FIBER MISALIGNMENT EFFECT ON COMPRESSIVE PROPERTIES OF JUTE AND KEVLAR COMPOSITE UNDER IMPACT AND STATIC LOADING

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DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

Signed……………………………………………………..(Lim Kwan Huei)

Date……………………………………………………………(23/7/2022)

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This thesis is the result of my own investigations, except where otherwise stated.Other sources are acknowledged by giving explicit references.
Bibliography/references are appended.

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LIST OF ABBREVIATIONS

HSC	High Speed Camera
IL	Impact Loading
JC	Jute/Epoxy Composite
KC	Kevlar/Epoxy Composite
SEM	Scanning Electron Microscope
SHPB	Split Hopkinson Pressure Bar
SL	Static Loading
UTM	Ultimate Tensile Machine
USM	University of Science Malaysia

KESAN PENYELENGGARAAN FIBER TERHADAP SIFAT-SIFAT MAPAT JUT DAN KOMPOSIT KEVLAR DI BAWAH KESAN DAN PEMBATAN STATIK

ABSTRAK

Pada zaman kini, bahan komposit sering digunakan kerana kosnya yang rendah, sifat kekuatan yang hebat, dan ringan, ia mempunyai pelbagai kegunaan. Walau bagaimanapun, masalah ketidakjajaran gentian sentiasa tidak dapat dielakkan semasa pembuatan dan mungkin menjejaskan kekuatan mampatan gentiannya. Gentian tenunan digunakan untuk menangani isu tingkah laku anisotropik komposit satu arah. Oleh itu, penyelidikan ini adalah untuk menyiasat kesan salah jajaran gentian ke atas sifat mampatan komposit jut dan kevlar di bawah beban hentaman dengan 1.0 bar, 1.25 bar dan 1.5 bar menggunakan split Hopkinson pressure bar (SHPB). Selain itu, ujian beban statik dilakukan menggunakan mesin tegangan muktamad (UTM) dengan kira-kira 0.08mm/s untuk mengkaji sifat mampatannya. Sokongan menggunakan mikroskop elektron pengimbasan (SEM), kamera berkelajuan tinggi (HSC) dan telefon kamera adalah untuk mengetahui mekanisme kegagalan spesimen jute dan kevlar di bawah parameter yang berbeza. Keputusan menunjukkan tegasan kegagalan dan terikan kejatuhan komposit jut masing-masing sebanyak 10.1% dan 2.11%, apabila beban hentaman meningkat. Di bawah beban statik, tegasan kegagalan dan terikan diturunkan berturut-turut sebanyak 12.5% dan 19.5%. Dalam semua bar tekanan ujian impak, komposit kevlar menunjukkan peningkatan tegasan kegagalan sebanyak 129.1% daripada 0° kepada 4° dan peningkatan ketara dalam ketegangan kegagalan sebanyak 533.3%. Tegasan kegagalan dan terikan kegagalan komposit kevlar meningkat dengan ketara sebanyak 252.4%, tetapi menurun sebanyak 3.9% di bawah beban statik, .

FIBER MISALIGNMENT EFFECT ON COMPRESSIVE PROPERTIES OF JUTE AND KEVLAR COMPOSITE UNDER IMPACT AND STATIC LOADING

ABSTRACT

These days, composite materials are frequently used. Due to its low cost, great strength, and light weight, it has a wide range of uses. However, fiber misalignment problem always inevitable during manufacture and might affects fiber its compressive strength. Weaved fibres aim to address the issue of the extremely anisotropic behaviour of unidirectional composites. Therefore, this research is to investigate the fiber misalignment effect on compressive properties of jute and kevlar composite under impact loading with 1.0 bar, 1.25 bar and 1.5 bar using split hopkinson pressure bar (SHPB). Besides, static loading testing is done using ultimate tensile machine (UTM) with about 0.08mm/s to study its compressive properties. The support of using scanning electron microscope (SEM), high speed camera (HSC) and camera phone is to figure the failure mechanism of jute and kevlar specimen under dissimilar parameters. The results demonstrate the failure stress and strain of the jute composite fall by 10.1% and 2.11%, respectively, as impact loading. Under static loading, the failure stress and strain are successively lowered by 12.5% and 19.5%. In all different pressure bars of impact testing, the kevlar composite shows an increase in failure stress of 129.1% from 0° to 4° and a notable increase in failure strain of 533.3%. The failure stress and failure strain of kevlar composite increased significantly by 252.4% but dropping by 3.9% under static loading.

