department and Dr.D.C.Vakaskar and Dr.R.K.George , both Readers, Applied Mathematics Department. Following is achieved through this work:

- Skeleton view of pyramidal and hemispherical shapes of given dimensions is generated on computer.
- Reed wire shapes for the same can be obtained.

Details of this work are given in Appendix.

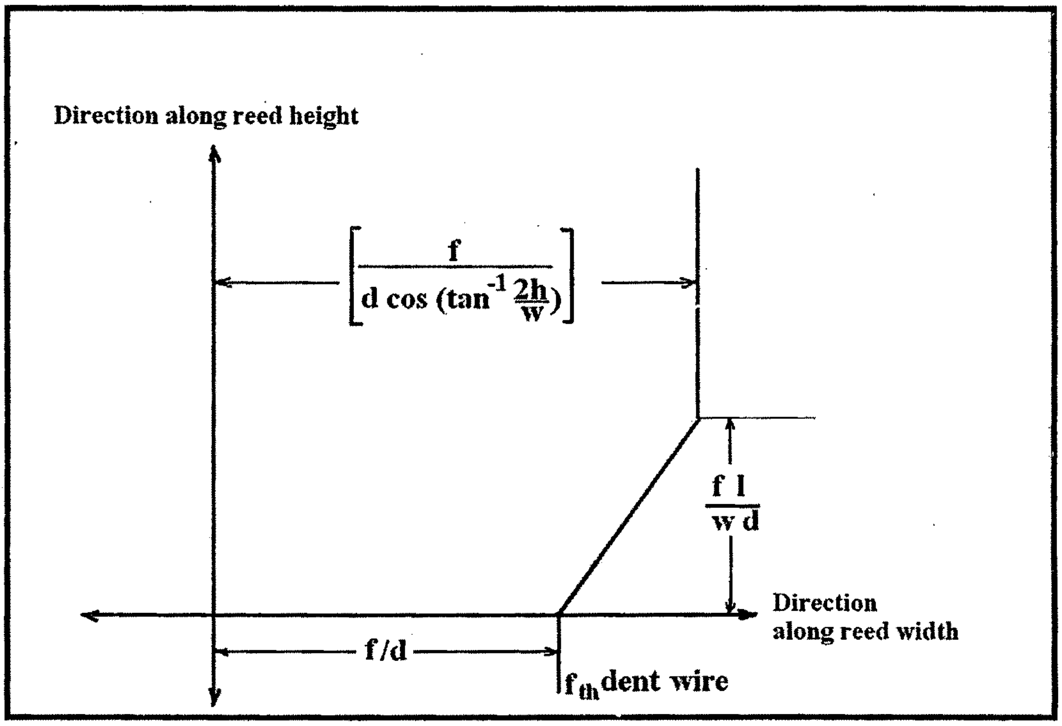

Direction along reed height
f
d cos (tan-1 2h/w)
f l
w d
Direction
along reed width
f/d
fth dent wire

Figure 3.27

Figure 3.28 shows skeleton view for a pyramidal shape and figure 3.29 shows reed wire shapes obtained for the same shape. Figure 3.30 shows skeleton view of a pyramidal shape and figure 3.31 shows reed wire curve shapes for the same.

3.3.5.3 Weaving pyramidal and hemispherical shapes on handloom using reeds with shaped dent wires:

3.3.5.3.1 Weaving a pyramidal shape:

Using reed with shaped dent wires a pyramid was woven without differential take up or weave effect. In next phase a pyramid was woven using reed with shaped dent wires, as well as selecting interlacement between warp and weft in such a way that it assist in increasing spacing of ends and picks as required for shape formation (Photo 3.3). A 200's single lift jacquard was used for shedding. Thus a pyramid shape was satisfactorily woven on handloom.

3.3.5.3.2 Weaving a hemispherical shape:

A hemisphere was woven on handloom as follows. If r is radius of hemisphere in centimeter and n_2 are picks per centimeter in ground then rn_2 gives total number of picks in half hemisphere. Initial non-shape portion is woven, keeping beat up line at bottom where all ends are equally spaced. If h is reed height of shape region, it is divided in rn_2 equal parts. For this a scale strip is fixed on reed. For example if total number of picks in half hemisphere equals 40 then h is divided in 40 equal parts is fixed on reed and numbered from 0 to 40 (Figure 3.32).

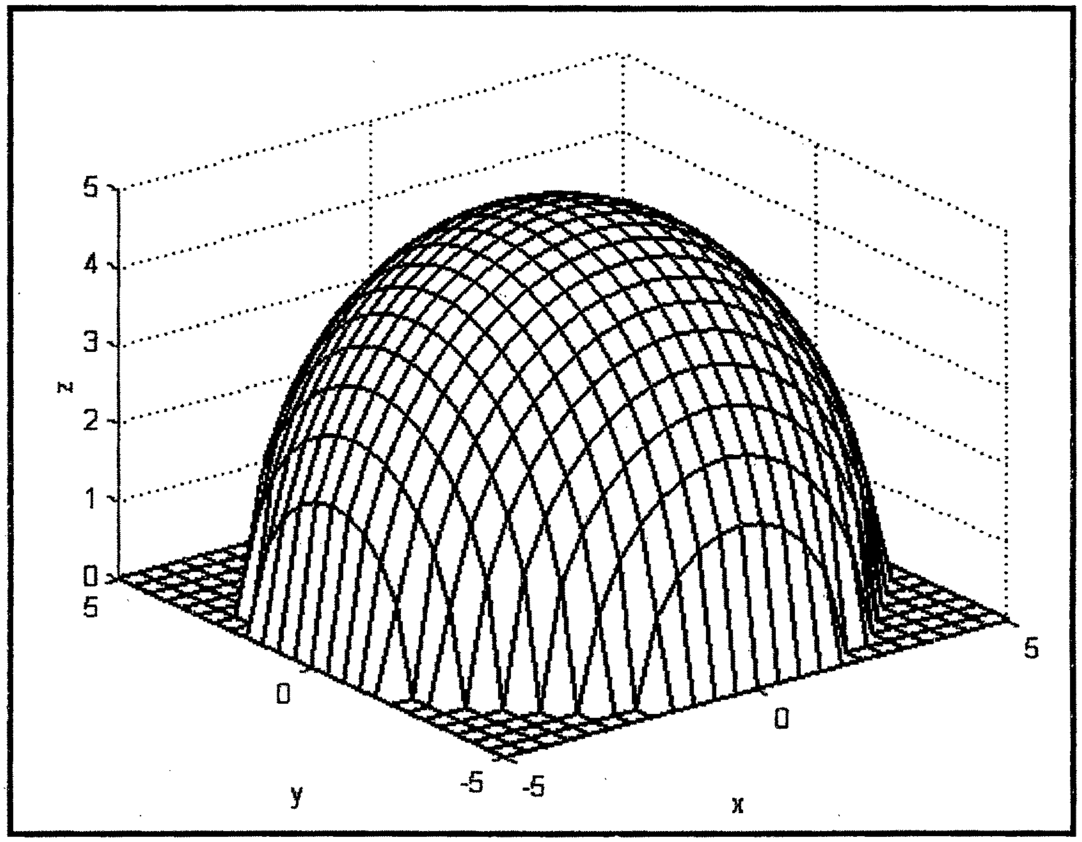


Figure 3.28

Skeleton grid view of pyramid

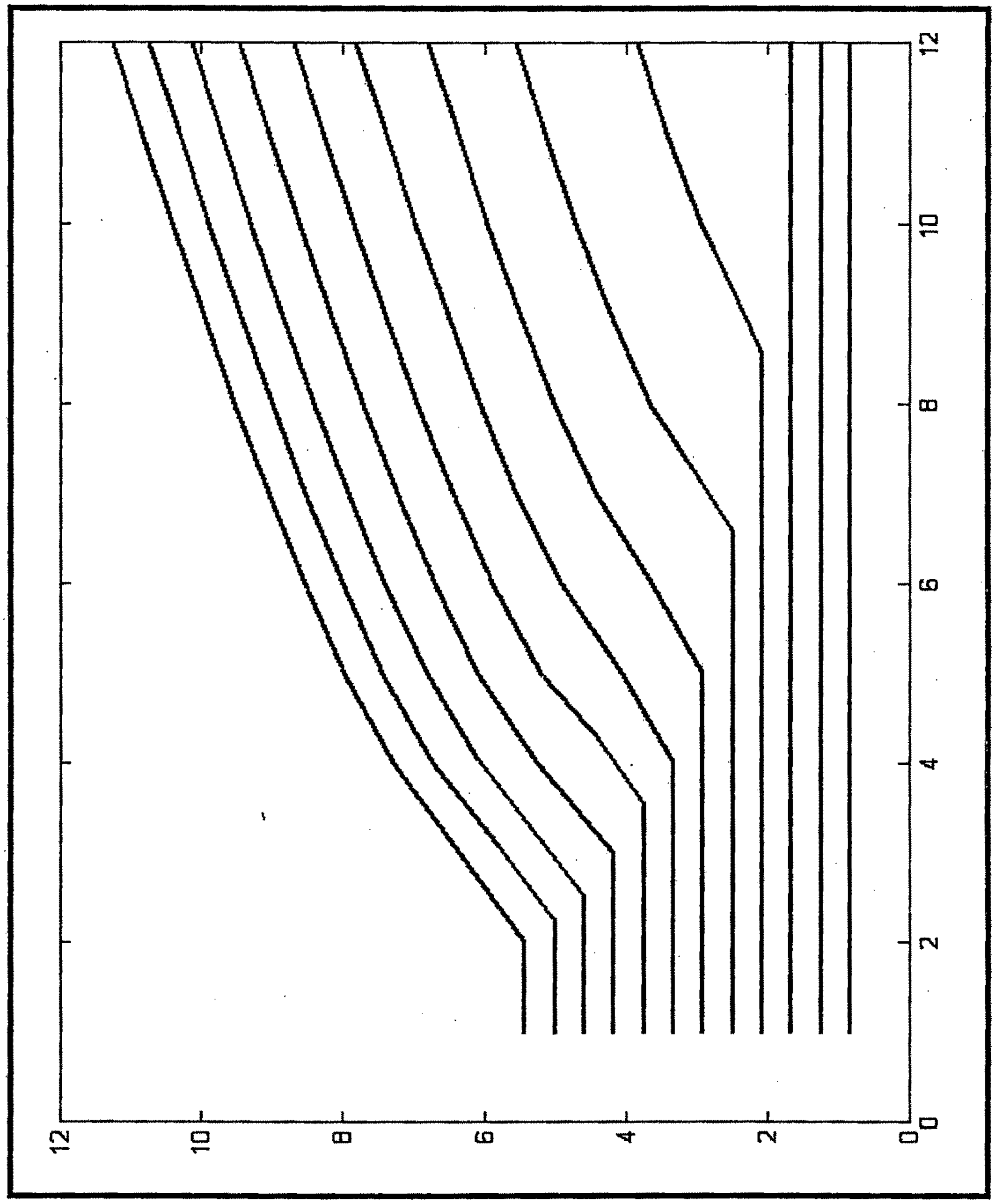


Figure 3.29

Curve shapes of dent wires for a hemispherical shape

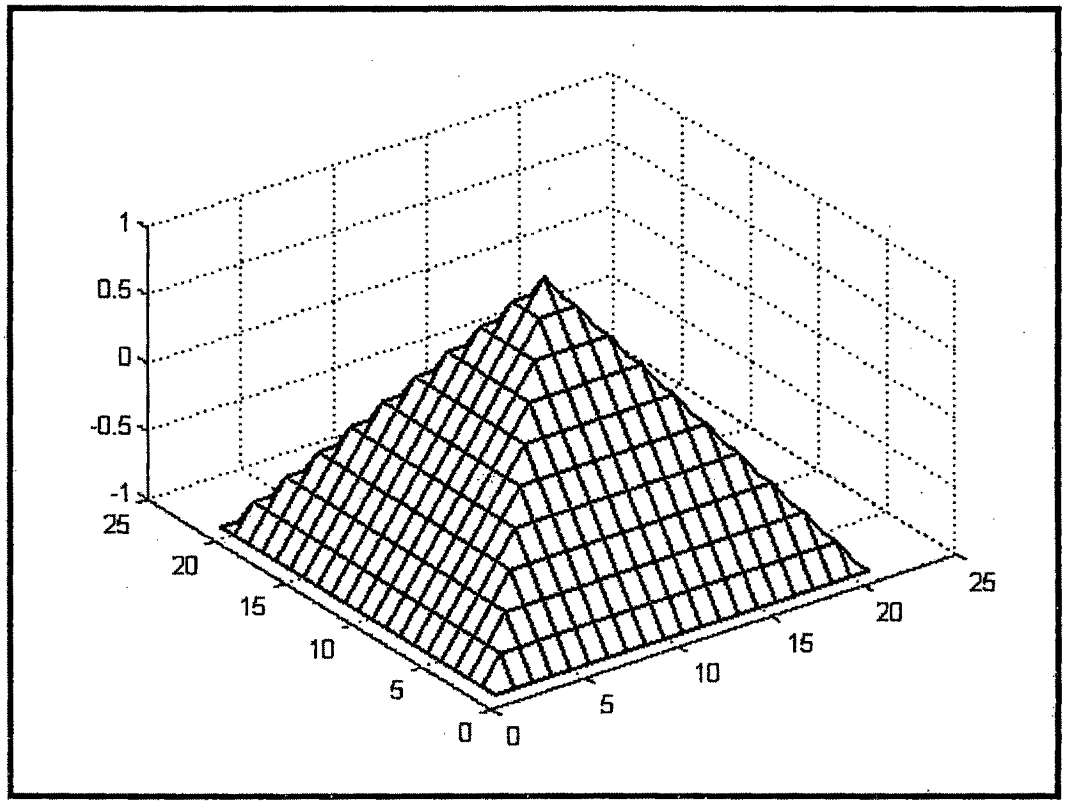


Figure 3.30

Skeleton grid view of a pyramidal shape

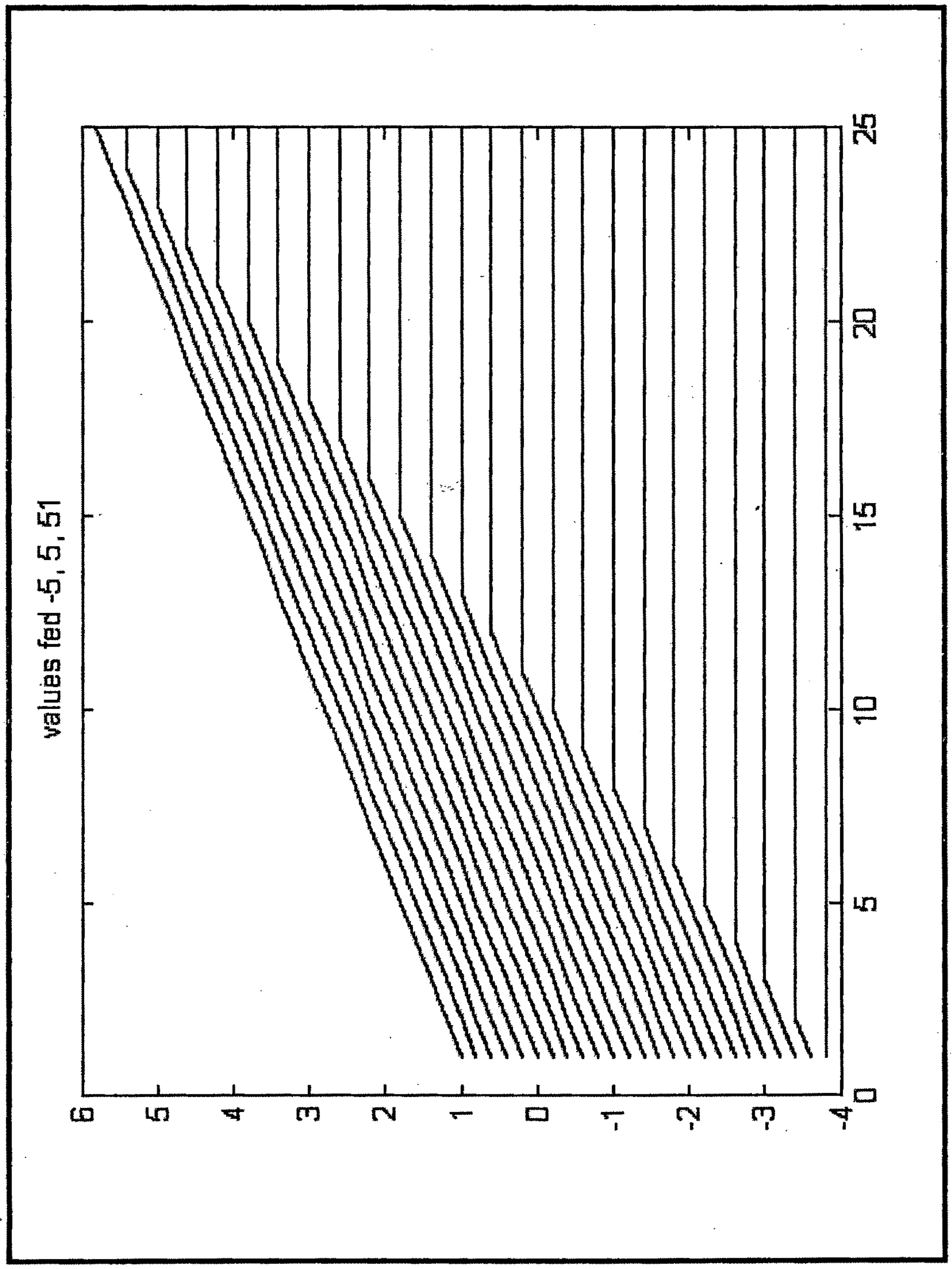
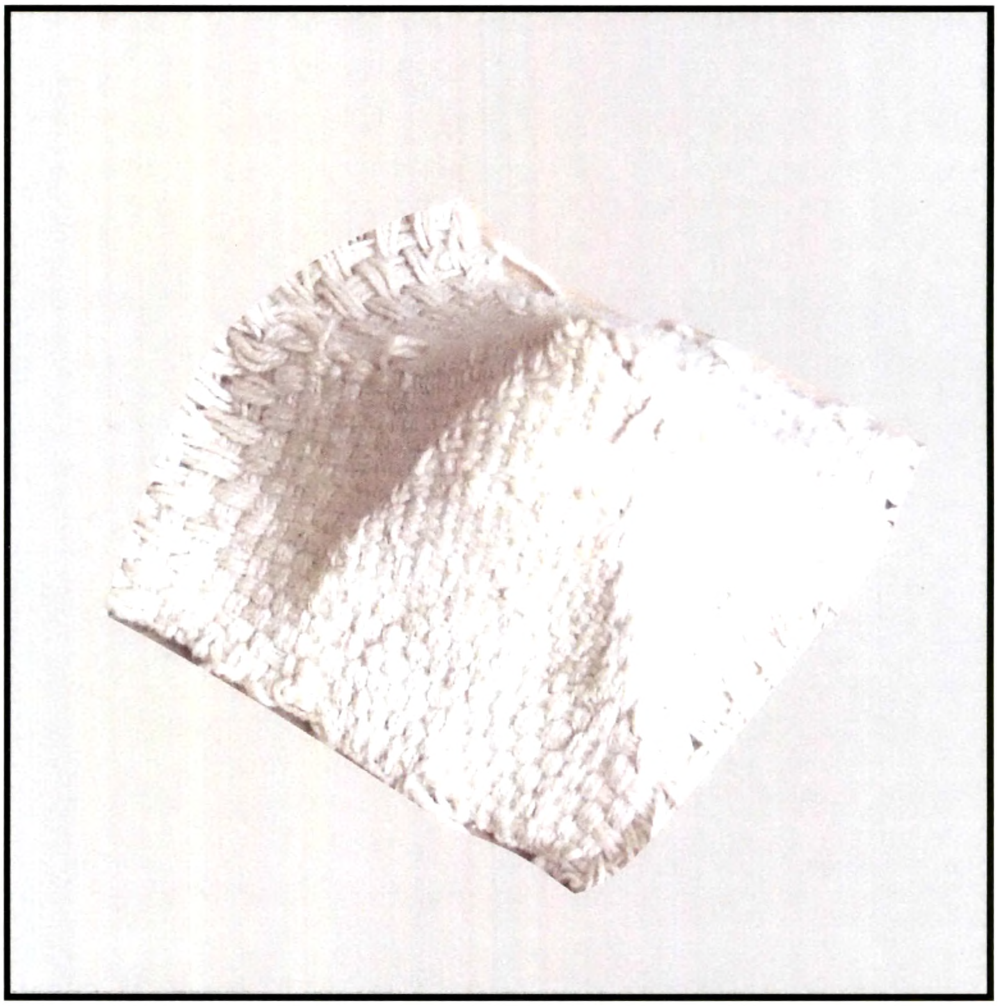


Figure 3.31

Shapes of curves of reed dent wires for a pyramidal shape



Photograph 3.3

Pyramidal shape woven on handloom

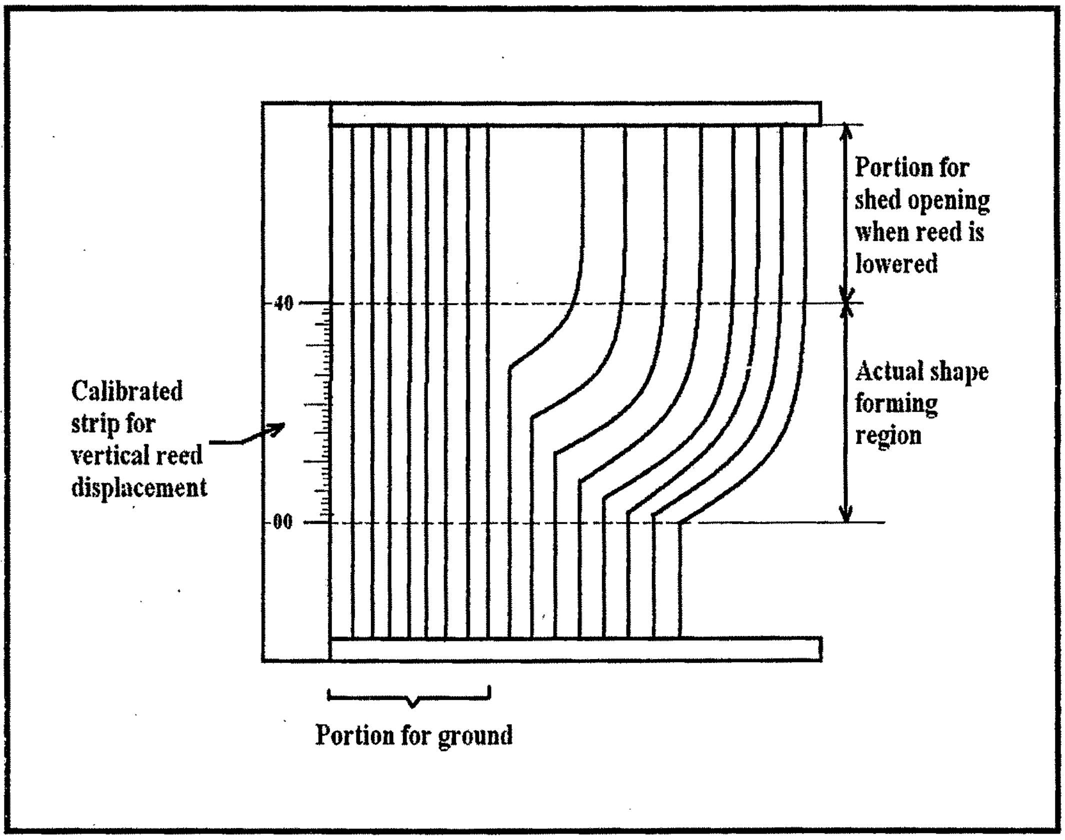

Portion for
shed opening
when reed is
lowered
Actual shape
forming
region
Calibrated
strip for
vertical reed
displacement
40
00
Portion for ground

Figure 3.32

As shape is woven in folded form as an open width double cloth, laying of 2 picks effectively lays one pick in fabric. Therefore, when weaving of shape is begun; during first half of hemisphere, reed is lowered to bring beat up line corresponding to its pick number level mark. While weaving second half of hemisphere, reed is correspondingly raised. Thus, a hemisphere was woven (Photo 3.4) with plain weave all over without any weave assistance or differential take-up. There was some deviation in shape, as suitable means was not provided to bring about required change in successive pick spacing.

