Developing Needle Punched Structure using Luffa Blended Fibres

By

NGAMPUILU MALINGMEI

(20PTF017)

A Thesis Submitted to the

Avinashilingam Institute for Home Science and Higher Secondary for Women, Coimbatore-641043

In Partial Fulfillment of the Requirement for the

Degree of Master of Science

In

Textiles and Fashion Apparel

May, 2022

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Certified as Bonafide Research Work

Signature of the Head of Department   **Signature of the Supervisor**

DECLARATION

I declare that the dissertation entitled **"Developing Needle Punched Structure using Luffa Blended Fibres"** submitted by me for the Degree of Master of Science (M.Sc.) is the record of work carried out by me during the period from 2021 to 2022 under the guidance of **Dr. U. Ratna,** M.Sc., M.Phil., Ph.D., Assistant Professor, Department of Textiles and Clothing, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore – 641 043 and has not formed the basis for the award of any Degree, Diploma, Associateship, Fellowship, Titles in this university or any other similar institution of higher learning.

Signature of the Candidate

CERTIFICATE FROM THE SUPERVISOR

I certify that the dissertation entitled **"Developing Needle Punched Structure using Luffa Blended Fibres"** submitted for the Degree of Master of Science (M.Sc.) Textiles and Fashion Apparel, by **Ngampuilu Malingmei**, is the record work carried out by her during the academic year 2021 to 2022 under my guidance and supervision and this work has not formed the basis for the award of any Degree, Diploma, Associateship, Fellowship, Titles in this University or any other similar institution of higher learning.

Signature of the Supervisor

Signature of the Head of the Department

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INTRODUCTION

1. INTRODUCTION

Textile industry is known for its wide scope in industrial sector, holding second biggest employment next to agriculture. This industry concerns more than the clothing and apparel but far wide to technical areas, to mention – Meditech, Geotech, Hometech, Protech, Buildtech, Oeko tech, Mobiltech, Packtech, Clothtech, Sportech and Indutech, depending on their end use, which altogether are known as technical textiles. Technical textiles are defined as the textile materials and products that are primarily employed for their technical performance and practical capabilities, rather than for their aesthetic or decorative qualities (ITTA, Indian Technical Textile Association, 2022).

Technical textiles are textiles that meet stringent technical and quality criteria like mechanical, thermal, electrical, durability, giving them the ability to offer technical functions (Khalifa, 2013). Over the last two decades, technical textiles had emerged as a unique area of research and development, focusing on the utility of a fabric rather than its looks. With an annual growth rate of 5 to 7 percent, the industry continues to grow, providing new opportunities and challenges for existing enterprises, as well as enabling advances in a variety of other disciplines (Kettley, 2011).

Nonwoven fabrics are broadly defined as 'sheet or web structures joined together by mechanical, thermal, or chemical processes that entangle fibres or filaments. These are produced from individual fibres or molten plastic or plastic film' (INDA, Association of Nonwoven Fabrics Industry 2022). Nonwovens are a part of category of fabrics besides weaving, knitting and braiding. Non-woven does not need to be an interlacing of yarn to get the internal cohesion, but also of un-spinnable fibres, thus share a part of manufacturing processes as engineering. It is often a form of sheet, web or batt of directionally or randomly oriented fibres bonded by friction, or cohesion and adhesion. Nonwovens found its use in hygiene and health care, in rooting and civil engineering to household products, automotive applications, filtrations, smart clothing and packaging (Wilhelm *et al*, 2001).

The nonwoven sector has evolved to include a diverse range of engineered fiber and polymer-based products, all of which are powered by high-speed, low-cost, creative, value-added processes. The nonwoven sector has constructed an ecosystem based on automation, which reduces the industry's reliance on low-cost labor and eliminates the need for production sites in low-labor-cost locations throughout the world. (Pourdeyhimi, 2019). Types of products produced by the nonwoven industries today are so vast that it concerns like agricultural coverings, agricultural seed strips, apparel linings, automotive headliners, automotive upholstery, carpeting, civil engineering fabrics, civil engineering geotextiles, disposable baby and adult diapers, envelopes, filters, house wraps, household & personal wipes, hygiene products like sanitary napkins, insulation, labels, laundry aids, roofing, sterile medical-use products, tags, upholstery and wall coverings (INDA, Association of Nonwoven Fabrics Industry 2022).

Composites are combination of two or more materials distinct from the others in which the materials' properties are based on the orientation of the materials viz., matrix and fibres. Composites are one of the most important and vastly used materials which can be natural or man-made, because composites are easily adaptable to various situations and environments. Many modern technologies require material with unusual combinations of materials, mostly those which possess superior properties, may it be physically, chemically, or mechanically than the others. The applications of composites are found in military aircraft and spacecraft for its light weight, stiffness and controlled thermal expansion. They are used as corrosion resistance to industrial chemicals, tanks and piping as they are environmental resistance. Commercially available composite is the Fiberglass, which are simply a plastic that is combined with glass fibres where it got its applications in bathtubs, doors, decking, and window frames. Another is the popular Kevlar, though it is not a composite itself, is use as a part of composite materials for its extreme high tensile strength and found in airplanes, boats, bicycles, automobile parts, motorcycle clothing and sports shoes (Webteam, 2018).

Composites are classified into different factors as based on matrix materials and reinforcing materials. Matrix material composites are metal matrix composites, ceramic matrix composites and polymer matrix composites. Reinforcing material composites are divided into Fibre reinforced composites and Particulate reinforced composites (Priyanka *et al*, 2015).

Thus, composites attend considerable importance as a very potential operational material in the textile sector. In spite of such important properties, most composite materials are restricted from being used for long periods yet, they can endure regular environmental conditions for ten years. Moreover, composite recycling and reprocessing methods are unavailable so far when the matrices used in the composites are obtained from the origin of petroleum. Composites are currently fast taking over other traditional textile materials as superior alternative in high pressure and aggressive environmental situations resulting the applications of composite to increase tremendously along with the concurring need for knowledge generation in this particular field. (Mohamad *et al*,2020).

Needle punching is also known as the felting process, originally developed to produce nonwovens mechanically bonded by fibres. It is a process through which a vertical motion of needles imparts cohesiveness to a fibre matt obtained by superimposing several web layers by carding (Giovani, 2008). Needlepunching is the second most popular technique next to spunbonding for manufacturing nonwovens, which is widely used in engineering applications. The use of needle-punched nonwovens as wheel arch liners is one of the most effective composite nonwoven applications. These are the first exterior automotive parts made using nonwoven composites. Borgers invented the textile wheel arch liner in 1995 (Kellie, 2016).

Factors which influence the properties of needle-punched fabric are raw materials, web formation, machine variables, machine design parameters and finishing. Needle felts have a high breaking tenacity and rip strength, but they have a low modulus and poor recovery following extension. In order to improve the recovery, it is conventional to include yarns, nets or fabric trims in the structure. Longer fibre lengths produce greater strength, felt density, and air permeability. Smaller felt thickness and decreased air permeability are the results of finer fibres. To attain acceptable strength qualities, needling finer fibres necessitates the employment of finer needles. The needle felts with a higher crimp provide better tear resistance, elongation, and dimensional stability. Applications of needle-punched fabric can be seen in automotive, geotextiles, filter media, insulation padding, floor coverings and more (Karthik *et al*, 2016).

Natural fibers show advantages such as low cost, low density, availability in abundance, environmental-friendly, nontoxicity, high flexibility, renewability, biodegradability, relative non abrasiveness, high specific strength, modulus and some are ease in processing (Cotton, jute and flax fibers are commonly used for research and used by manufacturers for preparation of needle-punched nonwovens), (Mohamad *et al*, 2020). Natural fibres are fibre materials produced by geological processes, or from the plants and animals. In terms of utilization, there are two general classifications of plants producing natural plant fibres: primary and secondary. Primary plants are those plants grown especially for their fibre content while secondary plants are those where the fibres come as a by-product from some other primary utilization. Jute, hemp, kenaf, sisal and cotton were common examples of primary plants while pineapple, cereal stalks, agave, oil palm and coir are most common examples of secondary plants. Commercially, apart from wood fibres, useful fibres come from bast, leaf, and seed coverings of some specific plants, of which the principal application lies in textiles (Shah, 2013).

Depending on the fibre type, there is a wide range of fibre properties which were considered for their applications in textile areas. Low density, exceptional strength, and high stiffness are all advantages of cellulose-based fibres (also known as plant, vegetable, and lignocellulosic fibres, or biofibres). They are currently being realised as environmentally acceptable alternatives to synthetic fibres because to their annual renewability and biodegradability. The use of cellulose-based natural fibres as reinforcements, on the other hand, has a long history. Cellulosic fibres are a vital component of the textile industry's raw materials. They're employed in garments, home textiles, and a variety of non-woven fabrics. Textile fabrics, such as nonwoven and knitted fabrics, can be manufactured entirely of cellulose or a combination of cellulose and other synthetic fibres. Feminine hygiene products, absorbent goods, household wipes, baby wipes and diapers, pillows, surgical dressings, and shoe linings are all made from cellulosic fibres (Ciechanska *et al*, 2009).

Archaeological evidence suggests that cellulose-based natural fibres like grass, hemp, banana, pineapple, sisal, coconut, palm, and others have been used by humans all over the world for millennia to make every day and ceremonial clothing, food storage vessels, to preserve foodstuffs, in hunting and defence tools, in early seafaring, and for construction. Natural fibres' strength made them useful in transporting and moving larger objects, fishing, the construction of hanging footbridges, rigging for naval ships, and likely many other applications. Natural fibres are still used to make a range of ropes, fabrics, nets, baskets, carpets, canvas, and paper. (Guven *et al*, 2016).

With the increasing damage given to the environment by manufacturing synthetic fibres as it requires high power, toxic for human, as well as may have to do with the CO2 production. Moreover, natural fibres are eco-friendly and neutral with respect to CO2. Therefore, many researchers and studies have been made more towards the environmental- friendly fibres on their characteristics and properties. In this context, increasing the use of renewable bio-composite materials in industrial products will be a huge step forward. As a result, bio-composite materials have recently become a hot topic in composite materials research. Natural fibres, on the other hand, have drawbacks in composites due to poor compatibility between fibre and matrix, as well as relatively significant moisture absorption, which weakens the interfacial link and reduces the composites' mechanical capabilities. (Ghali *et al*. 2011). Hence, to solve the issues associated with long-term durability, reliability, serviceability, characteristics, and sustainable production, substantial research has been conducted (Andrew and Dhakal, 2022).

Natural fibres have resurfaced as a result of their naturally derived properties from plants, as well as their light weight as compared to glass. Plant fibre reinforcements are resoluble, good heat and sound insulators, degradable, and inexpensive. Glass and carbon can be replaced with natural fibre. Apart from low cost eco-friendly and renewable in nature, natural fibres are more attractive as nonwovens and as a reinforcing material. Jute, coir, banana fibres are popular natural fibres focusing on eco-friendly and sustainable materials over the years. Needle punching method have been using in the production of higher performance fabrics (Gilder and Subramaniam, 2017).

Cotton fibres are the purest type of cellulose, which is the most common polymer in nature. Cotton fibres are made up of nearly 90% cellulose. Cotton fibres have the highest molecular weight and structural order of all plant fibres, i.e., highly crystalline, orientated, and fibrillar cellulose. Cotton is regarded as a premium fibre and biomass due to its high quantity and structural order of the most prevalent natural polymer (Hsieh, 2007).

Jute is one of the typical filaments with the highest cellulose content (almost 70%). Jute stem fibre has a thickness similar to other common strands, a high Young's modulus, and the highest elasticity among the related normal filaments. These characteristics make it suitable for use as construction and development materials, automobile components, and furnishings (Venkata *et al*, 2017).

Polyethylene terephthalate or known as PET, or polyester, were first commercialized in the 1950s and have expanded in popularity faster than any other man-made fabric. This expansion has been aided by a number of factors. Polyester's success is based on its unique physical features of strength, high modulus, elasticity, and durability. Because the fiber tailorable, it is possible to create an entire variant for a wide range of applications. The readily available and inexpensive cost of raw materials, ongoing developments in polymerization technology, and the adaptability of the melt spinning process have all contributed to polyester's position as the most popular man-made fabric. It is the world's best-selling synthetic fibre due to a combination of cost and characteristics. It comes in a variety of diameters, cross-sections, and lusters, much like any other produced fibre. It has a number of drawbacks, but because of its widespread use, many attempts have been made to modify the fibre to solve them (Edwards *et al*, 2006).

Luffa (*Luffa cylindrica*) is a cucurbitaceous plant that is also known as sponge gourd, loofa, vegetable sponge, bath sponge, or dish cloth gourd. Luffa have a large number of offspring as one matured luffa can produce minimum 10 to 20 seeds. There are two types of Luffas, *L. cylindrical* and *L. acutangala*, which are available in abundance in tropical and subtropical geographic regions like Africa, South America, India, Philippines, Indonesia and Pakistan where it was grown as are agricultural crop. The Luffa grow as sponge and vary in size from 8 to 24 inches long. One kind of Luffa are short and wide in structure which is usually used for scrub and the other type are longer and thinner, thus preferably cultivated for food (Marissa *et al*, 2005)

Luffa cylindrica or Loofah fibres obtained from the fruit are lightweight natural fibres that have the potential to be utilised in reinforcing lightweight composites due to their poly-porous structure, cheap and abundantly available, and their surface morphology, which can provide a good adhesion with the matrix. Luffa as a young fruit, is used for preparation of appetizing dish for its aroma while the mature fruit is use as a dish washing sponge, bath scrub or brush because of its porous skeletal fibrous body. Luffas has some inherent advantages over other fibres to mention- renewability, biodegradability, natural network, high strength and initial modulus (Boynard and D' Almeida 2000).

Luffa cylindrica finds wide applications in diverse areas such as material science, medical science, pharmaceutical industry, biotechnology and bioprocess engineering etc., due to its stable properties as one of the commercial edible vegetables (Labeeba *et al* 2019).

Plant-based fibres can replace petroleum-based fibres as a reinforcement in applications that the structures are exposed to vibration excitation, and in applications where the absorption of vibration has major importance. Luffa shows potential alternative as reinforcing material for polymer-bonded composite and Luffa fibre reinforced with unsaturated polyester are typical anisotropic material since it is generally controlled by the network of fibres in multi-directions (Genc *et al*, 2009).

