ISTANBUL TECHNICAL UNIVERSITY ★ FACULTY OF AERONAUTICS AND ASTRONAUTICS

DYNAMIC BEHAVIOUR OF STITCHED COMPOSITE PLATES SUBJECTED TO SHOCK LOADING

GRADUATION PROJECT

Alper Onur GÜLŞAN

Department of Aeronautical Engineering

Anabilim Dalı : Herhangi Mühendislik, Bilim

Thesis Advisor: Prof. Dr. Halit Süleyman TÜRKMEN

Programı : Herhangi Program

JULY, 2020

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Alper Onur GÜLŞAN,student of ITU Faculty of Aeronautics and Astronautics **110150031**, successfully defended the **graduation** entitled”**DYNAMIC BEHAVIOUR OF STITCHED COMPOSITE PLATES SUBEJCTED TO SHOCK LOADING** , which he prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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Jury Members :	**Prof. Dr. Melike NİKBAY** İstanbul Technical University	....
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Date of Submission : 13 July 2020
Date of Defense : 20 July 2020

To my family,

FOREWORD

First i would like to thank my graduation consultant Prof. Dr. Halit Süleyman Türkmen who supports and guides me with constructive criticizm.
I would like to express my sincere thanks to my friends for their support.
Finally the chief architect and chief engineer of our country, I feel that I owe the quality education I received, I remember Mustafa Kemal ATATÜRK with respect, gratitude and admiration.

June 2020 Alper Onur GÜLŞAN

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ABBREVIATIONS

ACT **:** Advanced Composite Technology Program
FRP **:** Fiber Reinforced Polymer
HWB **:** Hybrid Wing Body
NASA **:** National Aeronautics and Space Administration
PRSEUS **:** Pultruded Rod Stitched Efficient Unitized Structure
RFI **:** Resin Film Infusion
RTM **:** Resin Transfer Molding

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DYNAMIC BEHAVIOUR OF STITCHED COMPOSITE PLATES SUBJECTED TO SHOCK LOADING

SUMMARY

A material is formed by combining two or more materials that are mutually insoluble by mixing or bonding them in such how that every maintains its integrity called composite.

Composite materials had been efficiently used for structural applications, because of their structural blessings for excessive specific electricity and stiffness.The development of 3D fabric composites has been undertaken in large part by way of NASA. Furthermore, the marine, construction, and automobile industries have supported the tendencies of 3D composites. 3D Textile composites based totally on fabric preforms are manufactured with the aid of several textile processing techniques, resin infiltration, and consolidation techniques. Preforms are categorised into principal categories referred to as two and three-dimensional fabric preforms. 3D textile preforms can be divided into four major groups according to their manufacturing techniques: Braiding, Weaving, Stitching, and Knitting.

Stitching has long been recognised to have important uses in enhancing the energy and damage tolerance of composite structures. Because of this advantages stitched composites always had focus of research. NASA developed Advanced Composite Technology project for the development of better textile preforms and developed new techniques and machines for stitching which is still used in airplane production.

The stitching process is carried out using industrial stitching machines. Stitching machines can stitch various sorts of preforms with high performance yarns as stitching threads.

Various researches and experiments have been carried out on these 3D composites, which have many advantages, and their use is becoming more common every year.

The stitched composites being more resistant to various loads distinguish them from other 3D composites. Its resistance to pressure load and fatigue resistance is very high.

In this graduation project, there is an examination of a plate made of four layers of stitched composite subjected to time dependent shock loading. The purpose of this project; find about deformation and behaviour of this plate under the uniform time-dependent pressure loading.

For analysis of this behaviour ANSYS-LS DYNA programme is used.

ŞOK YÜKÜNE MARUZ BIRAKILMIŞ DİKİŞLİ KOMPOZİTLERİN DİNAMİK DAVRANIŞLARININ İNCELENMESİ

ÖZET

Bir kompozit, karşılıklı olarak çözünmeyen iki veya daha fazla malzemenin karıştırılması veya birleştirilmesiyle birleştirilmesiyle oluşturulur,. Fiberle Güçlendirilmiş Polimer (FRP) kompozitler olarak da bilinen kompozitler, mühendislik ürünü, insan yapımı veya doğal elyafla (cam, karbon veya aramid gibi) veya farklı bir takviye edici kumaşla güçlendirilmiş bir polimer matristen üretilir. Matris, lifleri çevresel ve harici zararlardan korur ve lifler arasındaki yükü aktarır. Lifler, matrisi güçlendirmek için mukavemet ve sertlik sağlar - ve çatlaklara ve kırıklara bakmasına yardımcı olur.

Kompozit malzemeler, aşırı özgül elektrik ve sertlik için yapısal avantajları nedeniyle yapısal uygulamalar için verimli bir şekilde kullanılmıştır. 3 boyutlu kumaş kompozitlerin geliştirilmesi büyük ölçüde NASA yoluyla gerçekleştirilmiştir. Ayrıca, denizcilik, inşaat ve otomobil endüstrileri 3 boyutlu kompozitlerin eğilimlerini desteklemiştir. Tamamen kumaş yapılara dayanan 3-D tekstil kompozitleri, çeşitli tekstil işleme teknikleri, reçine sızma ve konsolidasyon teknikleri yardımıyla üretilmektedir. Ham yapılar, iki ve üç boyutlu kumaş preformlar olarak adlandırılan ana kategorilere ayrılır.

Dikiş tekniğinin, kompozit yapıların enerji ve hasar toleransının arttırılmasında önemli kullanımlara sahip olduğu uzun zamandır bilinmektedir. Bu avantajlar nedeniyle dikişli kompozitler her zaman araştırma odağı olmaktadır. NASA, daha iyi tekstil ham yapılarının geliştirilmesi için İleri Kompozit Teknoloji projesini geliştirdi ve hala uçak üretiminde kullanılan dikişli kompozit teknolojisi için yeni teknikler ve makineler geliştirdi.