3.3.5.3.3 Outcome of weaving on hemispherical and pyramidal shapes on handloom using reed with shaped dent wires:

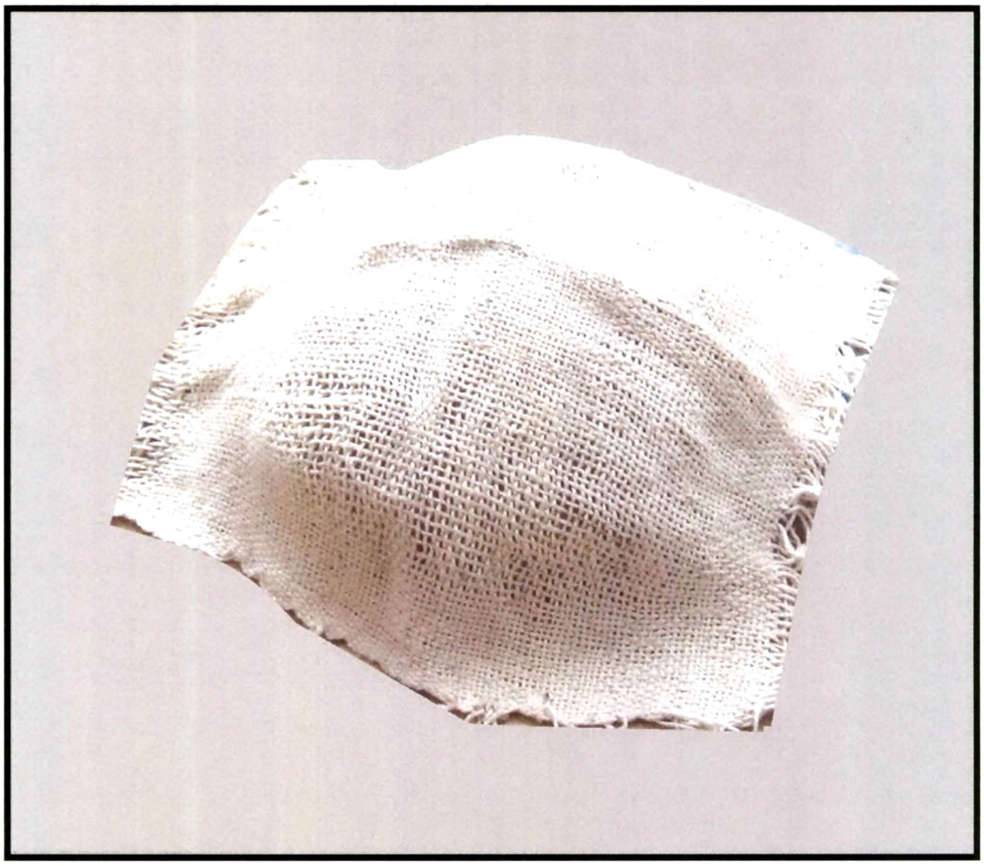
i. Fundamental approach for designing shapes of reed dent wires for pyramidal and hemispherical shapes is developed.

ii. With suitable mathematical approach, it is possible to obtain dent shapes for a given 3D shape, using computer.

iii. It was possible to achieve weaving of pyramidal shape satisfactorily with combination of reed and weave.

iv. Hemispherical shape was also reasonably developed as it was woven with plain weave all over and therefore weave did not assist in shape development.

v. The method of employing special reed seemed suitable for use on a power loom. Thus a method, that was found suitable for application on power loom, gave proper direction for further development on power loom.



Photograph 3.4

A hemispherical shape woven on handloom

3.4 Weaving any other shapes:

Reed for any other shape can be designed on the basis similar to that for pyramidal and hemispherical shapes. Of course as weaving of 3D shapes is to be carried out in folded fashion; the method will be suitable for symmetrical shapes.

Figure 3.33 shows half of an arbitrary shape, which is symmetrical. While designing reed, the logic applied will be similar to that described for pyramidal and hemispherical shape. The dent is to be so shaped that it brings about changes in warp spacings as it is in shape, as weaving progresses; i.e brings about changes in successive pick lengths as it occurs in shape.

3.5 Weaving 3D shapes on a power loom

Weaving on handloom revealed that in a 3D shape woven fabric size of cells vary in shape portion depending upon shape. Therefore, it can be said that desired 3D woven shape can be produced by creating such situation in weaving that cell size is varied to produce desired shape. To vary cell size space between successive ends and picks is to be varied. Special reeds are to be fabricated according to shape, which brings about change in en spacing. Suitable interlacement between warp and weft can also assist in achieving the same.

Pick spacing can be varied by combined effect of -

i. Differential take up across width during a pick as well as on successive picks and
ii. Suitable interlacement.

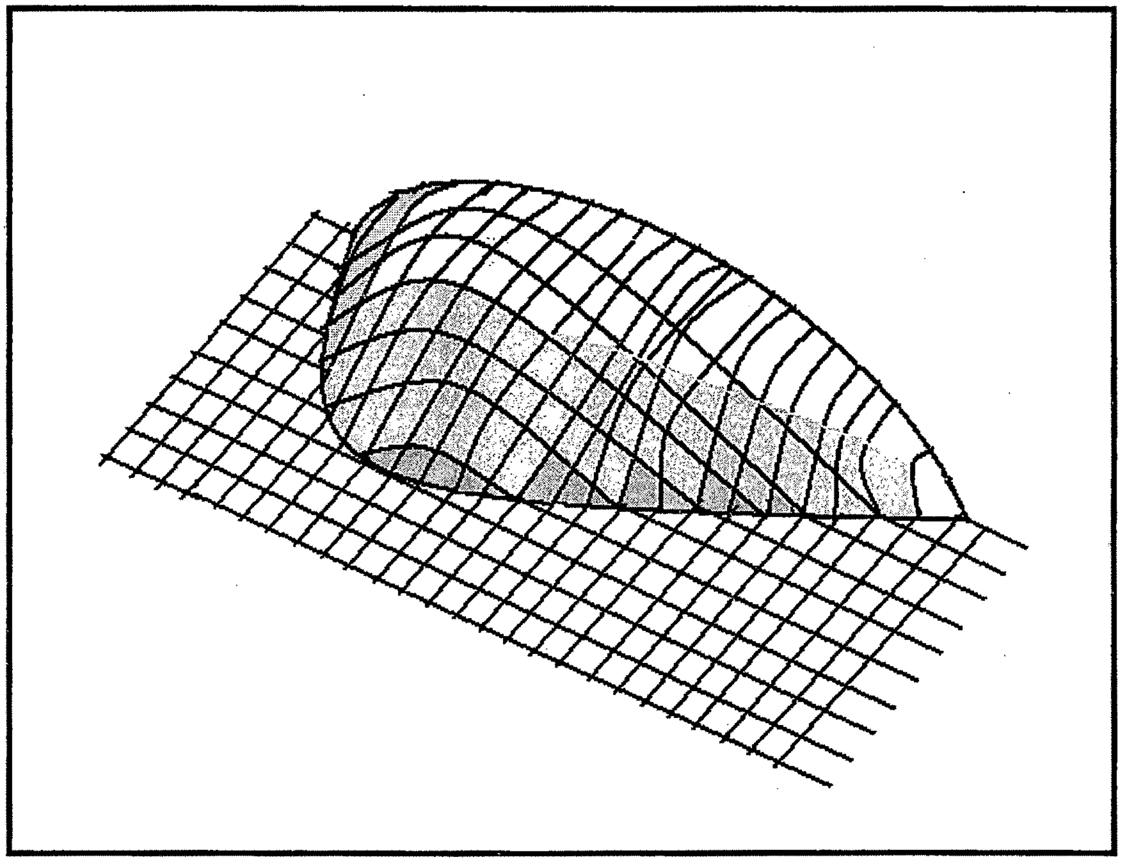


Figure 3.33

3.5.1 Essential requirements on power loom for 3D shape weaving:

3.5.1.1 Warp supply

Length requirement of warp threads in shape region is not same. Each thread in shape region has different length. Warp supply from a weaver's beam supplies equal length of all warp threads. Therefore while weaving 3D shape warp supply should be from a creel so that each end will be supplied according to its length requirement. Thus, a loom for 3D shape weaving requires warp supply from a warp-feeding creel. Creel should have arrangement for adjusting warp tension and keeping it constant at all stages of weaving.

3.5.1.2 Dent slope and reed displacement

Figure 3.34 (a) shows reed for weaving a pyramid. Design of this reed is discussed earlier in section 3.4.2.2.1. Pitch of reed for weaving ground portion is P_1 and is increased to P_2 for shape generation. While increasing this pitch reed dent becomes sloping. During weaving, to change from pitch P_1 to P_2,

reed is to be displaced by d_1. Φ_1 indicates angle of dent with vertical. As warp threads have to move along this dent space, for shed forming, higher slope would make shed formation difficult as it narrows down the gap between successive dent wires. Therefore this angle should be kept as low as possible.

Now, $\phi = \tan^{-1} \frac{P_2 - P_1}{d_1}$

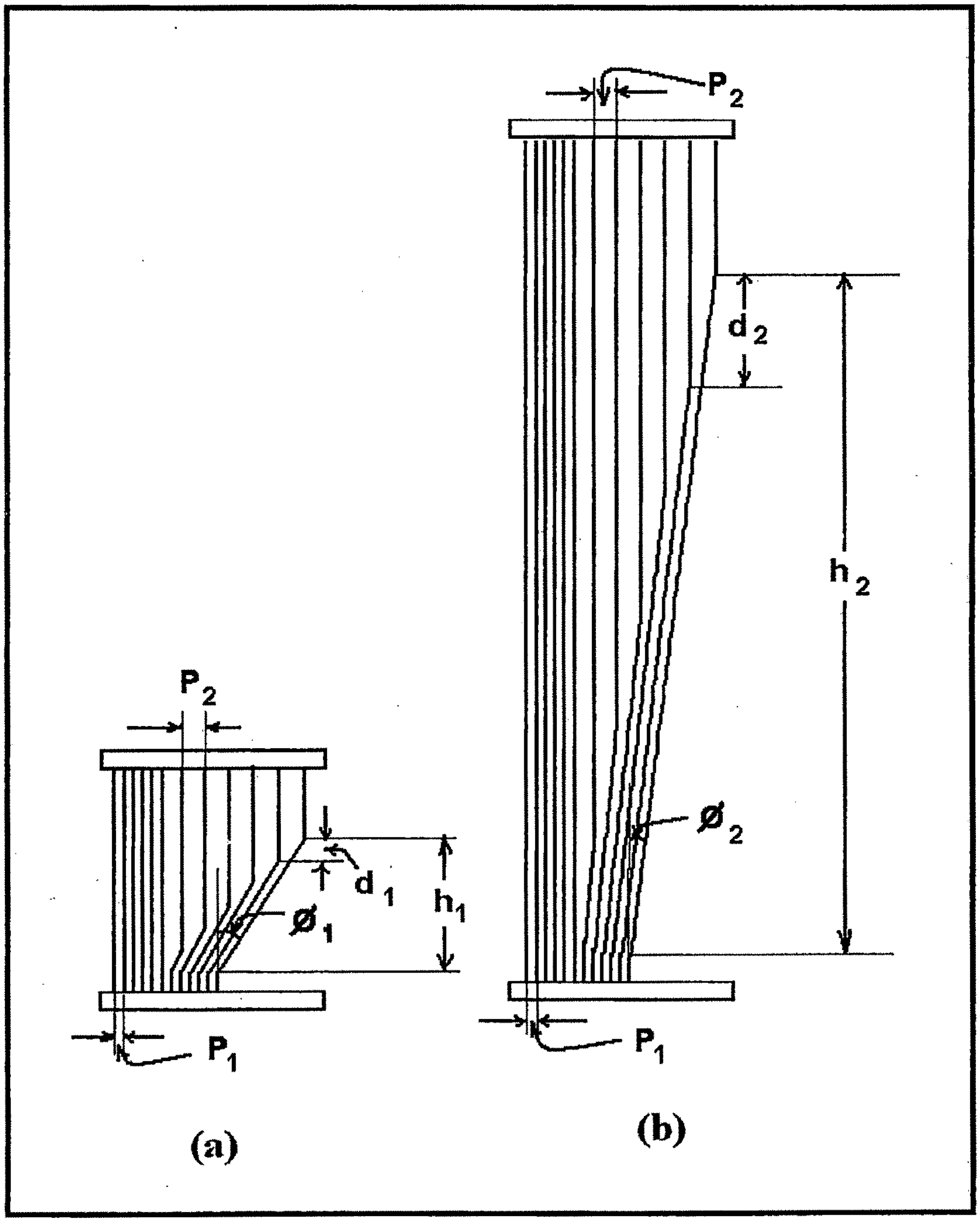


Figure 3.34

Therefore Φ can be reduced by increasing displacement 'd' which is shown in Figure 3.34 (b); i.e. reed is elongated along its height. Thus by taking higher reed height dent slope can be minimized. But this on the other hand increases reed height, and hence necessitates higher reed displacement to bring about same widening of space between ends. That is referring to (b) and (c); $h_2>h_1$ and $d_2>d_1$ against advantage of $\Phi_2<\Phi_1$. Therefore it is advantageous to have reeds with substantially higher dimension height wise for 3D shape weaving.

3.5.1.3 Reed fabrication and significance of dent rigidity:

Higher reed height will lead to longer unsupported reed wires. This would make reed fabrication difficult. Each dent would be substantially longer which is to be shaped specifically. All dent wires, shaped specifically, are to be assembled exactly and anchored at either end. Thus reed fabrication in this case has to meet requirements, which are different from fabrication of a normal reed for 2D weaving. Hence a suitable technique for reed fabrication had to be developed.

Here material for reed dent should be such that it allows shaping of dent wires as required. So a softer material would be preferable to meet this demand. However during weaving, reed wires have to be rigid enough so that their shapes are not distorted. During weaving reed wires have to bring about changes in spacing of ends. As reed wires are unsupported over longer lengths, they can be distorted by stresses of warp threads. If this happens, it can affect shape. Moreover if distortion can result in to touching of neighboring dent wires which can cause hindrance in shed formation. Therefore a hard dent material would be preferable from this point of view.

Thus demands are contrasting - on one hand; softer dent material is desirable from shaping point of view while on the other hand harder material is preferable for maintaining dent rigidity during weaving.

One option could be using softer dent material be while shaping and impart hardening treatment subsequently. However, hardening treatment should be such that it does not cause any distortion to shaped dent wires or fabricated reed.

3.5.1.4 Arrangement for reed displacement

Suitable arrangement is necessary to bring about required reed displacement vertically. Reed in usual 2D weaving is fixed whereas for 3D shape weaving, reed has to be mounted in suitable frame where it can slide. This frame has to be mounted on sley. Suitable arrangement has to be provided to displace it vertically, upwards or down wards, by required amount, in conjunction with shape development during weaving.

3.5.1.5 Shuttle guidance through shed

As reed is to be displaced vertically and has greater height, reed may not guide shuttle properly through shed. Manufacturing reed with absolutely even plane and stable dent wires would be difficult. Also setting correct reed position with respect to race board and shuttle boxes would be problematic. Even if these requirements are managed, reed displacement during shuttle flight might deviate shuttle path. Therefore the function of guiding shuttle through the shed cannot be assigned to the reed but some other alternative has to be sought.

3.5.1.6 Fabric control at fell of the cloth

In normal 2D weaving the total length of successive picks almost remain constant. In 3D shape weaving the lengths of successive picks vary in shape region. While weaving 3D shape in folded fashion, width of fabric at fell of the cloth varies from pick to pick in shape region. In 2D weaving temples are used to keep fabric stretched width wise at the fell of the cloth. Conventional temples like ring temple or roller temple will not be suitable for 3D shape weaving because they are designed to work under condition where fabric width at cloth fell remain same. Therefore, instead of conventional temples, a mechanism would be necessary that keeps the fabric stretched at the cloth fell at the same time allows changes in cloth width brought about by reed displacement.

3.5.1.7 Shedding mechanism requirement

Interlacement between warp and weft is to be selected in such a way that it assists in changing spacing between successive ends and picks depending upon shape to be produced. Therefore it is necessary to employ jacquard shedding.

3.5.1.8 Selection of comber board

In normal 2D weaving, the pitch of the reed and thereby width of fabric at the fell of the cloth remain the same during weaving. Comber board pitch is selected so that ends/inch in reed and that in comber board are same. This is done to ensure that ends remain parallel while passing through harness mail eyes and reed dent wires. In 3D weaving width at the fell of

the cloth changes during weaving of shape. Therefore ends would not remain parallel and this might cause some problem in weaving.
Thus points discussed above were to be borne in mind before proceeding further.