Natural Fibre Reinforced Composite is one entity which has revolutionised the concept of high strength and light weight which they can also solve both performance and environment related issues. The use of natural fibers for the reinforcement of composites has lately received increasing attention, both by the academia and by the industry (Bodros *et al*, 2003).

Considering all the given facts above, limited studies have been done on Luffa blended fibres, hence the investigator selected to study on **"Developing Needle Punched Structure using Luffa Blended Fibres"** with the following objectives:

- To select fibres for needle punching.
- To develop needle punched fibre-blended structures by using the selected fibres.
- To compare the blended natural and synthetic structures.
- To study the mechanical and physical properties of the needle punched structures.

2. REVIEW OF LITERATURE

Review of literature for the study on **"Developing Needle Punched Structure using Luffa Blended Fibres"** are discussed under the following headings:

2. 1 NATURAL PLANT FIBRES

2. 1. 1 Introduction

2. 1. 2 Classifications

2.1.3 Advantages

2. 2 COTTON

2. 2. 1 Introduction

2. 2. 2 Uses

2. 2. 3 Advantages

2. 3 JUTE

2. 3. 1 Introduction

2. 3. 2 Properties of Jute

2. 3. 3 Uses

2. 3. 4 Advantages

2. 4 SISAL

2. 4. 1 Introduction

2. 4. 2 Physical and mechanical properties

2. 4. 3 Advantages

2. 5 HEMP

2. 5. 1 Introduction

2. 5. 2 Properties of Hemp fibre

2. 5. 3 Uses

2. 1. NATURAL PLANT FIBRES

2. 1. 1 Introduction:

Natural fibre is derived from the earliest known cultivated plants and has the following inherent characteristics: low weight, low cost, high specific strength, and particular stiffness. These characteristics have made them particularly appealing to a wide range of industrial applications. Safety, mechanical strength, and stiffness increase of composites, density reduction, and environmental considerations are all factors to consider when employing natural fibres (Petroudy, 2017). Most composite compounds created from organic and inorganic phases have gotten a lot of attention lately, given the rising cellulose demand in the industrial market and pressure to address issues of sustainability (Alghamdi *et al*, 2017). Cellulose is the most essential structural component in natural plant fibres, yet it has poor thermal resistance. Structure, chemical composition, microfibrillar angle, cell size, and fibre defects are all essential elements in influencing the overall qualities of plant fibres (Bhattacharya and Kim, 2015).

2. 1.2. Classifications:

Plant fibres are mainly cellulose fibers. Plant fibres are categorized into primary and secondary depending on their utilization. Primary plants are grown form their fibers while secondary plants are plants extracted from the waste product. This fiber can be further categorized into following:(a) Seed fibre: Fibres which are collected from the seed and seed case such as cotton and kapok. (b) Leaf fibre: These fibres are collected from fibres leaves like sisal, agave, abaca, henequen, pineapple fibre. (c) Skin fibre or bast fibre: These fibres are collected from the skin or bast surrounding the stem of the plant. Skin or bast fibers have higher tensile strength than other fibres. For that reason, these fibres are used for packaging, fabric, durable yarn, and paper such as flax, jute, banana, hemp, kenaf, ramie, rattan, vine fibers, soybean fibre, and banana fibres. (d) Fruit fibre: These fibres are collected from the fruit of the plant, such as coconut (coir) fibre. (e) Stalk fibre: Fibers are found from the stalks of the plants such as straws of wheat, rice, barley, maize, rye, and oat. (f) Cane, grass and reed fibre: Fibres are collected from its original nature source like bamboo, bagasse, sabai, communis, and phragmites (Keya *et al*, 2019).

Seed fibres like cotton contains 80-90% and kapok 35-50% of cellulose. Bast fibres are obtained from stems or stalks of dicotyledonous plants like jute and flax containing 61-71% and 60-70% of cellulose. Leaf fibres are often referred to as hard fibres and have limited commercial value because they are stiffer and coarser. sisal contains 70% of cellulose (Smole *et al*, 2013).

2. 1. 3 Advantages:

Cellulose fibrils are made up of 30–100 cellulose molecules in an extended chain conformation and offer mechanical strength to all natural plant fibres. They have a diameter of around 10–30 nm and provide mechanical strength to the fibre. The most essential characteristics that determine the overall properties of the fibres are the structure, microfibrillar angle, cell size and defects, and chemical makeup of the plant fibres. The tensile strength and Young's modulus of plant fibers increase with increasing cellulose content of the fibres. (Petroudy, 2017).

Cellulosic fibres are hydrophilic in nature and thus absorb moisture. Lignocelluloses are polymeric composites comprised mostly of cellulose, hemicelluloses, and lignin that are three dimensional. While the chemical composition of lignocellulosic fibres varies, they all have very similar qualities within specific limits. That is, they all inflate and shrink when the cell wall's moisture content varies, they burn, decay, and can be damaged by acids, bases, and UV light (Dhakal and Zhang, 2016).

Many parameters, including chemical composition, crystallinity, degree of polymerization, and fibrillar orientation have been observed to influence the flammability of plant fibres. In general, fibres become more combustible as their cellulose content increases, whereas hemicellulose decomposes at lower temperatures than cellulose, making fibres with a high hemicellulose content more susceptible to heat deterioration and ignition. Lignin decomposition contributes more to char formation than cellulose and hemicellulose, however lignin decomposition begins at a lower temperature, between 160 and 400°C. As a result, the higher the lignin content in plant fibres, the more combustible they are (Fu and Liu, 2017).

2. 2 COTTON

2. 2. 1 Introduction:

Cotton is a member of the plant family Malvaceae. Cotton is grown as an annual plant that grows from seed to seedling to a plant with vegetative growth and produces a lovely coloured flower. The plant's natural wind dispersion system, the capsule, develops after the flower fades. Thousands of fibres grow in the green capsule, first in length, then in diameter. When the capsule reaches maturity, it pops open, releasing the lint into the wind for distribution and the beginning of a new cycle. Cotton is picked in the mature capsule stage in order to remove the fine fibres by ginning. Natural varieties have evolved to adapt to the climate and environment in order to ensure reproduction (Rohr, 2011).

Cotton fibers are mainly composed of cellulose (88.0–96.5%) Cotton fibres have different chemical compositions depending on their variety, growing environment (soil, water, temperature, pests, etc.) and maturity. Proteins (1.0–1.9 %), waxes (0.4–1.2 %), pectins (0.4–1.2 %), inorganics (0.7–1.6 %), and other (0.5–8.0 %) compounds are among the non-cellulosics. Non-cellulosic content is substantially higher in less developed or immature fibres. Cotton fibres' primary cell walls include less than 30% cellulose, as well as non-cellulosic polymers, neutral carbohydrates, uranic acid, and other proteins (Hsieh, 2007).

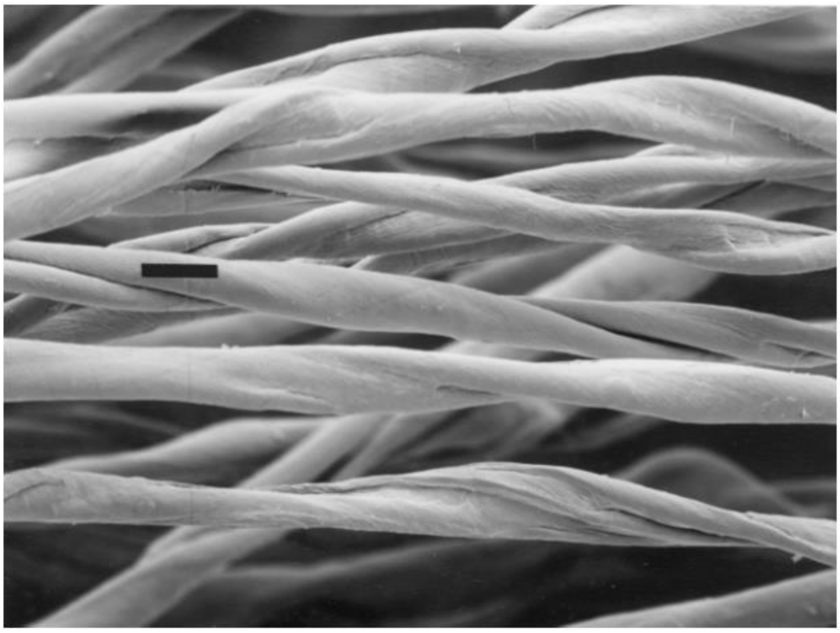


Figure - 1

SEM IMAGE OF MATURE COTTON FIBRES (Hsieh, 2016).

2. 2. 2 Uses:

Studies shows that regular length staple cotton should be considered for needle punching. Longer fibres perform better and needles of 36-42 gauges have been found appropriate for the production of cotton needle-punched nonwovens. Needle-punched cotton nonwovens are found to have highly efficient filter media due to the irregular fibre shape and absorption properties.

The personal care product segment is one of the strongest and growing application areas of cotton nonwovens products. Some of the significant applications are:

Table I

EXAMPLES OF COTTON IN NONWOVEN PERSONAL CARE PRODUCTS

Cosmetic removal pads	**Diapers**		**Feminine hygiene products**
Training pads	Shields	Baby diapers	Sanitary napkin
Adult inconvenience	Pantyliners	Briefs	Feminine pads
Disposable underwear	Underwear	Insert pad and pant	Sanitary pads
Nursing pads	Underpads	Bladder control pads	Panty liners
Adhesive for dental plates	Bed pads	Guards	Panty shields
Nasal strips			Tampons
Dry and wet wipes			Sanitary napkins

(Imran *et al,* 2020).

2. 2. 3 Advantages:

As cotton cell walls consist of high purity cellulose nanofibers, (CNFs), strong hydrogen bonding occurs between CNFs when they are dried. Moreover, because of cotton high purity with small amounts of amorphous polymers (such as hemicelluloses or other impurities), the cotton CNFs had high crystallinity and thermal stability. Cotton CNFs are promising nanofibers for a wide range of applications and can replace existing CNFs because of their renewability, abundance, high purity, high aspect ratio, high crystallinity, and high thermal stability. Cotton CNFs can also contribute to the determination of the effects or properties of hemicelluloses within materials (Chen *et al*, 2014).

2. 3 JUTE

2. 3. 1 Introduction:

Jute is considered as the most widely produced bast fibers followed by flax and hemp fibers which has a higher lignin content, making them a distinguish property from flax and hemp. It is a fast-growing annual plant after cotton, producing the second most significant fibre.

Jute plants achieve a height of 2.5 to 3 metres in 4-6 months in a hot and humid atmosphere. The pod of *Corchorus capsularis* is globular, but the pod of *Corchorus olitorius* is cylindrical. The majority of the jute is collected when roughly half of the plants are in pod because good quality jute fibre bundles can be obtained at this stage of growth (Pujari, 2014).

Jute is a standout amongst the most cost-effective natural fibres, coming in second only to cotton in terms of volume delivered and variety of applications. Jute filaments are formed primarily of cellulose and lignin (Venkata *et al*, 2017).

2. 3. 2 Properties of Jute:

TABLE II

PROPERTIES OF JUTE FIBRES.

Properties	**Jute (%)**
Cellulose	61-71
Hemicelluloses	14-20
Lignin	12-13
Waxes	0.5
Tensile strength	393-773
Young's modulus, GPa	26.5
Elongation at break	1.5-1.8
Density, g/cm^3	1.3
Moisture regains at 65% RH, %	12.5
Fibre fineness, tex	2.08

(Kumar *et al*, 2019, Debnath and Madhusoothanan 2010).

2. 3. 3 Uses:

Jute was once regarded solely as a source of raw material for the packaging industry. However, it is currently widely used as a versatile raw material in a variety of industries, including construction, and automobiles, as a soil saver, decorative and furnishing materials, Geo-textiles, Paper and paper pulp, Jute composites, Jute floor covering, Jute particle board, Apparel and home textile, Handicrafts and decorative materials, and so on. Technologies for production of these jute products have been developing. Raw jute is an environmentally favourable crop because it is biodegradable and renewed year after year. Raw jute is mostly utilized in the manufacturing of packaging products in the industry. Twine, yarn, hessian, sacking, and carpet backing garments are the most common Jute products (Biswas, 2021).

2. 3. 4 Advantages:

Commercial exploitation of jute reinforced thermoplastic laminates and composites, products developed in substitution for currently utilized thermoplastic and manmade fibre reinforced composites promises great potential with high physical properties and excellent performance at low weights, i.e., high stiffness, high strength and low density (Gon *et al*, 2012).

2. 4 SISAL

2. 4.1 Introduction:

Sisal fibres are made from the leaves of the Agave sisalana plant and have a high strength. The leaves can grow up to 2 meters long. The plant was first cultivated in Central America and is now grown in East Africa and East Asia. The sisal fibre's adherence to the polyolefin matrix is improved by acetylation (Johannes, 2013). Sisal plants come in four types in India, -Sisalana, Vergross, Istle, and Natale. Different plant species produce different amounts of fibre. The leaves of the first two kinds produce more fibre than the leaves of the other two varieties. The amount of fibre content in a plant varies depending on its age and origin. Moisture (87.25%), fibre (4%), cuticle (0.75%), and other dry matter make up the chemical composition of the leaf of 8% (Chand and Fahim, 2021). Chemically the vegetable fibres comprise cellulose, hemicellulose, lignin, pectin and a small number of waxes and fat. It was found that the fabrication of these composites was fairly easy and cost of production was quite low. Tensile strength of sisal epoxy composites was found to be 250-300 MPa, which was nearly half the strength of fibre glass-epoxy composites of the same composition. Because of the low density of the sisal fibre, however, the specific strength of sisal composites was comparable with that of glass composites (Joseph *et al*, 1999).

2. 4. 2 Physical and mechanical properties:

Sisal fibres are compatible for reinforcements because of their excellent physical and mechanical properties:

TABLE III

PROPERTIES OF SISAL

Properties	Values
Linear density tex	21.05
Bulk density ($g.cm^{-3}$)	1.47
Average length (mm)	894.3
Tensile strength (MPa)	695.3
Young's modulus (GPa)	23.5
Breaking extension (%)	2.33
Specific strength (MPa/gcm^{-3})	473.0
Specific young's modulus (GPa/gcm^{-3})	16.0
Moisture content (%)	11.14

(Joseph *et al*, 2014).

2. 4. 3 Advantages:

Sisal fibres have some environmental friendly advantages, such as low density, lower availability, and high specific strength and modulus, making them suitable for use as reinforcement in composites, as well as in the manufacture of roofing tiles, carpets, fancy items such as purses, wall hangings, and automotive parts as well as some construction materials (Puttegowda and Saba, 2018).