CHAPTER 1
INTRODUCTION

1.1 Overview of Jute Fiber and its Composite

The most popular natural fiber used as reinforcement in green composites is jute. Jute is one of the low-cost natural fibers and is now the bast fiber with the highest production volume. It belongs to bast fibers (fibers extracted from the inner or outer bark of plants) like kenaf, hemp, flax, ramie, etc. It is a type of bast fibre from the Tiliaceae family and has the scientific name 'Corchorus Capsularis' since it is harvested from plants of the corchorus genus. Although jute is naturally associated with the Mediterranean, the best types for its cultivation are mainly provided by India, next are Bangladesh, People's Republic of China, Uzbekistan, Thailand, Indonesia, and Brazil [1,2]. Around 2300x103 to 2850x103 tonnes of jute fibre are produced globally each year [2,3]. Jute can grow up to 2-4 meters long, and fibers are white to brown in color. Jute can grow to a height of 2-3.5 meters, but due to its high lignin content (up to 12–16 percent), it is exceedingly fragile and has a short extension to break. However, moisture, acid, and UV light resistance in jute fibres is lower. It has become one of the most economically valuable and versatile fibers in the world, hence it is also called as 'golden fibre' [4].

All-natural fibres have greater acoustic insulation qualities and novel thermal properties than other synthetic fibres because they are lignocellulosic by nature. In general, synthetic fibres have better mechanical qualities than natural fibres, but those properties can be improved even further by applying various surface treatments to the fibres, such as silane or alkali treatment. Natural fibres are highly demanded in the industries for the enhancement of composites because they have high specific strength, low densities, and high specific modulus [5].

While natural fibres have a greater specific modulus than glass fibres, glass fibres have a higher tensile strength than plant fibres. These factors contribute to the widespread usage of natural fibres in a variety of green composite applications. The mechanical properties of jute fiber is mentioned in Table 1.1 and according to different authors' studies, the primary determinants of the physical and mechanical qualities of jute fibres are their density, young's modulus, and tensile strength [6].

Table 1.1 Properties of jute fiber as reported by different authors

Tensile Strength (MPa)	Young's Modulus (GPa)	Elongation at brake (%)	Length (cm)	Diameter (cm)	Density (g/cm^3)	Source
393-773	26.5	1.5-1.8			1.3	[2]
460-553	2.5-1.3	1.16	150-360	.005-0.028	1.3	[7]
393-773	2.5-26.5	1-2		.0025-0.2	1.3-1.45	[4]
400-800	10-30	1.5-1.8			1.46	[8]
393	55	1.5-1.8			1.3	[9]
394	55			.001		[10]
300-700	20-50	1..6-4.0			1.3	[11]
393-773	26.5	1.5-1.8			1.3	[12]
393	55				1.3	[13]

Utilizing compression moulding and both woven and non-woven jute fibres as reinforcement, jute-based composites were created and described. Different mechanical characteristics, such as flexural strength, tensile strength, elongation at break, tensile and flexural modulus, were noted and observed in these composites. It was discovered that developed composites exhibited the best characteristics when reinforced with 60 weight percent of jute felt or fabric.

Composites are processed similarly to plastics or composite materials. Thermoplastic and thermoset bio-composites are another category for these. Natural jute fiber reinforcing thermoset composites were made using both closed mould techniques like compression moulding and resin transfer as well as open mould techniques like hand lay-up. Press moulding and pultrusion techniques were also applied to the winding of short and chopped NFs filaments. Typically, compounding and extrusion are used to create polypropylene composites with all-natural fibre reinforcement [25]. Unsaturated polyesters, epoxies, and phenols are the thermosets that are employed the most frequently. The three most prevalent thermoplastic matrices are polypropylenes, polyethylenes, and elastomers [15].

Due to the advantages of jute composites has lower cost and better recycle ability than glass fiber, natural jute fiber also has a significant advantage, that is, in the process of producing jute fiber, the energy consumption is lower (2% of the energy consumption of the same glass fiber output, which makes jute fibers more attractive as reinforcements. Jute composites are used in a variety of applications, such as: lamp shades, suitcases, helmets and bathtubs; enclosures for electrical appliances; plumbing, letter boxes, roofs, grain storage bins, interior dividers and ceilings, biogas containers and low-cost mobile buildings objects (this type of building is effective against natural disasters such as floods, tornadoes and earthquakes).