3.5.2 Establishing set up for 3D shape weaving on a power loom:

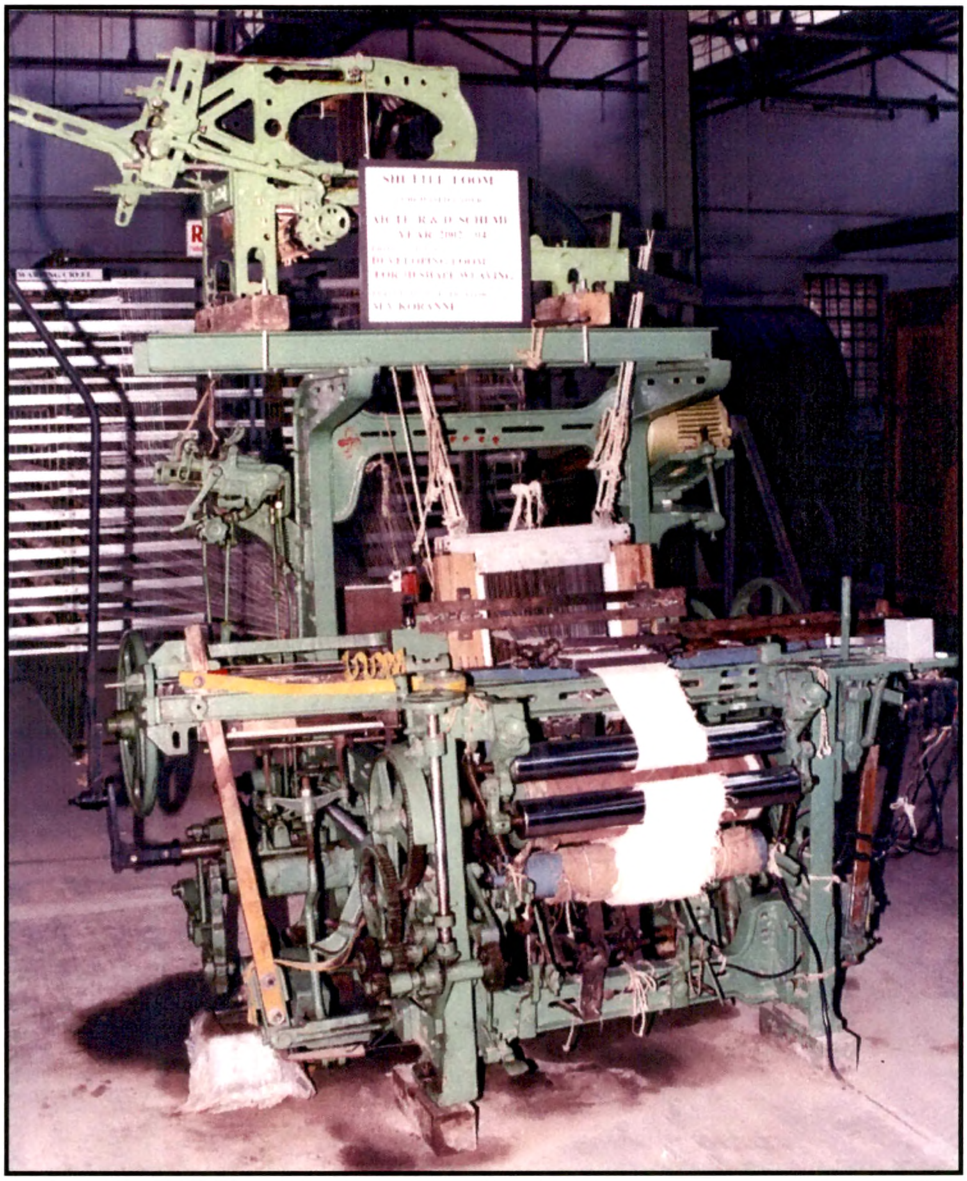
As 3D shape weaving proposed set up is quite different from normal 2D weaving; there was uncertainty of its successful working on actual power loom. Therefore it was advisable to go step by step so that hurdles are overcome one after the other. Several doubts arose in mind – like how shuttle would run without reed support; how a large reed would be fabricated, whether it would displace vertically as per requirement or not, whether shuttle would travel properly etc. Therefore it was preferable to start with the simplest possible set up and try modifications one by one. The work progressed through following stages.

i. Procurement of a suitable power loom
ii. Design, development and fabrication of warp feeding creel
iii. Modification in loom for guidance of shuttle through shed without support of reed
iv. Design, development and fabrication of bracket for mounting and supporting reed
v. Fabrication of reed with shaped dent wires
vi. Mechanism for displacing reed vertically
vii. Design, development and fabrication of fell control mechanism

3.5.2.1 Procurement of suitable power loom:

First step was selection of a suitable power loom. As 3D shape was to be woven in folded form; actual width of 3D shape would be twice it is in folded form. Therefore a narrower loom was thought to be most suitable. Narrower loom would also facilitate development, fabrication and movement of various modifications. Keeping this in mind, a narrower loom with following specifications (Photograph 3.5) was selected. For initial trials, it was decided to employ dobby shedding which would be simpler as compared to jacquard shedding.

- Loom width 20"
- 4x1 multiple box motion
- Photo-electric type weft feeler so loom is semi-automatic i.e. loom is stopped automatically when pirn is exhausted except bunch portion.
- Loom provided with a leverage type of automatic let off motion.
- Weaver's beam diameter 13"
- Side weft fork motion
- 7 wheel take up motion
- 16 jack double lift single cylinder climax type dobby for shedding



Photograph 3.5

View of Power Loom

3.5.2.2`Design, development and fabrication of warp feeding creel:

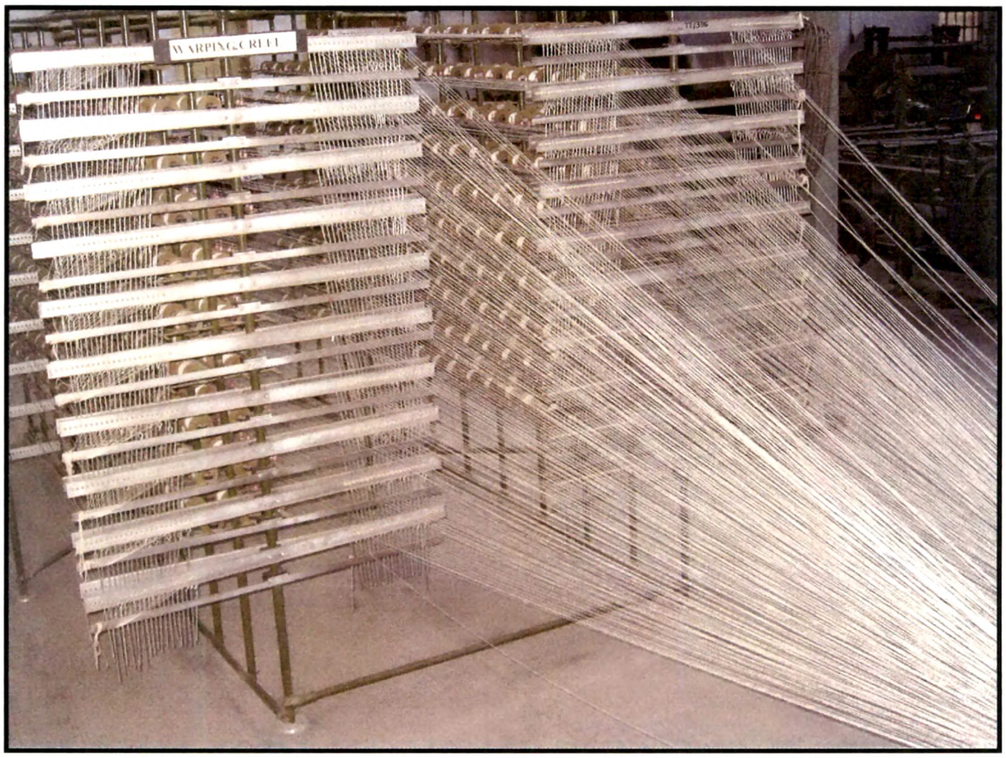
An 800 capacity warp-feeding creel was designed and developed for feeding warp threads individually to loom (Photographs 3.6 and 3.7). Instead of cones or cheeses, double-flanged bobbins of length 68 mm and flange diameter of 70 mm were selected as supply packages in creel.

As double flanged bobbins are smaller in size it offers two advantages.

- Because of smaller size of package creel became compact in size.
- Weaving can be done with minimal quantity of yarn per bobbin.

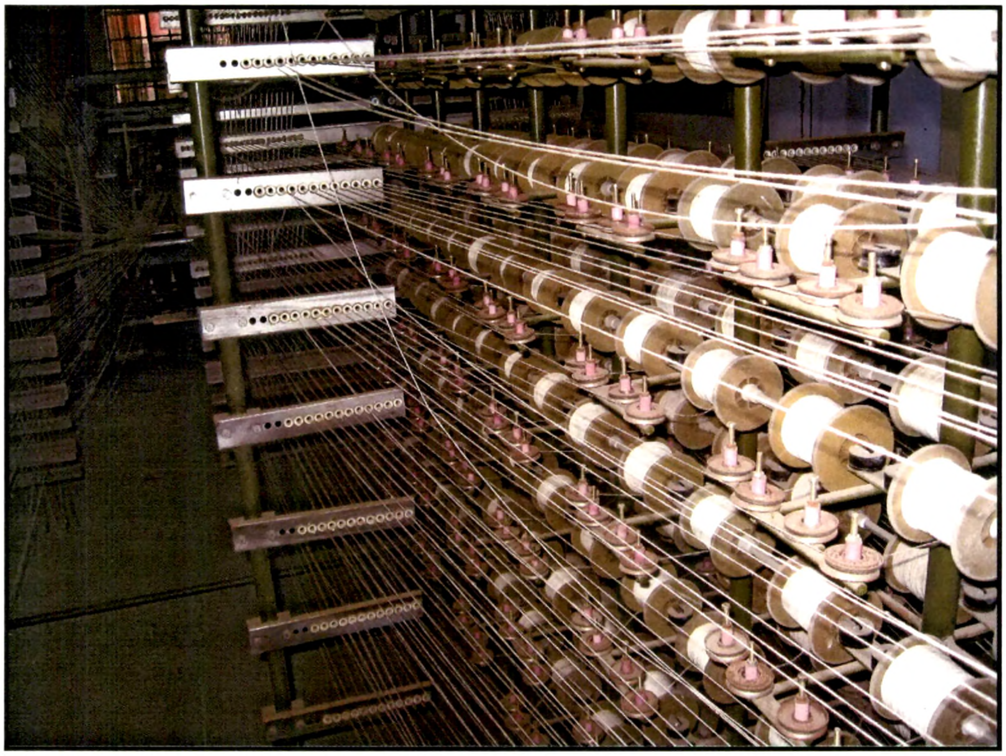
The double-flanged bobbins were wound on old drum winding machine available in the department. By rearrangement of pulleys and leverage change in traversing mechanism on this drum winding machine desired traverse length was obtained.

Figure 3.35 shows supply packages on creel. A supporting rod mounted on two brackets carry two double-flanged bobbins. An end from each bobbin passes through two disc and washer type of tensioners. The creel is in four sections. Each vertical row of bobbins in a section carry ten bobbins and each horizontal row carry 20 bobbins. Thus there are 200 ends in each section. Ends coming from tensioners of rear ten bobbins of horizontal row pass through a row of ten guides. These ends, along with ten bobbins of front horizontal row pass through a row of twenty guides located at front end of creel. At front each end of creel each warp thread is suspended with a dead weight to act as a tension compensator.



Photograph 3.6

Warp feeding creel



Photograph 3.7

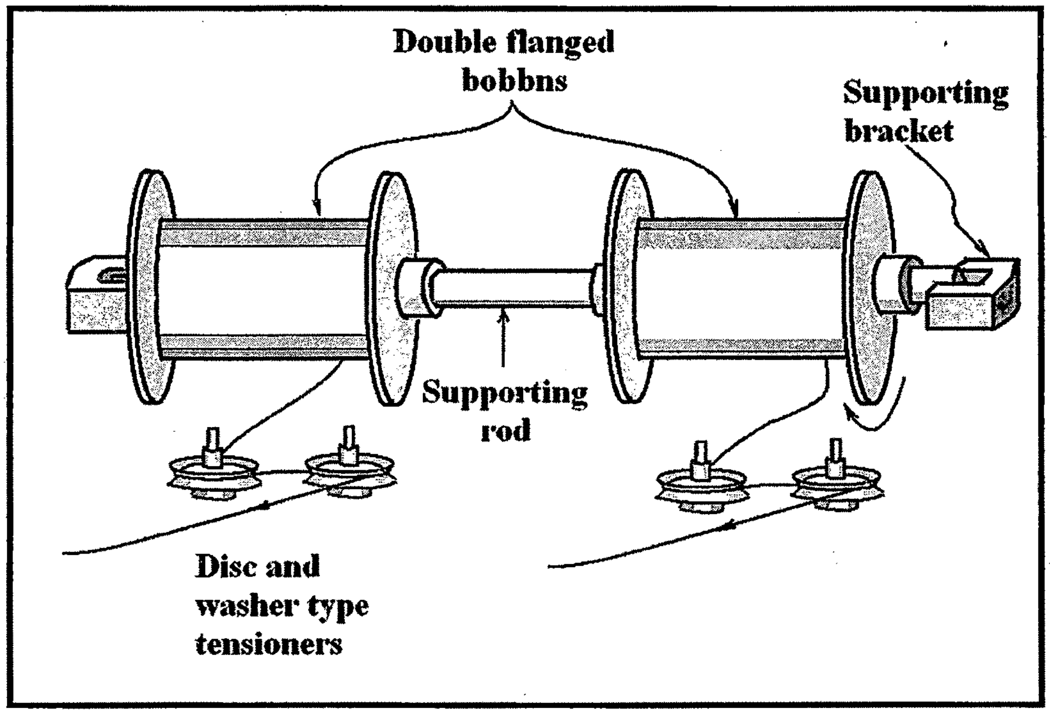


Figure 3.35

Supply packages on creel with tensioning devices

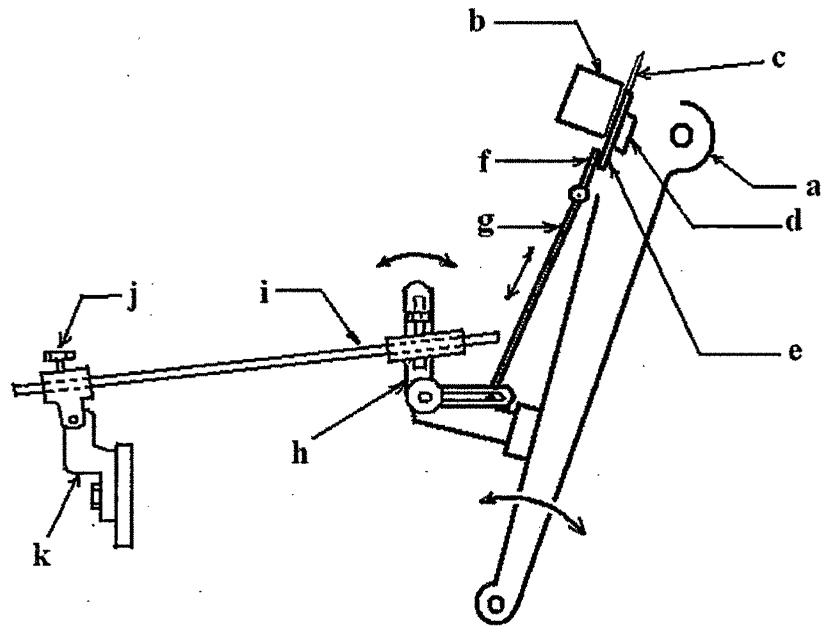
3.5.2.3 Modification in loom for guidance of shuttle through shed without support of reed:

For guiding shuttle through shed without reed, needle bar mechanism, as provided in lappet weaving was employed. This consists of a series of needles fixed on a wooden strip called needle bar 'c'. This needle bar is raised and lowered through shed, whose motion is derived from sley reciprocation. This needle bar is located in place of normal reed.

The needle bar move up and penetrate through bottom line of warp to guide the shuttle through the shed. When shuttle enter on of the boxes and sley advances for beat up, the needles are lowered below line of race board allowing beat up of laid pick (Figure 3.36). The reed should be located just behind this needle bar mechanism.

3.5.2.4 Design, development and fabrication of bracket for mounting and supporting reed:

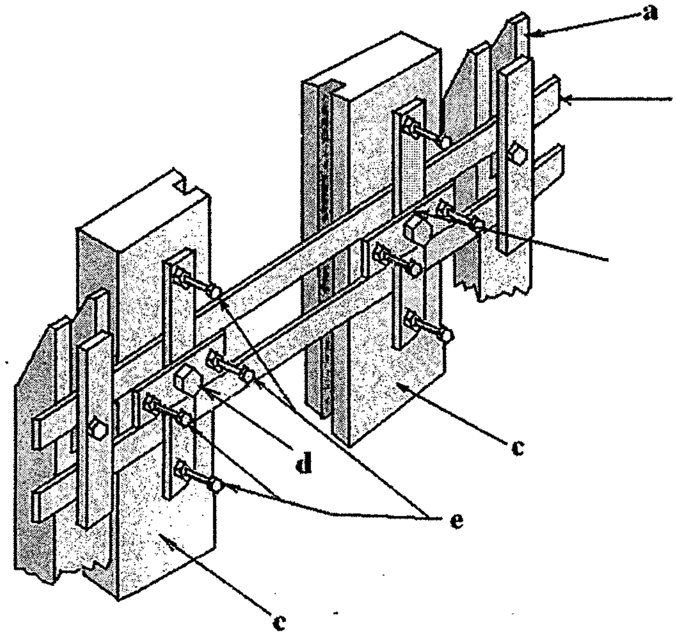
Next job was to fabricate a reed as well a bracket with a slide, mounted on sley sword in which reed is supported. The reed should be capable of moving vertically along slide without great friction. Two slides (guiding slots) 'c' (Figure 3.37), one for each side, were fabricated from wood. For mounting them on sley, sley cap was removed. A mounting bracket 'b' consisted of mainly two iron strips, fitted on sley cap. The wooden slides were fitted on this bracket. The slides can be aligned with each other using set screws 'e', so that reed would slide without excessive friction. The slides should be set in such a way that they remain out of path of moving needle bar. Any misalignment would not allow reed to move freely and working would be difficult.



a - Sley sword
b - Race board
c - Guide for needle bar
e - Needle bar
f - Hinge
h - Bell crank lever
i - Connecting rod
j - Set Screw
k - Bracket fixed on loom frame at front end

Figure 3.36

Needle bar mechanism for guidance of shuttle



a - top end of sley sword
b - Bracket for mounting slides
c - Wooden slide
d - Bracket for fixing slide
e - Bolt for fixing slide with bracket
e - Set screws for alignment of slides with each other

Figure 3.37

Bracket for supporting reed

For proper alignment four setscrews for each slide were part of fabrication that allowed slide alignment.

3.5.2.5 Fabrication of reed with shaped dent wires:

For fabricating reed, dent material should be such that it can be given required shape. The dent material, therefore, should be soft enough for shaping. But at the same time it should be hard enough to retain its shape against stresses acting during weaving. If dent wires do not retain their shape then it can adversely affect shape to be produced. If a dent deforms and touches its adjacent dent, warp breakages can occur. Dent stability can be increased by increasing dent cross section. Therefore, a flat dent would be more suitable. So flat strips, which are thinner but wider, would be more suitable for dent. Considerable effort was required for evolving suitable technique for fabricating reed. The procedure for reed fabrication is as follows.

As shown in figure 3.38, a drawing sheet with reed drawing is fixed on a wooden board with cello tape. The length of the board is equal to the distance required between reed staves.

As shown in Figure 3.39 reed wires are shaped as per drawing and positioned on board one by one. The length of the dent wires is taken greater than board so that they protrude out equally on either side. Two 'C' channels are taken with slot width little greater than depth of the dent. The channels are positioned from either end so that the protruding dent wires pass through channel slot. Care is taken so that the channels remain co-planar and parallel with each other. The dent wires and channel are fastened together using adhesive paste. Araldite is used as an adhesive.