Dikiş işlemi, endüstriyel dikiş makineleri kullanılarak uygulanır. Dikiş makineleri, dikiş iplikleri olarak yüksek performanslı ipliklerle çeşitli ham yapıları dikebilir.

Avantajları oldukça fazla olan bu 3 boyutlu kompozitler üzerine çeşitli araştırmalar ve deneyler yapılmıştır ve kullanımı her geçen yıl yaygınlaşmaktadır. Dikişli kompozitlerin çeşitli yüklere karşı daha dayanıklı olması onları diğer 3 boyutlu kompozitlerden ayırmaktadır. Basınç yüküne ve yorulmaya direnci oldukça yüksektir.

Bu mezuniyet projesinde, zamana bağlı şok yüküne maruz kalan dört dikişli kompozit tabakadan oluşan bir plakanın davranışları incelenmektedir.Bu projenin amacı; bu plakanın homojen zamana bağlı basınç yüklemesi altında deformasyonu ve davranışı hakkında bilgi edinmektir.

Bu davranışın analizi için ANSYS-LS DYNA programı kullanılmışır.

1.INTRODUCTION

This thesis examines the plates' behaviour under the uniform time-dependent airblast loading.

1.1 Purpose of Thesis

The purpose of this project; find about deformation and behaviour of this plate under the uniform time-dependent pressure loading. Furthermore, this information about dynamic behaviour can help to improve better stitched composites which can make better and lighter aircrafts.

1.2 Literature Review

The NASA Advanced Composites Technology(ACT) application was began in 1989 to develop composite primary structures for commercial shipping airplanes with expenses that are competitive with the ones of contemporary metallic airplanes. This project improved and developed the 3D composites which are used since. 3D composite structures have several advantages. Due to these advantages 3D structures are used heavily in airplane production. Because of these there are always in the center of attention by researchers.

In literature there are some researches about stitched composite's behaviour. Caprino (2006) examines about stitched graphite/epoxy laminates in different and states that thinner laminates are better in low velocity impact but thicker laminates have better dynamic behaviour under high velocity impact. Sickinger's study investigates the stitching technique and how to improve stitched composites. Yudhanto (2015) analyzes different stitch parameter's effect on 3D stitched composite. Also determines carbon/epoxy stitched laminates' mechanical properties.

1.3 Method

First the information and history about 3D composites will be given. After the technique about stitching and advantages of stitched composites is discussed. Plate will be drawn in CATIA and analysis will be done in ANSYS-LS DYNA.

2. COMPOSITE MATERIALS

Composites, also known as Fiber-Reinforced Polymer (FRP) composites, are crafted from a polymer matrix that is strengthened with an engineered, man-made or natural fiber (like glass, carbon or aramid) or different reinforcing fabric. The matrix protects the fibers from environmental and external harm and transfers the load between the fibers. The fibers, in turn, provide strength and stiffness to reinforce the matrix—and help it face up to cracks and fractures.

FIBER: Provides power and stiffness (glass, carbon, aramid, basalt, herbal fibers)

MATRIX: Protects and transfers load among fibers (polyester, epoxy, vinyl ester, others)

FIBER COMPOSITE MATRIX: Creates a fabric with attributes advanced to either thing alone

In lots of our industrial products, polyester resin is the matrix and glass fiber is the reinforcement. But many combinations of resins and reinforcements are used in composites—and each fabric contributes to the specific residences of the finished product: Fiber, powerful however brittle, provides power and stiffness, whilst more bendy resin provides shape and protects the fiber. FRP composites might also also comprise fillers, additives, core materials or floor finishes designed to improve the manufacturing process, appearance and overall performance of the very last product.

Man-made composites are often tailored to satisfy special needs like high strength and stiffness combined with light weight. The resulting high-performance and expensive materials are increasingly getting used in aircraft, space, and defense applications. Composite materials are utilized in the aerospace industry over the past three decades. due to their good toughness, corrosion resistance also made them more usable. Fibre composites' lightweight makes these materials very crucial. Future areas of application for this technology involve a substantial reduction in costs while maintaining the structural properties.

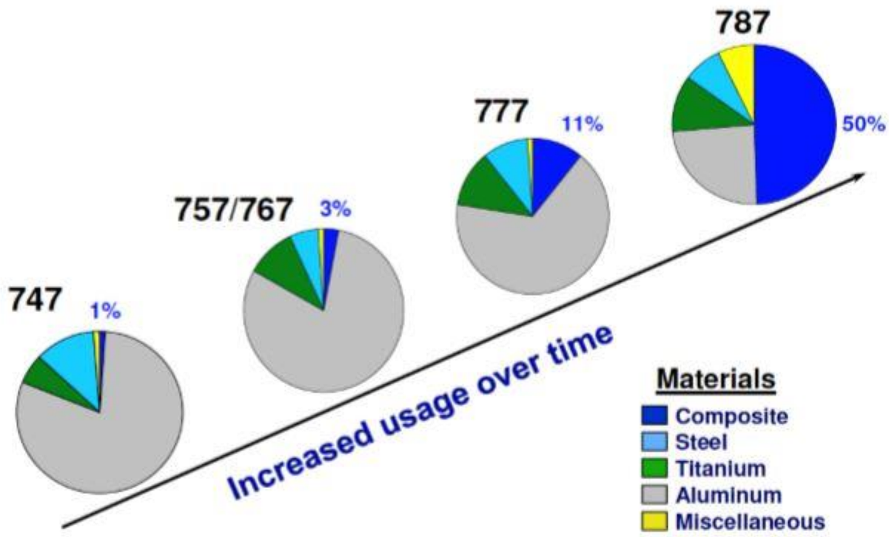

Figure 2.1 Composite usage over time in Boeing's airplanes

Boeing 747 made first flight in 1969 and 787 in 2009. Figure 1 shows how much composite materials are expanded and developed in 40 years.