2. 5 HEMP:

2. 5. 1 Introduction:

Hemp is one of the ancient plants cultivated by humans for textile use. It is believed that hemp cultivation started in western Asia and gradually spread worldwide. Currently, more than 30 countries are involved in the global hemp trade due to its capability of growing in pesticide and herbicide-free environment, noticeable resistance to rodents, fungus and many types of weeds, wide geographical range of cultivation, and multipurpose uses.

Hemp fibres, like all natural fibres, contain moisture because one of their primary functions is to transport moisture and nutrients to different parts of the plant. Hemp is classified as industrial hemp containing less than 0.2% Δ9-tetrahydrocannabinol (THC) and drug type hemp with greater than 0.2% THC. Although the history of the uses of hemp dates back to 5000–4000 BC, prohibition on its cultivation was imposed in many countries in the 20th century because it resembled marijuana. However, after being correctly classified and realizing its environmental and financial benefits, this prohibition is now lifted for industrial hemp. A resurgence in hemp cultivation is seen since the European Union and the US, and other countries, have legalized the cultivation of industrial hemp, and many other countries have reintroduced hemp cultivation with low THC levels (Ahmed *et al*, 2022).

2. 5.2 Properties of Hemp fibre:

TABLE IV

CHEMICAL COMPOSITION OF HEMP FIBRE.

Cellulose (wt. %)	Hemicellulose (wt. %)	Lignin (wt.%)	Waxes (wt.%)
68	15	10	0.8

(Shahzad, 2013)

TABLE V

MECHANICAL PROPERTIES OF HEMP FIBRE.

Tensile strength (MPa)	Elongation at break (%)	Young's modulus (GPa)	Density (g/cm^3)
550-900	1.6	70	1.48

(Keya *et al*, 2019).

2. 5. 3 Uses:

Hemp fibres have a broad usage in the sector of textile industry. Some of the important areas where hemp fibres have its applications are given below (Ahmed *et al*, 2022):

Technical fibre

- Reinforcement
- Automotive
- Construction materials
- Paper
- Geotextiles
- Insulation
- Home textiles.

Textiles

- Clothing
- Handbag
- Shoes
- Diaper

2. 6 LUFFA FIBRES

2. 6. 1 Introduction:

Luffa, also known as Loofah or *Luffa cylindrica* is a large climber with a stout stem, seed 1–2 cm long and 0.8 cm wide. The petiole of Luffa cylindrica is made up of alternating and palmate leaves. The leaf has an acute-end lobe and measures 13 and 30 cm in length and width, respectively. It has serrated edges and is hairless. The yellow blossom of Luffa cylindrica blooms from August to September. Luffa cylindrica is monoecious, with a raceme-shaped male flower inflorescence and only one female flower. Its fruit, a gourd, is green and cylindrical in shape, and it climbs on other solid physical things (Marissa *et al*, 2005).

The preliminary phytochemical screening of Luffa cylindrica revealed that the plant contained anthocyanins, glycosides, flavonoids, triterpenoid, cardiac glycosides, saponins, carbohydrates, proteins, alkaloids and tannins. The plant has traditionally been used to treat cynocytosis, flu, and as an anthelmintic, stomachic, and antipyretic phytomedicinal medicine. The oil extracted from the seed are used for antifungal, anti-inflammatory, and anticancer properties (Mariod and Hussein, 2017).

The fibres were employed in the filter production for steam and diesel motors when Luffa was discovered as an industrial plant in Japan between 1890 and 1895. Because of its advantages as a natural fibre, the viability of employing luffa fibres for industrial wastewater treatment has been established and confirmed. It has also been noted for its excellent efficiency in the adsorption removal of heavy metals (Cu2+) from effluents and the removal of organic and inorganic solvents such as synthetic phenols. Biosorption of heavy metals from wastewaters, particularly from olive oil mill effluents, has been achieved using fungal bio sorbents immobilized on Luffa cylindrica sponges. The usage of Luffa cylindrica fibres in the discoloration process of specific solutions and water dyeing as a supportive material for immobilization has been documented in recent investigations (Labeeba *et al*, 2019).

2. 6. 2 Structure:

The exterior green covering begins to dry, when the fibres inside the fruit have completed ripening, and the fibrous structure develops beneath the dried outer layer. The size of Luffa plants varies depending on their location, ranging from 0.15 m to 1 m. (even more than 1 m in certain areas). A luffa fibre comprises cellulose, hemicellulose, and lignin in general, while the chemical makeup of luffa fibres varies depending on plant origin, weather conditions (which alter year to year), and soil. For instance, cellulose content ranges from 55

(a) **(b)**

Figure - 2

LUFFA SPONGE AND TS OF *Luffa cylindrica.*

to 90 percent, lignin content ranges from 10 to 23 percent, hemicelluloses content ranges from 8 to 22 percent, extractives account for roughly 3.2 percent, and ash accounts for around 0.4 percent. The interfacial compatibility between luffa fibres and matrix is acceptable even when no surface treatment is given to the luffa fibres, according to a scanning electron microscopy (SEM) photomicrograph of sample luffa composite structures.

To make luffa composite constructions, luffa fibres can be utilized with or without surface treatment, and a resin such as epoxy is employed as a matrix (Koruk and Genc, 2019). Shen *et al* in 2012, studied the structural strength of luffa sponge column and resulted that the structural strength has a close relationship with density of luffa sponge column.

2. 6. 3 Physical Properties:

Luffa fibres have a density of 0.82 to 0.92 g/cm^3, which is lower than that of several other natural fibres with a diameter (μm) 270±20 and Aspect ratio 340±5, and Microfibrillar angle (0) 12±2 (Saw *et al*, 2013).

2. 6. 4 Mechanical Properties:

According to Koruk and Genc (2019), the main characteristics of a material which affects the dynamic behaviour are density, damping and elasticity. As a result, before considering biocomposites for practical applications, their mechanical properties should be investigated. It is important to note that, luffa fibre has a density of roughly 800–900 kg/m^3, which is lower than some common natural fibres like sisal (1260–1450 kg/m^3), hemp (1480 kg/m^3), ramie (1500 kg/m^3), and cotton (1500–1600 kg/m^3). Tensile strength (MPa) of 178.20 and Tensile modulus (MPa) 0f 4263.84 with 3.12 % of extension was recorded for untreated Luffa fibres.

2. 6. 5 Thermal and Electrical Properties:

Thermal properties of Luffa National Fibre Composite were studied, specifying its behaviour when exposed to high temperatures, which involves several core aspects like melting point, thermal degradation, and crystallinity degree. Therefore, additional properties such as electrical and chemical are imperative in proving the reliability of such Luffa composites (Mohamad *et al*, 2020).

2. 6. 6 Composition of Luffa Fibres:

TABLE VI

COMPOSITION OF LUFFA FIBRES.

Components	Amount
Cellulose	63.0 ±2.5
Lignin	11.69±1.2
Hemicelluloses	20.88±1.4
Ash	0.4±0.10

The sponge is non-toxic and biodegradable and has a high degree of porosity, high specific pore volume, and stable physical properties. Because of these characteristics, it can be used as a support matrix for plant, algal, bacterial, and yeast cells. Plant origin, weather conditions, and soil nature all influence the chemical makeup of luffa cylindrical fibres (Chandrasekaran *et al*, 2018).

2. 6. 7 Uses:

Luffa cylindrica was used in wide application in packing medium, shoes mats, sound proof linings, bath sponges, utensil cleaning sponges, adsorbent for removal of heavy metal (such as nickel, lead, chromium, copper, etc) in waste water, and immobilization matrix for plant, algae, bacteria and yeast. It was used traditionally for the treatment of asthma, intestinal worms, sinusitis, chronic bronchitis pain, carbuncles, abscesses, inflammation, heat rashes of children in summer, bowels or bladder haemorrhage, haemorrhoids, jaundice, menorrhagia, haematuria, leprosy, spleenopathy, as anthelmintic, carminative, emmenagogue, galactagogue and as antiseptic. The fruit pulp of Luffa cylindrica was used to induce haemostasis, resolve phlegm and clear fever in traditional Korean medicine. The pharmacological investigation showed that Luffa cylindrica possessed anti-inflammatory, analgesic, antipyretic, hypoglycaemic, antibacterial, antifungal, antiviral, anthelmintic, antioxidant, anticancer, hepatoprotective, antiemetic, wound healing, immunological, broncho dilating, reproductive effect and in treatment of cataract. Parts of Luffa cylindrica like leaves, fruits and flowers were used as medicinal purpose (Al-Snafi, 2019).

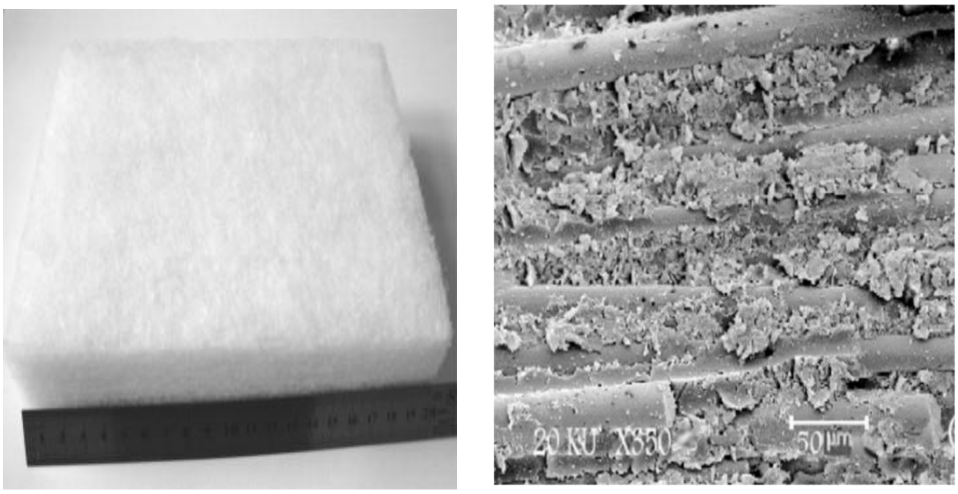
2. 7 POLYESTER

2. 7. 1 Introduction:

The term ‘polyester fibre’ generally comprises only fibres which consist of terephthalic acid and glycol. Unstabilised fibres are often used for the manufacture of nonwoven bonded fabrics, as they will shrink a little further in finishing. Thus, the final product will be appropriately close with a little more volume. After such treatment the fibres, which now will not shrink any further, have also got the desired dimensional stability. Shrinkage in polyester fibres may be directly influenced by varying the physical conditions or chemical conditions during manufacture.

A variety of polyester fibres are now available for wet-lay forming, either alone or in combination with other fibres. The majority of polyester fibres are made of Polyethylene Terephthalate (PET), however fibres made of PolyTrimethylene Terephthalate11 (PTT) and polyester fibre with an eight-leg cross-section known as 'deep grooved polyester fibre' are now available. The grooves are said to transfer fluids naturally inside the web, while the unique shaped fibres have a high surface area and provide bulk. This property makes them particularly appealing for use in absorbent product webs. Polyester fibres have a high tensile strength and chemical resistance, and they are currently accessible with a narrow fibre length distribution and defect-free cut ends (White, 2007).

Studies found that the nonwoven polyester fabrics with the trilobal fibre require slightly more needling density, higher dept of needle penetration and area density to have the same bending length as those of the fabrics made of round polyester fibre. Trilobal polyester nonwoven fabric is suitable for used in some industrial products where high thermal insulation is essential while hollow nonwoven fabric can be used where least permeability with moderate thermal insulation is required (Debnath and Madhusoothanan, 2009).



(a) **(b)**

Figure - 3

(a) MORPHOLOGY OF POLYESTER FIBRE (b) MICROSTRUCTURE OF GLASS FIBRE REINFORCED POLYESTER COMPOSITE (Liu and Chen, 2014, Bagherpour, 2012).

2. 7. 2 Uses:

Polyester fibres are used in fibre-reinforced concrete for industrial and warehouse floors, pavements and overlays and pre-cast products. Polyester micro- and macro-fibres are used in concrete to provide superior resistance to the formation of plastic shrinkage cracks versus welded wire fabric and to enhance toughness and the ability to deliver structural capacity when properly designed, respectively. Polyester macro-fibres can be used as a true alternative to welded wire fabric, steel fibres and conventional light gauge steel reinforcing for pre-cast slabs on grad and shotcrete applications (Fangueiro *et al*, 2008)

PET in medical textiles, may be used in orthopaedic bandages, plasters, surgical gowns, masks, drapes, blankets, protective clothing, etc. Commercially available biodegradable devices are employed in sutures, orthopaedic fixation devices, dental implants, ligature clips, tissue staples, skin covering devices, stents, dialysis media, and drug-delivery devices. It is also being evaluated as a material for tissue engineering (Farah *et al*, 2015).

Polyester fiber battings, also known as polyester wrap, are commonly used to provide enhanced aesthetic appearance in residential upholstered furniture. Polyester fiber battings provide significant barrier effect when tested with smouldering cigarette ignition; however, it fails to protect the underlying cushioning material when an open flaming ignition source is used. The polyester fiber melts away from the smouldering cigarette and extinguishes, whereas, once ignited, the polymer melts burn vigorously in the presence of flaming ignition, resulting in substantial weight loss and increased temperature of the system. Thus, the polyester fiber batting acts as an additional fuel and the whole system fails (Nazeré and Davis, 2013).

2. 7. 3 Advantages:

Polyester fiber wool has good elasticity and toughness, and it can be used as a filler for sound absorption (Liu and Chen, 2014). Polyester fibers take a leading position among all chemical fibers. The unique properties of these fibers are due to the presence of aliphatic and aromatic parts in macromolecular chains and the regular molecular structure. Poly(ethylene terephthalate) (PET) is the predominant polyester used for fiber production, not only because of its good end-use properties and economy of production but in particular because of the ease of physical and chemical modification, suppressing negative and enhancing positive properties of PET(Militky, 2009).

2. 8 NONWOVEN FABRIC

2. 8. 1 INTRODUCTION:

According to INDA (the American Nonwoven Association), the nonwoven is “a sheet or web of natural fibres and or of (chemically) manufactured filaments, excluding paper, which have not been woven and can be bound together in different ways”. Nonwoven fabric is a fabric-like material made from staple fiber (short) and long fiber (continuous long), bonded together by chemical, mechanical, heat or solvent treatment. The term is used in the textile manufacturing industry to denote fabrics, such as felt, which are neither woven nor knitted (Giovanni, 2008).

