Faculty of Engineering

SHEAR DEFORMATION OF CHAIN STITCHED AND TRICOT STITCHED NON-CRIMP FABRICS

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TS
1445
M697
2004

Bachelor of Engineering with Honours
(Mechanical Engineering and Manufacturing Systems)
2004

Borang Penyerahan Laporan Projek
Universiti Malaysia Sarawak

BORANG PENYERAHAN LAPORAN PROJEK

Judul: Shear Deformation of Chain Stitched and Tricot Stitched Non-Crimp Fabric

SESI PENGAJIAN: 2000/2001

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SHEAR DEFORMATION OF CHAIN STITCHED AND TRICOT STITCHED NON-CRIMP FABRICS

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from the

Faculty of Engineering

University Malaysia Sarawak

2004

Dedicated to my beloved parents, family and those who seek wisdom.

ACKNOWLEDGEMENT

Firstly, all praise to Allah S.W.T for giving the author a life that he has now and the chance to achieve the things he wish to accomplish in his present and future life and things he had achieved in the past.

The author would like to give his deepest gratitude to his project supervisor Miss Mahshuri for giving him the guidance and encouragement during the implementation of the project.

The author would also show his greatest appreciation Abg Masri, Rhyier, Zaidi, Sabariman and Ireman for their assistance in the project. The author would also express his thanks to his family and friends for giving him the support and understanding. Thanks to all individuals that were directly or indirectly involved in this project.

ABSTRACT

Non-crimp fabric is used to produce parts for rigid applications. During production the non-crimp fabric would experience shear deformation due to the stretching of the material. This experimental analysis was conducted to observe the shear deformation of the non-crimp fabric using the Picture Frame apparatus and the Testometric machine. Chain stitched non-crimp fabric and tricot stitched non-crimp fabric were the specimens of the analysis which were inserted parallel and perpendicular to the acting tensile force and the crosshead speeds are 10mm/min, 30mm/min and 50mm/min. Specific mathematical equations were used to obtain the data for analysis which includes shear force, shear angle and shear stress. The fabric shear locking angle was obtained by observing the occurrence of wrinkling of the fabric. From the analysis, it is discovered that fabric at 50mm/min crosshead speed displaced longer but experienced lower level of shear force and shear stress. The 50mm/min crosshead speed increased the shear angle rate higher for the non-crimp fabrics. The chain stitched non-crimp fabrics endured higher shear force and shear stress compared to tricot stitched non-crimp fabrics when inserted parallel to the acting tensile force throughout the analysis. For the non-crimp fabric inserted perpendicular to the acting tensile force, the diversification of the shear force and shear stress endured by the specimens were insignificant but chain stitched non-crimp fabric was subjected to higher level of shear force and shear stress during the displacement of the specimens. The fabric shear locking angle occurred at 9° to 12° for the chain stitched non-crimp fabric and 15° to 20° for the tricot stitched non-crimp fabric when inserted parallel to the acting tensile force. As for the non-crimp fabric inserted perpendicular to the acting tensile force, the fabric shear locking angle for both specimens occurred at similar range of displacement of about 60° to 65°.

