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# DEVELOPING A 3D WOVEN FABRIC ON A CONVENTIONAL LOOM

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## BONAFIDE CERTIFICATE

Certified that this project report titled "DEVELOPING A 3D WOVEN FABRIC ON A CONVENTIONAL LOOM" is the bonafide work of Mr.T.ARUMUGASAMY who carried out the research under my Supervision. Certified further, that to the best of my knowledge the reported herein does not form part of any other project report or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this for any other candidate.

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**DEVELOPING A 3D WOVEN FABRIC ON A CONVENTIONAL LOOM**

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## ABSTRACT

Complex woven textiles are nowadays very much needed in various fields like filtrations, automotives, medicals, aerospace, etc., and they need to have special properties. Textiles of higher thickness and complexity are used in composites materials to meet stringent quality requirement. Simple fabric structures are not enough which lead to invention of 3D fabrics.

3D fabrics have 3sets of yarn crossing one another at 90deg to conventional fabric having only 2 sets of yarn i.e. warp and weft. 3D fabrics used in space and defense applications, have been produced in special purpose machines, whose technical details are not known

In a conventional loom shedding was altered by making only the 1st heald shaft to go up and down. While 2nd, 3rd and 4th remained stationery. Weft insertion was done manually by using a needle. Beat-up was also carried out manually. 3D structure was produced y inserting weft yarns in the 3 sheds formed one above the other without beat-up , take-up and let-off once 3 picks are inserted one above the other Z warp position was changed and all picks were beat up together.

Using this process it was possible to produce a 3D fabric. By altering the weft thickness, we can vary the thickness of the 3D fabric. In this project, an attempt has been made to produce 3D fabric in a conventional loom.

# ACKNOWLEDGEMENT

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# CHAPTER 1

# INTRODUCTION

A fabric in which the constituent yarns are supposed to be disposed in a three mutually perpendicular plane relationship is known as 3D fabrics.

Three dimensional fabrics are needed to make performs for technical applications like making a helmet, seat shell, fitting, wheel rim, artificial joints and limbs etc. 3 D fabrics are already been made on specially developed hi-tech looms which are of highly expensive and technological. With a country like ours with a numerous number of conventional looms already in use for normal fabric production, we need to find some alterations on the same old weaving machines to make 3 D fabric.

Applications requiring 3 directional woven structures usually are those where extremes in temperature and highly stressed states are encountered. Various high strength and high temperature fibrous materials in tow or yarn forms are used in weaving.

Complex woven textiles have many versatile characteristics that have enabled them to infiltrate industries such as engineering, aerospace, automotive, biomedical, leisure and even Art and design applications. Primarily they were introduced in high performance fibers such as carbon and glass as an alternative to traditional metal structures. They offer a light yet strong, drapable and moldable textile where reinforcement could be tailored to meet mechanical requirements in specific regions. Their potential for cost-effective processing and waste reduction made them attractive especially in the aerospace industry. Many research programmes have developed a substantial array of 3D reinforced weave architectures that can only be produced on specialist machines However, only selective structures such as the angle interlock architectures have been widely used.

Thus a 3D woven fabric structure is analyzed and its types are examined. By correlating all the factors, alterations are made on let off. The recent development of the dual-directional shedding operation makes it possible for the first time in weaving history to create multiple column-wise and row-wise sheds. As a consequence, a multiple layer warp disposed in grid like arrangement can be interlaced with a set of horizontal and vertical wefts to create fully interlaced 3D fabric. This process can produce solid, shell, and tubular types of 3D fabrics directly. Such 3D fabrics are generally of the narrow type and intended for certain technical applications.

These machines are very complicated and expensive so that the 3D fabric cost is unimaginable, so we can attempt to make a 3D fabric which can be made on a conventional loom. In this project a conventional loom factors are studied in detail. For shedding, picking, beat up, and take up mechanisms on a basic conventional loom to produce a 3D woven fabric.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 3D fabrics

3D Fabrics are defined as 'Multi-directional woven products allow for placement of fibers in various directions to obtain required weave architecture and physical and mechanical properties' by fiber materials Inc[1]

A fabric, the constituent yarns of which are supposed to be disposed in a three-mutually-perpendicular-planes relationship[2].

