Weaving Seamless Three Dimensional Shapes on Handloom

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Abstract— **Rapier looms to produce seamless woven three dimensional desired shapes find their use in manufacture of composites and technology to produce them is developed in Germany. However this technology is quite complex and expensive. Simple technique to produce desired seamless woven three dimensional shapes on handloom developed by the author is discussed in this paper.**

Keywords— Hemispherical, pyramidal, shaped fins

I INTRODUCTION

Fabrics produced on weaving machines usually produce two dimensional (2D) fabrics. But several end uses e.g. a garment such as a trouser require fabric converted in 3D shape that is mostly obtained by tailoring together several pieces of 2D woven fabric. For some specific end user applications, three-dimensional (3D) woven shapes are produced on shuttle looms by progressively eliminating ends of a multilayer fabric and subsequently cutting them[1-4]. However, places where ends are cut and eliminated may lead to some irregularities. Around 1990, work of developing a rapier weaving machine was undertaken in Germany to produce seamless woven 3D shapes without the need to eliminate and cut ends subsequently[5-8]. This development was intended to produce seamless 3D woven shapes to produce performs mainly used to produce composites, for example 3D hollow shells for producing helmets. This technology is quite complex and expensive.

The author of this paper worked towards development of a shuttle weaving machine to produce seamless 3D woven shapes[9]. Before reaching to stage of weaving on a shuttle loom, developmental work was carried out on handloom that developed weaving base which is discussed in this paper.

II PRODUCING 3D WOVEN SHAPE MANUALLY:

To begin with, it was necessary to understand basic structure of a 3D shape woven fabric. A 3D woven shape was produced by manual means. For this purpose, a half cut tennis hemispherical rubber ball was taken. 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 and taken carefully to beat up position using a comb. Figure 1 shows figure to clarify this method of producing a small hemispherical woven shape manually. Observation of this woven 3D shape provided clue for next step. In a 3D shape, the points of intersection do not lie in same plane but are shifted to other planes depending upon profile of 3D shape. To produce a given 3D shape, weaving process need to be modified to shift interlacement points to different planes depending upon shape profile.

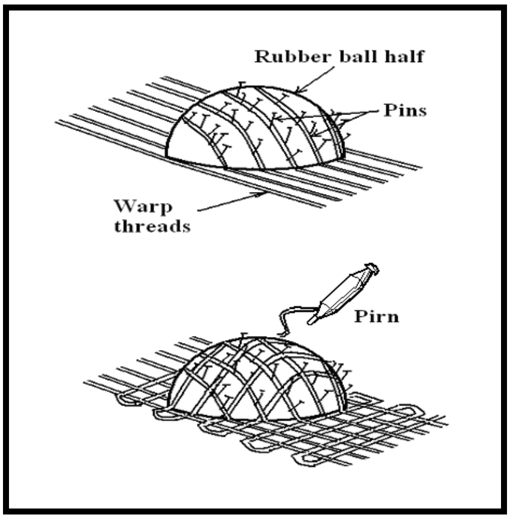

Fig 1. Weaving a hemisphere manually

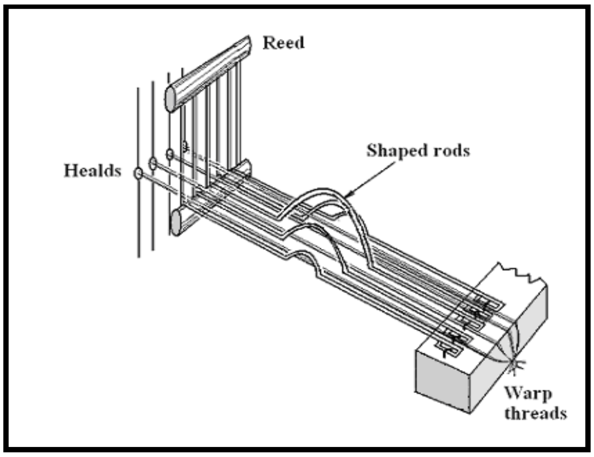

Fig 2. Weaving a hemisphere on handloom with shaped rods

III PRODUCING 3D SHAPE ON HANDLOOM USING SHAPED RODS:

In a 3D shape, the points of intersection do not lie in same plane but are shifted to other planes depending upon profile of 3D shape. To produce a given 3D shape, weaving process need to be modified to shift interlacement points to different planes depending upon shape profile.

To produce a 3D woven shape, several specially shaped rods were taken. These rods were fixed on a wooden frame of handloom at front end as shown in Figure 2. Each rod had straight as well as curved portions over its length. The shaped portions of these rods together formed a hemisphere. These rods were passed through reed dents. Shed was formed by heald shafts. Heald shafts, located at rear side of the reed formed the shed. The curved portions of the shaped rods were within the weaving zone of the fabric. Weft was laid through the shed by inserting pirn through the opened shed. This was beaten up by reed up to the fell of the cloth. It should be noted that during beat up, shaped rods would not move with the reed as they are fixed at front end. It was thought that on continuing weaving with this set up, the fabric would follow the shape of rod and interlacement points would be shifted to other planes following contour formed by shaped rods and hemisphere would be woven.