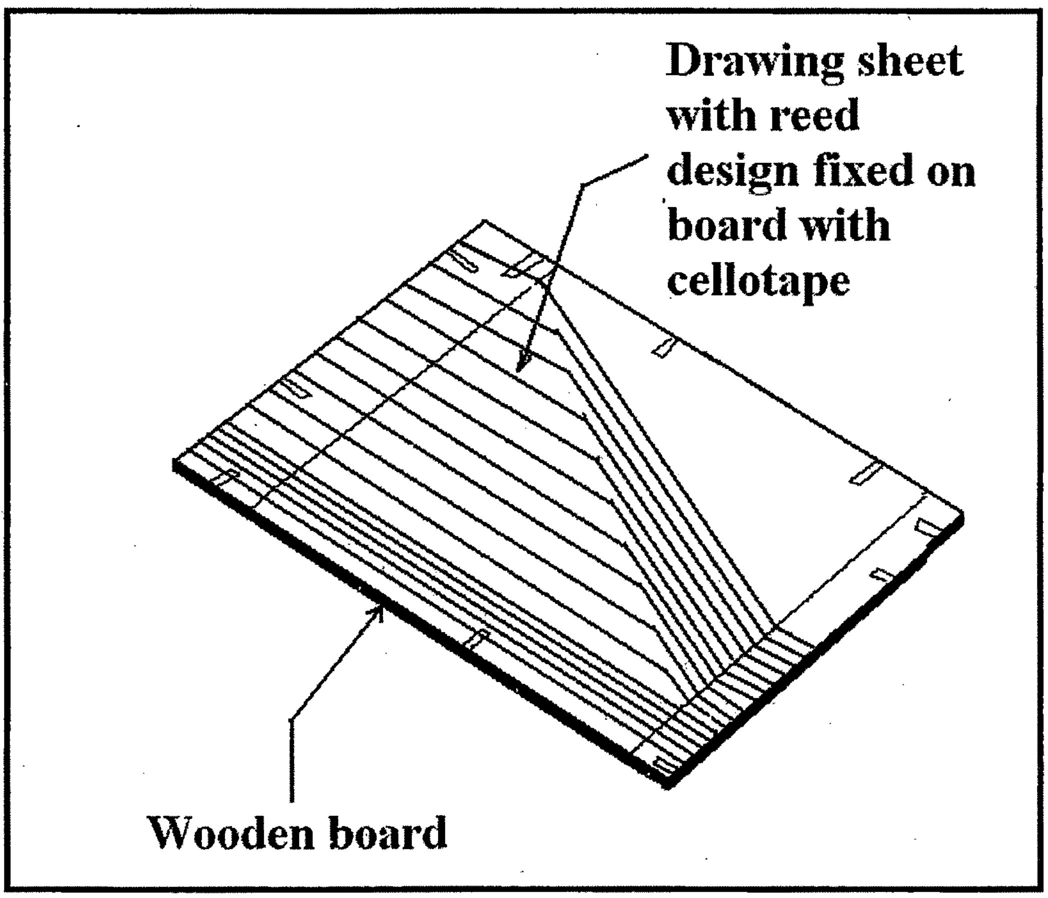

Drawing sheet with reed design fixed on board with cellotape
Wooden board

Figure 3.38

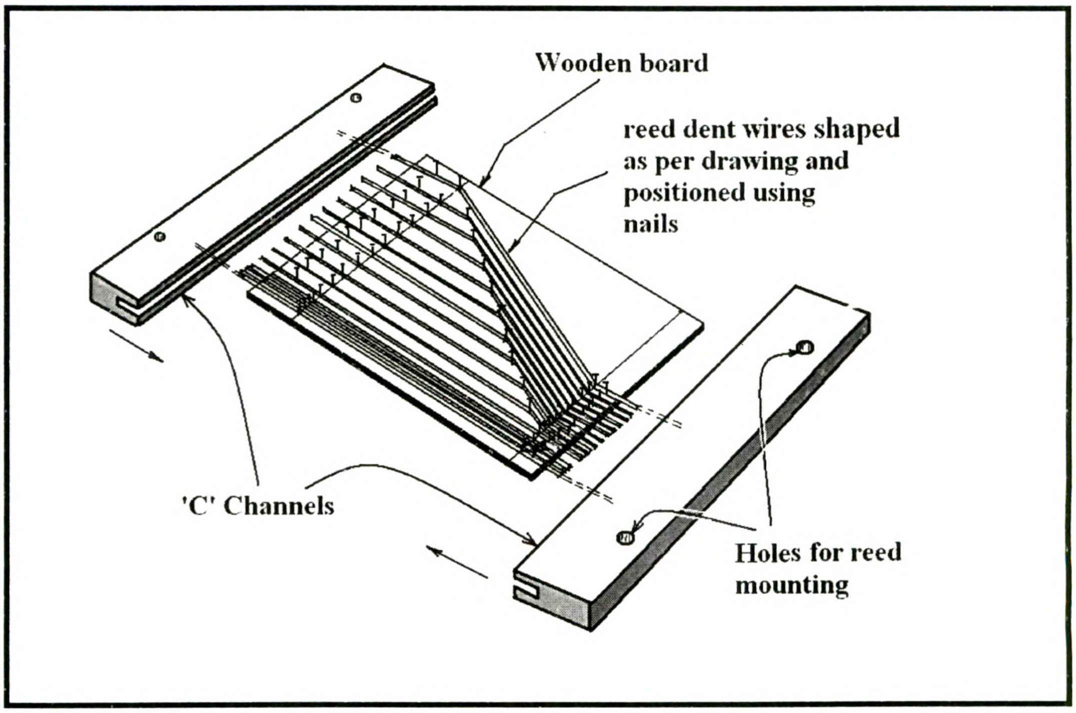

Wooden board
reed dent wires shaped as per drawing and positioned using nails
'C' Channels
Holes for reed mounting

Figure 3.39

Araldite alone is not used as it is costly at the same time not available in thick paste form. Therefore iron powder is mixed with araldite to make a thicker adhesive paste. Thus iron powder act as a filler material, reduces consumption of araldite and enable formation of a thick paste. On curing of adhesive, reed is ready. Holes are drilled in channels to mount reed on loom. If required the channels can be fastened with each other using two bars fixed with channel with rivets. The reed after fabrication is shown in figure 3.40.

After construction of reed it was necessary to check whether reed would slide properly or not. With suitable alignment of slides reed was found sliding smoothly without any hindrance.

3.5.2.6 Mechanism for displacing reed vertically:

Simultaneous efforts were going on to develop a suitable mechanism for changing vertical position of reed to change line of beat up. The first mechanism developed was as follows (Figure 3.41). Bracket 'a' is fastened on rocking shaft 'b'. This bracket carries a ratchet 'd', a wooden heart cam 'e' and a notched disc 'f'. Ratchet carries 50 teeth. Shaft 'c' carries a pawl lever 'g'. Pawl lever 'g' is connected to a link 'h' whose one end is pivoted on loom frame. As sley rocks, pawl lever also gets rocking movement, which in turn drive ratchet. Heart cam 'e' is followed by a follower carried on lever 'i'. Lever 'i' is connected with a connecting rod 'j' which is connected at top with reed. Rotation of ratchet causes rotation of heart cam, which in turn causes movement of lever 'i', which ultimately causes reed displacement. A dead weight 'K' balances the reed weight.

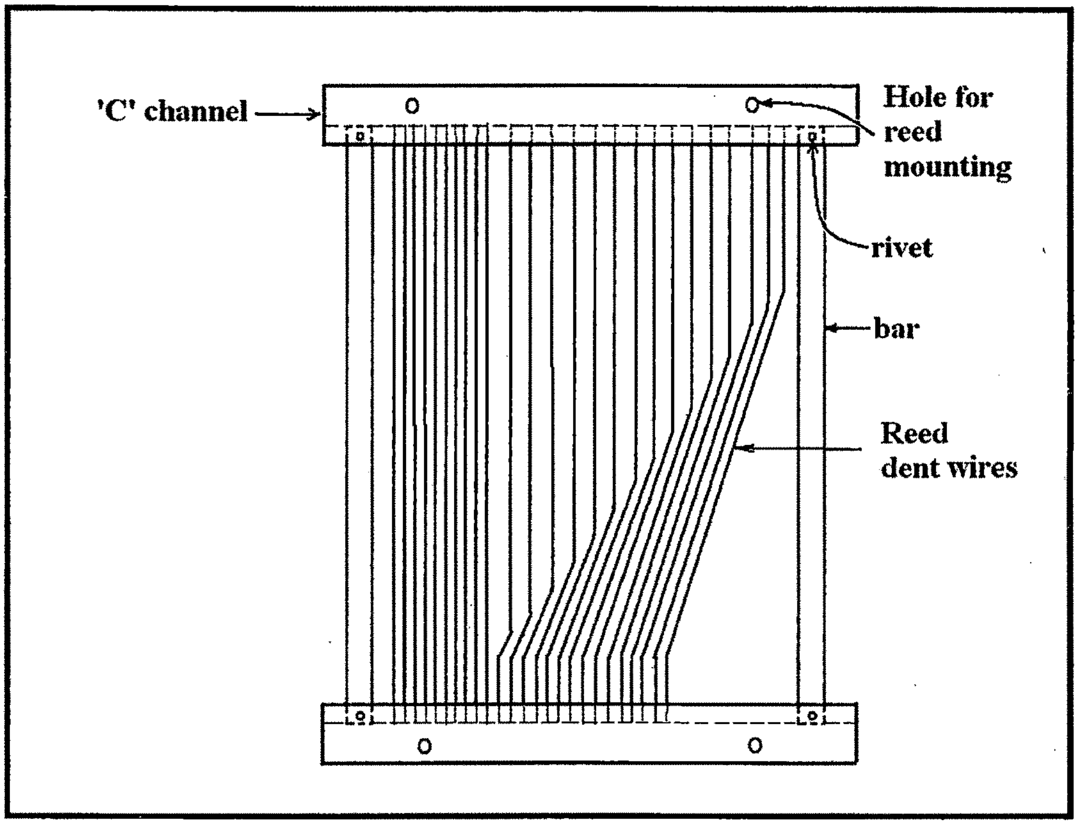
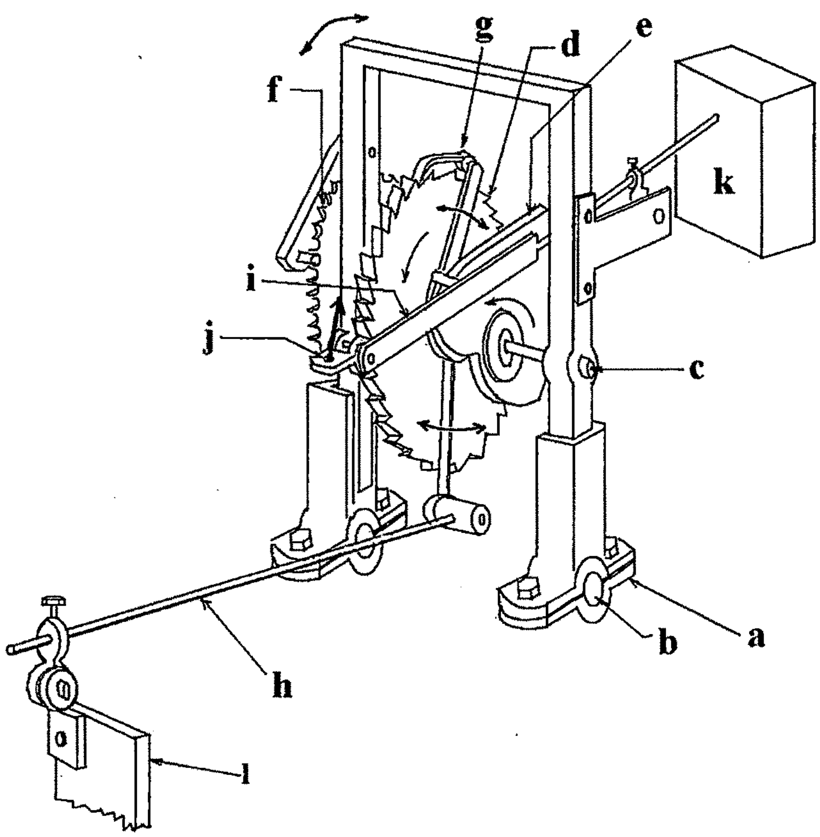


Figure 3.40

Fabricated reed



a - Bracket fastened on rocking shaft
b - Rocking shaft
c - Shaft on bracket
d - Ratchet
e - Heart cam
f - Notched disc
g - Pawl lever
h- Connecting link
i - Follower lever
j - Connecting rod connected with reed
k - Dead weight for load balancing
l - Bracket mounted on loom frame at front end

Figure 3.41

Mechanical arrangement for reed position control

One rotation of ratchet brings about one rotation of heart cam. As ratchet teeth are 50, 50 teeth movement of ratchet corresponds to one rotation of heart cam. As heart cam is symmetrical, 25 teeth movement of ratchet completes single stroke of reed. Heart cam profile gives equal movement to reed per single teeth ratchet movement. If ratchet is rotated every pick, number of picks per repeat of shape would be less i.e. only 25, as two picks laid effectively becomes one pick as fabric is woven as a double cloth . Therefore to make a lager shape, ratchet should not be rotated continuously every pick, but after interval of some picks. If we rotate ratchet once in 8 picks, then shape repeat size becomes (8x50)/2, i.e. 400 picks. As 2 picks effectively lays one pick, number of picks in shape would be 200. Ratchet rotation was stopped by connecting driving pawl of ratchet with a dobby jack with a string. Lifting of dobby jack would disengage driving pawl and disconnect pawl drive for that pick. During weaving of ground portion too, pawl was kept disengaged. Notched disc acted like star wheel in a dobby and prevented excess rotation of ratchet. Maximum possible reed displacement with this arrangement was 140 mm.

Thus a mechanical arrangement for bringing about vertical reed displacement was fabricated. Loom was run without warp to test this set up. The arrangement worked satisfactorily.

3.5.2.7 Design, development and fabrication of fell control mechanism

While weaving 3D shape portion, the reed is displaced vertically that changes warp thread spacings or in other words change the lengths of the successive picks. This changes width of the cloth at cloth fell. Thus this is a typical situation weaving where width at cloth fell keep on changing.

Therefore usual temples at cloth fell have to be replaced by some other means that allows width changes caused by reed at the same time retain them.

For this purpose a mechanism with two combs is developed. The two combs are located one behind the other across the entire width of cloth. Front comb is positioned close to reed in its front most position and the rear one few millimeters behind it. Front comb is lifted when reed moves towards front center for beat up and is lowered at front center. The comb penetrates fabric at front center and 'locks' changes in warp thread spacings brought about by reed. The lifting of rear comb begins after front center and is lowered before the front comb starts lifting. The rear comb retains the thread spacing when front comb is lifted up. Figure 3.42 describes the details of this mechanism.

Bracket 'a' is mounted on loom frame. This bracket carries two cylindrical housings on left and right sides. Each housing carries another cylindrical housing, which carries a spring-loaded rod 'c'. If there is shuttle trap, the spring retracts and provides safety.

The ends of rods 'c' carry a bracket 'd'. Bracket 'd' carries brackets 'e' that carries rod 'f'. Rod 'f' carries two long levers 'g' on which front comb 'h' is mounted.

Similarly bracket 'd' carry rod 'i' that carry short levers 'j' on which rear comb 'k' is fitted. Rods 'f' and 'i' act as fulcrum for front and rear combs respectively. Comb levers 'g' and 'j' are connected with flexible cords 'l' and 'm' respectively. These cords are operated through two cams fitted on bottom shaft.

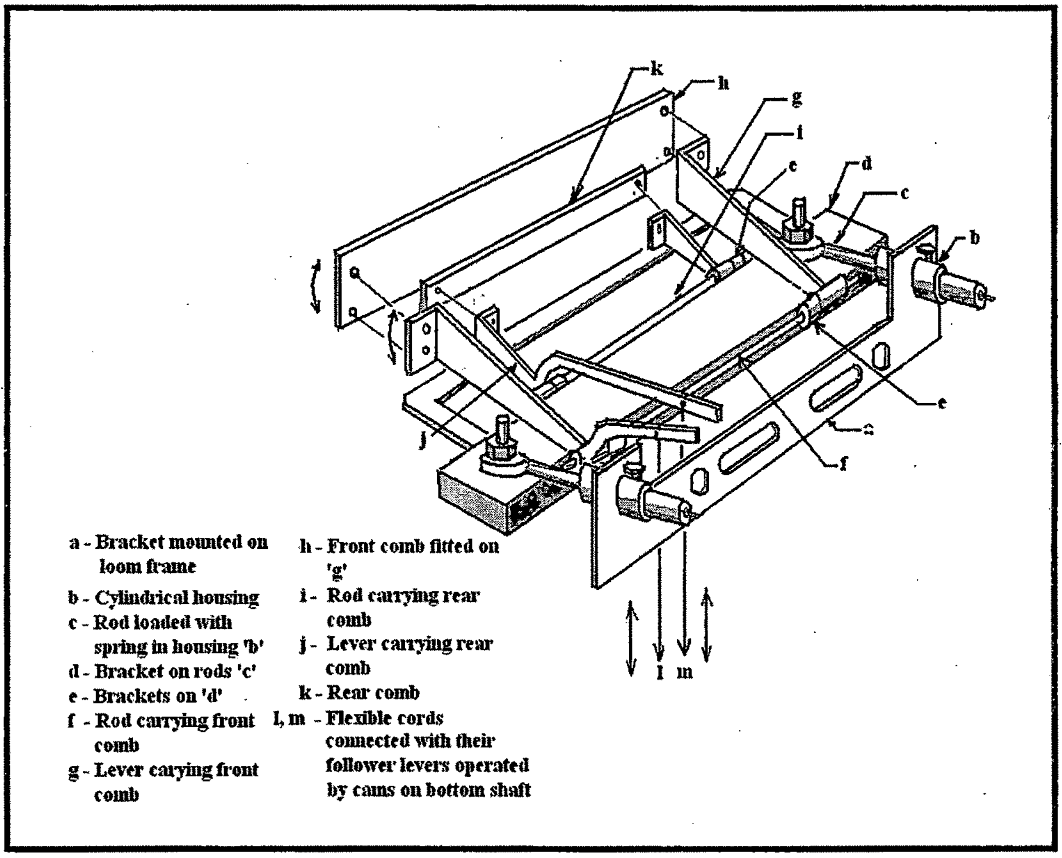

k
h
g
i
e
d
c
b
e
a
f
j
l m
a - Bracket mounted on loom frame
b - Cylindrical housing
c - Rod loaded with spring in housing 'b'
d - Bracket on rods 'c'
e - Brackets on 'd'
f - Rod carrying front comb
g - Lever carying front comb
h - Front comb fitted on 'g'
i - Rod carrying rear comb
j - Lever carrying rear comb
k - Rear comb
l, m - Flexible cords connected with their follower levers operated by cams on bottom shaft

Figure 3.42

Figure 3.43 shows two cams mounted on bottom shaft. These cams are followed by their follower levers. Arms of follower levers are connected with comb levers through flexible cords. Reversing springs keep followers in contact with their cams and also lower combs on fabric.

For fabricating comb sewing needles were woven on handloom periodically in weft direction in a narrow strip of fabric as shown in figure 3.44. This strip was then pasted with araldite on a thin metal strip to form a comb. This strip was fixed on a bar that was fastened with comb levers.

A pyramidal shape was woven with this set up.

3.5.3 Out come of weaving on power loom:

Out come of weaving on power loom with modifications like mechanical control for reed displacement vertically, fell control mechanism with combs, warp supply from creel etc. and various problems faced/ solutions sought is as follows.

i. The mechanical system for displacing reed vertically worked.

ii. Some problems were observed with respect to picking. Figure 3.45 shows view of loom weaving a pyramidal shape. The selected loom is with 20" reed space narrow loom. Therefore the length of shuttle boxes is almost of same as reed space. Here as reed is to be displaced vertically, it needs guiding brackets as well as frame portion in reed on either side. Therefore a considerable gap exists between R.H. shuttle box and last dent of reed on R.H. side.

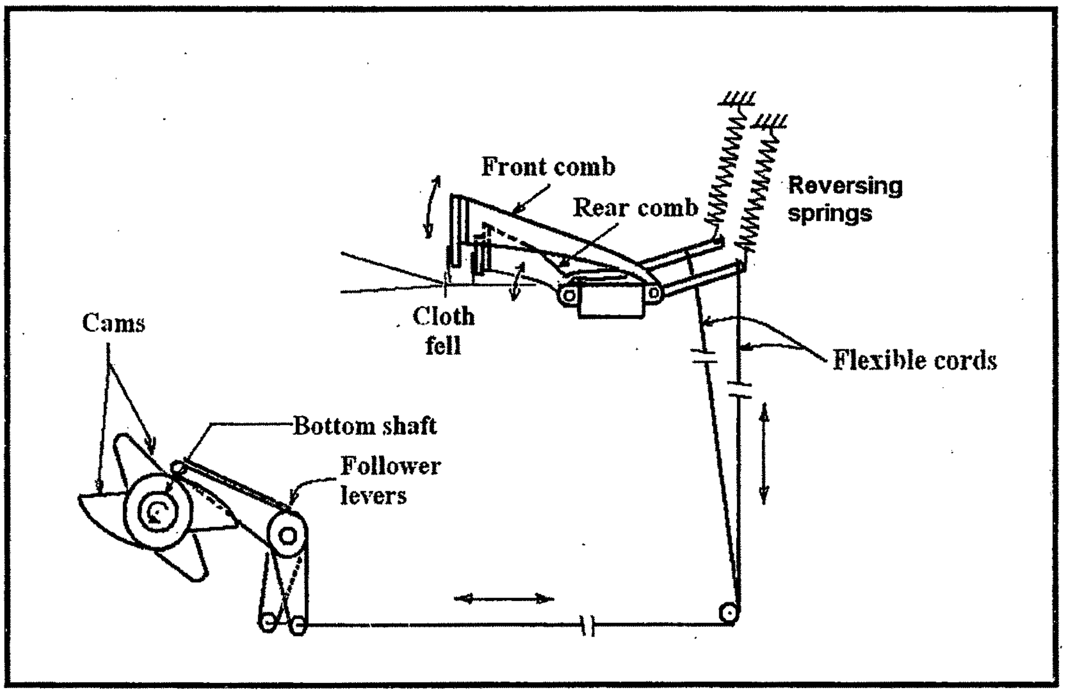

Front comb
Rear comb
Reversing
springs
Cloth
fell
Cams
Flexible cords
Bottom shaft
Follower
levers