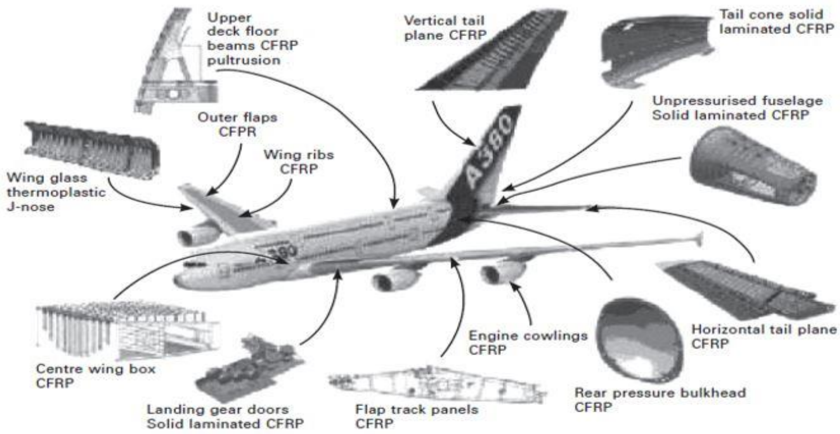

Figure 2.2 Composites in Airbus A380

Also figure 2 shows how many and different places composite materials can be used.

2.1 3D Composites

Three-dimensional composites use fiber preforms made of yarn or towers organized in complex 3D structures. These can consist of a 3D weaving process, a 3D weaving process or a series of 3D short fibers. A resin is applied to the 3D preform to form the composite material. Three-dimensional composites are incredibly designed to achieve complex mechanical properties and are especially used in technical applications. Three-dimensional composites are designed to react to stresses and strains in methods that cannot be achieved with conventional composite materials consisting of unmarried road towers or woven composites or stacked laminate materials.

First generation of composites are 2D laminates. These composites have high stiffness and strength properties, but their put-of-plane characteristics are weak. Also their production process rather slow. to beat these weaknesses 3D composites are developed. These 3D textile composites have more impact resistance and low fabrication cost. Textile composites were considered to enhance structural performances and reduce costs for several components.

3D composites mainly have three-dimensional textile preforms that improves stiffness and strength in thickness direction. They manufactured by resin infiltration and consolidation techniques. These preforms can be classified into two main categories; two and three-dimensional textile preforms. Three-dimensional preforms also divided into four categories; braiding, weaving, stitching and knitting. Fibre composite structures with high performance and low cost are often realised within the future with the help of the resin injection technologies.

Many three-dmensional preforms are converted into complex composite materials while a resin is applied and cured within the preform to create a stable fiber bolstered matrix. The most common shape of resin utility for 3D preforms is the resin Transfer Molding technique wherein a mould is created in the shape of a preform and the preform is then positioned inside. The mildew is closed after which the resin of the matrix fabric is injected underneath unique temperature and pressure, then allowed to cure. the mold is then removed from the outdoors of the 3D composite fabric.

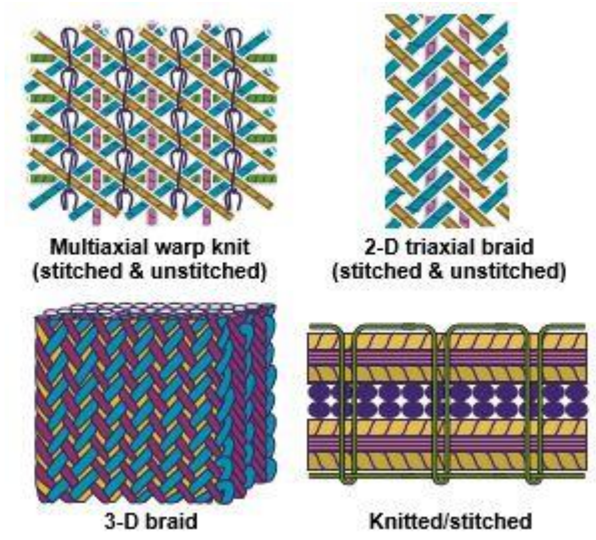

Figure 2.3 Main types of textile preforms(review nasa)

2.1.1 3D Woven Composites

The 3D woven cloth is a version of the 2D weaving process, and it's miles an extension of the very old approach of making double and triple woven cloth. 3-D weaving lets in the manufacturing of fabric up to 10 cm in thickness. Fibers placed in the thickness route are referred to as z-yarn, warp weaver, or binder yarn for 3D woven fabric. More than one layer of cloth is woven at the identical time, and z-yarn interlaces warp and woof yarns of various layers at some stage in the process. At the end of the weaving process, an integrated 3D woven structure, which has a extensive thickness, is produced. (1)

By using jacquard woven techniques such as bifurcation, the 3D woven preforms may be created into nearly limitless shapes starting from a standard I-Beam to a complicated sine curve I-Beam, to aircraft airfoils, and many other shapes. 3D woven composites are used for numerous engineering applications, consisting of engine rotors, rocket nostril cones and nozzles, engine mounts, aircraft framework, T- and X-shape panels, leading edges for plane wings, and I-Beams for civil infrastructure.

2.1.2. 3D Braided Composites

3D braided fabrics era is an extension of the well-set up 2-D braiding era in which the material is built through the intertwining of two or greater yarn structures to shape an vital structure. (2) Developed inside the late 1960s, in order to avert the issues related to 2D composite laminates but at the identical time preserve the benefits of the braiding manner. Braided structures, used as composite preforms, have various of benefits over different competing processes, along with filament winding and weaving.