## 2.2 3D Textile Materials

a) 3 D weaves
b) 3 D warp knits
c) 3 D weft knits
d) 3 D braids

## 2.3 Types of 3D Weave Structures

1. Angle interlock
    a. Weft interlock
    b. Warp interlock.
2. Sandwich weaves
3. Orthogonal interlock

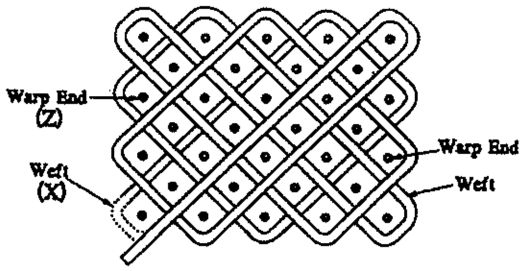


Fig.2.3.1.a Weft interlock

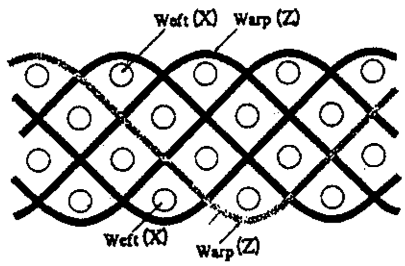


Fig.2.3.1.b Warp interlock

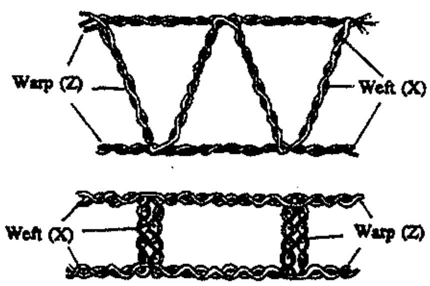


Fig.2.3.2 Sandwich weaves

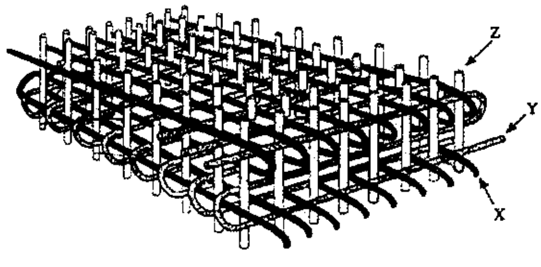


Fig.2.3.3 Orthogonal interlock

## 2. 4. 3D fabric view

### 2.4.1 Cylindrical view

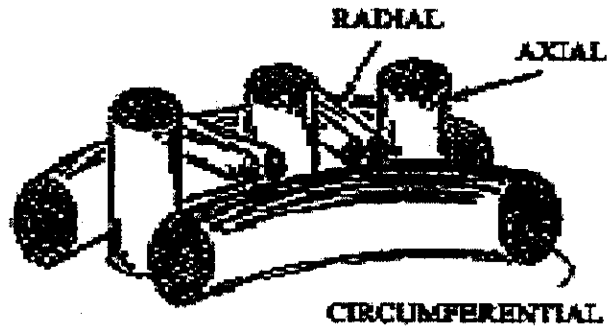


Fig.2.4.1 3D cylindrical view

### 2.4.2 Orthogonal view

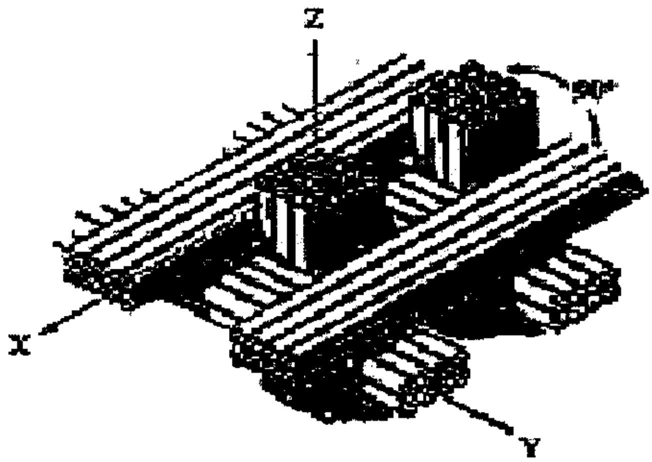


Fig.2.4.2 Orthogonal view

## 2.5 Comparison of 2D And 3D Fabrics

3D woven textiles exhibit higher through thickness. 3D has higher interlaminar properties.