Figure 3.43

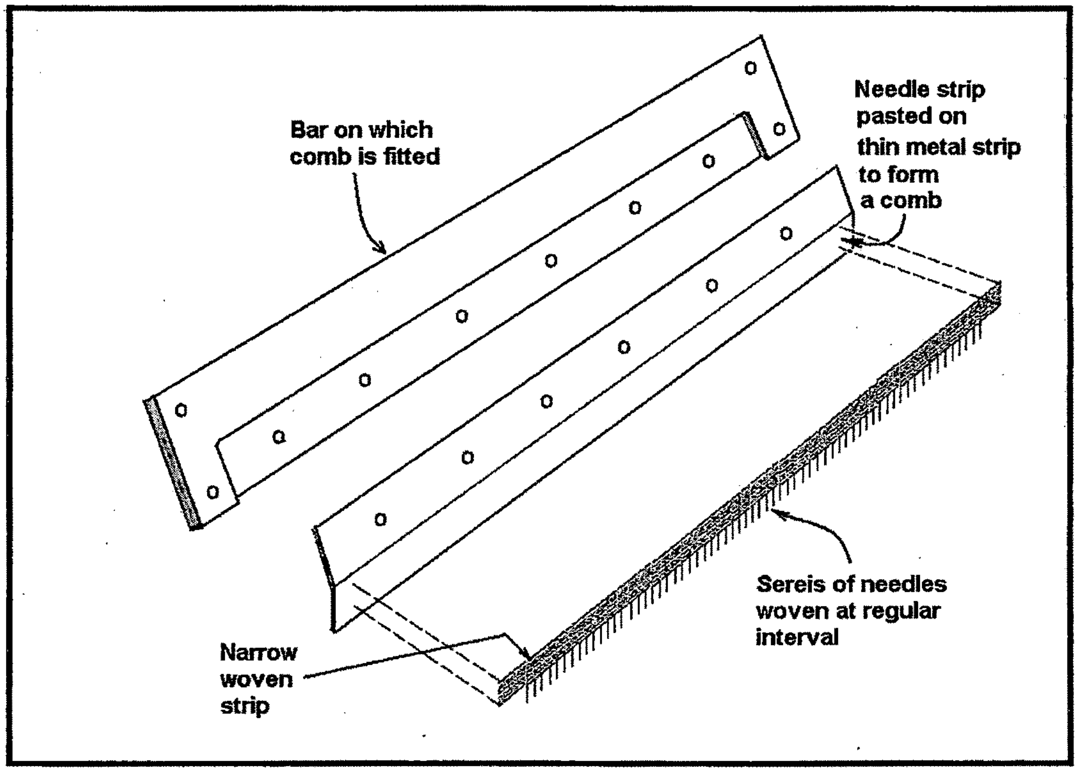
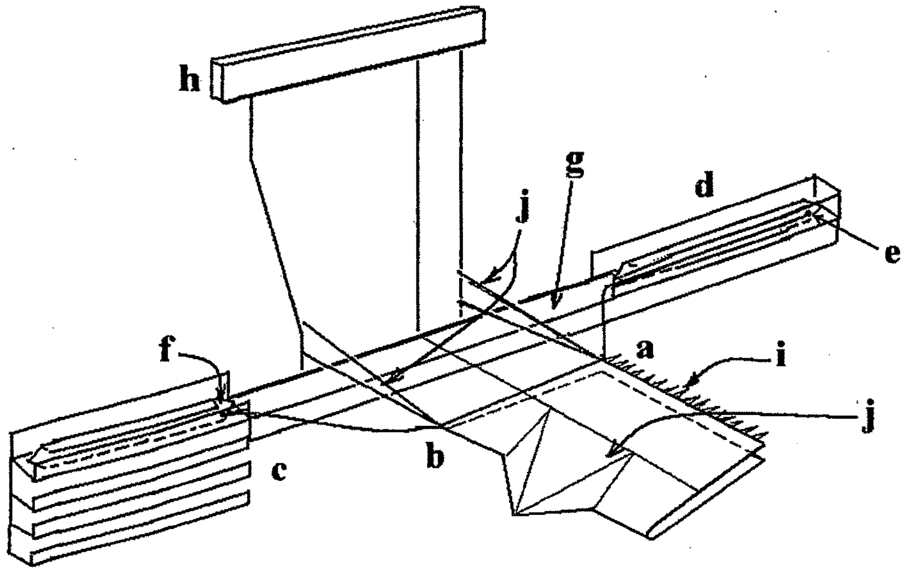

Bar on which
comb is fitted
Needle strip
pasted on
thin metal strip
to form
a comb
Sereis of needles
woven at regular
interval
Narrow
woven
strip

Figure 3.44



a - R.H. fabric selvedge
b - L.H. fabric selvedge
c - L.H. multiple box side
d - R.H. multiple box side
e - Shuttle eye position in R.H. box
f - Shuttle eye position in L.H. box
g - Race board
h - Reed
i - Shed
j - Woven pyramidal shape

Figure 3.45

iii. Due to this shuttle eye remains closer to the end of R.H. shuttle box when shuttle is housed in R.H. shuttle box where as it remains closer to L.H. shuttle box entry when it is housed in L.H. shuttle box. Therefore distance between 'a' (R.H. selvedge) to 'e' (shuttle eye when shuttle is housed in R.H. shuttle box) happens to be greater than that between 'b' (L.H. selvedge) to 'c' (shuttle eye when shuttle is housed in L.H. shuttle box). Because of this loops of weft are formed at R.H. selvedge.

iv. To overcome above problem two holes were drilled; one in the middle of shuttle and the other one around 2" away from it in front wall, at weft groove. Yarn guides were fixed in each hole as shown in figure 3.46. Weft thread coming out from shuttle eye passes through weft groove and then through first guide and goes inside the shuttle and is then passed through second yarn guide where it comes out of front wall of shuttle.

v. However this threading increased weft tension. Also guide thickness has to be smaller than front wall of shuttle box otherwise weft will be trapped between front walls of shuttle and shuttle box when shuttle is in R.H. box, and break.

vi. Fabric width is the narrowest while weaving ground portion and it keep on increasing on left while weaving shape. Therefore wide gap exist between L.H. shuttle box and shed especially while weaving ground non-shape portion. Therefore shuttle does not get support from shed for substantial length as it leaves L.H. shuttle box. This can lead to shuttle fight.

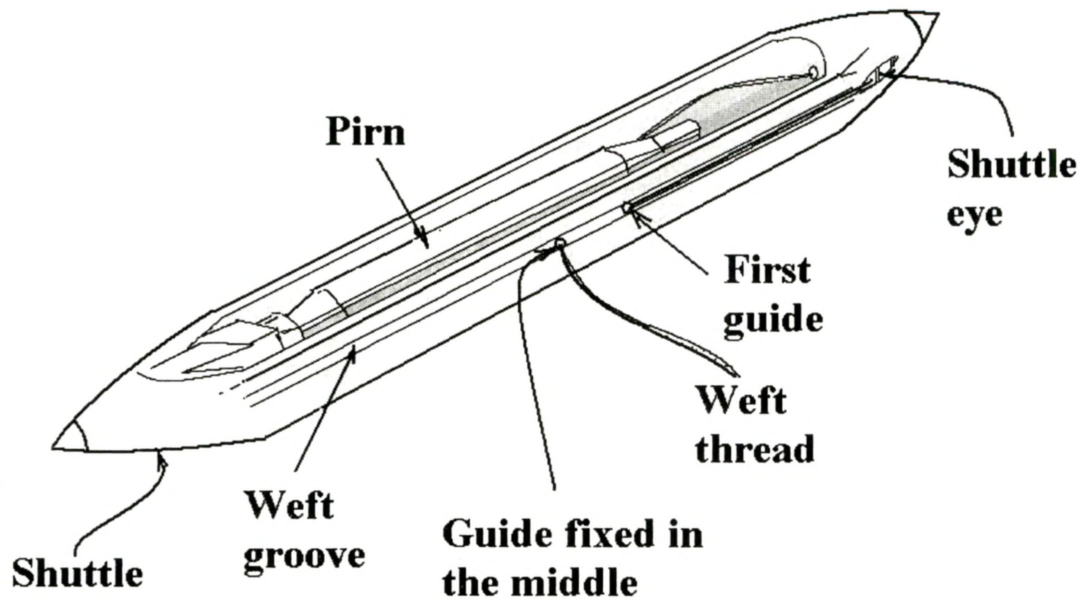

Pirn
Shuttle eye
First guide
Weft thread
Weft groove
Guide fixed in the middle
Shuttle

Figure 3.46

vii. As weaving of pyramid shape begins, there is an increase in fabric width at left side. The fell has to be controlled very effectively. The change in width at fell has to be allowed and retained. Proper tension has to be maintained in warp as well as in fabric portion. As shown in figure 3.47, the tension in warp tends to pull increased width portion towards reed. If this happens, shed opening towards left decreases and uniform beat up force is not applied throughout width. Also higher tension in weft, when shuttle travels from left to right, causes grouping (crowding) of ends on left side as shown in figure 3.47.

viii. Also it does not allow spreading of fabric at fell by the amount determined by reed dent profile and position. Therefore width of warp in reed become higher than that at cloth fell. Therefore the ends will not pass straight through reed and fabric but will deflect around reed wires at left end as shown in figure 3.48. This puts pressure on dent wires and causes dent wires at left end touch one another. This causes hindrance in shed formation. This also causes all ends of bottom line of warp passing through a dent line up vertically. This causes shuttle flight.

ix. Therefore it is very essential to maintain uniform tension across fabric width at all times, as well as allowing and maintaining changes in warp spacings caused by reed.

x. In 3D shape weaving reed is positioned on the rear side. Because of this the front most position of reed shift backwards. Position of cloth fell depends upon weaving resistance. For given sett of ends, weave and weft count, cloth fell position depend upon weft density. For lower weft densities, weaving resistance will be low. Therefore cloth fell will be located at front most position of reed.

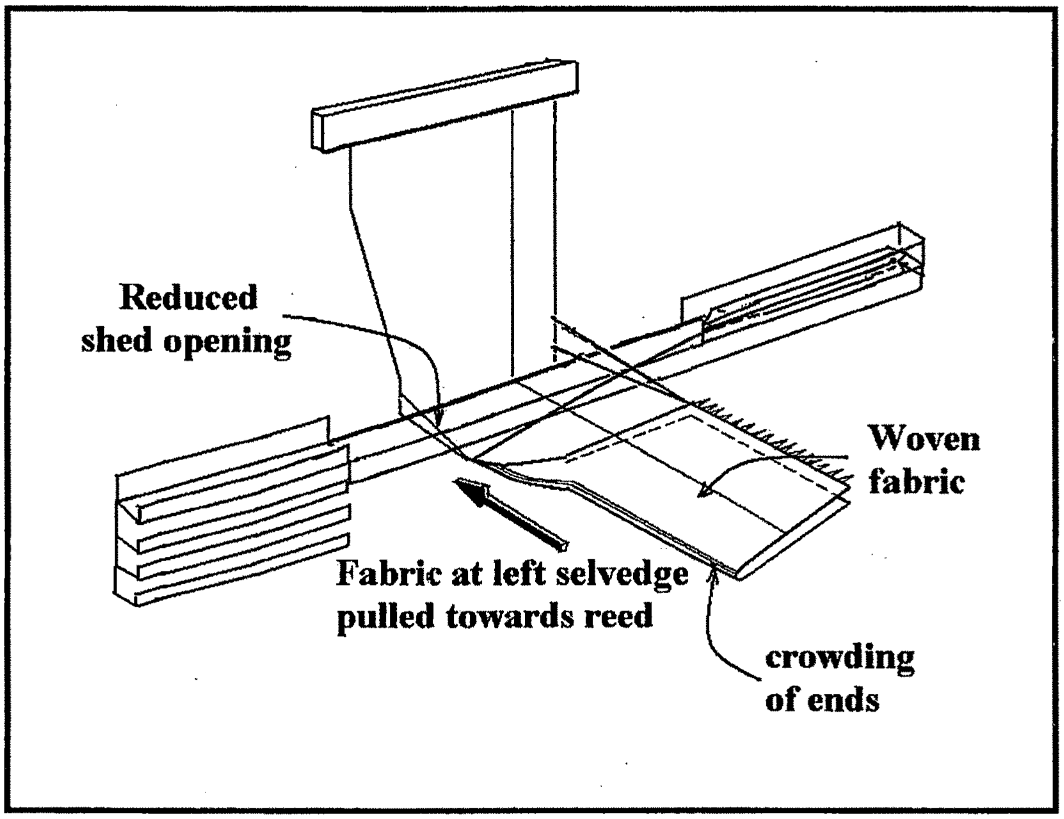

Reduced
shed opening
Woven
fabric
Fabric at left selvedge
pulled towards reed
crowding
of ends

Figure 3.47

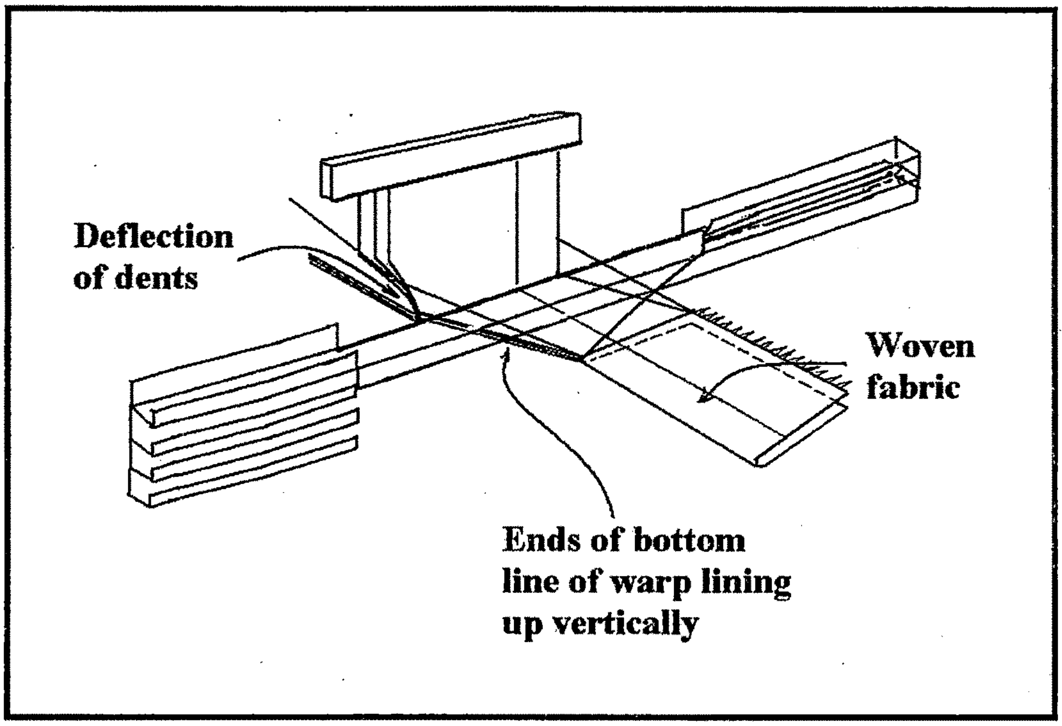

Deflection
of dents
Woven
fabric
Ends of bottom
line of warp lining
up vertically

Figure 3.48

xi. As weft density is increased, weaving resistance will increase, and hence cloth fell position will shift backwards. As the mechanism to control cloth fell can not be located behind front most position of reed, it will be difficult to retain changes in spacing of warp threads brought about by reed. Cloth fell position can be kept closer to front most position of reed by keeping very high warp tension.

xii. Shifting of cloth fell backwards cause two more problems. Firstly it reduces shed opening for the shuttle. Secondly it can cause problem in needle bar movement. When the sley approaches for beat up, needles of the needle bar are lowered and they lie few millimeters below the fabric at beat up. When the sley start moving backwards after beat up, the needles start rising. If cloth fell is located backwards, the rising needles can penetrate fabric instead of warp.

xiii. Weaving was carried out with dobby shedding. Therefore there was no influence of weave in increasing spacings of warp and weft. There was only influence of reed, which mainly aimed at increasing spacings of ends but not picks.

xiv. Reed should have been displaced every pick. If reed would be displaced every pick, number of picks in pyramid would equal to number of teeth of ratchet of drive explained in section 3.5.2.6, i.e. 50. However, to weave a pyramid with bigger dimensions, reed was displaced once in eight picks as explained in section 3.5.2.6. Even though no major visual disturbances were observed in shape.

xv. Thus, this work revealed that it is possible to weave 3D shape, with system for changing warp thread spacings comprising of reed with shaped dent wires on a power loom. Suitable mechanism that allows and retains changes in warp thread spacings brought about by reed is necessary.

3.5.3.1 Necessary requirements for further development:

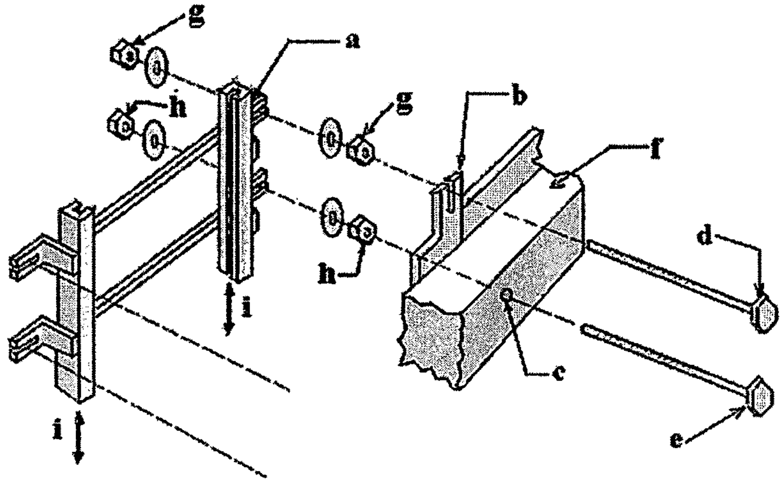
Gaining experience from this work, next stage of development was to be aimed at following:

i. System with greater flexibility in terms of adjusting reed displacement was to be developed.
ii. Improved bracket for supporting and guiding reed.
iii. Finding solutions to overcome various problems faced during weaving.
iv. Dobby shedding was to be replaced by jacquard shedding.
v. Assistance of weave was to be taken in changing thread spacings as per 3D shape to be produced.
vi. Developing a differential take up that can take up fabric at differential rate across width after a pick is laid so as to vary spacing of picks depending upon shape profile.

3.5.4 Weaving set up for 3D shape weaving with jacquard shedding and programmable stepper motor drive for reed position control and other improvements:

3.5.4.1. Bracket for supporting reed:

A bracket was to be designed, developed and fabricated which was to be mounted on sley. A frame was to be designed and developed that is supported on this bracket and can slide freely in it. Reed is to be fixed on this frame. As shown in figure 3.49, ‘b’ is top end of sley sword where reed cap is fixed. A bracket ‘a’ is fastened at ‘b’ using a bolt ‘d’ and nuts ‘g’.



a - Bracket fastened on sley
b - Top end of sley sword
c - Bolt for fastening sley with sley sword
d, e - Bolts
f - Race board
g, h - Nuts
i - Slot in bracket 'a' for reed frame

Figure 3.49

Bracket for supporting reed

Another nut 'e' that fastens sley with sley sword is extended back and that too fastens bracket 'a' with nuts 'h'. Figure indicates fastening of bracket 'a' on right hand side. Similar arrangement is on left hand side. Bracket 'a' carry slots 'i' in which an aluminium frame can slide freely. Reed is fastened on this aluminium frame. Rigid structure of frame always maintains alignment of slots 'i'.

3.5.4.2 Programmable stepper motor drive:

For displacing reed a programmable stepper motor drive was developed. Through a programmable drive, stepper motor can be rotated by desired number of steps in desired direction. Through a suitable drive mechanism from stepper motor to reed, desired reed displacement can be obtained.

3.5.4.2.1 Stepper motor

200 steps, 60 kg-cm torque stepper motor was selected and procured for this purpose. Thus minimum programmable rotation of stepper motor is $\frac{1}{200}$ rotation. Through suitable reduction in transmission of drive from stepper motor to reed, reed displacement per step movement of stepper movement can be reduced. This can give greater flexibility in adjusting reed displacement per pick. 60 kg-cm torque would be sufficient to displace reed.

3.5.4.2.2 PLC controller for stepper motor

A PLC drive controller was developed to control rotation of stepper motor. The controller has five counters.

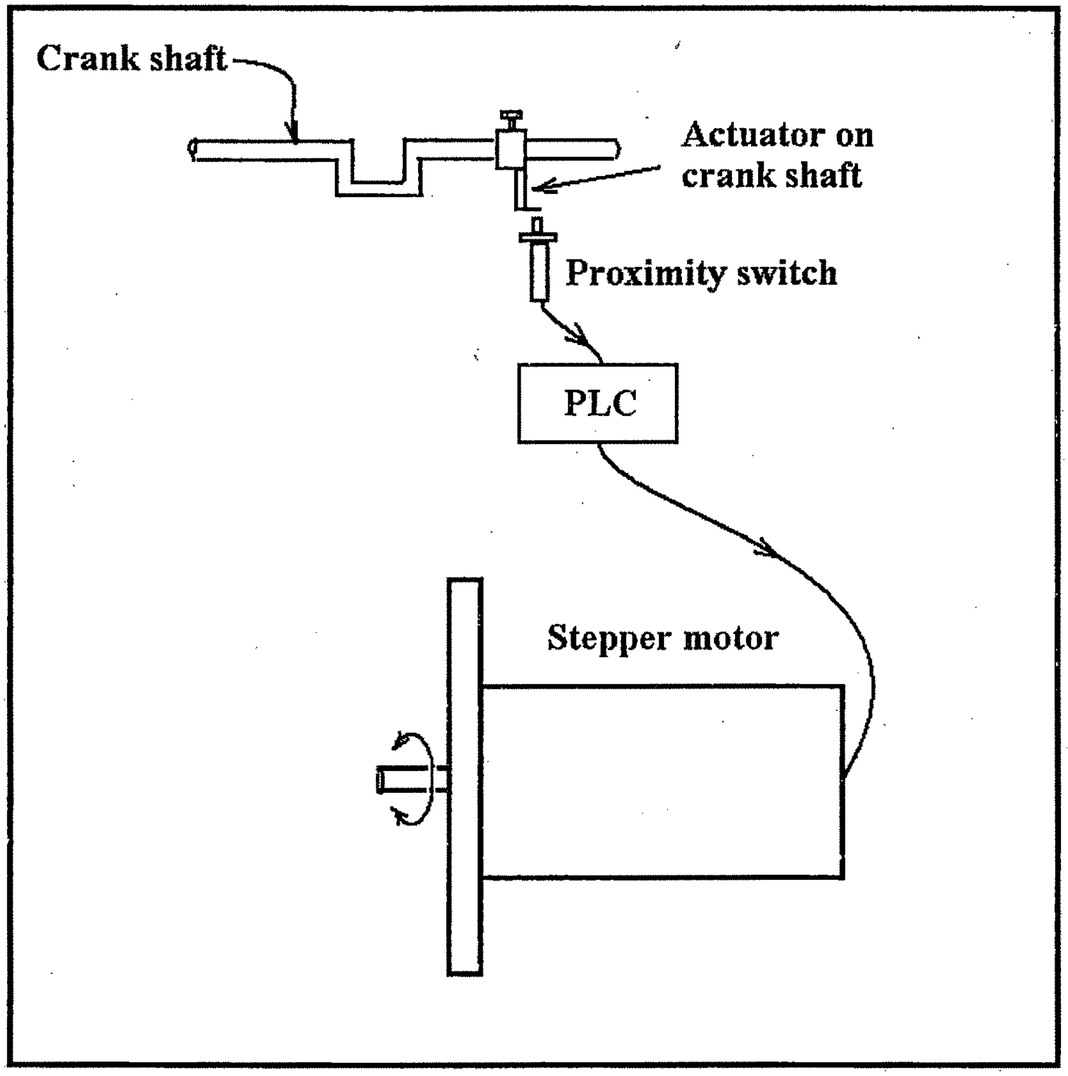

Crank shaft
Actuator on
crank shaft
Proximity switch
PLC
Stepper motor

Figure 3.50

As shown in figure 3.50, each rotation of loom motor generate a pulse through an actuator mounted on crank shaft and proximity switch. This pulse serves as a means to count number of picks. This pulse is received by PLC controller. Three values are to be entered in each counter of controller. One value is to decide direction of stepper motor rotation as well as number of steps movement of stepper motor and the other one for number of picks for which this movement is to be carried out. Number of steps can be selected between 1 to 99 in either direction. For entered value between 1 to 99 stepper motor turns in one direction by number of steps movement equal to entered digit whereas for entered values between 101 to 199, it turns in opposite direction by number of steps equal to entered value minus 100. Value 0 or 100 entered for number of steps idicate no movement of stepper motor.

