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Effect of Woven Fabric Crimp on Composite Materials

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Abstract

Wide ranges of textile materials are used in many applications like apparel, medical textile and protective textile etc., also used in Geo textile application as composite material. In this composite, textile materials are used as Fibre, yarn, 2D fabric and 3D fabric. There are different techniques to prepare composite material using textiles as reinforcement. In recent days 3D fabric has developed in different method and structure. In this project, we studied about effect of crimp present in the fabric on properties of composite material.

Literature shows that if crimp increases the properties of composite will become decreases. So, we selected low crimp weave woven fabric structure like Diamond and Dice weave. These structures woven as 2 layer, 3 layer and 4 layer fabrics and converted into composite material keeping these 3D fabrics as reinforcement. Reinforcement has been woven in handloom with jacquard. After completion, the testing of composite material for their flexural, tensile and impact characteristics has been done and it was observed that compared to plain and Dice weave structure has very low tensile, flexural characteristics than Diamond. But in case of impact strength Diamond 2 layer, 4 layer and Dice 3 layer has maximum values.

Keywords: *3D Fabric, Composite materials, Reinforcement, Diamond weave, Dice weave, Handloom, Jacquard, Flexural characteristics.*

I. INTRODUCTION

From past to modern times, wood, stone, steel and concrete have been the widely used materials for any construction. In history of the previous century, there is always some limitations of using polymer resins, glass and other fibres, and their incorporation into fibre- reinforced composites. With the modest technical demands and advanced applications of composites in aerospace use of carbon or other high-modulus fibres is more expensive. Also in construction industry there are vast demands in technical requirements to develop structured composites. By a recent article in the University of Cambridge alumni magazine by Professor Cam Middleton with the title "Constructions is not on the list of hi-tech efficient industries". There is always need of production methods that provide less cost and better performance. In latest developments, uses of three dimensional (3D) preforms in manufacturing of composite materials for different structural applications are mandatory. The form of 3D fabric preforms may be woven, knitted or braided.

The objective of this research is to evaluate and assess the composite material for different applications, which is made from different type of woven structures. It is noted that from the literatures the woven fabric with more waviness (crimp %) will affect the properties of composite material. This research also focused on most suitable woven fabric structure with reduced crimp for better performance of composite. This will helps the various industries to use of different woven fabric.

This research will contribute to the understanding of textile composites in various applications and the textile parameters (mainly on crimp) that affect the performance characteristics of these materials. The performance characteristics of the 3D woven fabric composite are related to different construction parameters, such as thread density in each layer, yarn linear density, arrangements of warp, weft and z-yarns.

Objectives

1. To produced multilayer 3D fabric.
2. To develop the textiles reinforced composite using low crimp weave (Diamond & Dice Weave).
3. To study the performance characteristics of composite materials compared with plain structure.

DIFFERENT METHODS OF 3-D FABRIC

There are different methods of producing 3D Woven Architectures for different applications,

1. 3D Solid Structures
2. 3D Hollow Structures
3. 3D Shell Structures
4. 3D Nodal Structures

3D Solid Structures

3D solids structures refers to those woven preforms that have solid structure either in a broad sheet or in a net shaped preforms as shown in figure.1. It is a structure may be comprised of multiple walled sections in three directions, X-length, Y-width and Z-thickness directions. This type of fabric has solid structure without any tunnel like openings. For producing this type of textile preforms multi-layered, angle interlock or orthogonal principles may be used.

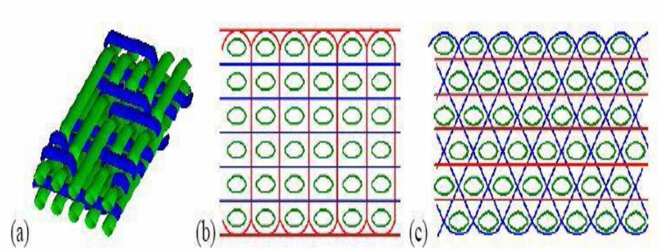


Figure.1 Cross sectional views of 3D solid architectures

3D Hollow Structures

Three Dimensional hollow structures, in this context the fabric which refers to those having hollow like openings any directions like warp, weft or in thickness directions. These architectures are two different types; one is with even flat surface and other with uneven surfaces as shown in figure. 2. These types of hollow structures are produced with the multi-layer principle.