2D weaving –all warp yarns interlace with filling but in 3D woven fabrics, multiple layers of warp and fill yarns are arranged one above the other to selected architecture or yarn path. In 2D fabrics, take-up takes place after every single pick insertion whereas in 3D woven fabrics, several picks can be inserted before take-up occurs. The picks get stacked one below the other, creating the thickness of the fabric.

Integrally woven 3-D fabrics include braid and multi-ply, triaxial and multi-axial weaves. Multi-ply weaves can produce solid panels or cored structures. These fabrics can be manufactured using 2D-weaving process also by employing multi-layer warp yarns. But this process brings about interlacement of the multi-layer warp and weft by forming a shed across the fabric-width direction only. This is because the 2D weaving process is limited in its design to displace the multi-layer warp yarns in the fabric thickness direction only. Because of this limitation, the conventional 2D weaving process cannot bring about interlacement of multi-layer warp and vertical set of yarns which are laid across the fabric thickness direction during the production of non-interlaced 3D fabric. In other words, according to N.Khokar[1], the 2D weaving process cannot displace the multi-layer warp yarns in the fabric width direction to form sheds across the fabric thickness direction. As a consequence, the 2D weaving process cannot bring about 'full' interlacement of the employed three orthogonal sets of yarns.

It can bring about interlacement of the sets of yarns X and Y with the rows and the columns respectively of the axial yarns Z. The sets of yarn X and Y may be referred to as the sets of horizontal and vertical wefts respectively. It has the ability to subject the multi-layer warp (Z) to the operation of shedding to form sheds not only across the fabric width direction, but also across the fabric thickness direction for enabling interlacement of the multi-layer warp (Z) with the set of horizontal weft (X), and the set of vertical weft (Y). such a 'dual directional shedding' of course taking place successively in a given cycle and not simultaneously.

## 2.6 Fabric Technology and Machinery

### 2.6.1 Fibers Used

Fibers and filaments woven include quartz, zirconia, silicon carbide, carbon, graphite, tungsten and impregnated yarns.

### 2.6.2 Parameters In Loom

Fiber type, direction, spacing and volume fraction has to be varied to meet specified strength, modulus, and density, electrical and thermal properties.

### 2.6.3 Loom Technology

Dobby and Jacquard weaving are the two methods of cloth forming that have been utilized for the design and production of 3D reinforced performs.

The suitability of Dobby woven textile performs for reinforced composites was investigated by McLaughlin and Harper where a range of multilayer shaped fabrics were produced in cotton and glass fiber yarns using a 24 shaft Dobby handloom. The production of a diverse range of constructions including T-Sections, I-beams, and locally reinforced fabrics, demonstrated that these structures could be replicated on a larger scale, in different fibers with the potential for mass production.

Limitations of the Dobby handloom, the drawbacks associated with a UN automated design system and other related production difficulties indicated the need for more advanced technology and design tools. This necessitated the introduction of the electronically controlled Jacquard power loom and textile design system Scot weaves. The transfer from Dobby to Jacquard design and loom technology facilitated the fabrication of a diverse range of flat and shaped preforms in more complex configurations with new technical and design attributes.

The design and specification of the program ensured the format required to form 3D fabrics on a standard loom was compatible with conventional practice. All the processes combined continue to enhance the cost-efficiency of 3D multilayer reinforcement manufacture.

### 2.7 3D-Weaving Processes

3D Weaving process differs from the conventional weaving mainly in three factors. These have been describes[5] .

1. A grid like multiple- layer warp.
2. A shedding operation that enables column wise and row wise sheds to be formed.
3. Two orthogonal sets of wefts(x-set of horizontal wefts and Y –set of vertical wefts).

#### 2.7.1 Shedding

Shedding is known as the heart of weaving. .This is distinguishes 3D Weaving process from Conventional weaving process. In this process the shed is formed both in the direction of the warp and weft. This is known as dual-directional shed. Such a shedding operation is required to enable the multiple layer warp yarns to be displaced in two directions.i.e in the directions of the fabrics thickness and width to form multiple-row wise and column-wise sheds.