For example if entered values are 5 and 125, it will turn stepper motor by 5 steps in one direction for 125 picks and for entered values 105 and 125 it will turn stepper motor by 5 steps in opposite direction for 125 picks. There are five counters in controller therefore five different sets of movement of stepper motor can be programmed.

Through suitable mechanical arrangement programmed rotation of stepper motor is to be converted into desired reed displacement. Initially a screw mechanism was designed and fabricated for this purpose.

3.5.4.3 Mechanisms to transmit drive from stepper motor to reed:

3.5.4.3.1 Screw mechanism for reed displacement:

It was thought that a screw mechanism would be suitable to convert rotational motion of stepper motor into linear motion of reed, i.e. stepper motor would drive a screw and nut following screw would drive reed.

As shown in Figure 3.51, a plate is fastened on rocking shaft, which is drilled with two bores. The stepper motor is mounted vertically on this plate and its shaft passes through bore 'a' of the plate downwards. Through other bore passes a screw that is supported on a housing that is fixed on plate. Housing carries bearings for supporting screw. Drive from motor shaft is transmitted to screw through gears located below the plate. Screw carries a nut that extends out side slot carried in housing. The housing is fixed ant top with reed carrying bracket. Plate, along with stepper motor and screw, rocks with sley. The programmed rotation of stepper motor causes rotation of screw that in turn causes displacement of nut. Nut is linked with frame that carries reed from bottom. As described in 3.5.4.1, the frame-carrying reed can slide freely in slot of bracket that is mounted on sley. Therefore displacement of nut causes displacement of reed.

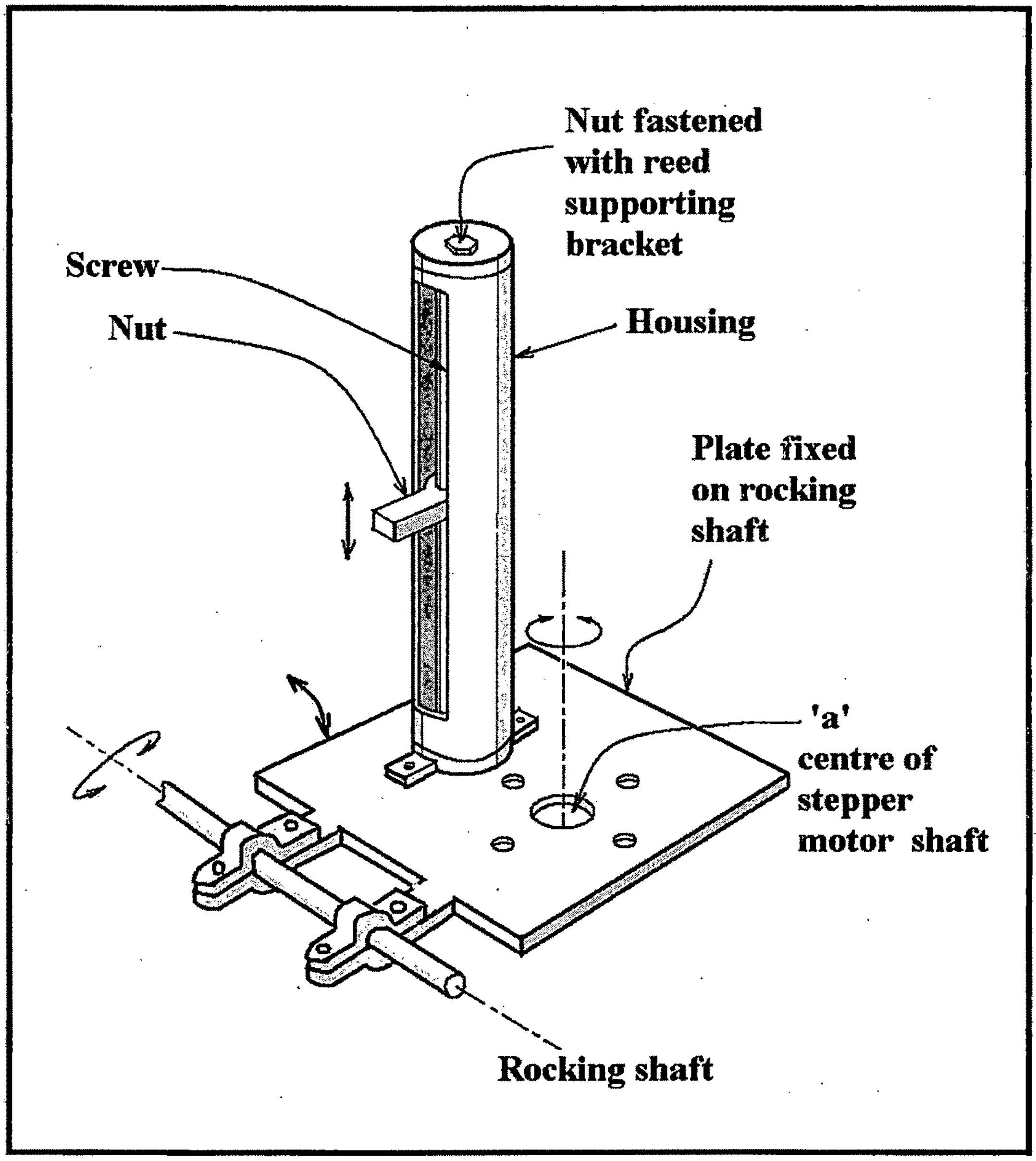

Nut fastened
with reed
supporting
bracket
Screw
Nut
Housing
Plate fixed
on rocking
shaft
'a'
centre of
stepper
motor shaft
Rocking shaft

Figure 3.51

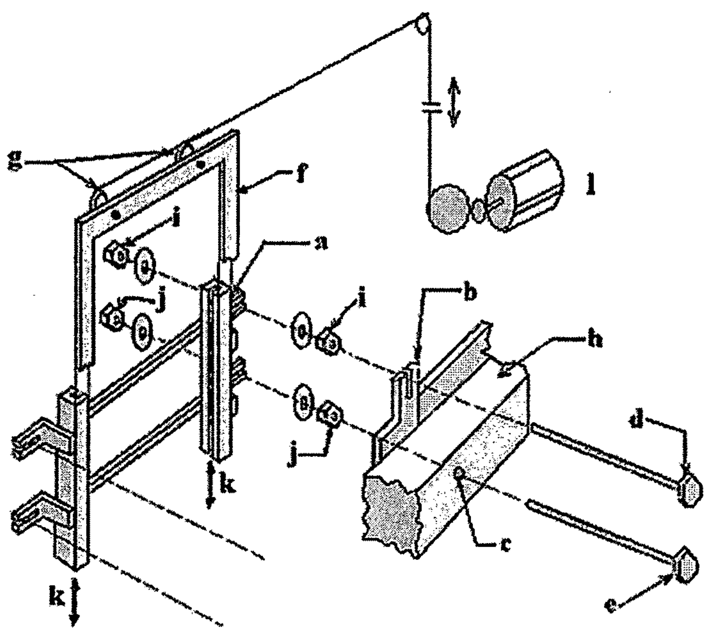
3.5.4.3.1.1 Performance of screw mechanism:

i. In spite of spending several months in developing this mechanism, it ***did not work satisfactorily***. Stepper motor along with screw became too massive to rock with sley. So position of plate on rocking shaft was getting disturbed.
ii. Movement transmission to reed was from a single point at bottom. Therefore ***misalignment*** between screw and reed used to take place that caused ***overloading on stepper motor***. Therefore it was unable to displace reed. Problem was severe when greater reed displacement per pick was desired.

Therefore some means was to be thought that would avoid heavy masses on sley and allow a balanced and trouble free movement of reed. Subsequently a simple mechanism consisting of winding and unwinding of a cord on pulley was developed.

3.5.4.3.2 Pulley and cord mechanism for reed displacement:

As shown in figure 3.52, bracket 'a', on which the frame-carrying reed is supported, is given an extension 'f'. Extension 'f' carries two pulleys 'g'. Stepper motor 'l' is fastened to a bracket anchored with floor on right hand side of loom about 160 cm away from right side of reed frame frame. Thus stepper motor is mounted out side sley. A pinion of 24 teeth mounted on stepper motor shaft drive a pinion of 90 teeth. A pulley of diameter 64 mm is coupled with this gear. One end of a chord is anchored with pulley and the other end passes around pulleys 'g' and is subsequently connected with reed carrying frame at top.



a - Bracket fastened on sley
b- Top end of sley sword
c - Top end of sley sword
d, e - Bolts
f - Exension of bracket 'a'
g - Pulleys
h - Race board
i, j - Nuts
k - Slots in bracket 'a'
l - Stepper motor drive

Figure 3.52

Rotation of stepper motor winds or unwinds cord on pulley and there by displaces reed. The movement transmission is negative here, i.e. the reed is lifted by stepper motor and lowered by weight of reed plus frame. If necessary, dead weights may be put at bottom. Photograph 3.8 shows view of stepper motor.

3.5.4.3.2.1 Performance of pulley and cord mechanism for reed displacement:

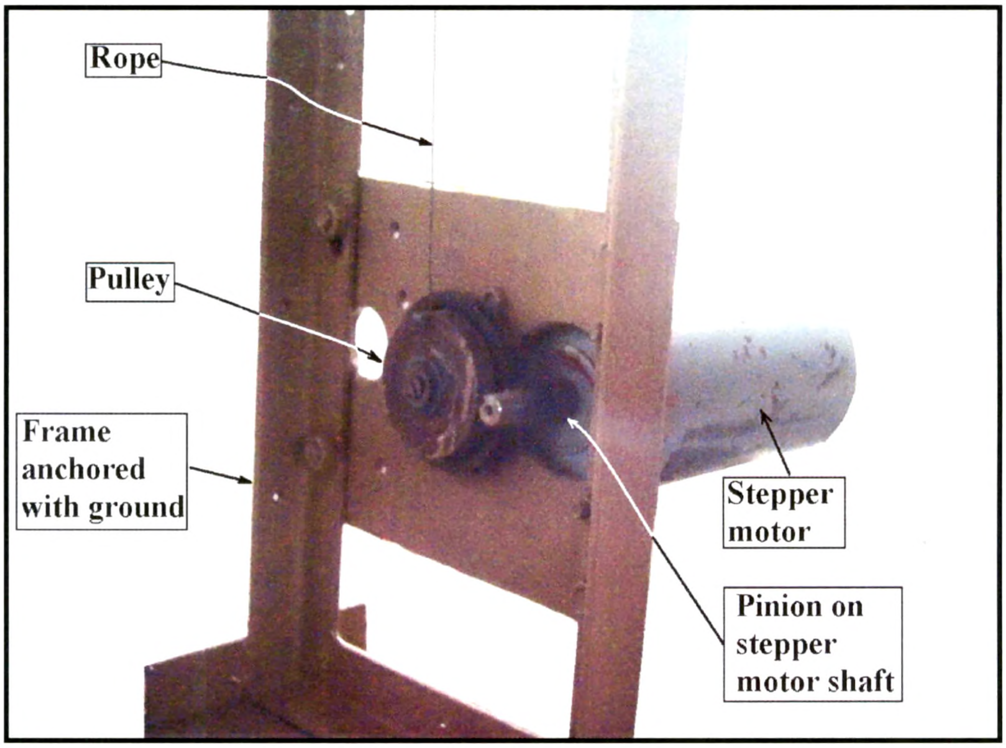
(i) This simple mechanism worked satisfactorily. As stepper motor pulley is kept away from reed, practically there is no influence of sley reciprocation on reed position.

(ii) Greater reed displacement per pick can be achieved without any overloading on stepper motor. This mechanism was found suitable for use.

3.5.4.4 PLC programming for weaving a 3D shape:

Figure 3.53 show drive from stepper motor to reed.

Consider an example of weaving a 3D shape as shown in Figure 3.54. For weaving this shape, four counters will be needed. The setting at the counters is as follows. For weaving portion AB, 200 picks are involved. As a double cloth is woven, 400 picks laid in a double cloth would weave 200 picks in single cloth when unfolded. Therefore number of picks (pulses from proximity switch) to be set are 400. As no reed movement is required number of steps to be input is 0. Extending same logic for remaining portions the counter setting will be as shown in table 3.1.



Photograph 3.8

Stepper motor

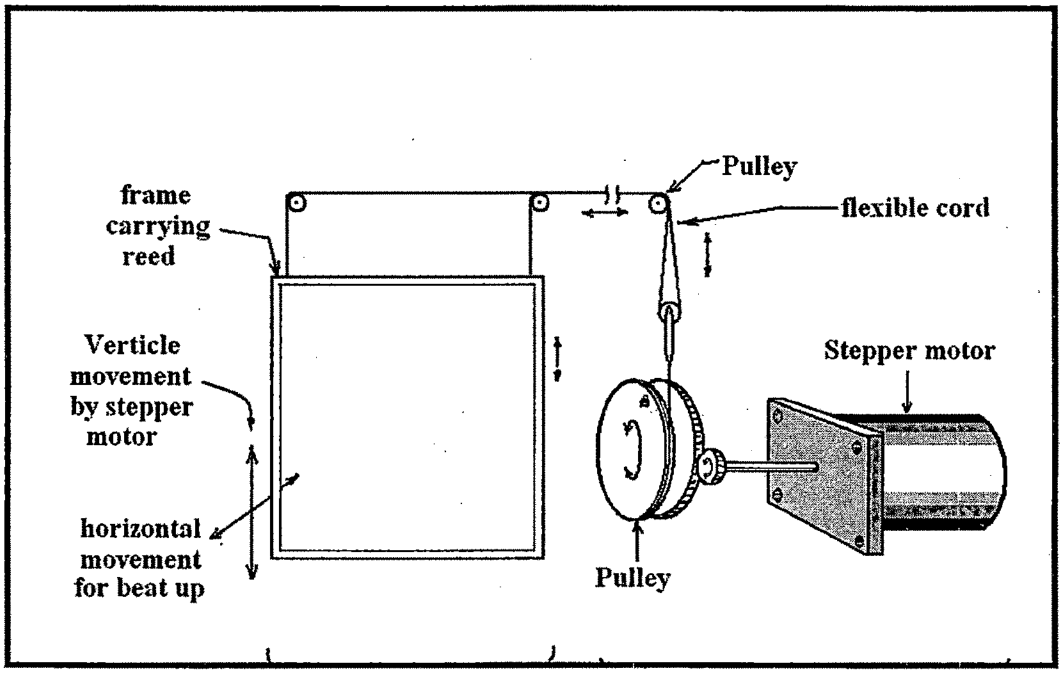
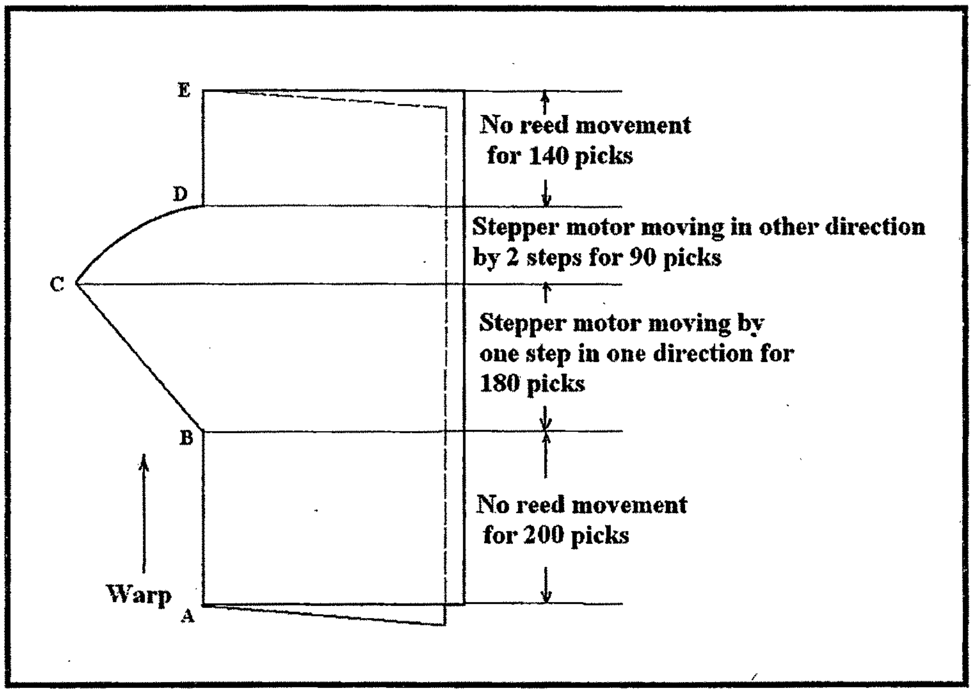


Figure 3.53

Stepper motor with pulley



E
D
C
B
A
Warp
No reed movement
for 140 picks
Stepper motor moving in other direction
by 2 steps for 90 picks
Stepper motor moving by
one step in one direction for
180 picks
No reed movement
for 200 picks

Figure 3.54

	Number of picks in double Cloth (pulses)	Setting for stepper motor Movement
Counter 1 (For portion AB)	400 (200 x 2)	0 (Stationary)
Counter 2 (For portion	360 (180 x 2)	1 (1 step rotation in one direction every pulse)
Counter 3 (For portion	180 (90 x 2)	102 (2 steps rotation in opposite direction every pulse)
Counter 4 (For portion	280 (140 x 2)	0 (Stationary)

Table 3.1

Setting for weaving a symmetrical pyramidal shape can be understood from Figure 3.55. Referring to figure 3.55 (a), let 'p' be the number of picks in half fabric. Number of picks in initial portion without shape is 'p_1' and in subsequent half pyramid shape portion is 'p_2'. The reed is to be positioned vertically during weaving initial portion without shape, i.e. for p_1 number of picks so that line of beat up is along line indicated by 'a' in figure 3.55 (b). The reed position is not changed during weaving 'p_1' number of picks.

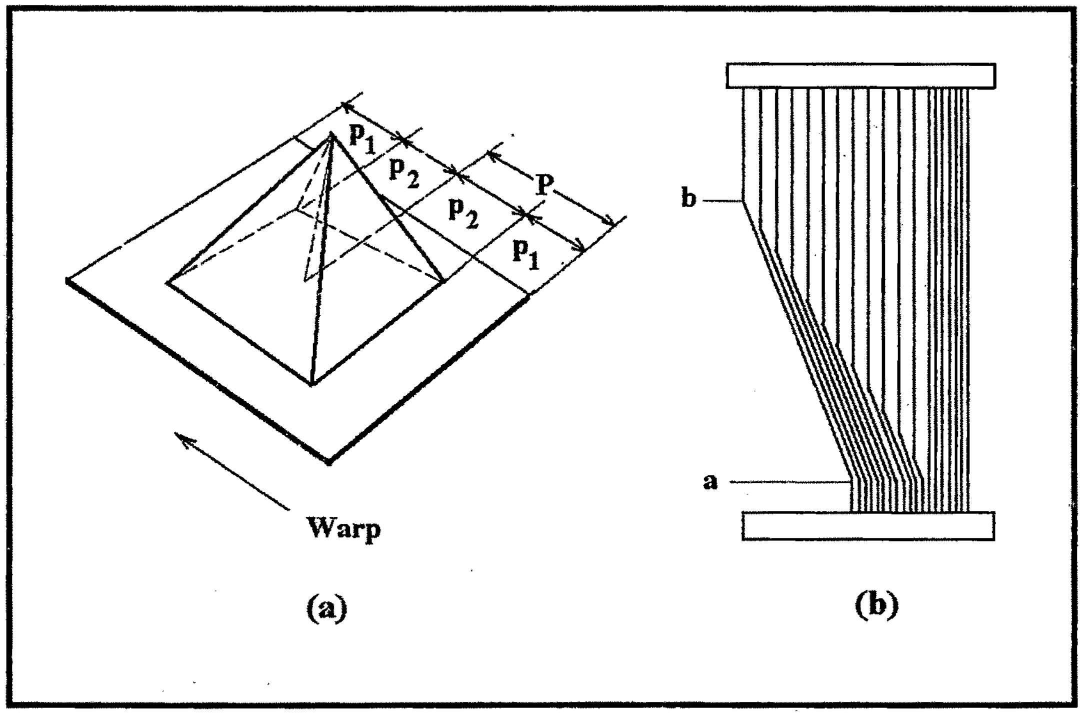


Figure 3.55

While weaving next portion with shape, i.e. weaving half pyramid shape, the reed should be displaced so that its line of beat up would shift from a to b as shown in figure 3.55 (b), with equal displacement per pick. Stepper motor step movement has to be selected so that this desired movement is obtained. The reed has to be lowered during this phase. Similarly during weaving next half pyramid portion, reed has to be displaced so that its line of beat up would shift from b to a (figure 3.55 (b)). The reed has to be raised during this phase.