Braided composites have superior sturdiness and fatigue power in contrast to filament wound composites. Woven fabrics have orthogonal interlacement while the braids can be built over a wide range of angles, from 10 to 858. (3)

Braids may be produced either as seamless tubes or flat fabric with a non-stop selvedge. Composites produced with the braided preforms showcase superior energy and crack resistance in evaluation to broadcloth composites, due to fiber continuity

Braided composites have very large applications such as propeller blades, propulsion shafts, propellers.

2.1.3. 3D Stitched Composites

Stitching has long been recognised to have important uses in enhancing the energy and damage tolerance of composite structures. Saunders, an English builder, received a patent in 1898 for a method of using copper wires to sew skinny layers of wood for a ship hull. Several navy aircraft applications have stitched carbon/ epoxy prepreg with Kevlar thread to beautify the structural integrity and damage tolerance of thin composite structures. Among the competing textile processes, NASA judged sewing to have the greatest potential for the manufacture of cost-effective and damage tolerant structures. (4)

In evaluation to the standard 3D vital woven, knitted, and braided preforms, sewing is characterized by means of the insertion of through-the-thickness yarns into conventional 2D preforms as a secondary processing step following lay-up. The blessings of such through-the-thickness stitching encompass not most effective the cost-powerful joining of fabrics with an advanced ease-of-dealing with of the dry preform however also advanced interlaminar fracture durability and effect damage resistance of composite parts. Out-of-plane effect damage resistance can be advanced because of the insertion of the through-the-thickness yarns, the in-plane mechanical overall performance which includes tensile strength, tensile modulus, compressive strength, and compressive modulus can be improved, significantly degraded or unchanged relying at the kind of composite, the sewing parameters, and the loading conditions. (5)The damage may occur in various paperwork including damaged fibers, resin-rich regions, and fine-scale resin cracking; however, fiber kinking and misalignment appear to have the greatest detrimental consequences at the houses, particularly underneath tensile and compressive loading.

The stitching of laminates inside the through thickness direction with a high strength thread has proven a simple, low-cost technique for producing 3D composites. The stitching process essentially includes stitching high tensile electricity yarn, through an uncured prepreg laminate or dry cloth plies the usage of an business stitching machine. The statistics assembled for stitched laminates screen that the tension, compression, flexure, shear and open-hole strengths are progressed or degraded as much as 20% by means of sewing relative to the ones of unstitched laminates. (6)

3D stitched preforms have a look at encompass woven fabrics as the outer layers and knitted fabric as the internal layers. The concept of this structure was primarily based on the subsequent issues whilst the composite is used for better resistance against effect:

(a) In the back and front layers, the effect strain waves should be quick transmitted alongside the panel direction (material plane direction) because of the straighter orientation of the yarns inside the woven fabrics, for this reason allowing a large quantity of yarns to undergo the impact load. Consequently, less harm is expected to be resulting from the effect load.

(b) In the internal layers, the knitted fabric have to soak up the transmitted impact strain waves in the thickness direction (perpendicular to the cloth plane direction). Due to the loop structures in the knitted fabric, large deformations will take place while the impact load is applied, and therefore, a larger amount of power can be absorbed.

(c) The stitching yarns play an vital position in maintaining all material layers together. When the effect load is implemented to the composite, compression on the

upper half of and extension on the bottom half of the panel will take place, and therefore, the sewing yarns can help to avoid delamination from occurring.
Stitched composites mostly used in lap joints, stiffened panels and aircraft wing-to-spar joints.

Textile Process	Advantages	Limitations
Low Crimp Uniweave	High in-plane properties Good tailorability Highly automated preform fabrication process	Low transverse and out-of-plane properties Poor fabric stability Labor intensive ply lay-up
2-D Woven Fabric	Good in-plane properties Good drapability Highly automated preform fabrication process Integrally woven shapes possible Suited for large area coverage Extensive data base	Limited tailorability for off-axis properties Low out-of-plane properties
3-D Woven Fabric	Moderate in-plane and out-of-plane properties Automated preform fabrication process Limited woven shapes possible	Limited tailorability for off-axis properties Poor drapability
2-D Braided Preform	Good balance in off-axis properties Automated preform fabrication process Well suited for complex curved shapes Good drapability	Size limitation due to machine availability Low out-of-plane properties
3-D Braided Preform	Good balance in in-plane and out-of-plane properties Well suited for complex shapes	Slow preform fabrication process Size limitation due to machine availability
Multiaxial Warp Knit	Good tailorability for balanced in-plane properties Highly automated preform fabrication process Multi-layer high throughput material suited for large area coverage	Low out-of-plane properties
Stitching	Good in-plane properties Highly automated process provides excellent damage tolerance and out-of-plane strength Excellent assembly aid	Small reduction in in-plane properties Poor accessibility to complex curved shapes

Figure 2.4 Application Ability of Fabric Reinforced Composite Materials for Plane Structures (7)

3.NASA'S ADVANCED COMPOSITE TECHOLOGY PROGRAM

In the early 1980s, Langley Research Center commenced to explore the capability of fabric techniques for producing cost-effective and harm tolerant aircraft primary structures. Langley concentrated on adapting enterprise strategies to make fabric composites with a reinforcement preform of dry carbon tows made using weaving, knitting, braiding, or stitching procedures. The preform would be packed with epoxy resin in a resin transfer molding (RTM) or resin film infusion (RFI) operation. Finally, as with traditional composites, the component would be cured the usage of heat and pressure. (4)

NASA's early composites research provided the aircraft developers with important technology but the industry lacked the confidence to apply laminated composites to manufacture wing and fuselage structures. (8)The barrier problems had been high fee and low damage tolerance. Industry desired composite systems that price much less than aluminum and that were robust enough to withstand the trials of airline services. However, low damage tolerance remained an trouble despite important efforts to develop new tough epoxy resins. (8)