##### 2.7.1.1 Dual directional shedding

To enable the yarns of the grid like warp to be displaced for forming multiple column wise and row wise sheds, they required to be disposed separated from each other, and not closely, in the shedding zone. But the multiple concurrent sheds of the vertical and horizontal directions are formed alternately, and not together. This is because the vertical (y) and horizontal(x) wefts would be required to be respectively picked in the sheds of their respective directions.

Arranging two conventional mono-directional shedding units perpendicular to each other cannot help carry out the dual-direction shedding operation. It is impracticable to produce column-wise and row-wise sheds this way.

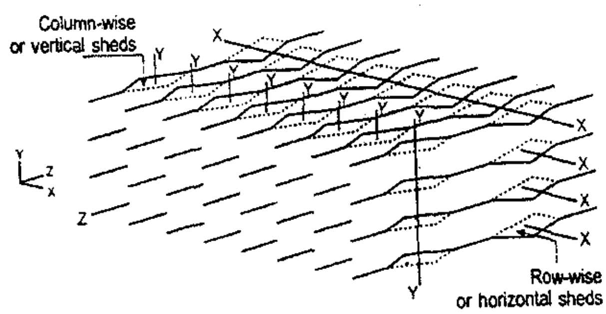


Fig2.7.1.1 Dual directional shedding

At present only two methods are available for carrying out the dual-directional shedding operation:

a) The linear-linear method and

b) The linear-angular method.

Development of this both methods has described in detail the working principles of these methods. Here only the general arrangement of the former is described because the experimental 3D-weaving device developed incorporate this [5].

The dual-directional shedding operation can be performed by using special healds only. To carry out the linear-linear method, each of the healds has a series of oblong and circular openings, as indicated. Two sets of such healds are arranged in a mutually perpendicular arrangement as shown. The yarns of the grid-like warp are drawn through the openings in the healds and also through the other obtaining open spaces between the healds. The arrangement shown is the level position of the shedding system. Displacement of the horizontal healds towards either the left or right side from its level position, as illustrated. Displaces certain warp yarns correspondingly to form multiple column-wise sheds C1-C4. Similarly, displacement of the vertically orientated healds either upwards or downwards from its level position, displaces certain warp yarns correspondingly and creates multiple row-wise sheds R1-R4. This method is called linear –linear because the healds of both the sets are reciprocated linearly in their respective directions.

**2.7.2 Picking**

In 2d fabrics, take up takes place after every single pick insertion whereas in 2d fabrics, several picks can be inserted before take-up occurs. in order to form a 3d fabric two sets of weft yarns are required. Weft is inserted in both horizontal and vertical directions. In each shed a pair horizontal and vertical picks will be present like narrow fabric picking mechanism.

**2.7.2.1 Vertical picking**

The yarns of the grid like warp z are initially in their level position. Then multiple concurrent column wise sheds are formed into which vertical wefts (Y yarns) are inserted and all the sheds are closed. The picking is done in a positively controlled manner using specially designed needles.

**2.7.2.2 Horizontal picking**

After the vertical picking, the warp yarns are subjected to shedding operations and multiple concurrent row wise sheds are formed. Horizontal wefts are picked into this shed and all the sheds are closed.

### 2.7.3 Beat-up

Since there are wefts in two directions, normal reed cannot be used for beat- up. The reed should be in such a way that it should not hinder the formation of either horizontal or vertical shedding.

### 2.7.4 Let-off

This machine uses a negative let-off mechanism. A creel is used to hold the individual warp packages in a grid-like fashion.

### 2.7.5 Take-up

More over the structure and profile of the 3d woven fabrics have to be preserved. For this purpose the fabric is not wound in rolls, but linear take-up mechanism is used.

### 2.7.6 Non interlacing 3D fabric forming process

This is another method of producing 3D fabric. But this cannot be termed as 'true' 3D weaving process because of the shedding operation it uses. This process requires essentially three orthogonal sets of yarns-one set of unaxial yarns z and two sets of binding yarns x and y. The set of UN axial yarns z forms the principle axial yarn of the fabric. The set of unaxial yarns z is organized in a grid like manner to facilitate alternate insertion of the sets of binding yarns x and y through them from two mutually perpendicular directions. The sets of the binding yarns x and y are laid in turns across the rows and the columns of the disposed unaxial yarns z respectively by employing suitable yarn traversing means.