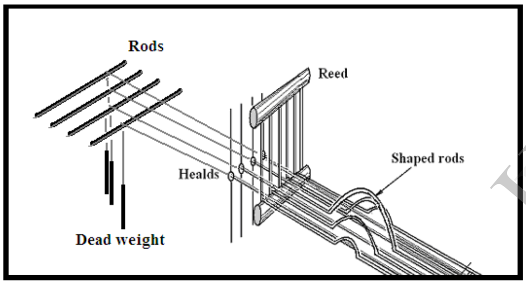

Fig 3. Warp supply

However, it was not possible to weave hemisphere with this method because fabric formed on beating up weft did not adhere to rods as weaving progressed due to warp tension. Warp tension caused fabric to become planar and therefore 3D shape could not be woven as per expectation. However inspiration for subsequent method came through this effort.

Length of warp threads in a 3D shape woven fabric is not the same. Different warps have different lengths depending upon profile of shape. Therefore, warp threads should be supplied during weaving in such a way that a warp is delivered according to its requirement maintaining uniform warp tension throughout weaving. It is difficult to achieve this with warp supply from a weaver's beam. For weaving on handloom warp threads were supplied as shown in Figure 3.

IV PRODUCING 3D SHAPES USING SHAPED FINS:

Previous method with shaped rods revealed that to produce 3D shape, the modification should efficiently shift interlacement points and their shifted position must be retained sustaining weaving stresses. In subsequent method, instead of rods specially slotted fins were used shown in Figure 4. Each fin carried a triangular cut at its rear end which was the same for all fins. This triangular cut was followed by a narrow slot extending up to its front end. Following triangular cut, narrow slot was straight initially over some length followed by a shaped portion over some length. The end portion of slot towards front was straight again. Rear end of each fin with triangular slot passed through dent of a reed used for beat up. Front end of reed also passed through a stationary reed of the same pitch. As front and rear ends of fins are passed through reeds of same pitch, fins remain parallel to one another.

Fig 4. Photograph of woven pyramidal and hemispherical shapes

Front end of each fin carried a hole through which a rod in direction parallel to reed is passed. Due to this rod, the fins cannot displace along their plane maintaining relative positions of fins the same that is very important from weaving point of view. If relative positions of fins are disturbed, it will cause distortion in 3D shape. The shaped portion of each fin depends upon 3D contour to be produced. Figure 4 is for producing a pyramidal shape. Dimensions of fin are determined by dimensions of shape to be produced. Height of fin should be adequately greater than height of shape to be produced. Length of fin is determined by maximum dimension of shape to be produced lengthwise. The length would be maximum dimension of shape to be produced lengthwise plus length covered by triangular portion in fin. Shed opening is formed at triangular opening in fins through which pirn is to be passed through for picking. Triangular opening in fins should be large enough for convenient insertion of weft. Considering passing of one fin through each dent, space between consecutive fins is given by pitch of the reed. To determine contour of shaped slot in each fin, cross sections of shape are taken lengthwise by planes spaced apart by distance equal to reed pitch. Thus, shaped slot of each fin would be different from one another. For a pyramid shown in Figure 4, it will have a slating slot followed by horizontal slot and ending with a slanting slot. For a hemispherical shape, it will be the arcs of circle. The slots for some outer fins are straight without any shaped portion to produce 2D fabric surrounding 3D shape on left and right side. The slot width should be greater than thickness of fabric to be produced. The slots in fins together forms a sort of ***'mould'*** in which fabric was confined to weave.

During weaving of 3D shape, shed is formed by the heald shafts. Shed opening is formed around fins. Weft is inserted manually with a pirn through opening available at triangular opening given in all fins. The reed is then moved forward for beat up. It should be noted that while beating of first pick, it would pass through shape regions initially ending into 2D region. Thus, first few picks would form 2D and then shape region would start. The weft should be carefully beaten up. During beat up in shape region, reed should be perpendicular to warp for proper shape formation.

Using this method, pyramidal and hemispherical shapes were woven as shown in photograph in Figure 5. The same principle can be used for other shapes also. Fins were made from thin, hard card board material. Other material like acrylic or plastic sheet can also be used. Cross sections for cutting slots were computer generated. Slots were cut manually. Fin material should be stiff and strong enough to withstand weaving stresses. Metal sheets can also be used and slots can be cut using sophisticated techniques like wire cutting. Cotton yarn of 2/20's was used for warp and weft.

V CONCLUSIONS

The simple technique discussed produced seamless woven 3D pyramidal and hemispherical shapes. Using this technique, other shapes can also be produced at low cost.

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