2. 8. 2 CLASSIFICATIONS:

The non-woven fabrics can be divided into many types according to different manufacturing processes. They are:

i) Spun Lace Nonwovens.
ii) Heat Bonded Nonwovens.
iii) Air Laid Bonded.
iv) Wet Laid Non-Woven.
v) Spun Bond Nonwovens.

vi) Melt Blown Nonwovens.

vii) Acupuncture Nonwovens.

viii) Stitch Nonwovens.

ix) Needle punching.

2. 8. 3 NONWOVEN MANUFACTURING:

Nonwovens manufacturing starts with the arrangement of fibres into webs or sheets. The manufacturing process can be of different methods. Some of the methods are:

2. 8. 3. 1 Mechanical bonding:

The process of physically entangling fibers to strengthen webs is refer to as Mechanical bonding. Stitch bonding is a nonwoven development where the fabric is framed by stitching or knitting the fibers to frame a fabric with the presence of a knit fabric. It includes warp knitting of yarns through a fibrous mat such nonwoven materials are utilized warm protection of coverlets, covers, coats (Chaion, 2022).

2. 8. 3. 2 Bonding by Hydroentanglement:

High-speed water jets are used to bind the fibres or filaments in a web in this kind of bonding. The contact of high-energy water jets with web fibres and the backing surface promotes the interlacing of the fibres and causes displacement and new orientation of part of the web's strands. Complex tridimentional effects, openings and structured models can be produced by selecting proper backing surfaces allowing the coupling of two or more webs to produce multilayer fabrics (Giovanni, 2008).

Hydroentangling, spunlacing, hydraulic entanglement and water jet needling are the terms describing the process of bonding fibres or filaments in a web by means of high – velocity water jets. The interaction of energized water with web fibres and the support surface enhances fibre entanglement and generates web fibre segment displacement and rearrangement (Anand *et al*, 2007).

2. 8. 3. 3 Thermo – bonding:

Thermo bonding requires a thermoplastic component to be present in the form of homofil fibre, powder, film, web, hot melt or as sheath as part of a bicomponent fibre. Practically, heat is applied until the thermoplastic component becomes viscous or melt. The polymer flows by surface tension and capillary action to fibre - fibre crossover points where bonding regions are formed. These bonding regions are fixed by subsequent cooling. In this method, no chemical reaction takes place between the binder and base fibre at the bonding sites. Thus, a mechanical bond is formed as a result of thermal shrinkage of the bonding material, which while in the liquid state encapsulates the fibre crossover points. Thermal bonded products can be relatively soft and it can be bonded uniformly throughout the web cross section in high bulk production. Moreover, 100% recycling of fibre components can be achieved (Pourmohammadi, 2007).

2. 8. 3. 4 Chemical bonding:

Binder is an adhesive compound that is used to bind the fibres together inside the structure of a nonwoven. The term "binder" refers to the function of a component in the final product composition. In the technical literature, the terms “binder”, “binding agent”, “binder composition”, “binder system”, “nonwoven binder”, and “chemical binders” are used to describe the polymer, polymer plus carrier, total or partial formulation used for chemical bonding; the meaning of these terms varies depending on the context. The binder not only holds the fibres together, but it also influences the nonwoven's final qualities, such as mechanical properties such as compression and tensile strength, stiffness, softness, breathability, evaporative capacity, and flammability (Giovanni, 2008).

2. 8. 3. 5 Felting:

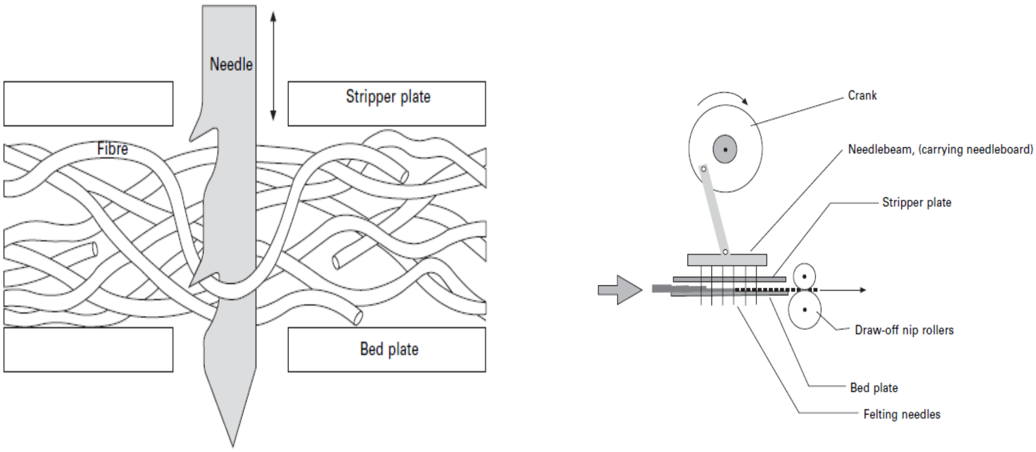
Felt is the main way of manufacturing nonwovens. According to ASTM, felt is a structured build-up from the interlocking of fibers by means of appropriate combination of mechanical work, chemical action, moisture and heat without spinning, weaving, or knitting. Felted Fabric can be Cotton felt, jute felt, Flax Felt, Synthetic Fiber Felt fabric and much more (Hossain, 2020).

2. 8. 3. 6 Carding:

Carding is a mechanical process that begins with the opening of fibres, which are then mixed and conveyed to the next step. The card teeth are nourished by the tuft. The toothed roller interacts with the fibre to separate it. The web can be parallel-laid, with the majority of the fibres laid in the web's travel direction. To produce the entire nonwoven, each web was processed through the carding machine and needle-punching (Sathiva *et al*, 2021).

2. 8. 4 Needle punching:

The process of needle punching, also known as needle felting was originally developed to produce mechanically bonded nonwoven fabrics from fibres that could not be felted like wool (Bhat and Malkan, 2007).



(a) **(b)**

Figure - 4

(a) ACTION OF A BARB NEEDLE (b) OPERATION OF SIMPLE NEEDLEPUNCHING MACHINE (Anand *et al*, 2007).

As for needle punching, the webs were layered on top of the other after the web construction. The laying procedure was used to improve the web's thickness. The thickness of the end product can be obtained whenever it is desired. Studies shows that regular length staple cotton should be considered for needle punching since longer fibers perform better and needles of 36–42 gauges have been found appropriate for the production of cotton needle-punched nonwovens. Needle-punched cotton nonwovens are found to have highly efficient filter media due to the irregular fiber shape and absorption properties.

2. 8. 4. 1 Advantages:

Needle-punched non-woven fabric (needle-punched non-woven fabric) has a short process flow, high raw material adaptability, simple equipment construction, low one-time investment, and products with good strength, fluffiness, and water permeability. Geotextiles, waterproof materials, filter materials, synthetic leather foundation fabrics, carpets, early-known felts, automobile textiles, mattress padding products, and other fields have benefited from its performance. The needle-punched nonwoven (nonwoven) production line has maintained an annual growth rate of around 25%, greatly above the overall development level of nonwovens (Sunshine, 2021).

2. 8. 5 Uses of Nonwovens:

Nonwovens covers almost all of the textile application sector like given in the Table VII.

TABLE VII

USES OF NONWOVENS

Hygiene	Household products	Home textiles	Apparel	Technical applications
Sanitary napkins	Floor cloths	Upholstery	Protective clothing	Insulation
Baby & Adult napkins	Wiping cloths	Floorcoverings	Footwear materials	Filtration
Wet wipes	Disposable	Wall coverings		Building and construction
	Pan scourers, scouring sponges and pads	Furnishing fabrics		Agriculture
	Floor pads			Automotive

(Albrecht, 2006).

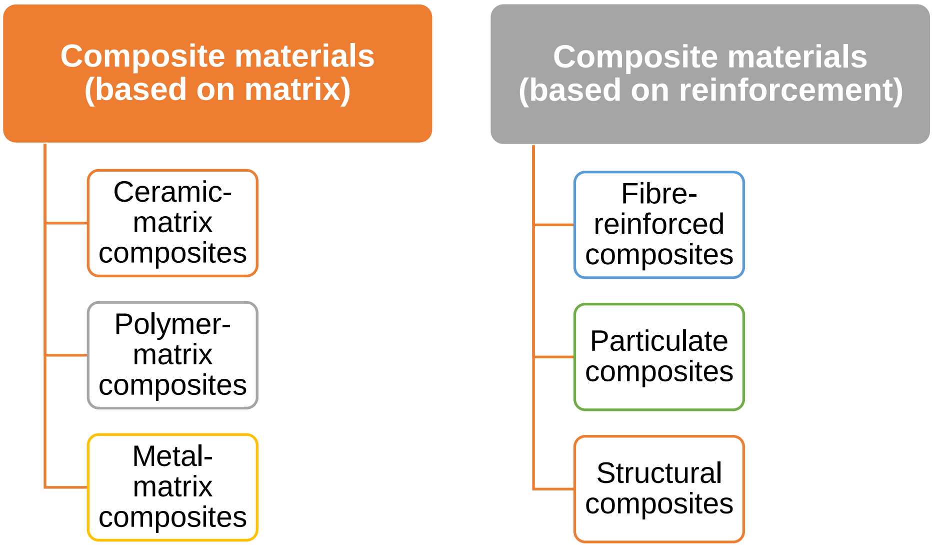
2. 9 COMPOSITES

2. 9. 1 Introduction:

Composites are one of the most widely used materials because of their adaptability to different situations and the relative ease of combination with other materials to serve specific purposes and exhibit desirable properties. A composite is a combined material created by the synthetic assembly of two or more components - a selected filler or reinforcing agent and a compatible matrix binder, a resin, in order to obtain specific characteristics and properties (Rosato, 1982).

2 9. 2 Classification:

Composites can be as based on Matrix and Reinforcement and they are classified below:



2. 9. 3 Advantages:

Advantages of nonwoven woven are given as (Sunshine, 2003):

i) Weight reduction.
ii) High strength or stiffness to weight ratio tailorable properties can tailor strength or stiffness to be in the load direction.
iii) Redundant load paths (fibre to fibre).
iv) Longer life (no corrosion).
v) Lower manufacturing costs because of less part count.
vi) Inherent damping.
vii) Increased (or decreased) thermal or electrical conductivity.

2. 10 STUDIES CONDUCTED:

Epoxy resin is the most common polymer used for preparing Luffa composites. About 53% of the research studies made use of epoxides for their polymer matrix. This is due to exceptional mechanical properties, high adhesion to many substrates, and good heat and chemical resistance of epoxy polymers. They are used across a wide range of fields as fibre reinforced materials, general-purpose adhesives, high-performance coatings, and encapsulating materials. Besides, the only other reported resins for Luffa composites are polyesters, polypropylene, polyethylene, vinyl esters, polyurethane, resorcinol formaldehyde resin, polylactic acid, poly caprolactone, poly butylene succinate-co-lactate. In the future, other novel polymers will likely be applied for Luffa-based composites and multi-polymer ternary systems may be employed. Impact strength of the Luffa fibre composite indicates the highest energy required to disrupt the material and it ranges between 22.60 and 68.42 kJ/m2 and 1.3 to 9 J, respectively. Stiffness of the composite materials (Young's modulus) was higher in polyester materials compared to other composite materials (Adeyanju *et al,* 2021).

Studies in Luffa natural fibre composites (LNFC) has significantly recognized in various engineering fields due to their remarkable mechanical properties. Luffa fibres were considered as a reinforcement for various types of matrixes, such as epoxy, polyester, formaldehyde, polylactic acid, high density polyethylene, vinyl ester, polyurethane, etc. SEM test show that Luffa has a flake-like fatty and waxy structure and increasing the fibre-loading in LNFC reduced its crystallinity and increased crystallite size. Different chemical treatments like sodium hydroxide, hydrogen peroxide, acetic acid, benzoyl chloride, acetone, hydrochloric acid, etc., were used to modify the characteristics of Luffa fibres. The highest mechanical properties were observed through selecting epoxy resin as a matrix (Mohamad *et al,* 2020).

The interfacial compatibility between luffa fibres and matrix is acceptable even when no surface treatment is given to the luffa fibres, according to a scanning electron microscopy (SEM) photomicrograph of sample luffa composite structures. To make luffa composite constructions, luffa fibres can be utilized with or without surface treatment, and a resin such as epoxy is employed as a matrix (Koruk and Genc, 2019).

Thilagavathi *et al* in 2017 used a desktop computer to determine the sound absorption coefficient from the measured transfer function data. It was discovered that luffa fibrous mats did not exhibit good noise reduction coefficient (NRC) if they were used alone, even though the fibrous mats had serrated surface and microporous structure. By increasing the thickness of the mats, the noise reduction coefficient of Luffa mats was improved.

Genc *et al* (2016) in their study on vibro-acoustic behaviours of luffa bio composites, obtained results that, damping characteristic of Luffa cylindrica fiber composite materials are higher than glass fiber composite materials. Also, the damping properties of Luffa cylindrica fiber is more effective than flax fiber as natural reinforcement. Therefore, this result is significant to find alternative green material. It demonstrates that plant-based fibres can replace petroleum-based fibres as reinforcement in applications that the structures are exposed to vibration excitation, and in applications where the absorption of vibration has major importance.

Dielectric loss factor, electrical conductivity and dielectric constant of pure polymer matrix, and treated and untreated Luffa fibre composite have been studied by Parida *et al* in 2015. Change in the fibre concentration caused changes in the composite sound absorption coefficient was discovered (Jayamani *et al*, 2014).

R. Paneerdhas *et al*, (2014) studies the variation of compressive, impact, tensile and flexural properties of the luffa fibre and groundnut reinforced epoxy polymer hybrid composites for 10%, 20%, 30%, 40% and 50% fibres content as a function of alkali treatment. After the alkali treatment, it was found that, the treated composites possessed higher values of mechanical properties. In previous studies, Kocak (2013) studied Luffa cylindrica fiber with different chemical processes using conventional and ultrasonic processes. Shen *et al*. (2013) presents in their study on a series of compressive tests to examine the stiffness, strength and energy absorption characteristics of the luffa sponge material under quasi-static compressive load. The result of TGA and DTGA obtained by Kaewtatip and Thongmee, 2012 show that Luffa fibres improved the thermal stability of starch reinforced composites.