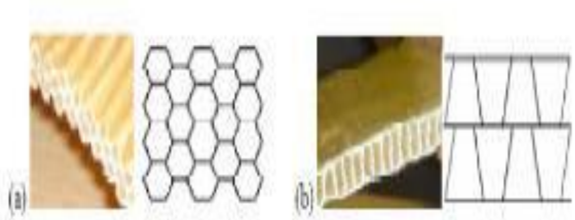


Figure.2 3D hollow structures with (a) uneven and (b) flat surfaces

3D Shell Structures

It is a structure which comprises of united single-walled sections in all the directions. 3D shell architectures shown in figure.3, this type of shell structure can be woven by using various type of weave combination, as far as mechanism is concerned discrete take-up must be used, and also for formation of shell different shapes of moulding must be manipulated.

Figure.3 3D shell architectures by (a) Different weave (b) Discrete take- up (c) Mouldings

3D Nodal Structures

3D nodal architectures have single-walled or multi-walled units in both fabric width and thickness directions. It has several numbers of tunnel-like openings in fabric length direction based on applications.

Figure.4 3-D Nodal Structures

Technique of 3-D Weaving on Conventional Loom:

As discussed earlier there are different 3D fabrics producing principles are discussed in various literatures, a simple solid structure 3D fabric preforms may be produced by following different principles:-

- Multilayer Principle
- Orthogonal Principle
- Angle interlock Principle

Above three principles can be produced by using conventional looms.

Different Methods of Producing Composites:

The form of preforms used in producing composites are may be in form of laminates, in this, fabrics are laid one on the other until required thickness made. The other form of preform is integrated structure as in solid structure. The integration is made by providing required number of stitches to each layers.

Effect of Crimp

As per past research there are various woven fabric parameters that affect the properties of fabric reinforced composites, they are thread density, linear density of yarn used in X, Y and Z-directions, number of layers, number of stitches and crimp. Since this research is primarily focused on the effect of crimp on properties of composite material two different type of weaves with less crimp used for this study. As mentioned earlier, in particular strength of composite materials is having direct relationship with yarn crimp. The other characteristics like stiffness of fabric are decreasing with increase in yarn crimp. When the tensile load is applied on the structure having reinforcement with no crimp and straight, then full load will be faced in tension at complete strength. However, if tows with some crimp, the yarns are bent when the yarns are interwoven together, the primary load applied will be expended for straightening of bent tows, then it requires lesser loads to break the composite, subsequently leads to lower strength. The later concept as shown in figure.5, the load is applied in the two directions of F1 and F2 (Warp), this force is initially utilized for push the weft thread to upward direction. This is clear that this process consumes the energy of warp yarn, resulting in reduced strength on warp direction and vice-versa.

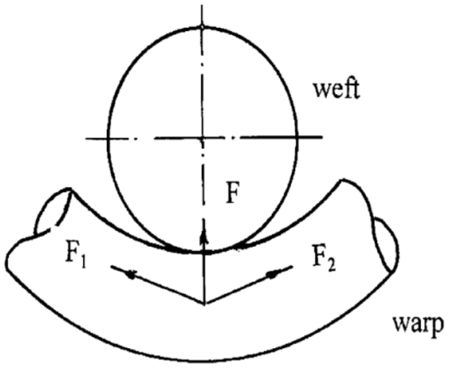


Figure.5 Force analysis

MATERIALS

In composite material, there are various parameters which will affect the properties of textile composites like material, count of yarn, crimp of yarn, fabric structure, and fibre volume fraction.

Irrespective of material used composite properties is based on fabric structure, crimp, and fiber volume fraction. So, in this project, we are used 2/30 Ne (350 Denier) 100% polyester spun yarn. The material has been selected based on better weavability.

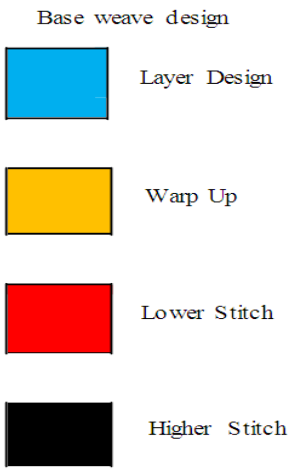
Using this 3-D textile reinforcement has been developed and converted into composite material.