During weaving last portion without shape, reed has to be kept stationary, with beat up line along 'a'.

Number of step movement of stepper movement is to be calculated as follows (Figure 3.56):

Let number of step movement of stepper motor per pulse = n
Displacement of reed on 'n' step movement of reed = x
Number of picks in half pyramid shape portion = p_2
Total reed displacement during weaving half pyramid shape = s
Therefore, reed displacement per pick = s/p_2
Number of teeth of pinion on stepper motor shaft = t_1
Number of teeth of gear meshing with pinion = t_2
Diameter of pulley = d
Reed displacement during 'n' steps rotation of stepper motor = $(n\ t_1\ \pi\ d)/(200\ t_2)$
Step movement of stepper motor has to be selected so that desired reed displacement per pick is obtained.
i.e. $(n\ t_1\ \pi\ d)/(200\ t_2) = s/p_2$
$\therefore n = (200\ s\ t_2)\ /\ (n\ t_1\ \pi\ d\ p_2)$

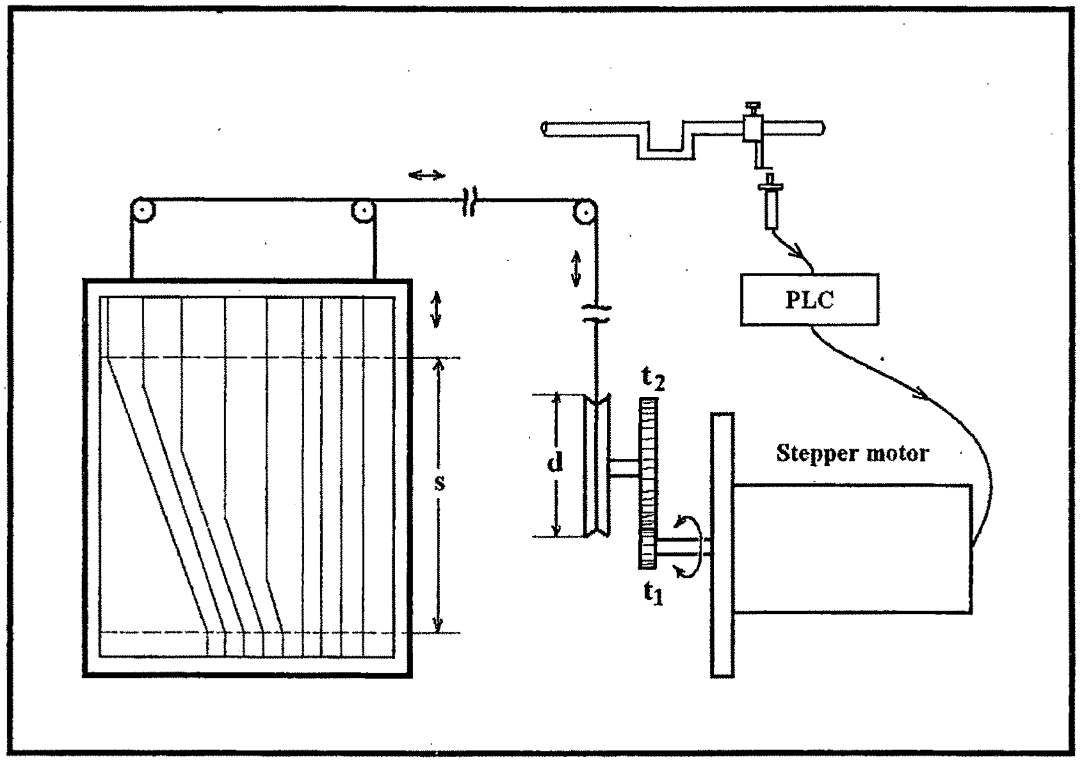


Figure 3.56

Parameter 's' should such that desired displacement per pick is obtained with 'n' as a whole number. Photograph 3.9 shows PLC controller.

3.5.4.4.1 Stepper motor programming through a computer:

While controlling stepper motor through PLC controller, values are required to be entered in controller every time for a new programme. Therefore an interface is developed between computer and PLC controller. Values for a given programme are to be entered in to computer instead of in controller. Several programmes can be stored in a computer. Thus programme entered in computer controls stepper motor movement via PLC controller (Photograph 3.10).

3.5.4.5 Setting up jacquard shedding:

A double lift double cylinder jacquard of 800's capacity was found suitable to weave 3D woven shapes of desired dimensions (Photograph 3.11). Several difficulties were faced in setting up jacquard as conditions of weaving 3D shapes are different from those while weaving normal 2D fabrics. The difference is as follows as follows:

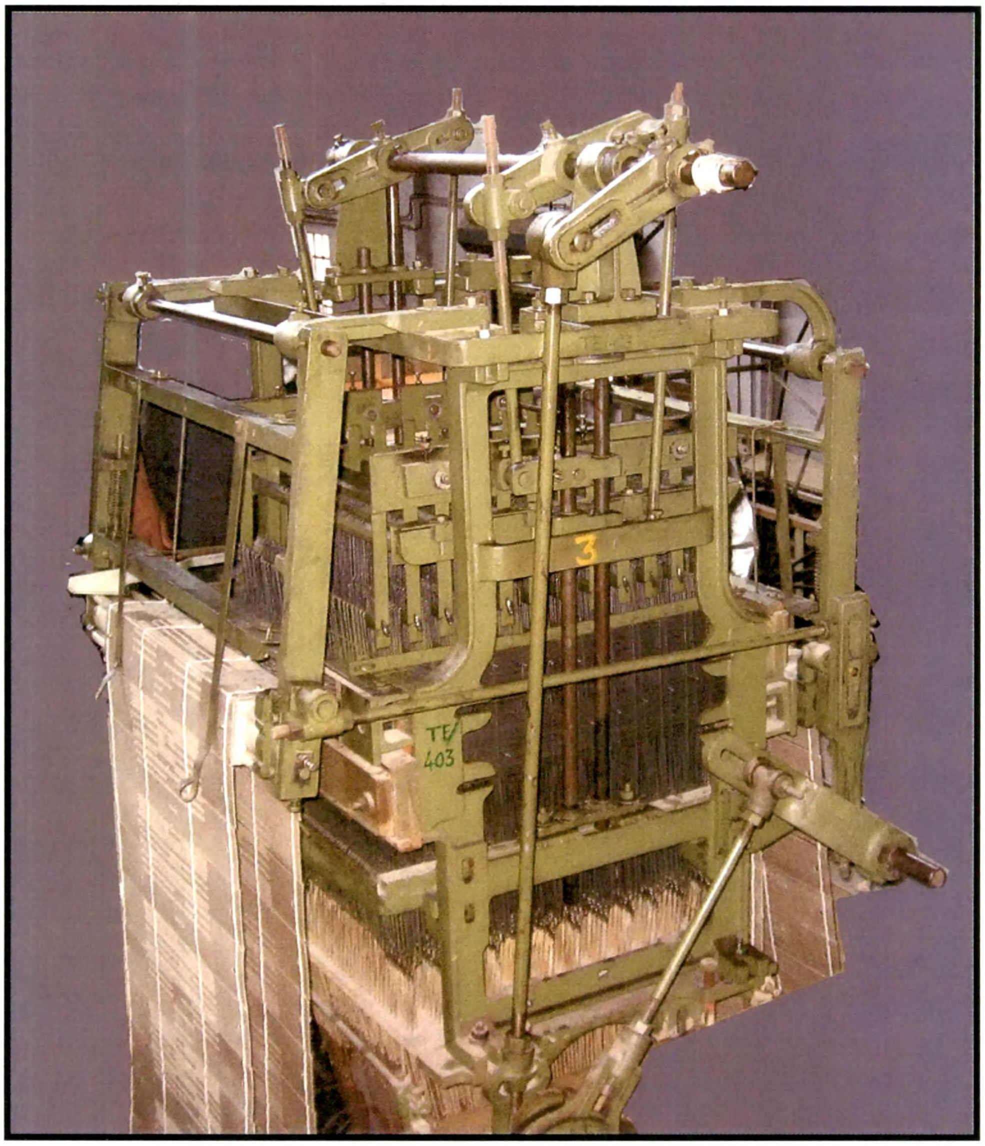
i. While weaving normal 2D fabrics width of fabric at cloth fell always remain same. Therefore ends per inch through out weaving remain same. Count of comber board is selected so that ends per inch in reed equals ends per inch in comber board. Therefore ends would always remain parallel between heald eyes and reed. But while weaving 3D woven shape, spacing of ends keep on varying across width of the fabric on successive picks.

Photograph 3.9

PLC controller

Photograph 3.10

Interface between PLC controller and computer



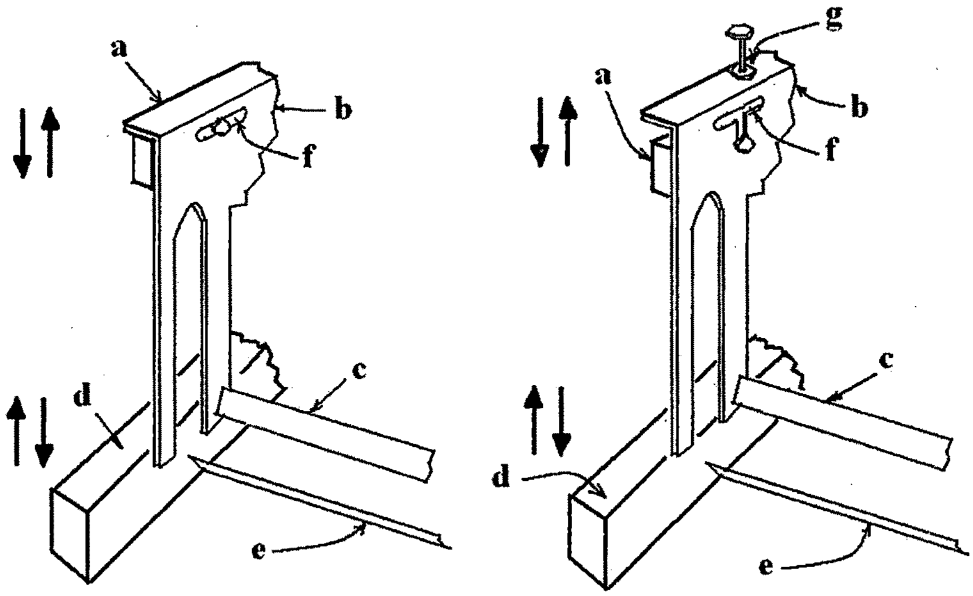
Photograph 3.11

Double lift double cylinder jacquard

ii. Change in spacing of ends makes it difficult to decide suitable comber board. Ultimately 72's comber board was selected as most of the fabrics woven up till then had around 72 ends per inch in non-shape portion.

iii. Reed height is very small in normal 2D weaving. Therefore comber board can be placed closer to rear most position of sley. In 3D shape weaving, reed is very long height wise and is located on rear side as compared to usual reed. More over supporting bracket for reed also occupy space on the rear side. Because of this comber board was required to be shifted backwards. Due to this heald eyes are positioned away from cloth fell. Therefore, greater lift is required for healds.

iv. As shown in figure 3.57 'a' and 'd' are griffe frames of jacquard. These frames move vertically, diametrically opposite to each other. By adjusting radius of driving crank, lift of these frames can be increased which ultimately increases lift of harness. When griffe frame 'a' is in its lowermost position, griffe frame'd' is in its uppermost position. The two frames are nearest to each other in this position. On increasing lift, the two frames get closer to each other. Therefore lift can be increased only up to certain extent. On increasing lift clearance between hooks and knife increases. To adjust the clearance the connecting rod length between driving lever and griffe is required to be adjusted. It is to be shortened when lift is increased. For doing this to griffe frame 'd' beyond certain limit, the two frames tend to interfere with each other.



(a) (b)

a - Griffe frame 1
b - Plate fastened to griffe frame 1 carring knives
c - Knife on griffe 1
d - Griffe frame 2
e - Knife on griffe frame 2
f - Slot in plate
g - Set screw

Figure 3.57

To prevent this, as shown in figure 3.57, a vertical slot was made in slot 'f' of plate of griffe frame 'a' and the plate was taken upwards. Set screw 'g' enabled leveling as well as clearance adjustment between knives of griffe frame 'a' and its hooks. This enabled increase in lift of healds.

Next job was to weave a 3D shape on this set up. A pyramidal shape was selected for this purpose.

3.5.5 Weaving pyramidal shape on loom:

3.5.5.1 Pyramid dimensions:

A set up was to be developed for weaving a pyramid of length and width of 6", and height of 4". These are actual dimensions to be obtained in shaped fabric outside loom.

3.5.5.2 Selection of warp yarn, weft yarn, weave and thread density:

2/6's cotton yarn was selected for warp and weft. In ground non-shape portion, a looser weave and greatest possible number of ends and picks per unit space were to be taken so that open portions created in shaped regions due to widening of thread spacings could be filled up by increasing thread interlacements or in other words weave would assist in increasing thread spacings. Ends/inch in reed should be less that in cloth so that on contraction desired thread density would be obtained. Hopsack weave was selected for ground non-shape portion and rib weaves for shape regions that would bring about desired change in end and pick spacing.

Through initial trials on handloom, 72 ends per inch in reed were found suitable. On weaving double cloth with 3/3 hopsack weave, 84 ends and picks per inch were observed in fabric after contraction (i.e. 36 ends and picks per inch in single cloth). Therefore, for subsequent designing 72 ends and pick per inch were considered in reed; and 84 ends and pick per inch in double) cloth.

For producing a pyramid of length and width of 6", total 252 ends and picks are required in shape portion (6 x 42). If 3" ground non-shape portion is taken on either side, there will be additional 252 ends for ground. Total 12 selvedge ends, 6 on either side, are taken. Thus total ends become 516, i.e. 43 short rows of comber board.

3.5.5.3 Design and fabrication of reed:

A reed was to be designed and fabricated that would produce the pyramid of desired dimension. Width of cloth in reed has to be higher than that in cloth depending upon contraction. As 3D shape is woven in folded form weaving, weaving width is half that in single clothe. System allows for maximum reed displacement of 400 mm. Considering these factors final reed dimensions were derived (Figure 3.58). Total reed displacement required was 396 mm.

In PLC step movement of 3 per pick produced desired reed displacement during weaving of shape region.

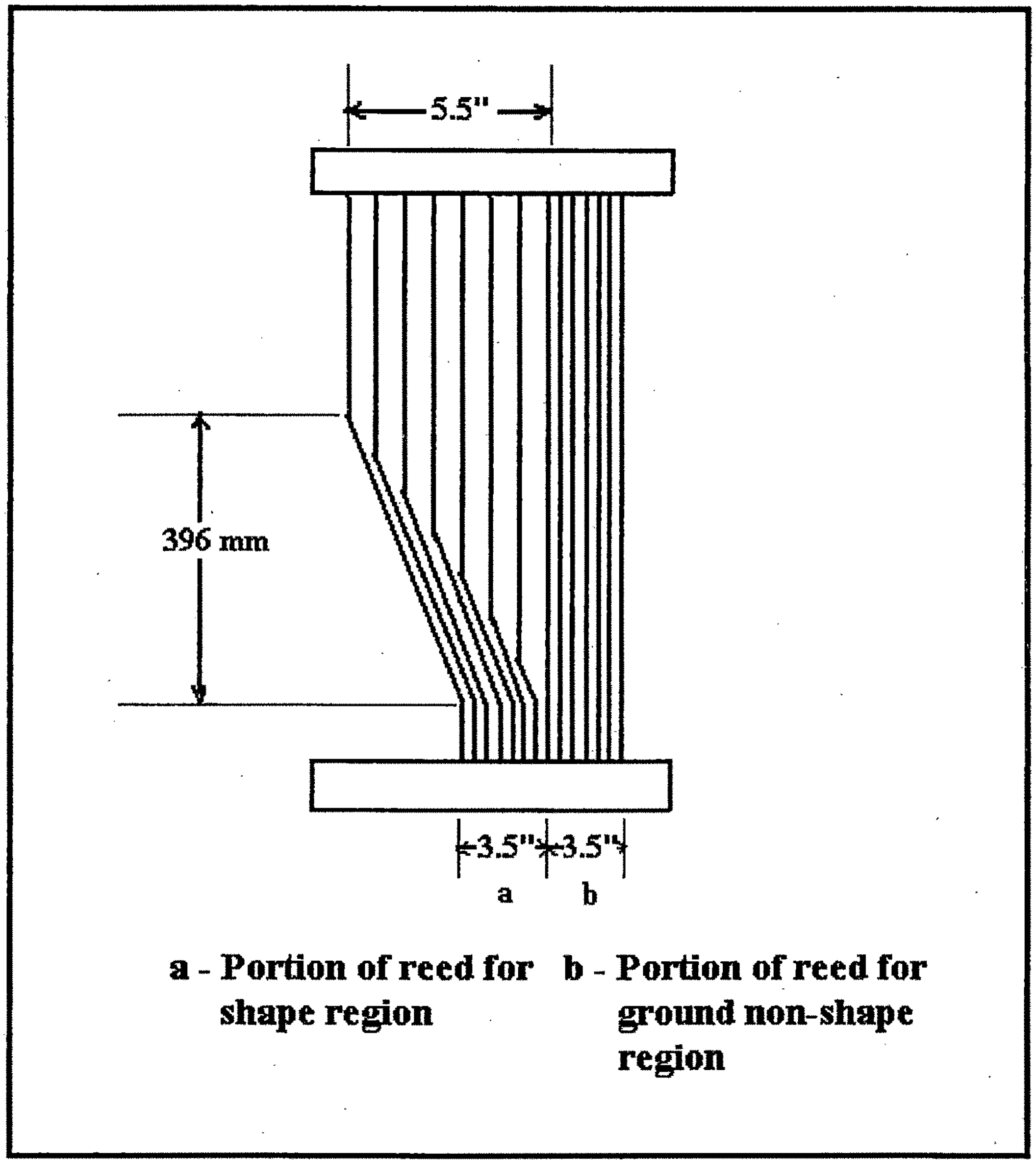

5.5"
396 mm
3.5"
3.5"
a
b
a - Portion of reed for shape region
b - Portion of reed for ground non-shape region

Figure 3.58

3.5.5.4 Jacquard design development:

Jacquard design was developed using Autotex 2000 jacquard designing software. 3/3 hopsack weave was taken for ground non-shape portion and 3/3 warp rib weave in shape portion where pick spacing is to be increased and 3/3 weft rib where warp spacing is to be increased.

3.5.5.5 Weaving pyramidal shape:

Weaving of pyramidal shape was begun using set up mentioned above. Reed displacement occurred without any difficulty. Combination of reed and weave brought changes in end spacing. Pick spacing changes were brought about by weave. However following difficulties were observed.

i. 2/6's weft was proving to be too coarse and offered greater weaving resistance.
ii. It was difficult to impart very high tension to warp threads due to warp supply from creel. Therefore problems as described in section 3.5.3 were faced.
iii. Weft tension proved to be too high. Therefore it caused grouping of ends at left hand selvedge.
iv. Fell of the cloth remained backwards from front most position of reed. Therefore comb mechanism, provided for fell control, was unable to maintain and retain change spacing of ends and picks as combs were lifted and lowered on every pick. Therefore fabric width at fell did not increase as per reed that caused problems in shedding and thereby in picking.
v. Wide gap between left shuttle box and shed caused difficulty in shuttle flight. Shuttle flight occurred quite often.

To over come these problems finer weft of 2/20's was used. Instead of comb mechanism for fell control, new arrangement using full width spiked rollers was developed. A freely rotating conical roller was placed between left shuttle box and left hand shed entry to control shuttle flight.