Ghali *et al*. (2009) present in their study that the Luffa fibrous were treated by two methods: alkali treatment and mixed treatments (sodium hydroxide and hydrogen peroxide). According to their result the alkali treatment (120 degree C; 3h, 4% NaOH) shows a good cleaning and the higher crystallinity index of treated fibres. Demir *et al*, (2008), used Luffa fibres to investigate and study as absorbent removal of methylene blue dye from aqueous solutions at different temperatures and dye concentrations. Luffa shows potential alternative as reinforcing material for polymer bonded composite and luffa fiber reinforced with unsaturated polyester are typical an isotropic material since it is generally controlled by the network of fibers in multi-directions. Treatment on the surface of the fibres is recommended to obtain good adhesion between the fibres and the matrix (Marissa *et al*, 2005).

Bodros *et al*. (2003) investigated about natural fiber-biopolymer composites in order to determine whether or not bio-composites may replace glass fiber reinforced unsaturated polyester resins. The major bio-materials like flax, jute, hemp, kenaf and sisal were also investigated in many studies. Despite the challenges such as cultivation and continuity use of these plant-based materials, enhanced features are gaining immense importance.

Boynard and D' Almeida (2000), used the sponge gourd (Luffa cylindrica) as reinforcement in resin matrix composite material's by investigating the morphology of the fibrous vascular system of Luffa's fruit and its mechanical properties. It is found that without any surface treatment the Luffa already has a high potential use as a core material in hybrid composites. Ghali *et al* (2009) present in their study that the Luffa fibrous were treated by two methods: alkali treatment and mixed treatments (sodium hydroxide and hydrogen peroxide). According to their result the alkali treatment (120 degree C; 3h, 4% NaOH) shows a good cleaning and the higher crystallinity index of treated fibres.

3. EXPERIMENTAL PROCEDURE

Experimental procedures pertaining to the study on "**Developing Needle Punched Structure using Luffa Blended Fibres"** are discussed under the following headings:

3. EXPERIMENTAL PROCEDURE

3. 1 MATERIALS

3. 2 FIBRE SELECTION

3. 3 FIBRE TREATMENT

3. 4 FABRICATION

3. 4. 1 Fibre Blending

3. 4. 2 Web Formation

3. 4. 3 Pre-Opening

3. 4. 4 Mixing

3. 4. 5 Carding

3. 4. 6 Needle Punching

3. 5 PHYSICAL AND MECHANICAL TESTS

3. 5. 1 INTRODUCTION

3. 5. 2 FABRIC WEGHT

3. 5. 3 FABRIC THICKNESS

3. 5. 4 FLAMMABILITY TEST

3. 5. 5 AIR PERMEABILITY TEST

3. 5. 6 ACOUSTICAL TEST

3. 5. 7 ABSORBENCY TEST

3. 5. 7. 1 Wicking test

3. 5. 8 BURSTING TEST

3. EXPERIMENTAL PROCEDURE

3. 1 Materials

In this study, two different fabric structure was developed, one with blended natural fibres and the other as synthetic blended fibres. Luffa, Cotton and Jute were taken for the fabrication of natural blended fabric while Luffa, Jute and Polyester as synthetic blended fabric.

3. 2 Fibre Selection:

Native Luffa fibres (Coimbatore, Tamil Nadu) were purchased from the shop. The invigilator also collected combed cotton, jute fibre and polyester.

3. 3 Fibre Treatment:

Initially, the seeds of Luffa sponge are removed were chopped into random shapes and sizes of 1 inch or less and washed them in tap water to remove dirt and impurities. Then, the fibres were immersed in Sodium hydroxide (NaOH) solution and immersed for 24 hours. The fibres are taken out from the solution, drained and let it dry at room temperature.

(a) **(b)**

(a) **(b)**

Figure - 5

(a) SEED REMOVAL (b) CYLINDRICALLY CUT (c) RANDOMLY CHOPPED (d) CHOPPED FIBRES TREATMENT IN NaOH SOLUTION

3. 4 Fabrication:

The investigator decided to make a blended structure from the selected and treated Luffa fibres by method of Mechanical Needle punching. Fabrication was processed in Textile Production Lab, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, Tamil Nadu.

3. 4. 1 Blending of fibres:

Generally, natural fibres are often blended with other existing natural fibres to improve their qualities (Udale, 2008). So, the cut staple fibres- luffa, cotton, jute and polyester, where the samples were given nomenclature as LCJ (Luffa, Cotton and Jute), and LPJ (Luffa, Polyester and Jute) for needle punching. They are blended in three different ratios as given in Table VIII.

TABLE VIII

PROPORTION OF FIBRES

Fibres	Laying type	Proportion (50g)	Percentage (100%)
LCJ		30, 10, 10	60%, 20%, 20%
LPJ	Random laid	30, 10, 10	60%, 20%, 20%
Total		50	100%

3. 4. 2 Web Formation:

Web formation is the process that arranges the fibers or filaments into a sheet or web form. In the scope of this work, the carding method was used for the formation of the web.

3. 4. 3 Pre-opening:

The opening of the fibre supply is the first step in the construction of the web. The fibres are mechanically separated throughout the opening process, ensuring full blending (Lchhaporia, 2008). The blended fibres were manually mixed and fed to the pre-opening equipment in the desired combinations. Two pairs of working rollers mounted at the cylinder intensified and levelled the fibre opening in the pre-opening machine (Albrecht et al, 2006). Feeding the fibre into the pre-opener should be done with caution. The correct choice of a fibre opening, cleaning mixing and blending system is therefore the utmost importance to ensure a profitable nonwoven manufacturing operation (Patel and Bhrambhatt, 2011).

3. 4. 4 Mixing:

Before entering the card, the fibres were intermixed after pre-opening. A suction method, consisting of a pair of bale openers feeding to a cross lattice, transports the fibre into a series of mixing zones (Balasubramaniam, 2009). As a result, mixing guarantees that the fibres are properly opened and blended. After that, the entangled fibres were fed into the fine opener.

Figure - 6

MIXING OF FIBRES IN CONVEYER BELT

3. 4. 5 Carding:

Carding is a mechanical process which starts from bales of fibres. These fibres are ‘opened’ and blended after which they are conveyed to the card by air transport. They are then combed into a web by a carding machine, which is a rotating drum or series of drums covered by card wire (thin strips with teeth). Carding is used to eliminate any impurities and separate the fibres, after which the fibres were aligned and delivered as a web.

(a) **(b)**

Figure - 7

CARDING MACHINE AND LAP FORMATION OF BLENDED FIBRES

Carding is considered as a good technique for making high-quality staple nonwovens because it is easy to use and inexpensive (Singh, 2010). This nonwoven carding machine, which has 200 hooks to open the fibre, was the focus of the point per square inch. The strength ratio of machine direction, i.e., cross direction in this investigation is 1:1, resulting in a compact web (Joseph, 2005). The strength of the condensed web will be consistent in all directions.

3. 4. 6 Needle Punching:

The selected fabric is formed by a process is called needle punching. Needle punching is process of bonding nonwoven web structure by mechanically interlocking the fibers through the web. Barbed needles, which are mounted on a board, punch the fibers into the web and then are withdrawn, leave the fibers entangled. The needles are spaced in a nonaligned arrangement and are designed to release fibers as the needle broad withdrawn. This mechanical interlocking is achieved by 1000 of barbed felting needles repeatedly passing into and out of the web (Kiekens, 2002). The separated soft fiber was converted into fabric using for needle punching technology, web formation and after production of needle punched non-woven fabric.

The fabric was formed using a process known as needle punching, in which the web structures were mechanically bonded by the interlocking of fibres. The lap was put into a needle punching machine, which produced needle-punched nonwoven fabric. The fabric was prepared with a DILO needle punching machine, type OD-1 1/6. A downward punching loom with a single board was utilized. Barbed needles were used to punch holes in the web. The needles were spaced in a non-aligned pattern, with the goal of releasing the fibre as the needle board was removed. The operation's effective width was 700 mm. Fabric thicknesses ranged from 1.5 to 3 millimetres. The machine could manufacture cloth with a weight of 250-350 GSM.

(a)

(b)

Figure - 8

(a) NEEDLE PUNCHING MACHINE (b) PROCESS OF NEEDLE PUNCHING A FABRIC

The needle loom is a fairly simple piece of machinery. The most typical way of operation is for the needles to oscillate vertically through web material suspended between two plates on a set stroke. The holes in the plates were bored to fit the needle board's needle design. The web was held in place until it reached the intake space between the two Plates. The rollers aided in the passage of the web into the needling zone. Nearly 1200 needles were utilized. The top plate (the stripper) will be inclined to allow greater area entry for bulkier web to pass through before needling. During needling, the bottom plate (the bed) supports these webs. The bed in the bottom plate supports the web during needling and the gaps between these plates is adjusted depending on the thickness of the web, in which the web is made to pass through without any hindrance. The needle punched fabric is drawn away from the zone of needling by take-up rollers. The fabric can be needle punched on the other side to add strength by increasing the penetrations of the needles. The needle punched blended structure is shown in Table VII.

TABLE IX

PARAMETERS OF THE NEEDLE PUNCHING MACHINE

PARAMETERS	**VALUES**
Machine width	0.8 m
Working width	500 mm
No. of the needle board	Up to 1310
Stroke frequency	60 mm
Type	Down stroke
Weight	1 Ton
Power	1 kw
Length of the machine	1.2 m
Height of the machine	1.5 m
No. of laps	6
Total Power	Single Phase, Neutral & Earthing.

3. 5 PHYSICAL AND MECHANICAL TESTS:

3. 5. 1 INTRODUCTION:

Textile testing is the process of inspecting, measuring and evaluating the characteristics and properties of textile materials. Standard test such as a fabric weight, fabric thickness, tensile strength and elongation, absorbency tests, acoustical test, flammability test, etc., were carried out for the natural and synthetic Luffa blended fabrics to study their properties.

3. 5. 2 FABRIC WEIGHT:

The fabric weight is measured by weighing a standardized width of a yard or meter on a scale. Fabric weight are also occasionally determined by weighing square yards of a quality, or by weighing yards per one pound. Fabric weight is always a prerequisite for subsequent tests of other fabric properties specimens of known dimensions are taken by cutting device or a template to obtain a consistent specimen size, in which grams per square meter (GSM) is used to find the weight of fabrics (Hasan, 2015). GSM cutter is used to cut circular fabric samples accurately. Five samples each of the fabrics are taken and weight in electronic weighing machine. The values were obtained directly from the readings of the balance. The weight of the fabrics was record and the main value was calculated.

(a) **(b)**

Figure - 9

GSM FABRIC CUTTER AND FABRIC CUTTING

3. 5. 3 FABRIC THICKNESS:

A fabric thickness is determined according to ASTM 01777-2002, to check the thickness value of non-woven fabrics by using thickness tester with a loaded weight of 4.14 kPa. The 5, 6 grams per square meter of non-woven fabrics were produced and the thickness also varied from 5 to 6 mm. Here, heavy weight fabrics were made to find the perfect material for acoustic textile material. When the grams per square metre and thickness increases, the value of the sound reduction property is also increases (Thirumurugan and RameshKumar, 2020). The anvil and pressure foot which works under a lever spring, action on a top at anvil and action on a top of anvil, indicate the thickness of the sample in 100g/1kg of an inch each dimension on the dial. The sample is placed in anvil plate and lever of the pressure tools or released very slowly and passed slightly on the sample. The sample readings were taken then the mean value is calculated and recorded.

(a) **(b)**

Figure - 10

FABRIC THICKNESS TESTER WITH SAMPLE

3. 5. 4 FLAMMABILITY TEST:

The flammability of fire retarded materials may be tested through different fire testing techniques. The most widely used laboratory flammability testing techniques have been reported in literature (Laoutid et al., 2009; Price et al., 2001; Wichman, 2003).

(a) **(b)**

Figure - 11

VERTICAL FLAMMABILITY TESTER CLIPPED WITH SAMPLE LCJ

A number of small, medium and full-scale flammability tests are used in both academic and industrial laboratories. They are employed for either screening the materials during production or testing the manufactured products. These techniques are cone calorimetry, pyrolysis combustion flow calorimetry (PCFC), limiting oxygen index (LOI), and underwriters' laboratories 94 (UL94) and Ohio State University (OSU) heat release rate tests (Mngomezulu *et al*, 2014). As for this study, the investigator used vertical flammability test to observe the fire retardancy of the sample fabrics.

In vertical flammability test, different parameters were measured as per the IS1871 method A which is equivalent to ASTM D 635. As per this method fabric sample was placed vertically and ignited with a flame of 38 mm height for 12 seconds of flame time.

3. 5. 5 AIR PERMEABILITY TEST:

The air permeability is defined as the volume flow rate per unit area of a fabric when there is a specified pressure differential across two faces of the fabric. The air permeability of needle punched nonwoven fabrics is measured using this test method. The rate of air flow moving perpendicularly across a known area under a prescribed air pressure differential between two surfaces of a material is referred to as air permeability. The fabric's air permeability at a certain pressure differential between two surfaces is usually expressed in cm3

/cm2 /s calculated at operational conditions. To achieve a prescribed air pressure differential between the two fabric surfaces, the rate of air flow travelling perpendicularly across a known area of fabric is adjusted. The suction impact varies greatly depending on the construction (Thirumurugan and RameshKumar, 2020).

The test specimens should be handled carefully so as to avoid altering the natural state of the material. Each test specimens were placed onto the test head of the testing instrument, and the test was performed as specified in the and continued as directed, until 20 specimens have been tested for each laboratory sample. The test was carried out at the standard atmosphere of 21+10C with the relative humidity of 65+ 2%. The air permeability test was determined in accordance with ASTM Test Method D 737 by using the equipment- Testtex model- FX3000. Air permeability is expressed in cm3 /cm2 /s.

Air permeability = $\frac{\text{(Average rate of air flow)}}{5.07}$.

3. 5. 6 ACOUSTICAL TEST:

A simple test is done by using quite simple apparatus has been set up to measure the permeability of sound through a needle- punched blended fabric. The equipment consists of a sound insulating box made out of thick wooden with removable top lid. Inside the vertical wall of the box, one sound source is fixed, and a decibel metre is fixed at 25cms coaxially opposite to sound generator outside of the box to measure the sound intensity. The fabric sample is fixed vertically in between these decibel meter and sound source (Saravana *et al*, 2015). A sound of particular decibel is created by operating the control panel. Decibel value is measured without placing the sample and is measured again after the sample is being placed. The decibel meter measures the value at the receiving end of the box. The sound reduction responsible for fabric which is expressed as the measure of sound insulation can be calculated as shown below (Karthik and Ganesan, 2015):

Sound Reduction = (Decibel reduction with sample) – (Decibel reduction without sample).