Thus the binding yarns of the sets x and y lie perpendicular to one another and also to the unaxial yarns z. The binding yarns of the sets x and y is laid into the rows and the columns of the disposed unaxial yarns z either as a single yarn of as a doubled yarn. Subsequent to the insertion of a given set of binding yarns across the corresponding rows and columns of the unaxial yarns z, the binding operation is carried out to integrate the produced structure. The binding operation is performed at the surfaces of the produced 3D fabric.

As seen, this non-interlaced 3D fabric forming process dispenses with the operation of shedding altogether, and is therefore characteristically different in operating principle from the 3D weaving process. In absence of any interlacement, the operation of binding becomes indispensable to integrate the structure. The sets of mutually perpendicular binding yarns x and y by interconnecting their respective directions outermost oppositely situated pairs of the unaxial yarns z, prevent the fabric structure from collapsing.

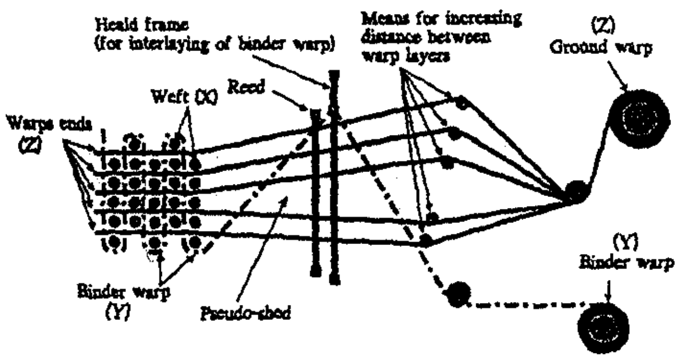


Fig. 2.7.6 Non interlacing 3D fabric forming Process

In an alternative arrangement, the yarns may be disposed multi-axially and bound by one set of binding yarns. In such an arrangement, binding in the fabric-thickness direction is sufficient. Such a non-interlaced 3D fabric is produced on a Raschel warp knitting device and is known as the multi-axial warp 'knit' fabric. As can be observed, the employed sets of multi-axial yarns are stacked on above the other in different orientations relative to each other and bound by a set of binding yarns. The disposed multi-axial yarns do not interloop one into the other. The LIBA system is a special device to produce a similar structure. These way more than three sets of yarns can be incorporated in different orientations in a non-interlaced 3D fabric. The incorporation of the multi-directionally oriented yarns in a 3D fabric allows providing strength in as many directions in a composite material.

**2.8 The Experimental Model**

A simple manually operated experimental 3D-wave device has been developed to demonstrate practically the dual-directional shedding operation and also to confirm that this process fully complies with the principle of weaving. As details of its construction will be described in another paper, the main features of the first experimental 3D-weaving device[6].

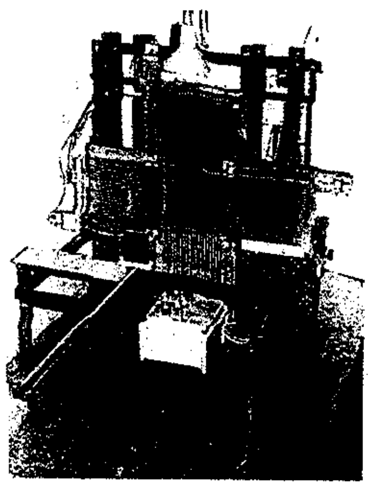

Fig. 2.8 The Experimental Model

A general view of the model developed is shown in the Fig.2.8. This experimental device is designed to produce plain-weave solid, shell and tubular 3D woven 3D fabrics by interlacing a grid-like warp having twenty rows and twenty columns of yarns with an equal number of wefts in each direction. However, depending on the profile and type of fabric to be produced, this can be varied accordingly. It is also designed to incorporate non-interlacing stuffer-warp yarns, if and when required, between either all or any of the pockets created by four adjacent warp yarns that interlace with vertical and horizontal wefts. Accordingly, nineteen columns and nineteen rows of stuffer-warp yarns can be included. To produce dense fabrics the warp yarns are disposed in a convergent form in the weaving zone. Fabrics having a maximum cross-sectional size of 25 x 25 mm and a length of 1 m are producible on this experimental device. To keep the working of the device simple, shuttles of specific construction have been employed. The shedding operation and traversal of shuttles are pneumatically controlled.