3.5.5.5.1 Fell control using full width spiked rollers:

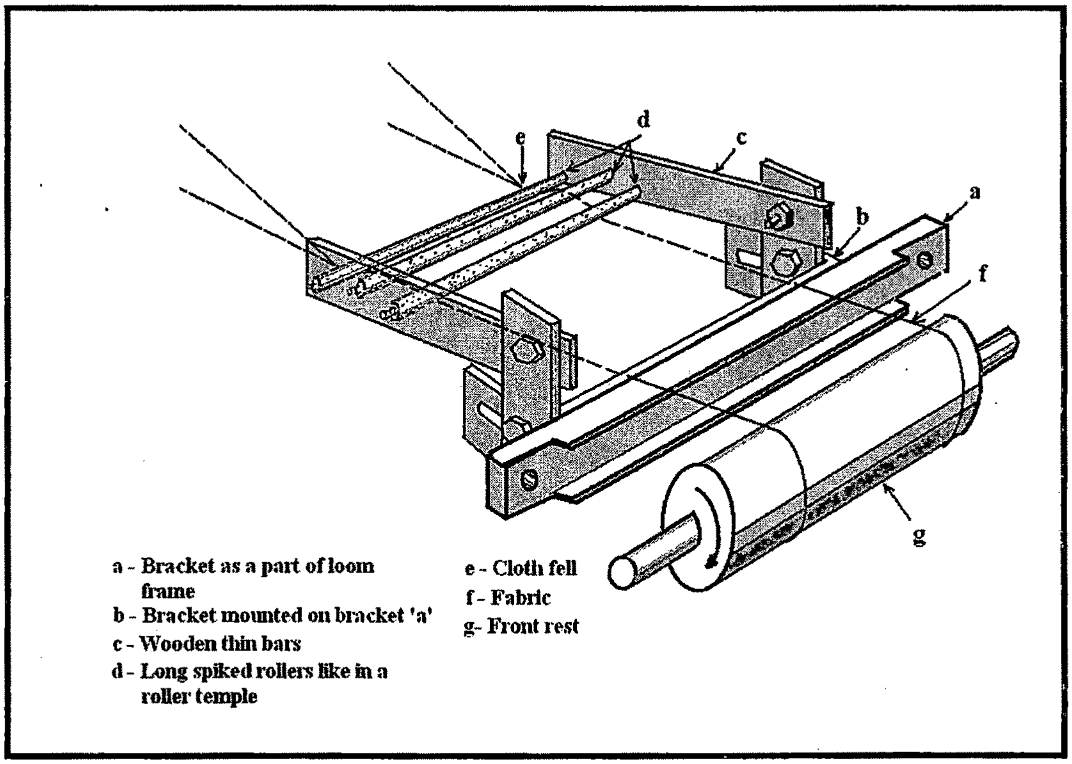
The mechanism was developed to allow and retain changes in cloth width occurring during weaving of shape region, employing series of spiked rollers running across fabric width.

The mechanism (Figure 3.59) consists of a bracket , 'a' which is part of loom frame near front rest 'g'. This bracket is fastened with another brackets that carry wooden thin bars that carry series of spiked rollers 'd' like roller temples across loom width. The front most roller (one nearest to cloth fell) is adjusted so that it is very close to reed in its front most position. The spirals of spikes is in opposite direction from the line separating shapeless portion and shaped portion so that it gives stretch to the fabric in outward direction.

The roller located in front 'locks' changes in width made. Subsequent rolls also help in retaining these changes.

3.5.5.5.2 Conical roller for control of shuttle flight:

As discussed in section 3.5.2.7 left hand fabric selvedge cannot be positioned close to left hand shuttle box. Therefore difficulty is experienced in controlling shuttle flight, especially during exit of shuttle from left hand shuttle box till entry in shed.



a
b
c
d
e
f
g
a - Bracket as a part of loom frame
b - Bracket mounted on bracket 'a'
c - Wooden thin bars
d - Long spiked rollers like in a roller temple
e - Cloth fell
f - Fabric
g- Front rest

Figure 3.59

This problem was over come by placing a conical roller between left hand shuttle box and warp shed. This roller keeps shuttle in contact with needle bar and race board and prevent shuttle flight.

As shown in figure 3.60, bracket 'a' mounted on sley carries a right-angled bracket 'b'. A conical roller 'c' is carried on a stud mounted on bracket 'b'. This roller tends to deflect shuttle towards needle bar and race board and prevent shuttle flight.

3.5.5.6 Weaving with fell control using spiked roller and conical roller for shuttle flight control

With finer weft, the cloth fell lied at front most position of reed. Spiked rollers for fell control allowed changes in cloth width at fell of the cloth and retained them. In fell control mechanism with combs, when combs are lifted, the expanded at cloth fell tend to contract. Therefore proper control is not exercised. In fell control with spiked rollers, the roller nearest to reed allows and retains changes in fabric width at cloth fell as it is positioned very close to reed at front centre of loom. The subsequent rollers help in retaining these changes, till the beaten pick move substantially away towards take up roll. Therefore better control is exercised.

Conical roller was very helpful in controlling shuttle flight and no problem was observed in picking.

As weave employed was one that would assist in developing 3D shape, it assisted in changing spacing of ends along with reed. The weave also brought about changes in pick spacing.

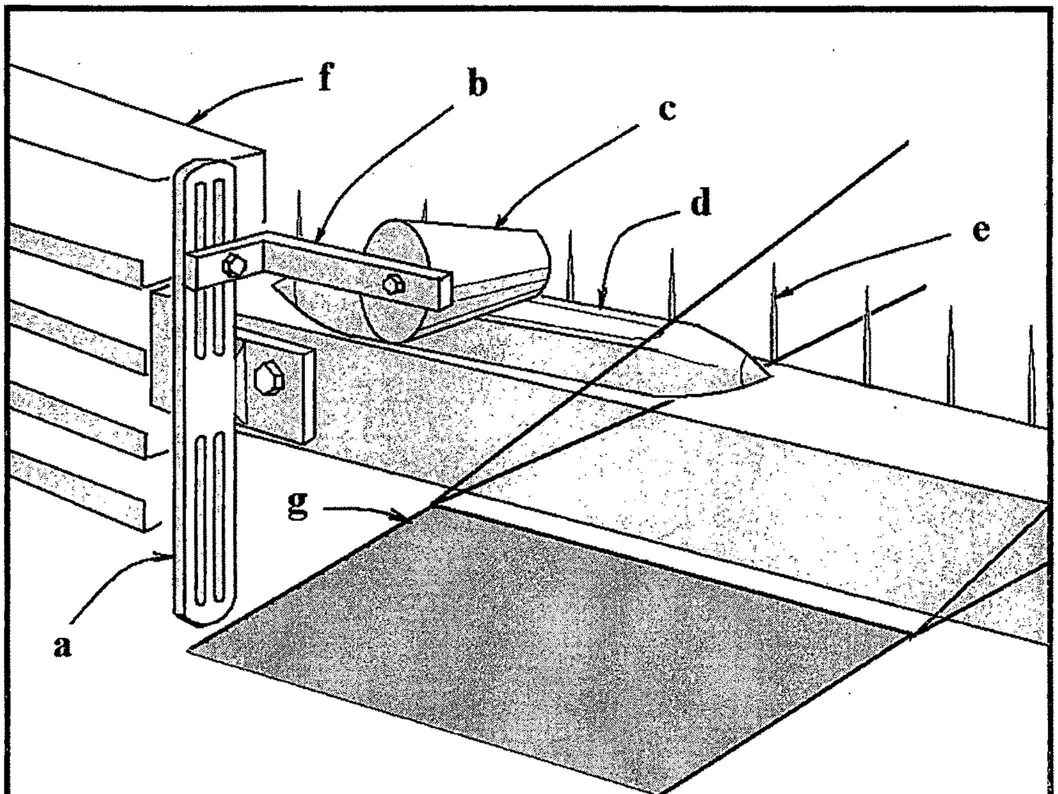


Figure 3.60

Conical roller for shuttle flight control

Due to this situation is created where in different lengths of fabric across width of loom on successive picks are formed. Therefore to maintain cloth fell parallel to reed, amount of take up on beating up a weft should not be same across width, but should be different. Regions which are woven longer should be taken up to larger extent while those which are woven shorter should be taken up to lesser extent. It should be noticed that on doing so fabric would no longer remain planar. Regions which are woven longer would tend to develop folds. Therefore a mechanism is necessary that would give differential rate of take up across width on successive picks depending upon profile of 3D shape.

In 3.3.4.1.2.1, principle of determining shapes of dent wires of reed for a pyramidal shape is discussed. As shown in figure 3.61(A), on face ADC of pyramid, spacing of ends gets widened and on face ABC pick spacing gets widened. The reed wires widen spacing of ends. While weaving pyramid in folded form, reed dents deflect path of ends and change their spacing as shown in figure 3.62.

It can be seen in figure 3.62 that spacing of successive ends in ground portion is less, which equals AB. Thus ends 1 to 5 are equispaced at pick 1. Reed deflects the path of ends when weaving of pyramid begins. It can be seen that at pick 2, space between end number 1 and 2 is widened to A'B'. At pick 2, end number 2 and 3 are inclined and are parallel to each other. Therefore their spacing measured in direction perpendicular to fabric remains unchanged.

Space between pick 1 and 2 is AA'. Ends are deflected mainly to change spacing of ends. It can be seen that deflection of ends increases pick spacing to certain extent.

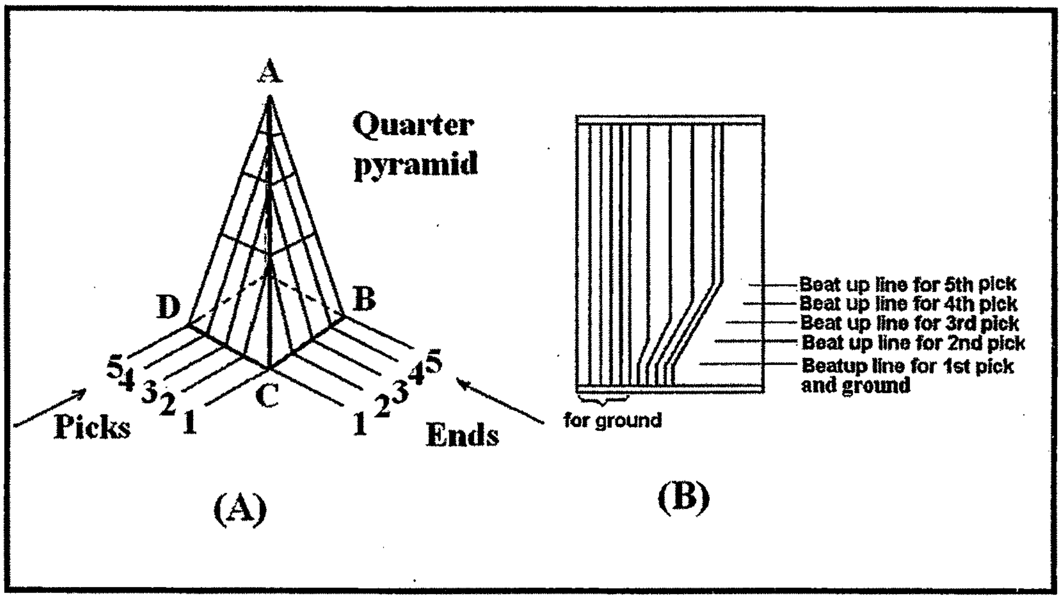


Figure 3.61

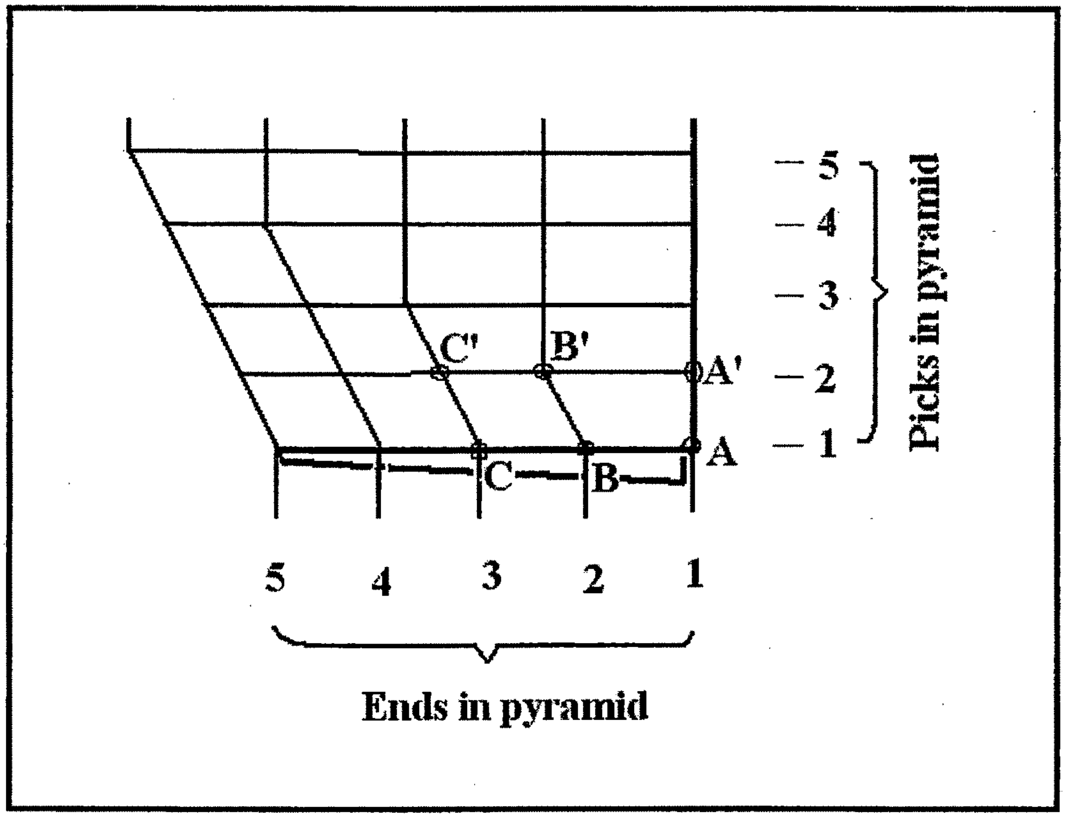


Figure 3.62

Distance between cross over point BB' is larger than AA'. How ever this increase in spacing in not exactly what it should be. Referring to figure 3.61(A), it can be seen that spacing between cross over points of picks 1 and 2 is not same. The space between cross over points of pick1 and pick 2 with end 1 equals to that in ground portion. The spacing between cross over points of pick 1 and pick 2 with ends 2, 3, 4 and 5 is widened. Therefore take up rate at pick 2 should be more for ends 2, 3 , 4 and 5 than for end 1 in such a way that this required difference of pick spacing is obtained.

Similarly at pick 3, the pick space is widened at ends 3, 4 and 5. Therefore take up rate should be faster for these ends. At pick 4 it is higher for ends 4 and 5and therefore they should be taken up more. Thus the function of differential take up is to take up ends at differential rate to increase spacing of picks as per profile of 3D shape. The action of differential take up should be at cloth fell. Increase in spacing of picks along a given end increases length of fabric woven along that end. In a 3D shape the extent of increase for different ends would be different. Therefore, during weaving a shape, different lengths will emerge out of differential take up at different ends.

As weaving was begun with weave assistance but without differential take up, different lengths were woven across width as weaving proceeded. As differential rate of take up was not provided, region where longer length was woven was not taken up and hence cloth fell in such regions started shifting towards reed. This would hinder shed formation and there by cause problem in picking. When these regions where taken up manually, weaving became possible. However, manually uniform control is not possible and therefore satisfactory result can not be obtained. Next job was to design and develop differential take up.

3.5.5.7 Differential take up:

As discussed in 3.5.5.6, rate of take up for individual ends is determined by extent of widening of space between successive picks required in shape. For geometrical shapes such as a hemisphere or a pyramid, this can be determined mathematically. The calculation would be relatively simple ignoring contraction. Following points are noteworthy before designing differential take up.

- During weaving of shaped region, ends do not lie parallel to length direction of loom but are lie at some angle. This widens gap between picks. This should be taken in to account while determining actual rate of take up.
- After determining rate of take up, it should be noticed that position of an end widthwise does not remain the same from pick to pick. Therefore differential take up should be designed in such a way taking up element for an end also shift by exact distance and direction width wise from pick to pick so that it would act on particular end only. The shifting of an end is determined by profile of reed dent wires. It is also influenced by contraction. If exact position of an end width wise is not estimated, an element of take up may act on another end and an error can be caused.
- Ideally differential take up should act at cloth fell, i.e. at the place where fabric is formed for generating an exact shape.
- When taken up at differential rate, fabric can not be wound, the way it is done while weaving 2D fabrics, because differential

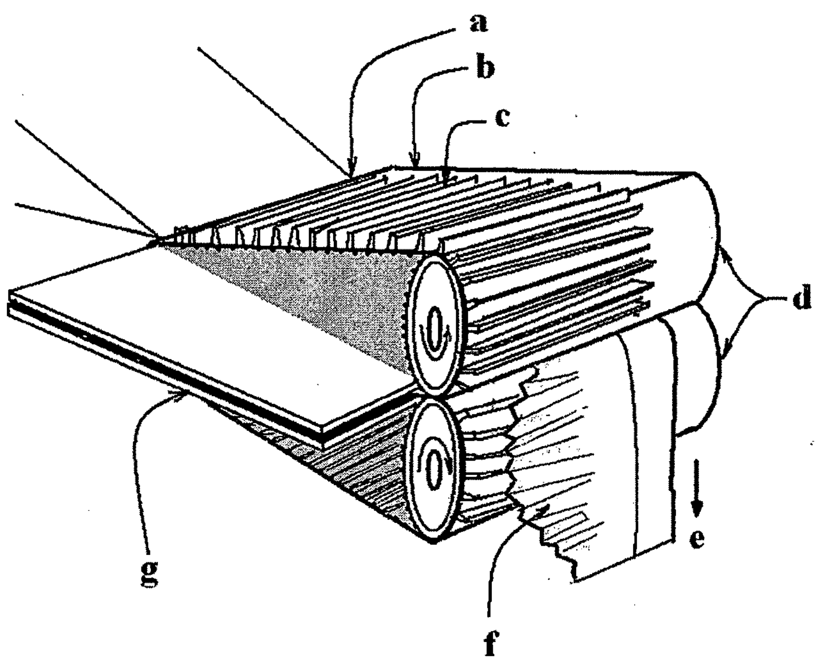
lengths are formed. If an attempt is made to wind it on a cylindrical roll, there would be non uniform build up on it since a 3D shape produced would have differential width and length produced. Therefore, the fabric being woven should be collected in some container. Therefore, the elements of differential take up should be sturdy enough to work against stresses of weaving and should take up fabric firmly.

- A differential take up can be imagined to be one in which conventional element of take up, i.e. take up roll, is broken up in to number of small segments, ideally equal to number of ends in fabric. Practically it is very difficult to provide a separate take up roll for each end. Each segment should be given individual drive and should be driven at a rate that is determined by space to be created between picks. These segment rolls should be located closest to cloth fell. To achieve this diameter of these rolls should be as small as possible, because with a larger roll distance between cloth fell and race board measured vertically would increase. Therefore bottom line of warp would remain very much above race board which is not permissible from picking point of view. If small take up rolls are considered, their surface should be such that it would give firm grip over the fabric. Again, each roll should be given an individual programmable drive. This drive has to work in synchronization with reed. Drive elements would also require space. With tiny drive elements a sturdy drive can not be ensured. Another complication arises if shuttle traps in the shed. In event of shuttle trap, the differential take up elements should retract the way it happens with temples.

- Alongwith fulfilling these requirements, the take up should also allow changes in width of fabric at cloth fell equal to those brought about by reed and retain them.

Considering the above points, complexity involved in developing differential take up can be understood. Major hurdle seems to be limitation of space and problem during trapping of shuttle. Instead of free flying shuttle, if picking mechanism incorporates some carriers like rapiers, those positively hold the shuttle and carry from one end the other, many existing elements of picking mechanism can be eliminated and space can be created for mounting of mechanism. At the same time risk of shuttle flight can also be eliminated. But this would require major changes in loom construction.

A different approach of differential take up was thought and attempted first on hand loom. As shown in figure 3.63, a two rollers 'd' carry wide belts 'b'. These belts pass around two plates 'g'. The function of the plates is to keep the belts pressed against each other. The fell of the cloth is located very close to belts where they move around plates. Fabric formed passes through the potion of belts pressed against each other by plates. On driving rollers in direction as shown in figure, belt take up fabric that is formed. System of take up like this would take up fabric across width at same rate. If the belts are provided with several projections which mesh with one another, fabric will be pushed in perpendicular direction and that region would be taken in wavy configuration instead of planar. The extent of this would depend upon amount of penetration of projections at given place.



a - Cloth fell
b - belt
c - Toothed projections
d - Driving rollers

e - 3D shape woven fabric
f - Folds in fabric
g - Plates

Figure 3.63

This penetration becomes an additional take up of fabric along with linear motion of belt. The projections should be designed in such a way that differential take up across width should be obtained on successive picks.

The requirements to be satisfied and probable difficulties while implementing this concept are as follows.

- There has to be perfect designing and manufacture of projections on belt.
- The two belts must rotate in perfect synchronization with each other.
- There should not be any slippage between driving rollers and belt. There fore, preferably, rollers as well as belts should be toothed.
- The belt thickness should be as less possible.
- If belt is thinner, it may not remain stable against stresses of weaving.
- Very thick belt would compel to keep cloth fell at greater distance above race board.
- There should be perfect synchronization between position of reed and belts.
- This construction would cause damage to the mechanism in event of shuttle trap.
- In absence of spikes on belt, it would be difficult to retain changes in cloth width brought about by reed.

This mechanism was tried on hand loom but it was very difficult to meet the conditions necessary for its correct working. Therefore it did not work.

Lastly, this work enabled understanding of 3D woven shapes, understand principle requirements for weaving desired 3D shape and bring about several modifications on a power loom to weave a 3D shape. However, a 3D shape could not be produced to exact dimensions as differential take up could not be developed.