3. 5. 7 ABSORBENCY TEST

3. 5. 7. 1 WICKING TEST:

The effects of fabric porosity structure, as well as the content of hydrophilic and hydrophobic fibres in the web mixture sample LCJ and sample LPJ, on the vertical wicking rate by nonwoven fabrics have been explored in this study (Dubrovski and Brezocnik, 2016). A strip of fabric (30 x 2 cm) was suspended vertically with an edge on resource of distilled water was then moisturized. To detect the position of water absorbed in the given time, a line is marked on the fabric. One end of the sample is placed in a glass rod and other with two grams weight attached to keep the samples straight. The sample is placed in the heavy wooden blocks. The sample was allowed to immerse in the tray of distilled water which was mixed with a dye for easy reading. The given time is counted in seconds (60 secs). The rise of water level in the strip was measured. The mean value is calculated.

3. 5. 8 BURSTING STRENGTH TEST:

The bursting strength is defined as the amount of hydrostatic pressure that causes a rupture in the nonwoven material when applied to a specific area, the procedure involves clamping the nonwoven material to a rubber diaphragm and subjecting the specimen to fluid pressure until point of rupture. The bursting strength of a material is generally measured in pound per square inch (PSI). The equipment used for determining Mag Solvics Model – Digi Burst.

Bursting strength is resistance of the nonwoven up to the point of rupture, when the fabric is subjected to increasing perpendicular hydrostatic or pneumatic pressure. This pressure is applied to a circular region of the specimen via an elastic rubber diaphragm pressurized by fluid. The specimen is firmly held to the edge of this circular region by a pneumatic clamping device. The application of this test and multidirectional force applied to the specimen during the test are demonstrated. When the pressure is applied, the specimen deforms with the diaphragm and the maximum pressure that causes fabric rupture is recorded as the bursting strength of the fabric (Koç and Çinçik, 2012).

4. RESULT AND DISCUSSION

The result and discussion pertaining to the study entitled **“Developing Needle Punched Structure using Luffah Blended Fibres”** are discussed under the following headings.

4. RESULT AND DISCUSSION

4.1. PHYSICAL AND MECHANICAL TESTS

4.1.1 FABRIC WEIGHT

4.1.2 FABRIC THICKNESS

4.1.3 FLAMMABILITY TEST

4.1.4 AIR PERMEABILITY TEST

4.1.5 ACOUSTICAL TEST

4.1.6 ABSORBENCY TEST

4.1.6.1 Wicking test

4.1.7 BURSTING STRENGTH TEST

4.2 CHARACTERIZATION STUDIES:

4.2.1 THERMO GRAVIMETRIC ANALYSER

4.2.2 X-RAY DIFFRACTION ANALYSIS

4.1. PHYSICAL AND MECHANICAL TESTS

4.1.1 FABRIC WEIGHT:

The fabric weight of the needle punched samples LCJ and LPJ are shown in the Table X and Figure 12.

TABLE X

FABRIC WEIGHT

Sl no	Sample	Mean (GSM)	t-value	Sig.
1	LCJ	4.97	74.439	0.00
2	LPJ	6.78	25.456	0.00

From Table X, it can be observed that weight of the needle punched sample LPJ is higher than the needle punched sample LCJ. Hence, it can be concluded that the bulkier sample LPJ which has polyester weight more than the LCJ sample.

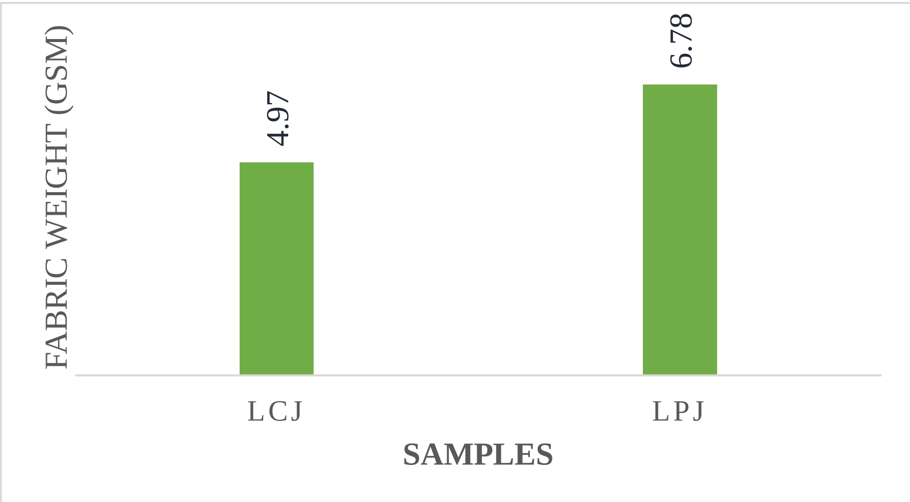


Figure - 12

FABRIC WEIGHT

4. 1. 2 FABRIC THICKNESS:

The thickness and grams per square meter values of needle punched non-woven fabric samples LCJ and LPJ are shown in the Table XI and Figure 13.

TABLE XI

FABRIC THICKNESS

Sl no	Sample	Mean (mm)	t-value	Sig.
1	LCJ	4.19	23.692	0.00
2	LPJ	5.30	113.351	0.00

From Table XI, it is clear that the thickness of Luffa blended polyester-jute (LPJ) fabric thickness value is high and Luffa blended cotton- jute (LCJ) fabric has lower value. The needle punched LPJ fabric structure has more bulkiness. So, it shows more thickness structure than natural fibre based (LCJ) non-woven samples. The grams per square meter of the fabrics directly influenced the thickness property of needle punched non-woven fabrics. As grams per square meter increases and the thickness also increases (Thirumurugan and RameshKumar, 2020).

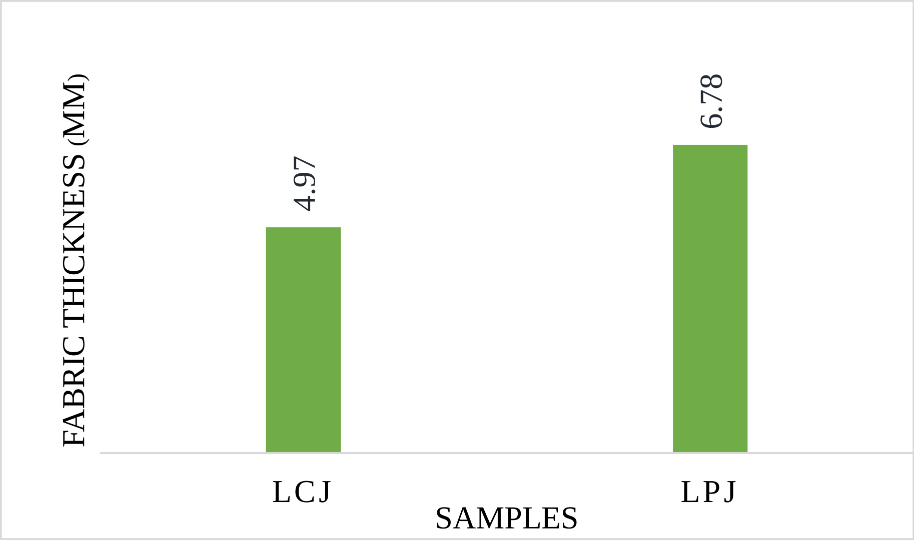


Figure - 13

FABRIC THICKNESS

4.1.3 FLAMMABILITY TEST:

The overall flammability performance of the blended structures can be observed in the Table XII.

TABLE XII

FLAMMABILITY TEST

Vertical flammability test (sample size:350×70) mm		
Sample code	**LCJ**	**LPJ**
Occurrence of flashing over the surface	Yes	Yes
Burning with flame time (sec)	12.6	11.70
Burning with afterglow time (sec) after flame stop	1,192	2
****Total burning time (flame time + afterglow time)**	1192+12.6	11.70+2
Char length (mm)	Nil	347
State of the fabric in contact with of flame	Completely burnt with afterglow	Self- extinguishment observed as partly burnt by afterglow

From Table XII it is evident that the needle punched LPJ sample flame time is just 11.70 secs with just 2 secs burning with afterglow. Comparatively, the needle punched LCJ sample flame time is much higher than the LPJ sample with a flame time of 12.6 secs and burning with afterglow for 18:56 minutes for complete burning. The total burning time of LPJ sample is 11.70+2 seconds while the sample LCJ took 1192+12 seconds. Hence, it can be concluded that the Luffa blended polyester – jute structure sample have extreme flame retardant property.

4.1.4 AIR PERMEABILITY TEST:

The air permeability test and analysis of values for the needle punched non-woven samples LCJ and LPJ are shown in Table XIII and Figure 14.

TABLE XIII

AIR PERMEABILITY TEST

Sl no	Sample	Mean ($cm^3/cm^2/s$)	t-value	Sig.
1	LCJ	24.8	259.550	0.00
2	LPJ	63.9	258.556	0.00

Table XIII shows the influence of thickness on air permeability characteristics of mechanically punched non-woven fabrics. It has been found that the thickness increases obviously it reduce the permeability property of non-woven fabrics. The entanglement structure of needle punched technique reduced the pores inside the non-woven fabric and permeability characteristics of the fabrics also get affected. The pore spaces into the fabrics are decreased because of fabric complex structure and the ability of air through the fabric structure will be reduced. The permeability of air is correlated directly with the structure of non-woven fabric. The entanglement effect of needle punched non-woven fabric influence the permeability of air through the fabric. The air permeability of nonwoven fabrics decreased with the increase in both thickness and mass per unit area (Thirumurugan and RameshKumar, 2020).

Natural fibres are more cohesion fibres and exhibits more bonding and reduce the permeability. The Luffa blended – polyester sample allow more air through its structure. This sample is a combination of all three fibres (25 % jute: 25 % polyester: 50 % Luffa). The combined effect of all the three fibres exhibits high air permeability, whereas the Luffa blended – cotton sample shows lesser air permeability. The sample combination is also of three fibres (25% jute: 25% cotton: 50% Luffa).

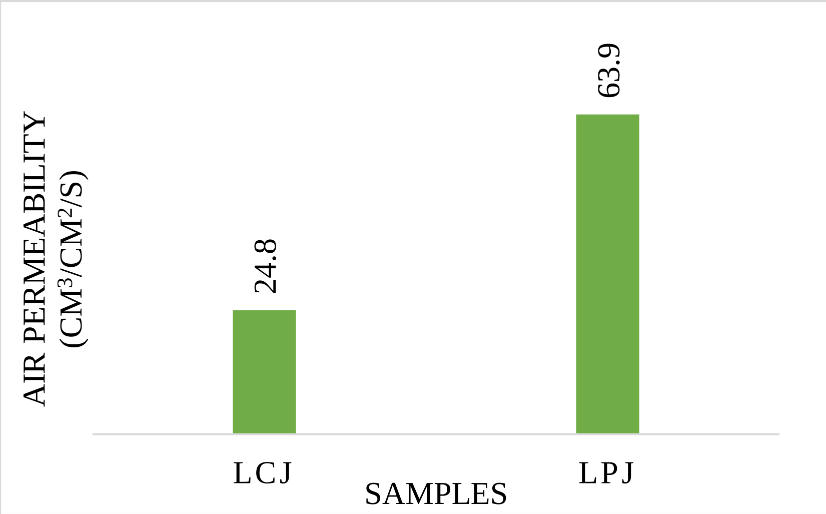


Figure - 14

AIR PERMEABILITY

4.1.5 ACOUSTICAL TEST:

Acoustical test for the needle punched nonwoven samples LCJ and LPJ are analysed and interpreted in the following Table XIV and Figure 15.

TABLE XIV

ACOUSTICAL TEST

Sound Transmission			**Frequency**					
Sl no	**Samples**		**Sound (Hz)**					
			100	500	1000	2000	5000	10000
1.	Control		65.6	84.4	84.6	75.2	83.4	67
2.	LCJ	Transmission	63.4	80.3	72.4	63.9	65.5	64
		Transmission Loss	2.2	4.1	12.2	11.3	17.9	3
		Loss%	3.3	4.8	14.4	15.02	21.4	4.47
3.	LPJ	Transmission	64.4	82.2	76.4	66.7	68	65.2
		Transmission Loss	1.2	2.2	8.2	8.5	15.4	1.8
		Loss%	1.8	2.6	9.6	11.3	18.4	2.6

The permeability of air through the fabric determines the capability of sound reduction. The sound absorption results of nonwoven sample are shown in Table XII. It is certain that as many researchers reported, the increase in basis weight influences the sound absorption positively. With the increase in frequency, GSM and the distance from the source, the extent of sound reduction increases in air permeability, the extent of sound reduction by the material is decreased (Teli *et al*, 2006).

So also in this research, the higher sound absorption coefficients were proved for the higher weights. The effectiveness of a material in sound absorption depends mainly on the frequency of the sound wave subjected to the material, basis weight, air permeability, fibre geometry, and fiber arrangement. Sound ingestion happens because of the effect of sound waves on material, frictional losses while moving in the pores and channels of the structure, and the decline in sound vitality. The increasing weight, fiber density, and porosity of random fibers, the sound wave will contact more fibers, and friction losses will increase. As a result, the sound energy will be reduced, and higher sound absorption coefficients will be obtained.

From the Table XIV , it is obvious that the sound transmission is 65.6 dB in control at 100Hz. This was reduced in both the samples LCJ and LPJ with 3.3% loss in transmission and 1.8% transmission loss of which it was higher in sample LCJ. At 500Hz sound frequency, the control was noted to be 84.4 dB This was reduced in both the samples LCJ (4.1%) and LPJ (2.6%) of which the transmission reduction was higher in sample LCJ. At 1000Hz of sound frequency, the control was noted to be 84.6 dB. The same trend was observed in the samples with higher transmission reduction in sample LCJ with 14.4% followed by sample LPJ with 9.6%.

It is also observed that at 2000 Hz, the control transmission was 75.2 dB. This reduced drastically in sample LCJ with 15.02 dB followed by the sample LPJ with 11.3 dB reduction. The percentages of loss for both the samples LCJ and LPJ by 21.4% and 18.4% respectively. At 5000 Hz, the control transmission was noted to be 83.4 dB where the transmission of LCJ sample occurred by 65.5 dB followed by LPJ sample by 68 dB in percentages count of 17.9% and 15.4% respectively. On the contrary, at 10,000Hz both the samples LCJ and LPJ shows a drastic change of transmission of 64 Db and 65.2 dB respectively over control value of 67 dB. The percentage losses of both the samples LCJ and LPJ are 4.47% and 2.6% from transmission loss of 3 dB and 1.8 dB respectively. Hence it could be concluded that the transmission of the sound waves is reduced when the prepared membranes are used. Though both the samples

Luffa – Cotton – Jute (LCJ) blended needle punched material and Luffa – Polyester – Jute (LPJ) blended needle punched material were compared, LCJ sample gave more satisfactory result than the sample LPJ.