1.2 Overview of Kevlar fiber and its Composite

Kevlar is a brand of commercial fibres made of para-aramids, which are strong, lightweight materials linked to aramids like Nomex and Technora. It is typically used as cotton fibres, textiles, and fabrics, or as a significant component of composite materials. Strong and weak electron system linkages in the linear and lateral orientations of polymer chains combine to give Kevlar fibre (KF) its yellow colour. The fibres twist internally if they are bent in a loop. These specific fibre qualities are carried over into the composites. For instance, multilayered Kevlar-epoxy single-direction fibres exhibit lateral weaknesses despite having high linear properties. The bend or flexure caused by load is a problem because the compressive resistance level is lower than the stress/tensile strength. The bend or flexure caused by load is a problem because the compressive resistance level is lower than the stress/tensile strength. Strong molecular-resistant chains made of poly meta-phenylenediamine, which does not melt or flow at high temperatures, are used in Nomex. Up to 3500°C, it is resilient and durable chemically and thermally.

The production of Kevlar, also known as poly-paraphenylene terephthalamide (PPTA), is costly. Additionally, there are difficulties in maintaining an aqueous insoluble polymer and applying concentrated sulfuric acid during the twisting and combination process (Yang, 1992). Long molecular PPTA chains make up KFs. The cloth is very robust due to the pre-existing interchain connections. The Kevlar resistance is increased by molecular hydrogen bonds formed between polymer chain protons and carbonyl groups [16].

Due to their light weight and strong mechanical qualities, fibre composites are becoming more and more in demand across a variety of industries today. Various fibre composites are available, including those made of carbon, basalt, glass, jute, kenaf, flax, hemp, and kevlar. Few research found it is nearly five times stronger than steel and shown that it can be used in replacement of steel. Kevlar is one of the best composite materials now on the market. High rigidity modulus, toughness, thermal stability, and strength are only a few of Kevlar's characteristics.[17]

Kevlar's great strength is derived from its extensive inter-chain bonding. Kevlar is stated to have a relative density of 1.44 and a strength of 3260MPa when it is spun. The properties of kevlar fabric are shown in Table 1.2 is from Yang [18] research, kevlar's general mechanical characteristics and particular characteristics are 1.44 g/cm3 density, 2800 MPa strength, and 124 MPa stiffness. Table 1.2 displays the various Kevlar qualities in relation to the various types of Kevlar. In terms of tensile strength and density, all varieties of Kevlar are suitable for use as a synthetic fibre in composites applications, provided that their ranges fulfil the general specifications of Kevlar as defined by Yang and Table 1.2 in the preceding specific properties.

Table 1.2 Different Properties for Different Grade of Kevlar

Grade	Density (g/cm^3)	Tensile Modulus (GPa)	Tensile Strength (GPa)	Tensile Elongation (%)
29	1.44	62-83	3.6	4.0
49	1.44	124-131	3.6-4.1	2.8
68	1.44	99	3.0	3.3
119	1.44	55	3.1	4.4
129	1.45	99	3.4	3.3
149	1.47	186	3.4	2.0

The chain lengths of other synthetic polymers, such as Dyneema, are affected by the inter-chain bonds created between NH centers and carbonyl groups. Kevlar maintains its resilience and strength, and to some extent, is slightly stronger at lower temperatures, even at temperatures as low as -196°C (Cryogenic temperatures). Kevlar is used in a variety of products, including bulletproof armour and race vehicles [17,19].

Accidents frequently occur with race cars. Because of its tensile strength, Kevlar is employed to strengthen its fuel tanks. This reduces the likelihood of a gasoline tank puncture during an accident or collision and lowers the risk of a fire. Kevlar is a perfect material because of its lightweight feature. Body armour has traditionally been made of steel. However, it was big and heavy. In contrast, Kevlar's high impact energy can be easily absorbed by kevlar due to its high tensile strength. This makes it the material of choice for protection from sudden crash. Steel cables can be replaced with kevlar cables since they are lighter, stronger, and more flexible [16].

1.3 Overview of Fiber Misalignment

The effective characteristics of composite materials can be determined by a micromechanical analysis using knowledge of the constituent qualities, their geometric arrangement, and their intricate interconnections. However, design and analysis often do not consider the effect of fibre misalignment on the composite response, which frequently can occur in modern composites. The impact of longitudinal fibre misalignment on the compressive failure response of composites, which has been widely researched in the literature, is a remarkable exception [20]. According to Kugler and Moon's [21] research, such misalignment can be caused by manufacturing flaws and faults, curved surfaces, and fibre waviness. Misaligned fibres are inescapably present in unidirectional (UD) high-performance composites, relate into unidirectional (UD) tapes technology in manufacturing woven fabrics which considered as important reinforced fiber nowadays. Fibre breakage is always the primary cause of failure in woven fabric composites, making it the favoured failure mode in general. Next, shear behaviour predominates as the material deforms in 3D textiles, with in-plane behaviour and interlaminar behaviour being the most significant deformations [19], [20], and [21]. Because 3D angle interlock fabrics have a wide range of applications in manufacturing, particularly in the case of forming processes, it is important to research the inter/intra-ply shear behaviour of these fabrics.