ABSTRAK

Fabrik *non-crimp* digunakan untuk menghasilkan produk tahan lasak. Semasa proses penghasilan produk, fabrik *non-crimp* mengalami perubahan disebabkan oleh selisih akibat pemanjangan fabrik tersebut. Kajian ini telah dijalankan untuk mengkaji perubahan selisih pada fabric *non-crimp* menggunakan apparatus *Picture Frame* dan Mesin *Testometric*. Fabrik *chain stitched non-crimp* dan fabrik *tricot stitched non-crimp* adalah spesimen kajian dimana spesimen ini dimasukkan selari dan bertentangan dengan arah daya tarikan yang diaplikasikan dan kelajuan pemanjangan ialah 10 mm/min, 30 mm/min dan 50 mm/min. Persamaan matematik khas digunakan untuk memperoleh data bagi kajian termasuk daya selisih, tekanan selisih dan sudut selisih. Sudut selisih maksima fabrik dapat diperhatikan melalui kejadian kedutan pada fabrik. Dari kajian, didapati bahawa fabrik pada kelajuan pemanjangan 50 mm/min mengalami lebih pemanjangan tetapi daya selisih dan tekanan selisih yang dilalui fabrik adalah pada tahap yang lebih rendah. Kelajuan pemanjangan 50mm/min juga menyebabkan kenaikan kadar sudut selisih fabrik *non-crimp*. Didapati bahawa fabrik *chain stitched non-crimp* mengalami daya selisih dan tekanan selisih yang lebih tinggi berbanding dengan fabrik *tricot stitched non-crimp* apabila dimasukkan selari dengan arah daya tarikan yang diaplikasikan sepanjang kajian. Bagi fabrik *non-crimp* yang dimasukkan bertentangan dengan arah daya tarikan, perbezaan daya selisih dan tekanan selisih yang dialami oleh spesimen tidak ketara tetapi fabrik *chain stitched non-crimp* mengalami daya selisih dan tekanan selisih yang lebih tinggi sepanjang pemanjangan spesimen fabrik tersebut. Sudut selisih maksima fabrik berlaku diantara 9° hingga 12° bagi fabrik *chain stitched non-crimp* dan 15° hingga 20° untuk fabrik *tricot stitched non-crimp* apabila dimasukkan selari dengan arah daya tarikan. Bagi fabrik spesimen yang dimasukkan bertentangan dengan arah daya tarikan, sudut selisih maksima berlaku diantara 60° hingga 65° untuk kedua-dua jenis spesimen fabrik.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The discovery of the application of materials has influenced the civilization of mankind and they started to explore the universe of materials. They began to understand the elements of the materials and when the knowledge expands, the innovation on the fundamentals of the materials inaugurated towards extending and improving the application of the materials. As mankind observed and manipulated the fundamentals of the materials that exist in nature, one of the new elements revealed was composite material.

Nature has given mankind the initial idea for the evolution of the composite materials through the matters surrounding their life. Wood, which is one of the materials mostly used by man, is an example of a natural composite material. The structure of wood comprised of sturdy and supple cellulose fibre cells and bonded by a robust material known as lignin in specific arrangements.

Man utilized all possible matter in nature and imitated the composite structure of wood to create new composite materials such as fibre reinforced polymer and concrete. The reason was that the composite structure that occurred in natural phenomenon has the ideal properties to broaden the application of the materials. Therefore, composite material is the unity of elements of the fundamentals of the universe of materials to compose superior materials as to fulfil the desire of mankind for development in life.