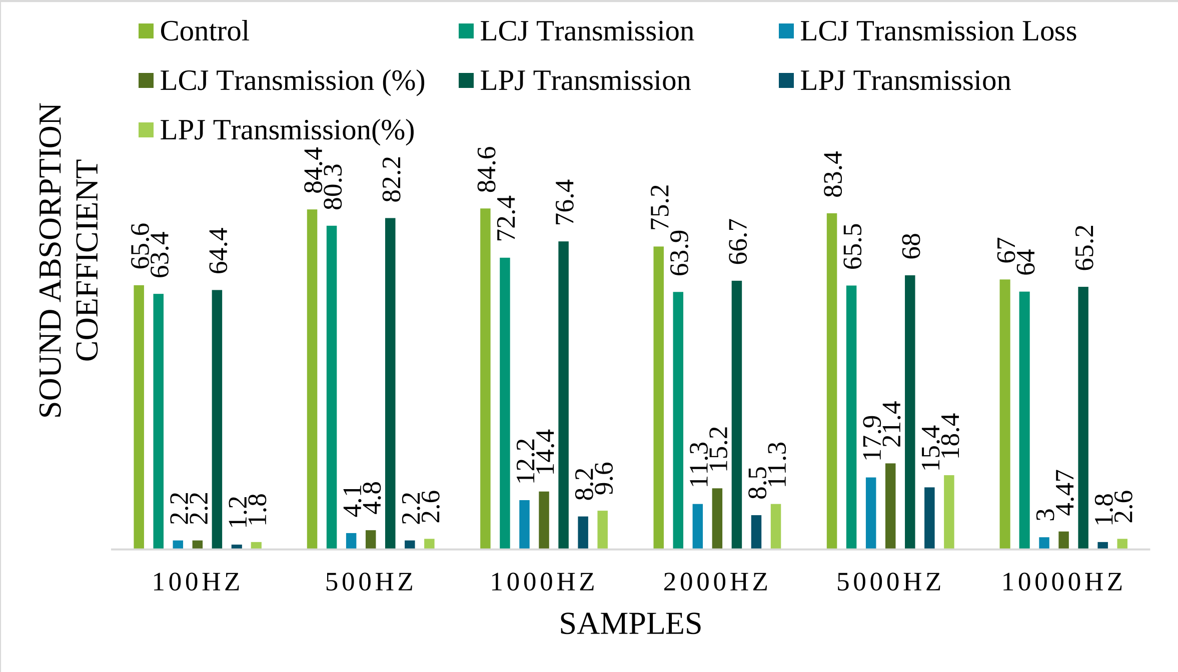


Figure - 15

ACOUSTICAL TEST

4.1.6 ABSORBENCY TEST

4.1.6.1 WICKING TEST

The prepared nonwoven fabrics were characterised for their absorption and wicking properties and the results are presented in Table XV and Figure 16.

TABLE XV

WICKING TEST

Sl no	Sample	Mean (cm)	t-value	Sig.
1	LCJ	0.24	5.622	0.00
2	LPJ	0.67	6.850	0.00

The results show that the sample LPJ exhibit better absorption and wicking behaviour than LCJ. The absorption value of sample LPJ was higher than the LCJ by 0.67 cm to 0.24 cm. This enhanced absorption is mainly due to the fact that the Luffa blended polyester-jute nonwoven structure have more porous structure and the fibres are well oriented within the fabric structure.

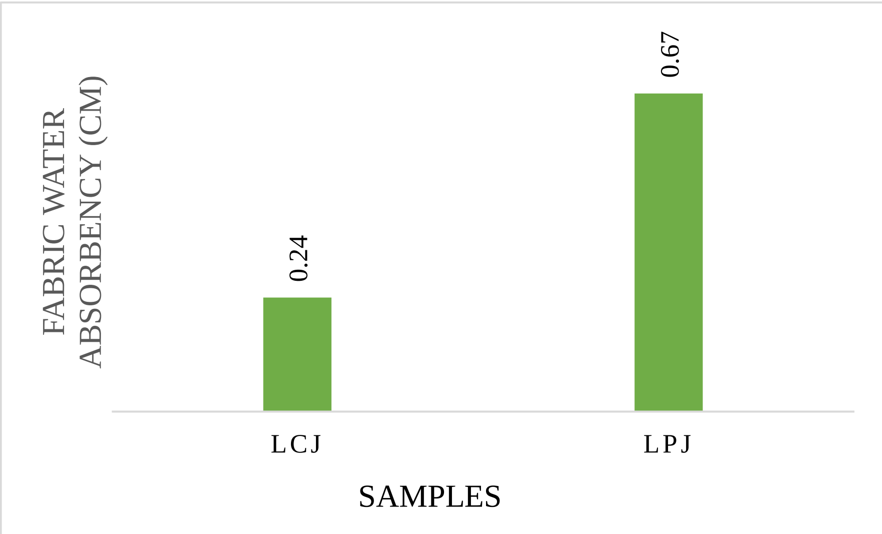


Figure - 16

WICKING

4.1.7 BURSTING STRENGTH TEST:

The bursting strength of Luffa blended needle-punched nonwoven as sample LCJ and sample LPJ were studied and analyse in the following Table XVI and Figure 17.

TABLE XVI

BURSTING STRENGTH TEST

Sl no1	Sample	Mean (PSI)	t-value	Sig.
1	LCJ	171.65	1792.826	0.00
2	LPJ	120.65	1260.148	0.00

From Table XVI, it is observed that bursting strength of sample LCJ is higher comparatively to sample LPJ although sample LPJ shows elevated numbers in fabric weight, fabric thickness, absorbency, sound transmission, but beyond some optimum punch density and depth of needle penetration bursting strength of fabric shows a declining trend. On the contrary, LCJ sample shows an extreme high bursting strength by mean value of 171.6 to 120.6 of LPJ in pound-force per square inch.

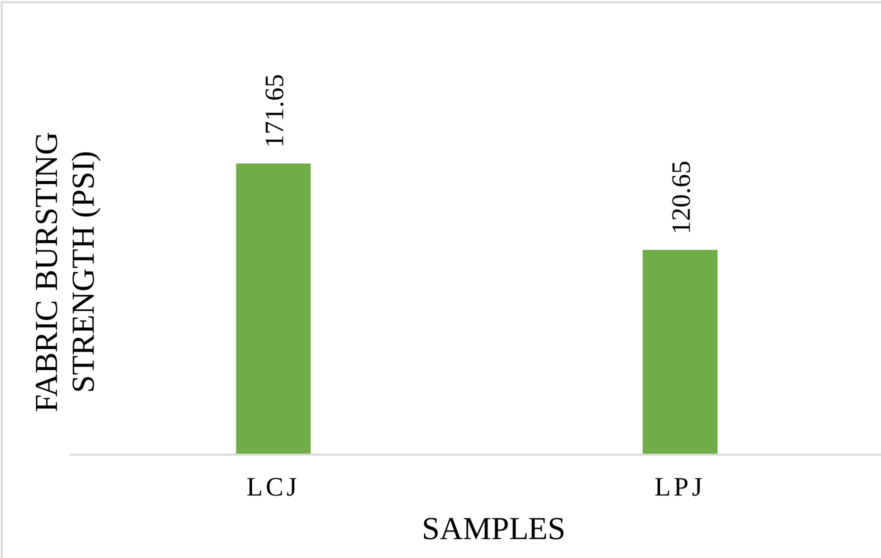


Figure - 17

BURSTING STRENGTH

4.2 CHARACTERIZATION STUDIES:

4.2.1 THERMO GRAVIMETRIC ANALYSER:

TGA was used to assess the thermal stability of luffa sponge fibres using a TG209 thermogravimetric analyser (Netzsch Corporation, TG209, Goliaths, Germany). The technique indicates the mass loss of a material upon temperature exposure for a time period (White et al, 2011). Thermogravimetric analysis is carried out on fibers in order to find out their thermal stability in turn to identify the suitable high temperature applications. The test results will provide the temperature points at which the various constituents such as cellulose, hemicellulose, lignin, moisture etc., present in the fiber getting degraded in the following tables and figures.

TABLE XVII

1ST DEGRADATION OF TGA

Sl no	Sample	Standard weight (mg)	1st degradation		
			Temp (^{o} C)	Weight (mg)	Percentage (%)
1	LCJ	4.410	200	3.700	35.4
2	LPJ	5.642	210	5.400	13.2

TABLE XVIII

2ND DEGRADATION OF TGA

Sl no	Sample	Standard weight (mg)	2nd degradation		
			Temp (^{o} C)	Weight (mg)	Percentage (%)
1	LCJ	4.410	370	1.500	39.9
2	LPJ	5.642	450	3.800	20

TABLE XIX

3^{RD} DEGRADATION OF TGA

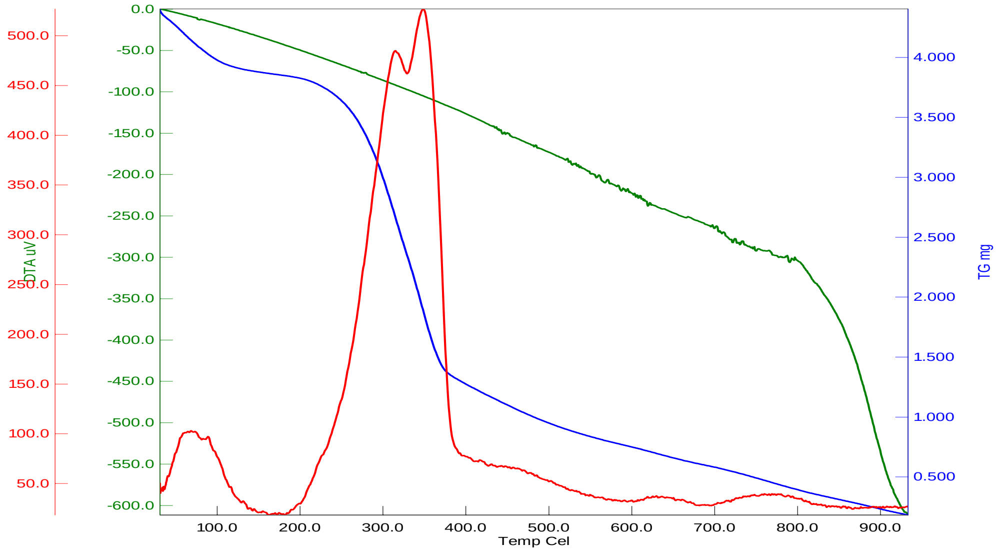
Sl no	Sample	Standard weight (mg)	3^{rd} degradation		
			Temp (º C)	Weight (mg)	Percentage (%)
1	LCJ	4.410	910	0.1	95.7
2	LPJ	5.642	910	3.30	40.5

From the Tables XVII, XVIII and XIX given above, it was observed that a minor weight loss occurred at first stage degradation below 100° C. In the case of cellulosic fibres, lignin degradation started around 180°C and other polysaccharides mainly cellulose is oxidized and degraded at higher temperatures. The second stage degradation occurred at a temperature range of between 220° C and 480° C. At temperature of 240° C and 360° C, it was observed that T10% and T50% weight loss occurred, respectively. The LCJ sample showed stability till 200º C. The standard sample weight is 4. 4l0 mg the first degradation is reduced up to 3.700 mg. The first degradation starts from 200º C. The percentage of weight loss of LCJ is at 35.4%. The weight loss at this temperature region corresponded to the formation of volatile product which arose from random chain scission and intermolecular transfer involving tertiary hydrogen abstractions from the hemicelluloses, cellulose and lignin.

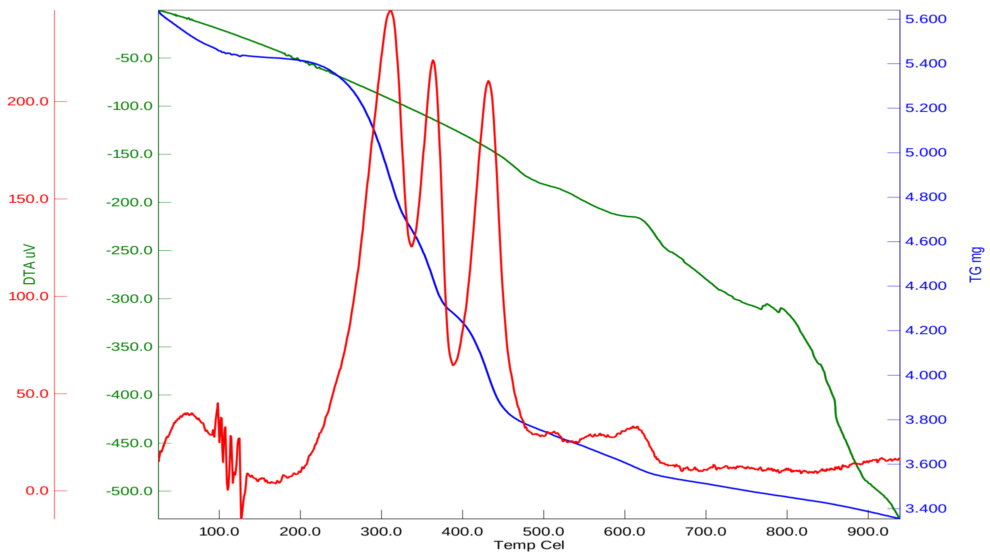
The major source of stability in cellulose is due to hydrogen bonding which allows thermal energy to be distributed over many bonds. As the less ordered region increases, the decreasing mobility of cellulose chains will strain and weaken the existing hydrogen bond, thus decreasing stability. Most natural fibres lost their strength at about 160° C. It was observed that the weight loss or degradation behaviour between temperature of 500° C and 800° C and after 800º C it become constant whereby no more distinct degradation was shown and this was on account of formation of ash content. The second weight loss was observed in the temperature range of 300^{O} – 400^{O} C at 1.9 mg with a percentage of 39.9 %. The last stage of degradation occurred at 910^{O} C lowered to 0.1 mg with a percentage of 95.7%.