### 2.9 System Requirements

A system was developed by using a cross-sectional schematic of multilayer weave architectures as the anchor feature to unite the design, manufacture and analysis disciplines.

The program would permit flexible design creation without restrictions to enable it to:

- Facilitate different numbers of warp and weft layers within and between cross-sectional groups (a group is defined as a section containing a proportion of yarns in the overall design repeat).
- Facilitate structures with varying ends per layer within and between cross-sectional groups.
- Ability to combine groups to provide a schematic of the repeating unit cell i.e., repeat across the fabric width and along the fabric length.

### 2.10 Design Approach

The system produces cross-sectional design across the weft as warp interlinking is the interlacing method most utilized on conventional looms and can therefore be more easily adapted to commercial applications. The program uses the monitor screen as a template so that warp and weft yarns can be displayed, manipulated into basic layer assemblages and allocated interlacement sequences to build up a group. The weave pattern used has some influence on the group size. This is often determined by the number of threads comprising the weave repeat within each layer, and the denting arrangement of the design. If a combination of weave structures is used, then the number of groups required depends on the lowest common multiple of all the repeats.

Individual yarns can be activated, repeats assigned and colors allocated for visualization purposes.

Accommodating changes to the number of warp and weft layers between groups and options to delete individual or whole rows of weft picks enabled the program to facilitate complex performing developments in the form of locally reinforced fabrics, tapered fabrics and a range of near-net shaped fabrics. Warp yarns can also be deleted, or if only weaving intermittently, can float on either top or bottom surface and will be trimmed after manufacture.

The program format permits the retention of equal numbers of warp and weft threads between groups, or has the option to build an alternative configuration if different numbers of warp threads are required between groups. With these additional features, the program format is therefore capable of accommodating the variety of weave architectures necessary for complex 3D performing as examined[3].

## 2.11 Applications

3D fabrics could be used mainly in aerospace industries. Textile composites have replaced aluminum and other metals for use in the body of aircrafts and space shuttles. This has reduced the cost and weight of the body. But the composites have some difficulties such as it cannot be made in spherical or any other special forms. Composites have to be cut and paste together to get such a shape. This makes them inappropriate choice for space shuttles where precision has very much importance.

Moreover the present of resin and different layers of fabric make the composite a little heavy.

It can be made in any forms by arranging the warp yarns in the desired shape. This enables the 3D fabric weaving process to produce fabric of shape round, spherical, conical etc. This is the main advantage of this process as it cannot be done in any other processes. Three dimensional fabrics are used for making helmet, seat shell, fitting, wheel rim, artificial joint. The thickness of the fabric can be changed by changing the no. of layers of warp yarns.. Because of flexibility of varying the thickness the, 3D fabrics can be used in the place of composites widely. Interlocking of 3 mutually perpendicular yarns give it high strength.

In the very near future, 3D fabrics will start replacing composites in aerospace industries. Some of the other areas where the 3D-weaving process could be considered are as follows.

i) Profiled performs for advanced composite materials of both rigid and flexible types.

ii) Body armour and shoe shells for ballistic protection.

iii) High performance sports shoe shells.

iv) Certain medical items like ligaments and scaffolds for growing bones / organs.

v) Thermal seals, casings / insulators

vi) Profiled lines having fins for aqua farming of oyster

vii) Dry / wet filters, mesh for making sintered cutting tools etc.

## 2.12 Summary of Literature

1. Three Mutually perpendicular yarns- 3D fabrics.
2. Higher thickness compare to 3-D, higher strength because of distribution of load in three planes.
3. Quartz, zirconia, silicon carbide, carbon graphite, tungsten and impregnated yarns can be used to make 3D fabrics.
4. Fiber type and other parameters can be varied to produce difference structure and properties of 3D fabrics.
5. Dual direction shedding is used for making 3D fabrics.
6. In picking, dual direction picking namely, horizontal and vertical picking is required for producing a 3D fabric
7. Normal reed cannot be used for beat-up of 3D fabrics, so high spaced reed is used for beat-up.
8. Negative let-off mechanism is used at present for producing 3D fabrics
9. Regarding take up of 3D fabrics when they are wound in rolls they get distorted. So linear take-up mechanism is used.
10. A heald frame is used for interlaying of the binder warp(Z yarn)
11. The shedding operation and traverse of shuttles are pneumatically controlled.
12. A 3D weaving machine should facilitate different no of warp and weft layer within and between cross sectional groups.
13. 3D fabrics are widely used in composite so that in the highly complicated aerospace industries.