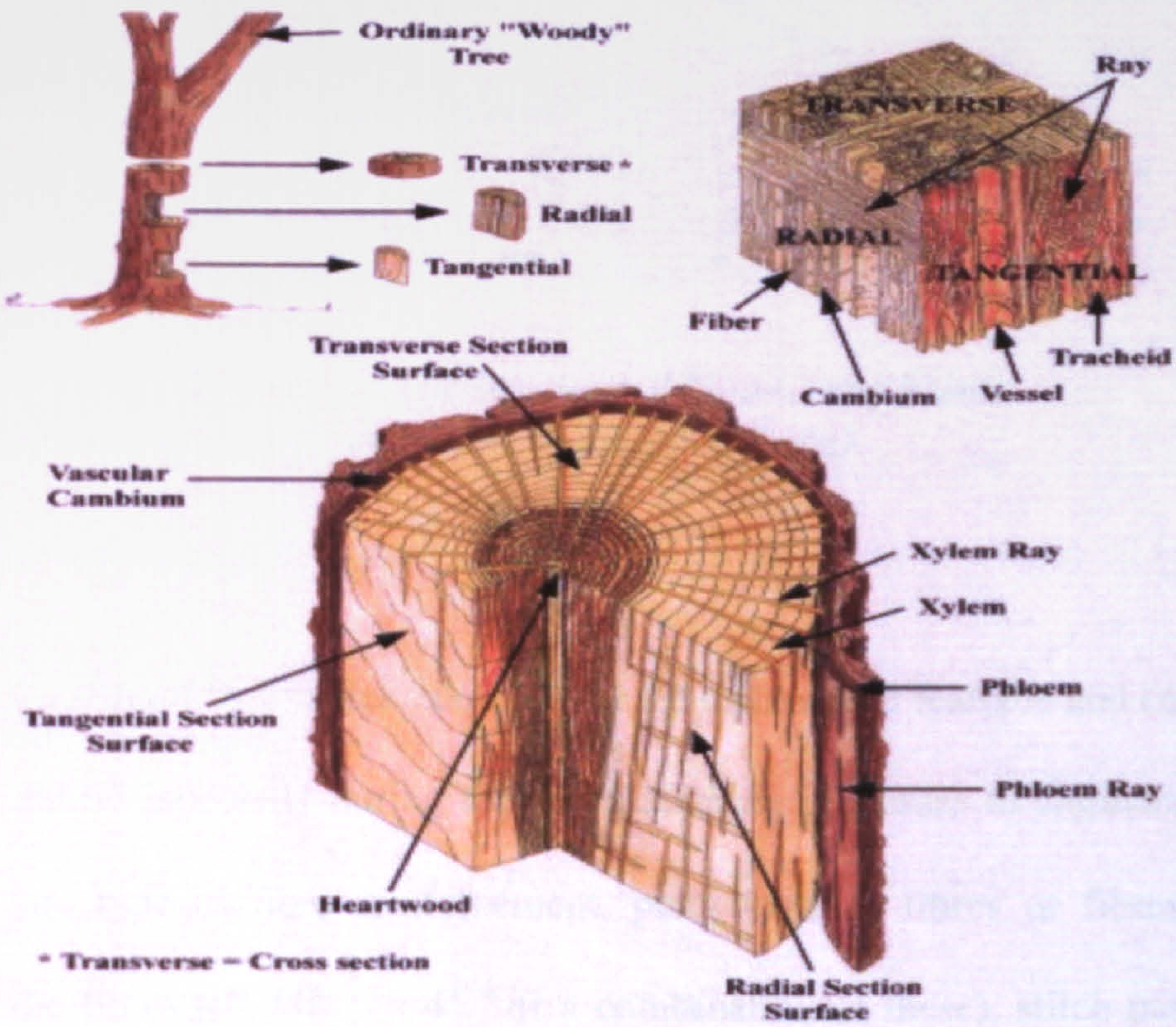


Figure 1.1: Structure of Wood
(www.wood.com)

1.2 Reinforcement Material: Non-Crimp Fabric (NCF)

One of the reinforcement material applied in reinforcing resins in composites is the non-crimp fabric. The material is made from various types of fibre such as glass fibres, carbon fibres or aramid fibres. The structure of the material is in plane layers of fibres, assembled in precise formations and merged by stitching or warp-knitting the layers in specific patterns.