As for LPJ, it was observed that a minor weight loss occurred at first stage degradation below 100° C and lignin degradation start around 130º C. the fabric was stable till 210º C. The standard weight of LPJ is 5.642 mg and the first weight loss occurred at around 5.400 mg from 5.642 mg, the fabric showed 93.2% weight loss. The second stage of degradation occurred at

450^{o} C with a weight loss of 3.800 mg and the percentage of weight loss was found to be 20%. At 910^{o} C, the final stage was occurred with the weight loss percentage 40.5% and the weight loss was found to be 3.3 mg.



(a)



(b)

Figure - 18

TGA/DTG CURVES OF SAMPLES LCJ AND LPJ

4.2.4 X-RAY DIFFRACTION ANALYSIS:

The crystallinity size (CS) of the samples LCJ and LPJ was determined by using XRD Analysis and the values were given in Table XX.

The CS of the samples LCJ and LPJ was calculated by using Scherer's formula:

$$CS = \frac{K\lambda}{\beta cos\theta}$$

where K = Scherer constant, 0.94

λ = X- ray wavelength, 0.1544

β = peaks at full width half maximum

ϴ = Bragg angle.

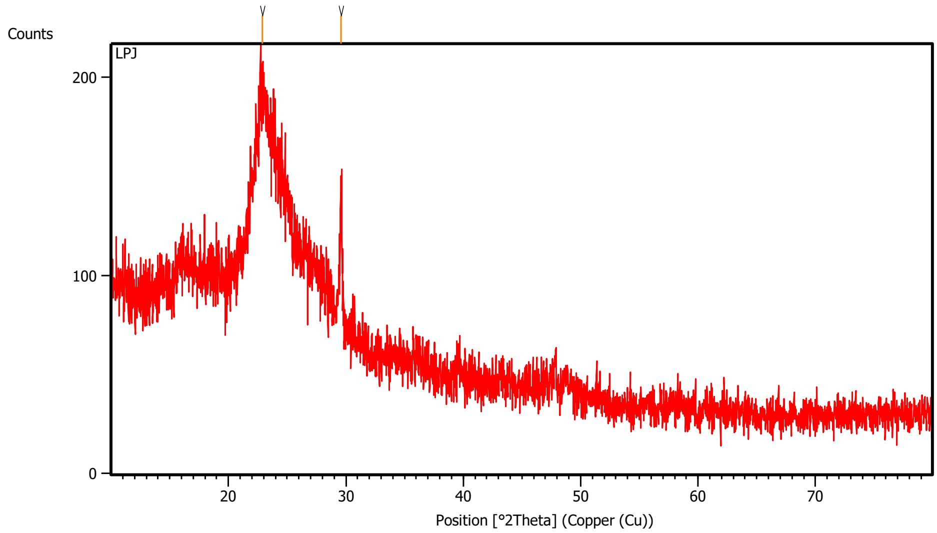
Crystalline Region X-Ray diffraction (XRD) study was carried out to investigate the crystalline behaviour of the LCJ & LPJ needle punched samples in the given Table XX. Figure 19 (a) and (b) represents XRD pattern of LCJ and LPJ, also show summary of its percentage of crystallinity.

TABLE XX

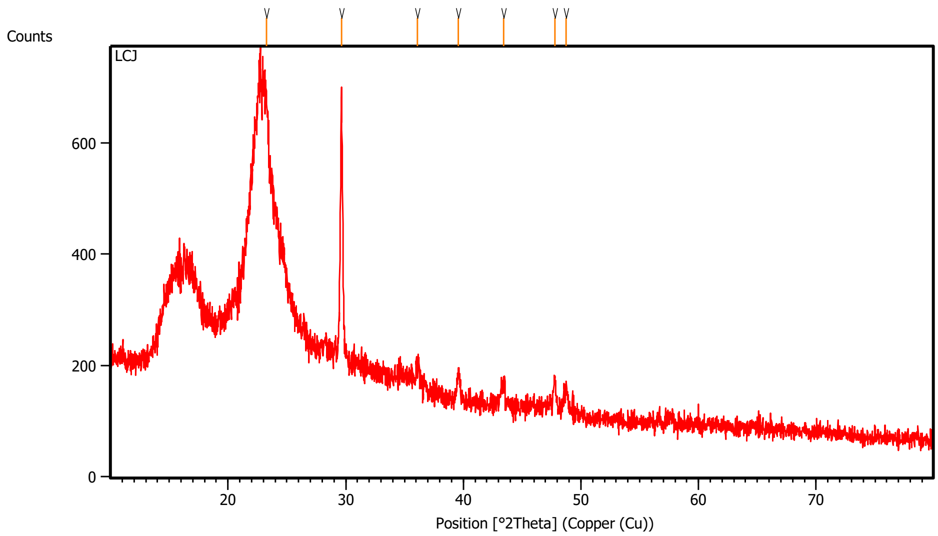
XRD ANALYSES OF SAMPLES LCJ AND LPJ

Sl no	LCJ		LPJ	
	2ϴ	FWHM	2ϴ	FWHM
1	23.2850	0.4015	22.8928	0.6691
2	29.6630	0.2007	29.5983	0.1673
3	36.1253	0.8029		
4	39.6038	0.2676		
5	43.4041	0.3346		
6	47.7605	0.2007		
7	48.7610	0.4015		

From the result, it proves that cellulose of LCJ & LPJ have crystalline nature. Crystallinity, crystalline size, order, degree of polymerization and crystal structure might influence the pyrolysis rates. crystallinity with a spiral angle of about 14^{o}. The superior mechanical properties of Luffa are associated with its high cellulose content and comparatively low micro fibrillar angle. Generally, the spiral angle of the fibrils and the content of cellulose influenced mechanical properties of cellulose based natural fibres. Increasing percentage of crystallinity and spiral angle in natural fibres influenced its materials properties such as thermal, physical and mechanical properties, thereby leads to the enhancement of materials performance in useful and diverse applications.



(a)



(b)

Figure - 19

X-RAY DIFFRACTION FOR (a) LPJ SAMPLE AND (b) LCJ SAMPLE.

5. SUMMARY AND CONCLUSION

The summary and conclusion pertaining to the study entitled **"Developing Needle Punched Structure using Luffa Blended Fibres"** are discussed as follows:

Technical textiles are the textile materials and products that are primarily employed for their technical performance and practical capabilities (mechanical, thermal, electrical, durability), giving them the ability to offer technical functions (IITA, 2022). It has been observed that technical textiles are concern with non-woven technology regarding the manufacturing process. Non-woven structures can be sheet or web structures joined together by mechanical, thermal or chemical processes that entangle fibres or filaments.

The nonwoven sector includes a diverse area of engineered fibre and polymer-based products, all of which are powered by high speed, low-cost, creative, value-added products. Additionally, natural fibres have acquired into nonwovens and composites by blending different kind of fibres, in which the products have shown their potentials in areas of reinforcement, agriculture, automotive, civil engineering, health and hygiene, household, filters and upholstery. Moreover, natural fibres have advantages over synthetic or made-made fibres in such as low cost, low density, availability in abundance, environmental-friendly, nontoxicity, high flexibility, renewability, biodegradability, relative non abrasiveness, high specific strength, modulus and some are ease in processing (Mohamad *et al*, 2020). In fact, that of ease in processing of natural fibre blended nonwovens, needle punching process is a widely used effective mechanical technique for manufacturing nonwoven structures.

In this study Luffa fibre was chosen to be the main fibre content along with cotton, jute and polyester to produce a blended structure. Luffa, cotton and jute were blended as for natural material sample whereas Luffa, polyester and jute were blended as for synthetic material sample, nomenclature were given as LCJ and LPJ respectively.

Luffa fibre or Luffa sponge is a lightweight fruit obtained from vegetable plant *Luffa cylindrica* which have the potential to be utilised in reinforcing lightweight composites due to their poly-porous structure, cheap and abundantly available, renewability, biodegradability, natural network, high strength and initial modulus. Plant fibres can replace petroleum-based fibres as a reinforcement in applications that the structures are exposed to vibration excitation, and in applications where the absorption of vibration has a major importance. Likewise, Luffa shows potential alternative as reinforcing material for polymer-bonded reinforcement since it is generally controlled by naturally bonded network of fibres in multi-directions. Luffa has wide application in packing medium, sound proof lining, utensil cleaning sponge, adsorbent for removal of heavy metals in waste water and immobilization matrix for plant, algae, bacteria and yeast.

Cotton is a cellulosic fibre having strong hydrogen bond, high purity, high crystallinity, high thermal stability and renewable. Cotton fibres are broadly use in textiles industry such as apparel sector as well as technical sector. Jute is the most widely used bast fibre which is considered as one of the most cost-effective natural fibres. It is once regarded solely as the source of raw material for packing industry. However, Jute fibre is widely used as a versatile raw material in a variety of industries including construction, automobiles, furnishings, home textiles and more. Jute has great potential in industrial applications because of their high physical properties like stiffness and strength and have excellent performance at low weights and low density.

Polyester fibre generally comprises of fibres which consist of terephthalic acid and glycol. Polyester fibres are available in varieties, majority of polyester fibres are made of Polyethylene Terephthalate (PET), and PolyTrimethylene Terephthalate (PPT) made Polyester is also available. Polyester dominates among all chemical fibres mainly the PET because of it has good end-use properties, economy of production, ease of physical and chemical modification, recyclable and reusable.

Considering the above facts, the invigilator selected to study on "**Developing Needle Punched Structure using Luffa Blended Fibres"** with the following objectives:

- To select fibres for needle punching.
- To develop needle punched fibre-blended structures by using the selected fibres.
- To compare the blended natural and synthetic structures.
- To study the mechanical and physical properties of the needle punched structures.

Methodology adopted:

- Fibres were collected and selected.
- Luffa fibre was treated with Sodium hydroxide in the ratio of 1:3 to fibre weight for 24 hours.
- The treated fibres are let to dry in room temperature for 4 days.
- The aim is to manufacture two different samples as Luffa – cotton – jute and Luffa – polyester – jute, given nomenclature as sample LCJ and sample LPJ respectively.
- Cotton and polyester were taken and outspreaded evenly.
- Jutes fibre was cleaned and chopped into 1" length and spread evenly.
- Needle punching method was selected as the manufacturing process.
- Mixing and web formation was done in carding machine where lap was formed.
- Layers of lap formed (4 layers) were taken and positioned in the conveyer belt and processed for needle punching process.
- At least the sheet is flipped over side by side twice or more for additional compression and compactness. Same process is done for all the samples.
- The needle punched fabric samples were studied and compared for their physical and mechanical properties.
- Characterization studies like TGA and XRD was done for both the samples LCJ and LPJ.

Findings of the study:

- The fabric weight of sample LPJ is higher than the weight of sample LCJ though the fibre ratios of both the samples as this fabric is influenced by the individual properties of polyester and cotton.
- The fabric thickness of sample LPJ is higher and bulkier than the sample LCJ, which is evident from the weight.
- It is clear that sample LPJ possessed an excellent flame retardant property.
- Sample LPJ showed good air permeability property due to the spaces observed in the interlocking fibres which may be due to the polyester fibres.

- Sample LCJ showed more strength than sample LPJ, which may be due to the compactness of fibres.
- Sound transmission is higher in sample LPJ than sample LCJ, thus LCJ shows satisfactory result for acoustic application.
- Sample LCJ showed lesser water absorption than the sample LPJ which may be due to absence of polyester in LCJ.
- Sample LCJ is found to be fully degraded as observed from the evaluation and analyse of Thermogravimetric test.
- XRD analyses proved that cellulose of both samples LCJ and LPJ showed the presence of crystallinity.

CONCLUSION:

The present study can be concluded that Luffa *(Luffa cylindrica)* nonwovens can be manufactured by blending intertwining fibres such as cotton and polyester as base by using the web formation process and needle punching technology. The investigation compares the needle punched Luffa blended structure samples LCJ and LPJ based on their mechanical and physical properties.

The Luffa blended cotton – jute proved to be a good sound insulator, has high strength and a good anti-water absorbent whereas, the Luffa blended polyester – jute possess excellent flame retardant property, good air permeability and is a good water absorbent. Therefore, for appropriate end uses, the developed structures may be utilized. With the increasing damage given to the environment by manufacturing synthetic fibres as it requires high power, toxic for human health, high release of carbon dioxide, researches and studies have been made more towards the environmental-friendly fibres on their characteristics and properties. Moreover, natural fibres are light weight, renewable as well as degradable so, it can help the industrial sector to be greener.

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APPENDICE – I

NEEDLE PUNCHED SAMPLES

SAMPLE LCJ

SAMPLE LPJ

APPENDICE – II

SAMPLES TEST REPORTS

PSGTECHS COE INDUTECH LABORATORY
CENTER OF EXCELLENCE FOR INDUSTRIAL & HOME TEXTILES
Promoted by Ministry of Textiles - Government of INDIA
Avinashi Road, Neelambur, Coimbatore-641062
Telephone: 0422 – 3933250 – 252, E-mail: testing.int@psgtech.ac.in

TEST REPORT

REF NO: COE/2022/FEB/9216

Receiving Date : 11-02-2022
Tested Date : 21-02-2022
Report Date : 21-02-2022

Name of the Applicant : **NGAMPUILU MALINGMEI.**
Avinashilingam University, Cbe.

Sample Description : NA

Type of sample : Nonwoven

Type of test : Air Permeability.

Results Summary / Conclusion:

Test	Test Method	Remarks
Air permeability	ASTM D 737	Refer Result

Muthukumar. V
Authorized Signatory

Page 1 of 2

IMPORTANT

PSGTECHS COE INDUTECH LABORATORY
CENTER OF EXCELLENCE FOR INDUSTRIAL & HOME TEXTILES
Promoted by Ministry of Textiles - Government of INDIA
Avinashi Road, Neelambur, Coimbatore-641062
Telephone: 0422 – 3933250 – 252, E-mail: testing.int@psgtech.ac.in

TEST REPORT

REF NO: COE/2022/MAR/9491

Receiving Date : 31-03-2022
Tested Date : 09-05-2022
Report Date : 09-05-2022

Name of the Applicant : **NGAMPUILU MALINGMEI.**
Avinashilingam University, Cbe.

Sample Description : NA

Type of sample : Nonwoven

Type of test : Bursting Strength.

Results Summary / Conclusion:

Test	Test Method	Remarks
Bursting Strength	ASTM D 3786	Refer Result

Muthukumar. V
Authorized Signatory

Page 1 of 2

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