In UD composite, the deviation of the fibers—which are not entirely parallel—is expressed by the term "fibre misalignment." This manufacturing flaw [22] would regulate the localised plastic microbuckling [23], which is widely acknowledged as the predominant failure mode in UD fibre composites [24], a mechanism of compressive failure as it was loaded.

1.4 Problem Statement

Among the topics discussed above, there are only a few research focusing on the effect of fiber misalignment on compressive properties of jute and kevlar composite under impact and static loading and the overall failure performance of the material after affection of fiber misalignment. Hence, this paper mainly studies the compressive properties of the material after undergoes impact and static loading. It goes same as to identify the failure mechanism of the jute and kevlar composites under high speed camera and the damaged specimens' surface under micro-level using scanning electron microscopic (SEM). From M.R Wisnom [25] findings, even with very slight misalignments, shear instability in the matrix significantly lowers the anticipated compressive strength. Due to the curvature's related misalignment angle, the similar tendency is anticipated for composites with initial fibre curvatures. The reduction in compressive strength often attributed to initial fibre curvature may therefore actually be due to fibre misalignment angles. Therefore, the decrease in compressive strength may really be brought on by fibre misalignment angles. His findings seriously put doubt on the possibility of determining a true ultimate compressive strength for this type of material because small misalignments are difficult to eliminate during the production and testing of composites.

1.5 Objectives

There are two main objectives of this study:

i. To study the fiber misalignment effect on compressive properties of jute and kevlar composite under impact and static loading

ii. To investigate the effect of fiber misalignment onto the impact failure surface of jute and kevlar composite under impact and static loading in micro-level by using SEM and overall failure mechanism under HSC.

1.6 Scope of Project

In order to study the mechanical compressive properties of jute and kevlar composite and fibre misalignment effect under static and impact loading, this project proposes usage of HSC, which can record in detail and slow down the crash destruction onto the specimens in the fill direction with different parameters from SHPB. SHPB is used to test the material properties of specimens with medium-low pressure rates under 1.0 bar, 1.25 bar and 1.5 bar, this loading is categorized as impact loading. Before this, the specimens were prepared into jute and kevlar material with 5 non-identical fiber misalignment angles, which are 0°, 1°, 2°, 3° and 4°. Graphs data are then extracted into picture and excel file. UTM machine is used as static loading testing with about 0.08mm/s, with according to each specimen thickness to obtain the compressive properties of each specimen. SEM used for scanning the most destructed part surface of specimens' microstructures with different degrees of misalignment, and an obvious trend of longitudinal compression load was observed. The final goal is to study the effect of fiber misalignment, how it may affect the compressive properties of the jute and kevlar composite, same to the failure behavior study of the specimens under impact and static loading.

CHAPTER 2

LITERATURE REVIEW

2.1 Literature review

Composites, usually referred to as composite materials, are natural or synthetic substances consisting of two or more ingredients and possessing physicochemical properties distinct from those of the individual substances. Fiber-reinforced polymers, glass-reinforced plastics, nacre, bone, and cement are a few examples of composites. These days, composite materials are frequently used. Due to its low cost, great strength, and light weight, it has a wide range of uses. These composite materials are now being investigated for use in automotive and aerospace applications. High performance resins have been used as matrix materials to help overcome the difficulties presented by the intricate designs of contemporary aeroplanes. However, high-performance composites that are nominally unidirectional almost always contain misaligned fibres. To address the issue of unidirectional composites' highly anisotropic behaviour, weaved fibres were first used. Orthotropic and having comparable characteristics in both the length and width dimensions, or the warp and fill directions, are woven fabric reinforced composites [26]. Key mechanical characteristics of the composite, such as the longitudinal compressive strength, longitudinal tensile modulus, fatigue resistance, shear strength, and delamination resistance, are known to be impacted by such misaligned fibres [27].