NASA has created the Environmentally Responsible Aviation (ERA) Project to explore the feasibility, benefits, and technical chance of advanced car configurations and enabling technologies so one can lessen the impact of aviation on the environment. Because of this idea Boeing and NASA worked together to develop a structural concept which has lightweight and more advanced than other composites.(Advanced Nasa) A vital factor of this pursuit is the development of a lighter, more strong airframe that will allow the creation of unconventional aircraft configurations that have better lift-to-drag ratios, decreased drag, and decrease network noise. The Hybrid Wing Body (HWB) configuration is a sizable development in aerodynamic overall performance compared to traditional tube-and-wing aircraft. In a HWB plane, the center frame is wider and flatter than a conventional tubular fuselage to permit the center section to act as a wing and convey lift. With this arrangement, the wings combination into the center segment to lessen drag. This arrangement impacts not most effective the shape of the vehicle, but additionally the vicinity of the engines, the manipulate requirements, and the inner structure as load transfers from the outer wings to the wide internal wings and the center phase. The structural challenge to creating a huge pressurized HWB layout is the non-circular pressure cabin which have to be light-weight and within your budget to produce. Developing a structural idea that helps the HWB cabin design is the primary technical venture to implementing this large lifting-frame design. To cope with this venture, researchers at NASA and The Boeing Company (Boeing) are running collectively to develop a new structural idea called the Pultruded Rod Stitched Efficient Unitized Structure (PRSEUS). (9) PRSEUS is an indispensable structural concept that advanced from stitching generation development started within the NASA-Boeing Advanced Composites Technology (ACT) Program within the 1990's. The aim of the ACT wing program turned into to develop stitching generation to reduce structural weight and fabrication fee of a traditional wing on a massive industrial transport plane. Through-the-thickness stitching changed into established to arrest harm and save you delamination. Under the ACT program, diverse styles of textile composites have been thoroughly tested however it changed into stitching blended with resin movie infusion that showed the greatest capacity for overcoming the cost and damage tolerance obstacles to wing systems. Assembling carbon material preforms, with intently spaced through-thethickness stitching furnished essential reinforcement for damage tolerance. (Stitching Machine) Also, stitching made it viable to comprise the numerous elements--wing skin, stiffeners, ribs and spars--into an imperative structure that would take away thousands of mechanical fasteners. Although research showed that sewing had the ability for cost-effective manufacturing, the essential want was for machines capable of stitching massive wing preforms at better speeds.

After ACT, Boeing labored with the Air Force to further stitching era for utility to navy transports, resulting in stitched composite touchdown gear doors on the C-17. While operating with the Air Force, Boeing evolved the PRSEUS idea. NASA began to work with Boeing on PRSEUS development under the NASA Subsonic Fixed Wing program. (9)

In the PRSEUS idea as implemented to a HWB, flat panels support massive bending hundreds in both in-plane instructions at the side of the stress load associated with internal cabin pressure. The use of a traditional composite material machine might require fasteners to suppress delaminations and to join structural elements, in the long run main to fastener pull-via issues or heavy pad-ups within the fastener regions. In contrast, thru-the-thickness stitches, applied thru dry fabric previous to resin infusion, update those fasteners during every essential panel. This technique eliminates fasteners and their associated holes, which significantly simplifies the assembly process, reduces part-count, and gets rid of a number one supply of crack initiation throughout the existence of the aircraft. Through-the-thickness reinforcement the use of stitches at discontinuities, such as alongside flange edges, has been proven to suppress delamination and turn cracks, which increases the layout space and ends in lighter designs. This manufacturing method ends in huge cost financial savings and eliminates the out-time concerns associated with traditional prepreg.

4. STITCHING TECHNIQUE

In the recent past, excellent fulfillment and progress will be achieved inside the area of textile preform technologies and injection strategies. Yet the promising first steps of the structural stitching method nevertheless require in addition development. Only whilst a bonding and fixation technique is to be had that is able to structurally link specific fabric preform technology with every other and that gives the possibility of making neighborhood three-d stiffness and strengths will the capability of this new idea be fully exhausted. Conventional prepreg fibre composite components are normally manufactured by a laminateshaped layering of unmarried fibre plies. The attainable particular in-plane stiffness and strengths have helped make the fibre composite technology successful inside the gift and within the past. However, a downside has grow to be evident: The out-of-aircraft stiffness and strengths are determined by way of the matrix and show a extensive loss in comparison to the in-aircraft homes which might be greatly influenced via the fibre residences. The significance of three-dimensional stress conditions at places of joints or load software or in areas liable to notches are increasing with the realisation of complicated, modern, highlystressed structural additives made with fibre reinforced composites. Delamination damage because of impact can significantly have an effect on the composite to the quantity that a large loss in compression energy should be expected. In the future increasingly complex and pretty harassed fibre composite systems will require a technology which permits for particular and nearby impact on the three-d homes of a cloth without drastically adverse the incredible structural in-plane homes.

The stitching process is administered using industrial stitching machines. Stitching machines can stitch various sorts of preforms with high performance yarns as stitching threads. The extent of through-thickness reinforcement in stitched composites structures is between 1 to five, which may be a same amount of reinforcement in 3D woven, braided and knitted composites (Bogdanovich & Mohamed, 2009; Tong, Mouritz, & Bannist, 2002). The utilization of through-thickness stitching in composite owes to the subsequent reasons: possibility to joining composite structures to supply high throughthickness strength and resistance to peel loads, decreasing the prices of component manufacture greatly by reducing RTM(resin transfer molding) tooling costs, improving interlaminar fracture toughness, impact resistance and tolerance, construct 3D complex shapes by stitching several separate preforms together, eliminating the necessity for mechanical fasteners, like rivets, screws and bolts, and also reducing theload and cost.