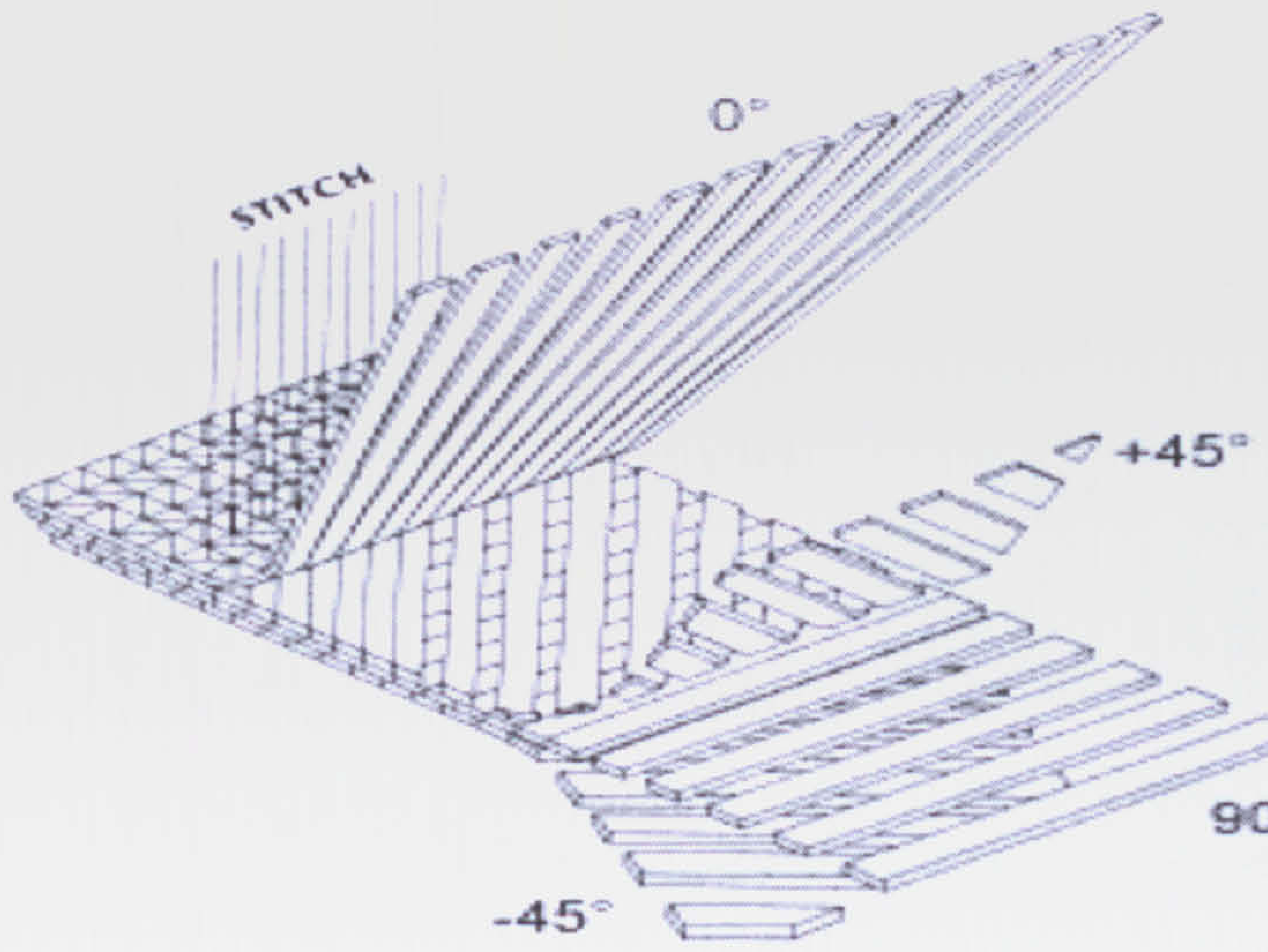


Figure 1.2: The structure of Non-Crimp Fabric
(www.MDAcomposites.org)

There are several factors that could affect the mechanical features and compositions of the non-crimp fabric especially during the manufacturing processes to engineer the material. These factors are type of fibre reinforcement, percentage of fibres or fibres volume, the orientation of the fibres (0°, 90°, +/- 45 ° or a combination of these), stitch patterns, type of resin, cost of product, volume of production that determine the best manufacturing method, manufacturing process of the non-crimp fabric and service conditions.