# CHAPTER 3

## OBJECTIVE

The aim of this study is to produce a 3D woven fabric on a conventional loom.

By altering the shedding, picking and beat-up mechanisms with additional to the let off and take off motions.

It is also used in heavy technical applications like aircraft bodies, aerospace, artificial joints and skull of submarines, etc.

# CHAPTER 4

# METHODOLOGY

1. Analyzing a plain conventional loom
2. Studying the parameters of a 3D woven structure
3. Correlating the loom parameters with the need
4. Altering the shedding, picking, beat up, let off and take up of a conventional loom to weave a 3D fabric.
5. Optimization of the process parameters
6. analyzing the fabric structural parameters
7. Producing a 3D woven fabric

# CHAPTER 5

# RESULTS AND DISCUSSIONS

## 5.1 Adoptations on conventional loom

The basic conventional loom has been modified in certain areas to make it to produce a 3D woven fabric. The primary mechanism like, shedding, picking and beat-up and secondary mechanism like take-up and let-off are slightly modified

## 5.2 Shedding

- Warp are sorted into three sections to form the plane form of woven constructions
- One heald frame is employed for the purpose of interlaying of binder warp
- Binder warp Z binds the produced structure in the fabric to thickness direction.

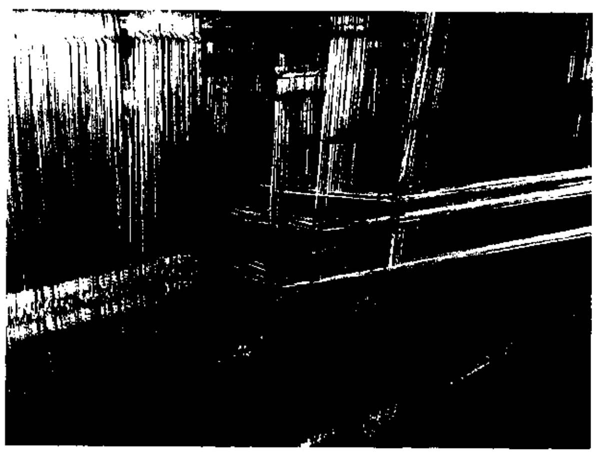

Fig. 5.2 Shedding

### 5.2.1 Action of heald shaft

- Shedding was altered my making only the first heald shaft to go up and down motion.
- While the 2nd, 3rd and 4th remains stationery.