Despite these advantages for stitched composites, there are some disadvantages with the stitching process. the most one among those may be a reduction within the in-plane properties of the resultant composite component. because the needle penetrates into the fabrics, it can cause localized in-plane fiber damages and fabric distortions, which are found to scale back the mechanical performance of the composites. Stitching process causes distortions within the fabric and in resin rich regions within the composite. This region mostly acts as a crack initiator which may decrease the performance of composite.

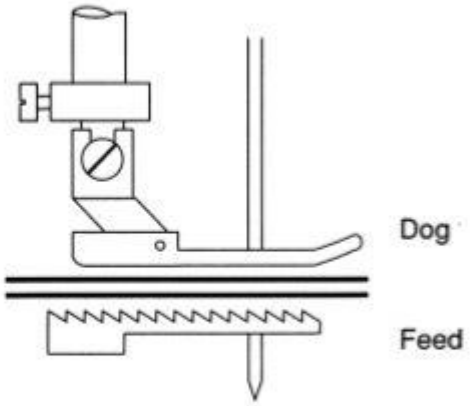

Figure 4.1 Stitching Composite Illustration (10)

4.1 Stitching Machine

A primitive single-needle sewing gadget, resembling a scaled-up model of a household sewing gadget, became the first prototype used to decide the blessings of stitched composites. This initial research identified that stitched composites offered higher ranges of harm tolerance than conventional laminated composites.

Under a six-yr NASA ACT contract, Boeing chose the stitching of dry fabric fabrics, along side the resin movie infusion (RFI) technique to increase cost-effective wing structures. (9) For sewing the skins of big take a look at panels, a multi-needle quilting system turned into received and modified to illustrate a manufacturing approach to sewing layers of carbon fabric. Although the multi-needle machine served essential needs within the wing improvement, it become relatively gradual and not able to sew thick layers of fabric.

The next step inside the improvement became a computer-managed single-needle gantry system that might stitch through the thick carbon fabrics. Both the multi-needle and single-needle gantry sewing machines had unique functions and capabilities; however, neither have been designed with the capability to quickly stitch massive, complicated contoured wing systems.

NASA presented Boeing a contract to broaden a larger machine capable of sewing whole wing covers for commercial transport aircraft. This high-speed, multi-needle system, known as the Advanced Stitching Machine (ASM), became designed and built beneath the NASA ACT wing program. Concurrent with the improvement of the big stitching system, NASA and Boeing proceeded with a building block approach to illustrate the layout and manufacture of stitched/RFI wing structures.

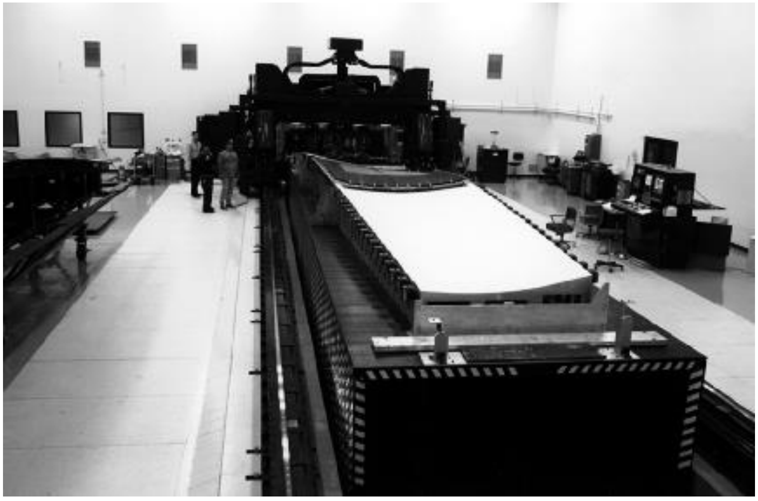

Figure 4.2 Advanced Stitching Machine (8)

4.2 Stitching Types

Lock stitch is one among the foremost common sorts of stitching techniques. it's composed mainly of a two loop between the needle and therefore the bobbin. this sort of sewing isn't appropriate for composites because the thread intersection within the middle of the fabrics causes a stress concentration. Hence, modified lock stitch is usually utilized in composite industry that permits the needle thread to maneuver on the composite surface rather than the center of composite. Another method, a chain stitch method is employed in composite industry. This method is very similar to the lock stitch. Other sewing machines can generate two sorts of stitches; tufting and dual-needle stitching.

Chain Stitch Lock Stitch Dual Lock Stitch Modified Lock Stitch

Figure 4.3 Stitching Types (11)

4.3 Advantages of Stitched Preforms

Stitched preforms has various advantages over 2D laminates.

-Plies in stitched preforms prevented from moving which improves handling of material.

-Their production can be cheaper and simple.

-Delamination resistance to ballistic impact or blast loading is higher.

-Effect harm tolerance is higher.

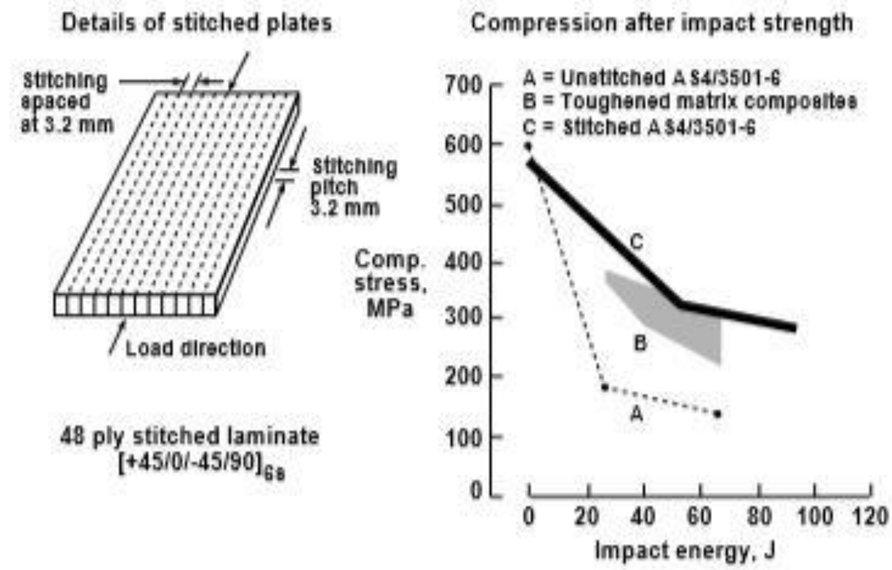

Figure 4.4 Effects of Stitching on Damage Tolerance of Composite Materials (7)

-Their modes I and II interlaminar fracture sturdiness improved.