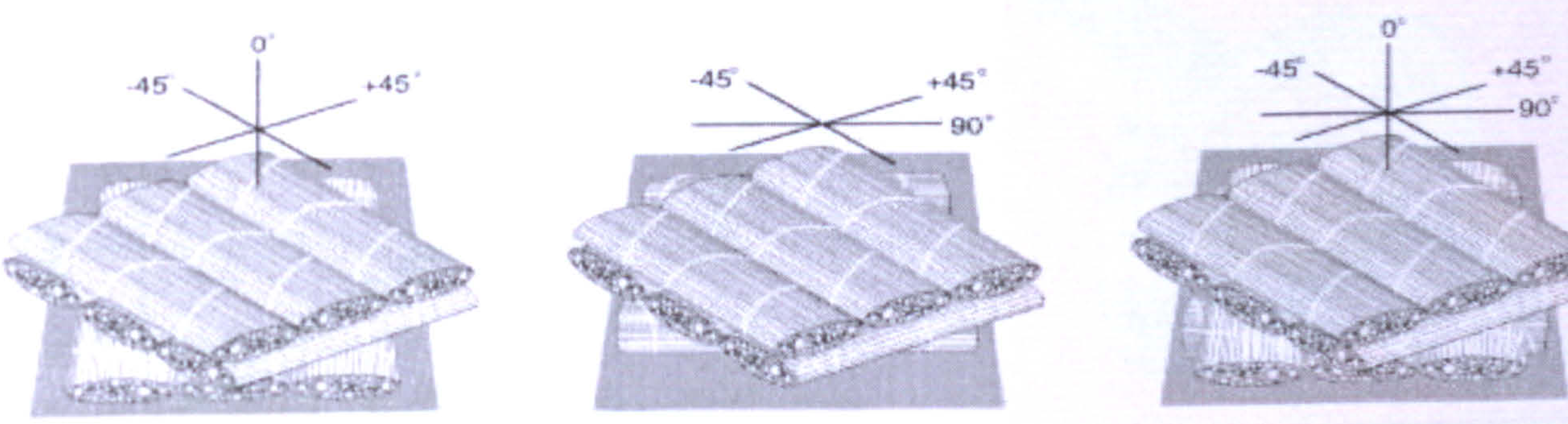


Figure 1.3: Orientation of fibre for non-crimp fabric
(www.MDAcomposites.org)