Table.1 Fabric Parameters

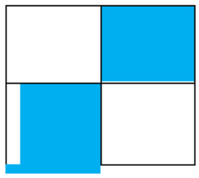
	WEAVE	EPI	PPI	Weft Crimp in %	Warp Crimp in %	GSM of Fabric	GSM of Composites
1	Plain 2layer	59	29	11.5	11.1	128.42	157.0
2	Plain 3layer	40	28	10.8	10.5	143.38	161.68
3	Plain 4layer	30	27	10.3	9.8	161.47	168.06
4	Diamond 2 layer	58	34	9.0	8.6	140.26	164.65
5	Diamond 3 layer	38	25	8.7	8.2	139.56	157.38
6	Diamond 4 layer	29	25	8.4	8.0	155.14	168.06
7	Dies 2 layer	59	38	8.9	8.5	144.94	177.17
8	Dies 3 layer	40	38	8.6	8.0	177.45	192.23
9	Dies 4 layer	30	27	8.2	7.8	159.1	165.60

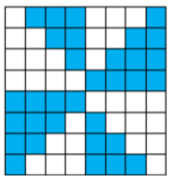
4.2 DesignDevelopment

- Plain weave
- Diamond weave
- Dice weave

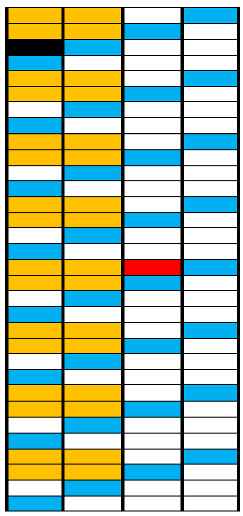


Plain weave (Figure.6)





Dice weave (Figure.8)



Plain 2 Layers (Figure.9)

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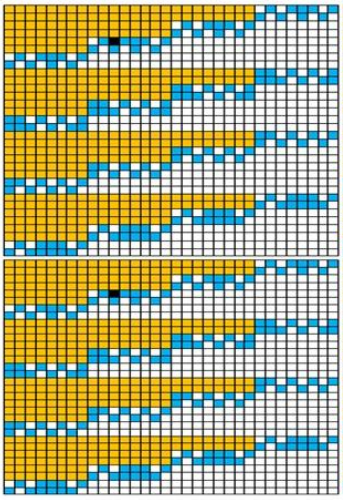
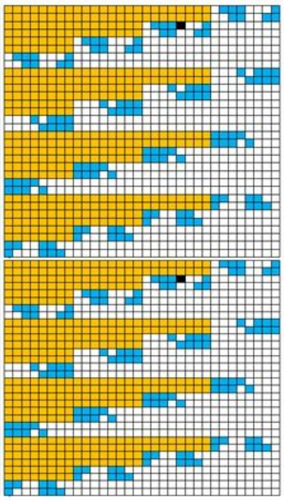
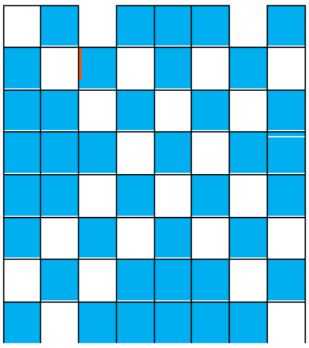
Diamond 4 Layers
(Figure.10)



Dice 4 Layers
(Figure.11)



Diamond weaves (Figure.7)



3-D Fabric Development

In this project we are using handloom with jacquard (400 hooks) for 3-D fabric development. Transfer the design point graph to punching cards. After the design development warping processes into the loom. After that to develop the 2 layers, 3 layers, and 4 layer 3-D fabric. While weaving the 2 layers fabric using 2 shuttles, 3 layer fabric using 3 shuttles, 4 layer fabric using 4 shuttles for avoid the salvage lock during weaving.

Figure.12 Fabric Development

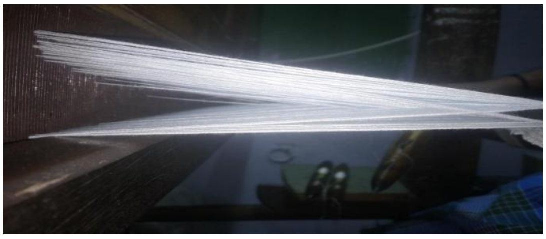


Figure.13 Shedding

Results:

Tensile Result

Table.2 Tensile Strength

Sample No.	CS Area [mm²]	Peak Load[N]	%	UTS [N/mm²])
1	75.0	1446.367	1.220	19.286
2	75.0	2047.259	1.600	27.301
3	75.0	2881.138	2.333	38.416
4	75.0	2047.828	1.713	27.301
5	75.0	2663.690	2.000	35.512
6	75.0	2228.037	1.847	29.705
7	75.0	2034.349	1.733	27.125
8	75.0	2478.241	2.000	33.040
9	75.0	2240.957	1.693	29.881

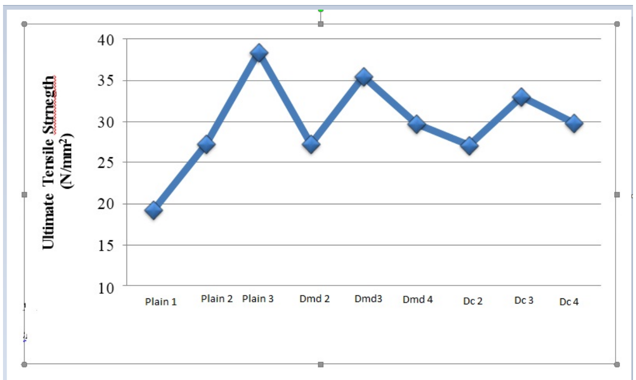


Figure.14 Tensile Strength

The tensile strength results shows that sample no:3 in highest tensile strength and sample no:1 in lowest tensile strength. Both of the samples are made from plain weave. Since diamond and dice weave shows nominal results which results in less deviation along the process.