- Joint strength beneath monotonic and cyclic loading improved.

-Interlaminar fatigue resistance is higher.

-Their through-thickness tensile modulus and electricity slightly developed.

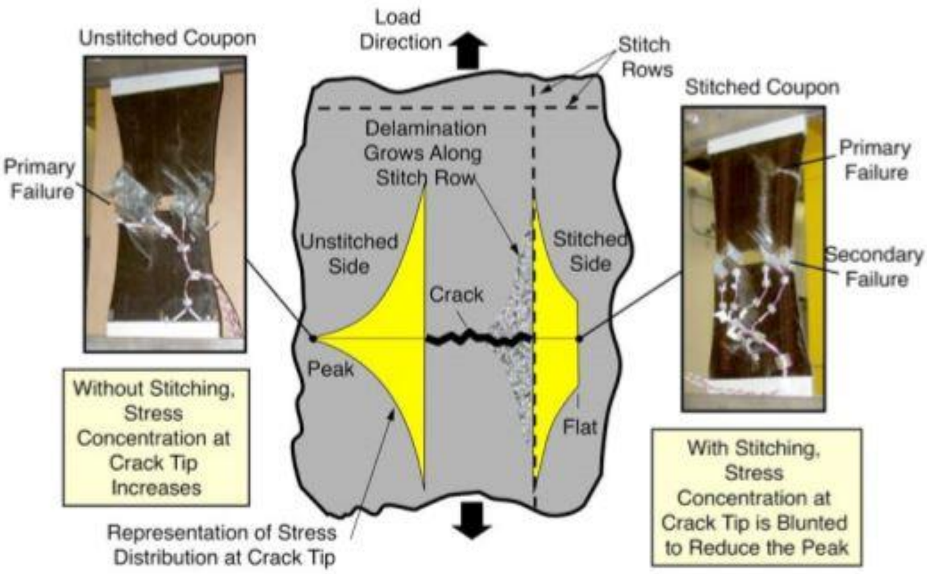

Figure 4.5 An Example of The Way Stitching Blunts The Pressure Concentration at The Crack Tip (9)

4.4 Issues Impeding the Use of Stitched Preforms

While stitching has the potential to be used for joining laminates, a number of scientific and technical issues still need to be resolved.

-Most stitching machines can't sew massive and thick composite systems.

-Sewing machines require get entry to to each sides of the preform.

-Most sewing machines can't stitch curved composite structures with a complex shape.

-The consequences of sewing parameters (eg. stitch density, yarn materials, yarn denier) on joint strengths is not absolutely understood.

-Stitching commonly degrades the in-plane mechanical properties.

-The environmental getting older and sturdiness of stitched composites isn't always absolutely understood.

-Predictive fashions for determining strength and fatigue performance have now not been satisfactorily developed.

5. MECHANICAL PROPERTIES

Density (g/cm^-3)	1.6
σ_{ult} (MPa)	720
ε_f (%)	1,52
E_x(GPa)	50
v_{xy}	0,321

Table 5.1 Mechanical Properties of Carbon Epoxy Stitched Composite (12)

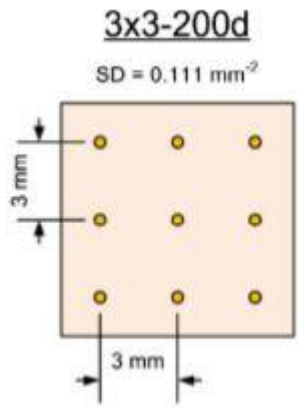

Figure 5.1 Schematic of stitched composite (12)

6.ANALYSIS

The pressure load applied on the all surface of the plate as a function of time. All edges of the plate are modeled by clamped boundary conditions.

The panel has 135 mm length and 135 mm width. Height of panel is 2mm.

$$P(t) = Pm\ (1 - t/tp)\ e^{-\propto t\ /tp} \quad \text{(Eq. 1) (13)}$$

Parameters	Load Case
Pm	28906 N/m^2
$\propto$	0,35
tp	0,0018 s
Pressure Distribution	Uniform

Table 6.1 Loading Conditions (13)

The maximum value of pressure over time: p_m

The pressure value at the edges of the panel as soon as pressure reaches the maximum value: p_c