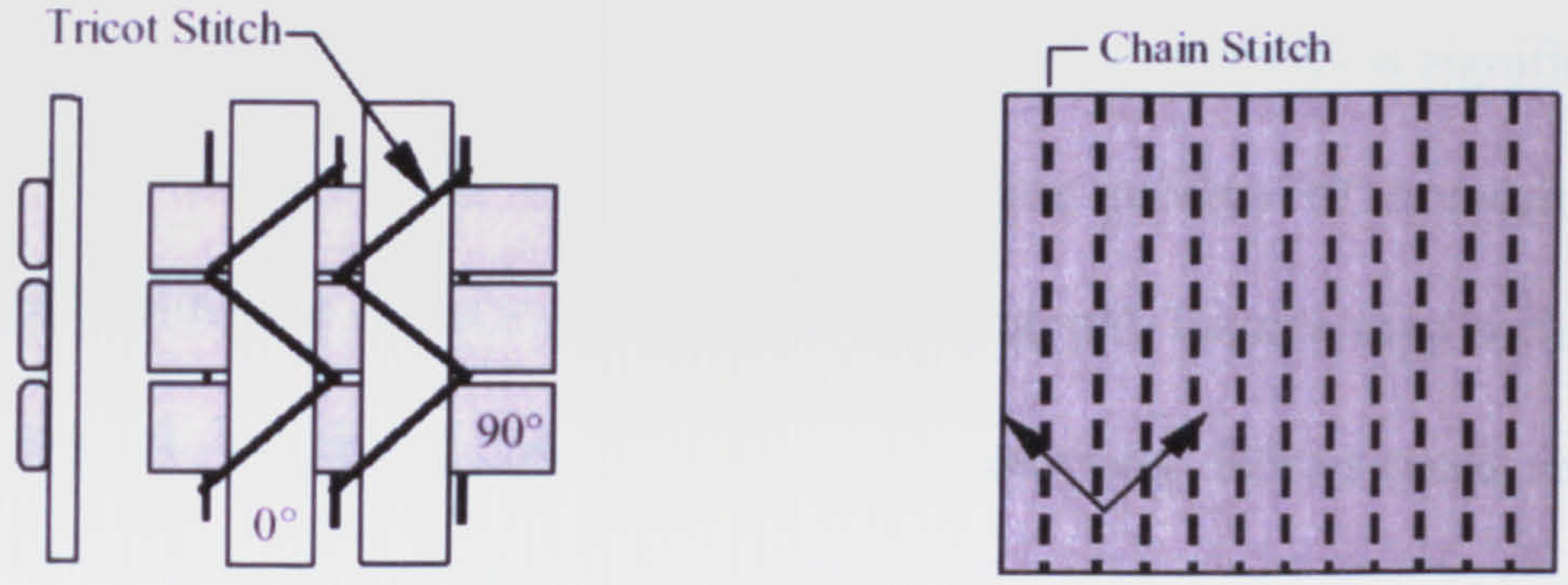


Figure 1.4: Example of Stitch pattern: Non-Crimp Fabric Tricot Stitch Geometry and Non-Crimp Fabric Chain Stitch Geometry (Phifer, 1998)

There are many improvements that developed since the existence of the non-crimp fabric. The structure of non-crimp fabric enables the optimum flow of resin as the composite is engineered permitting better composite manufacturing and at a low cost compared to others. Fabric characteristics also expand with non-crimp fabric as the material has high deposition rate and boundless shelf life. Non-crimp fabrics created no crimp during manufacturing therefore enhanced the out-of-plane mechanical properties of the material and the thread supplies several transverse reinforcement. This increased the through-thickness properties, strength and impact performance of the material.