Figure.15 Elongation

The elongation results shows that sample no:3 in highest elongation and sample no:1 in lowest elongation. Both of the samples are made from plain weave. Since diamond and dice weave shows nominal results which results in less deviation along the process.

Flexural Strength Test

Table.13 Flexural Strength

Sample No.	CS Area [mm²]	Peak Load [N]	Flexural Strength (Mpa)	Flexural Modulus (Gpa)
1	39	34.59	27.938	1941.78
2	39	71.113	57.437	2822.82
3	39	74.281	59.997	2760.13
4	39	78.48	63.388	2676.79
5	39	84.494	68.244	1059.32
6	39	67.454	54.482	2387.74
7	39	48.147	38.889	2037.24
8	39	57.634	46.55	2156.92
9	39	60.067	48.516	2631.01

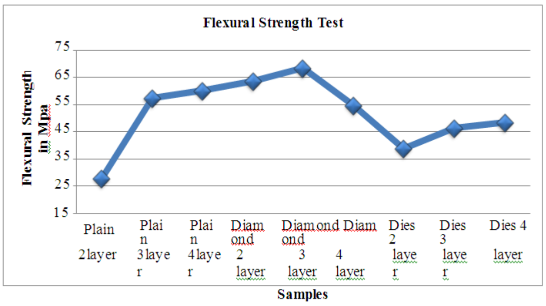


Figure.16 Flexural Strength

Flexural Modulus Test Results

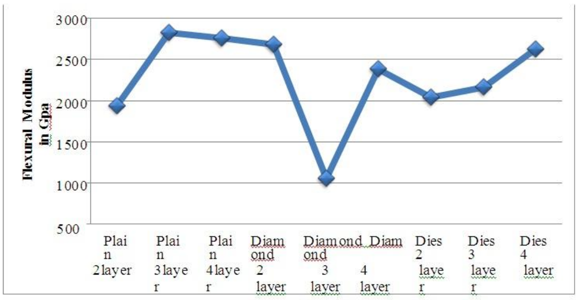


Figure.17 Flexural Modulus

Impact Strength

Table 5.12 Impact Strength

S.No	Izod Impact Value in J
1	0.35
2	0.40
3	0.35
4	0.45
5	0.35
6	0.45
7	0.30
8	0.45
9	0.40

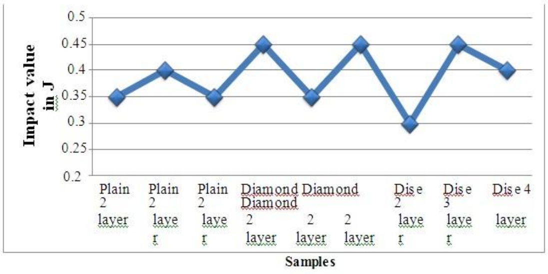


Figure.17 Impact Strength

Overall tensile strength and flexural strength is more for Diamond 3 layer fabric reinforced composite compared to other two weave structures. But in case of impact

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strength is low for Diamond 3 layer fabric reinforced composite material.. As discussed earlier impact strength is more for diamond 2 layer , Diamond 4 layer and Dice 3 layer has higher impact strength when compared to other samples.

Conclusion :

The objective of this project is to project the results of composite material which is produced from different weave structure. As mentioned in a literature, it was observed that the characteristics of composite material are depends on weave structure, number of layer and crimp present in the reinforcements. For comparison, plain weave has been taken, other two fabrics have developed with Diamond and Dice weave with low crimp % when compared to plain weave.

All the fabric reinforcements were developed in hand loom with jacquard, stitches has been given in every one inch of the fabric. Comp onsite material was developed using compression molding technique using epoxy resin. Those composite materials are tested for their characteristics of tensile, flexural and impact strength.

From the results obtained, it was observed that diamond weave structure fabrics reinforced composite material has superior in tensile and flexural strength when compared to other two fabrics (Plain & Dice). So it is concluded that Diamond weave is better than other two weaves.

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