Effect time of pressure: t_p

7. RESULTS AND CONCLUSION

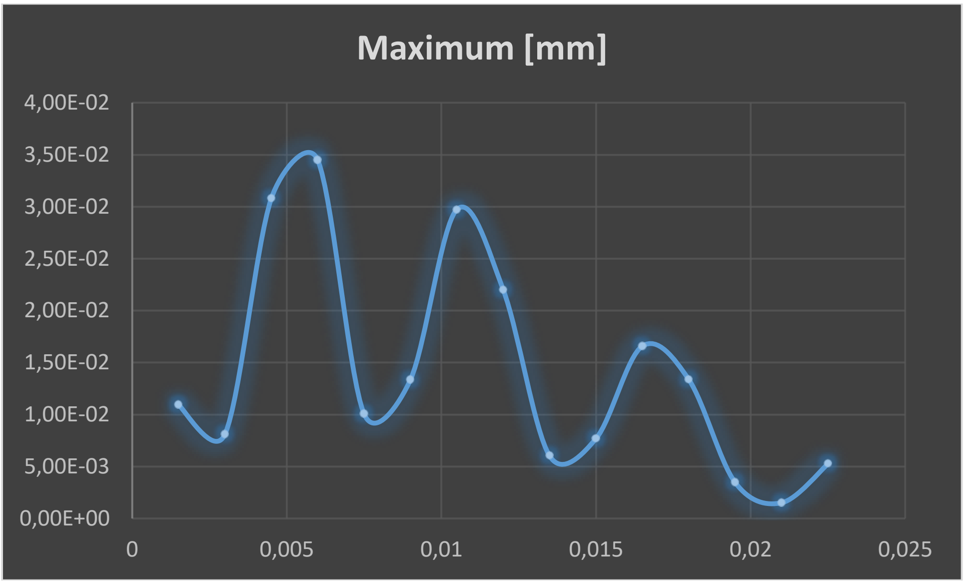

Figure 7.1 Maximum Displacement Under Pressure Loading (6 mm mesh)

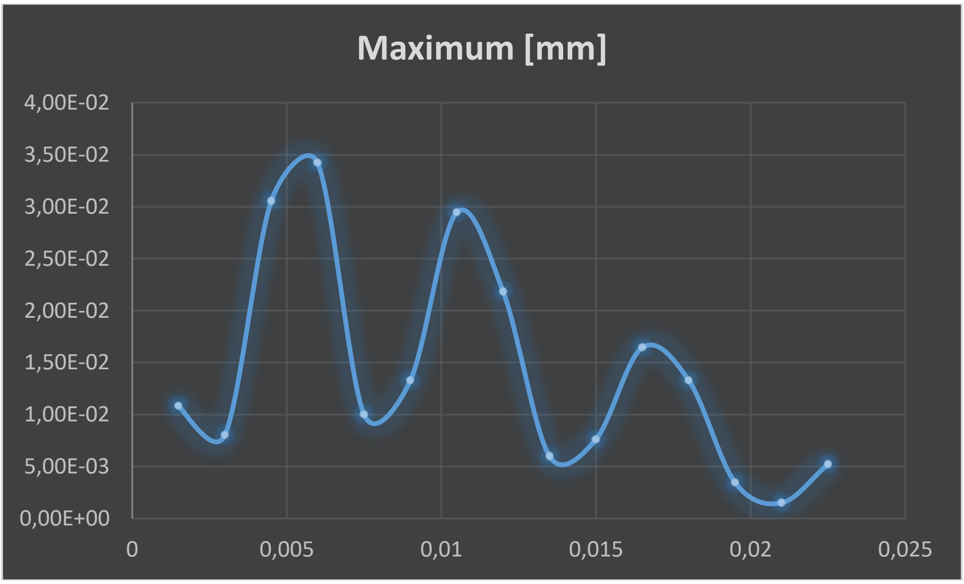

Figure 7.2 Maximum Displacement Under Pressure Loading (4 mm mesh)

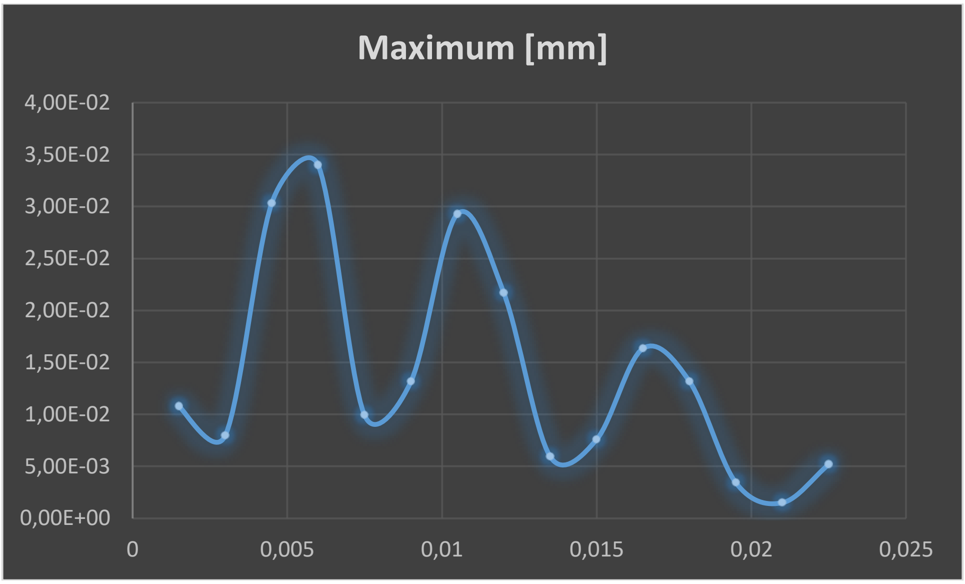

Figure 7.3 Maximum Displacement Under Pressure Loading (3 mm mesh)

In this study dynamic behaviour of stitched carbon/epoxy composite plate subjected to impact loading investigated. These conclusions apply to the case of plates with fixed boundary conditions.

Analysis is made in different mesh numbers by changing the dimensions of meshes. When dimensions are going smaller, there are more meshes.

Mesh Dimension	Nodes	Elements
6 mm	4608	2116
4 mm	5906	2743
3 mm	7688	3612

Table 7.1 Mesh Dimensions,Node and Element Numbers

Graphics shows that displacement curves are sinusodial.

Comparison between 6 mm mesh and 4 mm mesh shows that there are approximately %0,08 decrease. Comparison between 6 mm mesh and 3 mm mesh show that there are approximately %1,5 decrease.

For all cases stresses in the plate when displacement is maximum never exceed the strength of material.

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