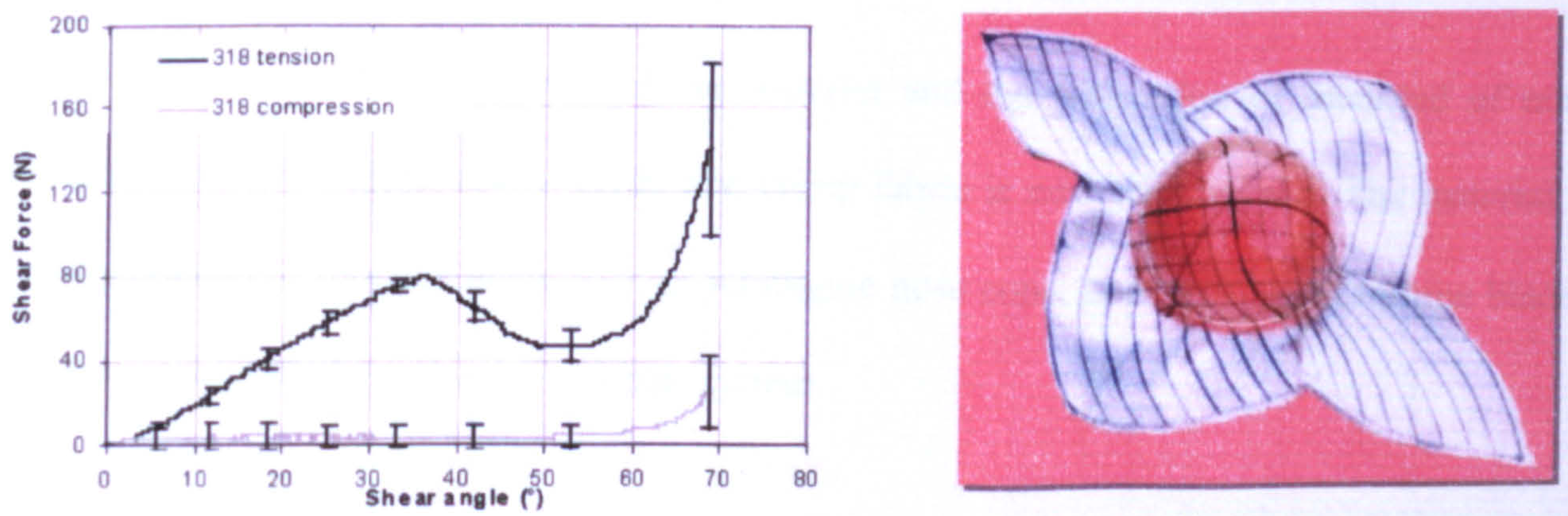
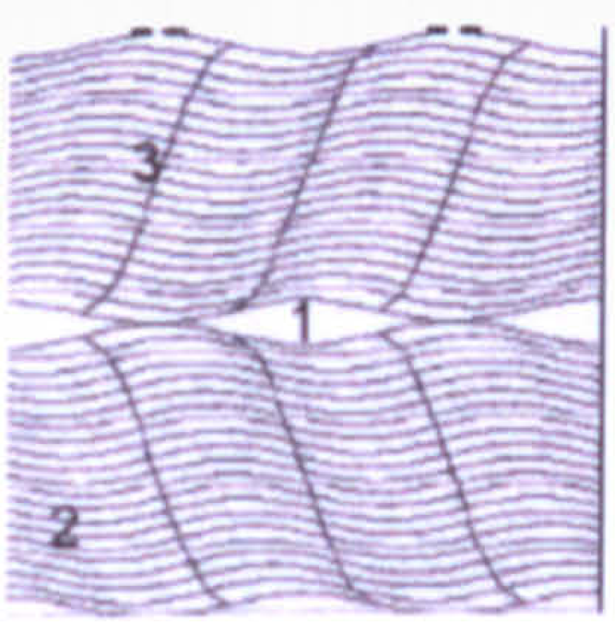


Figure 1.5: (a) The shear force data of stitching thread in tension and compression directional shear compliance of an NCF (+/-45 chain stitched fabric) (b) The hemispherical mould geometry of fibre pattern in NCF. (www.nottingham.ac.uk)

Though the enhancement introduced through non-crimp fabrics is significance, there is presence of weaknesses in the material. The stitching process of non-crimp fabrics is considered as spoiling the in-plane properties of the material. Fissure may occur at the stitch spot in the material. The thread used for stitching in non-crimp fabrics could also introduced defects related to fibre movement and region of high volume resin in composite. This also leads to mechanical degradation of the material under variable heavy loads. Another weakness recognized was the inadequate knowledge of the micro-structural failure process for the non-crimp fabric, which may be vital to the safety of the application of the material.