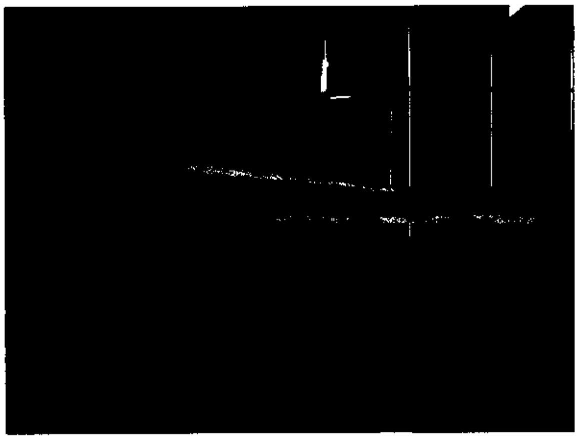

Fig.5.2.1.a Down- ward movement of heald shaft

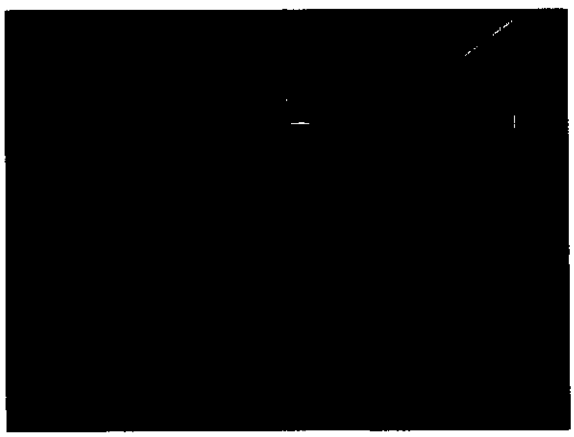

Fig.5.2.1.b Up- ward movement of heald shaft

### 5.3 Picking

- The weft yarn is laid into the shed by means of using needles for weft insertion
- It is necessarily laid over and under the top and bottom warp layer to aid binding of the structure at the surface
- In this several picks can be inserted before take up occurs
- The picks get stacked one below the other, creating the thickness of the fabric

Fig. 5.3 Picking

### 5.4 Beat-Up

- After picking gets over the reed is forced to make the weft in a compact with the fabric
- Normal reed cannot be used for beat-up insists of that an extra spaced reed is used.
- Beat-up was also carried out manually

### 5.4.1 Beat-Up Actions

Fig.5.4.1.a Beat-up starting point

Fig.5.4.1.b Beat-up finishing point

**5.5 Let-Off Mechanism**

- A creel is used to hold the individual warp packages in a grid like fashion

Fig. 5.5 Let-Off Mechanism

**5.6 Take-Up Mechanism**

- When the beating is over the take up roller winds the cloth to maintain the shed tension
- Regarding take up of 3D fabrics when they are wound in rolls they get distorted. So linear take-up mechanism is used.

Fig.5.6 Take-Up Mechanism

### 5.7 Fabric Structure

To place the 3D weaving process in its proper perspective, it is first compared with the 3D braiding and unaxial noobing processes. Though simple and capable of incorporating yarns linearly and parallel to the fabric-length direction, thick fabric is produced.

Fig.5.7 Fabric Structure

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The 3D braiding process has essentially two drawbacks. First; the placement of the yarns in the fabrics is not parallel to the fabric-length direction. Consequently, the tensile property of the high performance fibers cannot be utilized fully. To achieve a given performance level, it becomes necessary to incorporate more fibers, which results in relatively increased dimensions of fabric and fiber consumption then otherwise required. Second, the process is relatively complicated and slow.

The unaxial noobing process is not flexible because it can produce only a limited number of solid profiles. Shell and tubular fabrics cannot be produced. The noobed fabric lacks a network structure because its integrity comes from the bindings that occur at its surfaces. There is no natural built-in mechanism to hold the linear yarns of three directions together. Due to this shortcoming, it is easy to pull out the linearly occurring fibers. Also, if damage happens, or if a cut is made, either at the surface or even internally, the bindings are destroyed and the fabric becomes vulnerable to spilling up, either wholly or locally depending on the extent of the damage or cut.

**5.8 Characteristics of 3D Fabrics**

The yarn is mutually in three perpendicular planes. So equal distribution of load in three planes compare to load distribution in 2D planes in normal fabrics. This leads to higher strength of fabrics.

The thickness of the sample is significantly high (many times than the normal fabrics). The thread density of the 3D fabric is more. The weight of the fabric (GSM) is drastically improved. It has higher inter-laminar properties.

# CHAPTER 6

# CONCLUSION

Textiles of higher thickness and complexity are used in composites materials to meet stringent quality requirement. Simple fabric structures are not enough which lead to invention of 3D fabrics.

Thus a 3D woven fabric is made on a conventional loom with only a slight modification which makes the fabric produced cheaper in cost and simple in technology.

In a conventional loom shedding was altered by making only the 1$^{st}$ heald shaft to go up and down. While 2$^{nd}$, 3$^{rd}$ and 4$^{th}$ remained stationery. Weft insertion was done manually by using a needle. Beat-up was also carried out manually. 3D structure was produced y inserting weft yarns in the 3 sheds formed one above the other without beat-up , take-up and let-off once 3 picks are inserted one above the other Z warp position was changed and all picks were beat up together.

By altering the weft thickness, we can vary the thickness of the 3D fabric. It's possible to produce 3D fabric in a conventional loom. Since it is easy to make the applications for 3D fabrics can be explored in different fields starting from acquistic property to the filtration.

# CHAPTER 7

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