1. Disturbance due to stitching thread.
2. Undulated laminate.
3. Lines of maximum undulation.

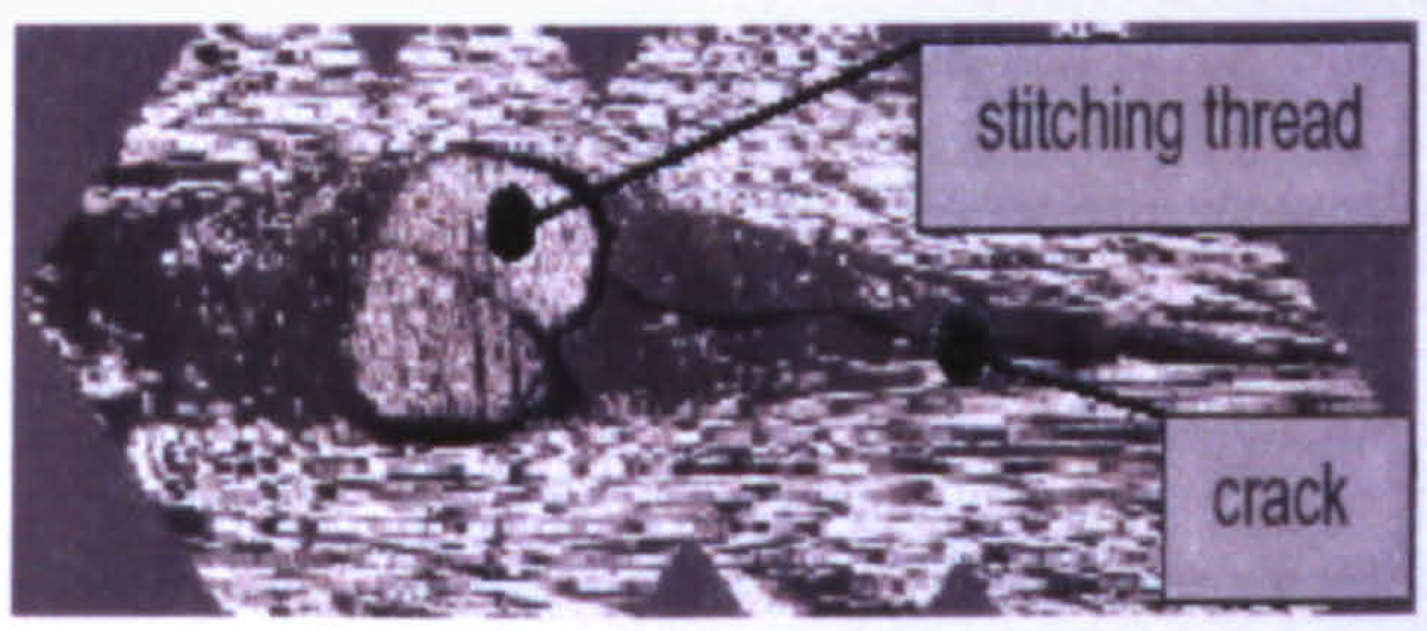


Figure 1.6: The disturbance caused by the stitching resulting in cracks of the related area.
(Sickinger and Hermann, 2000)

Despite the pros and cons of the material and the realization of mankind of non-existence of perfect materials on earth, non-crimp fabric is now widely used. The material is usually applied to produce items such as jet engine nose cone, boat hull, wind turbine blades and even bridge decks and column repair system.

1.3 Scope and Objectives

The primary objective of this research is to determine the shear deformation of the tricot and chain stitch of the non-crimp fabric (NCF), in terms of shear angle, shear stress and shear force. In order to achieve the primary objective, the Picture-Frame Test which is a fabric experimental analysis would be utilized to obtain the data related to the shear deformation of the tricot and chain stitch of the non-crimp fabric. The secondary objective of this research is to generally characterise the effect of tricot stitch and chain stitch on the mechanical properties especially on the shear characteristics of the non-crimp fabric through the experimental analysis related to fabric locking angle and shear stress.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The behaviours of the mechanical properties of fabrics could be observed through experimental analysis. Various types of experimental analysis methodologies have been designed to aid mankind in the research involving fabrics according to the respective mechanical behaviours of the material. In order to observe the shear deformation of the tricot and chain stitch of the non-crimp fabric, several experimental analysis related to the study have been recognized.

Bogdanovich and Pastore (1996) explained that every shear tests including shear deformation test for specimens evaluates the reaction of the structure of the specimens and not the reaction of the specimens towards the tests. They added that the information obtained from the tests would be related to mathematical characteristics concerning the retrieved data that would develop an engineering constant representing the properties of the specimens.

According to Postle, Carnaby and De Jong (1988), shear properties play an important role in the fabric specimens as it affects the mechanics of the fabric deformation. Asvadi and Postle (1998) mentioned that the standard fabric shear test available and frequently practiced