Jute fibres typically have the following characteristics, density of 1.5 g/cm^3, tensile strength of 393–773 MPa [2,12], and elastic modulus of 30 GPa. One of the most popular fibres is jute [8]. It is affordable, has a respectable amount of strength, and is rot resistant. Typically, jute is used for packaging (sacks and bales). Kevlar is stated to have a relative density of 1.44 and a strength of 3260MPa when it is spun and from Yang [18] research, kevlar's general mechanical characteristics and particular characteristics are 1.44 g/cm3 density, 2800 MPa strength, and 124 MPa stiffness.

For composite, bidirectional jute fibre epoxy composites made using the hand lay-up method [28] demonstrated improved hardness, tensile strength, and impact resistance with increase with jute weight. The interlaminar and flexural strengths first declined up to 12 weight percent of jute before increasing up to 48 weight percent as jute fibre loading increased. Decreased voids with increased jute fibre loading in composites is one of the factors contributing to the bidirectional jute epoxy composite's increased mechanical characteristics. The elastic modulus and tensile strength of jute reinforced with unsaturated polyester (UP) were [29] in the range of 393-773 MPa and 26.5 GPa, respectively. Kevlar.epoxy composite shows itself with flexural strength and flexural modulus about 115 MPa and 110 GPa respectively. In the same time, tensile strength and tensile modulus of 245 MPa and 275 MPa are shown based on Yahaya et. al. [30] research.

There are few research studied about the effect of fiber misalignment onto certain composites' mechanical properties. For example, it was expected that even with a slight misalignment angle of 0.25°, the strength of carbon fibre composites will decrease from 2720 MPa to 1850 MPa [25]. The effects of fibre alignment on the mechanical characteristics of composites made of recycled carbon fibre were also researched by Werken et al. [31]. The alignment level has been found to have the biggest impact on the elastic modulus and composite strength. The normalised tensile strength and module of recycled carbon fibre composites in the aligned composite improved by 100% and 137%, respectively. From Razali et al. [32] findings, the failure strain of specimens with 3 different fiber misalignment angles (0°, 1° and 2°) under 2 dissimilar strain rate condition (2.1mm/s and 8.4mm/s), appear to be almost constant with an average value of 0.05 and 0.063 respectively while the failure stress was decreases as fiber alignment increases when loaded under the range of 2.1~8.4mm/s.

Numerous factors, including constituent qualities, lamination geometry, state of stress, etc., influence how fibre composites fail. They can be observed at three different scales: the macroscopic laminate level, the microscopic level of fibre matrix interaction. At the microscopic level, the three main types of failure are bond failure at the fiber-matrix interface, tensile or compressive (buckling) failure of the fibres, and compressive or shear fracture of the matrix.

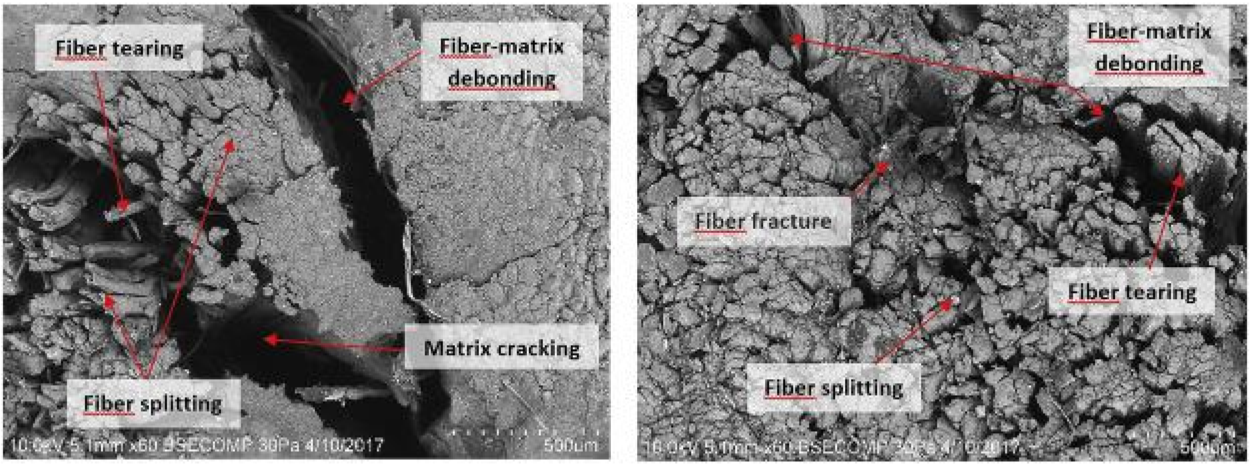


Figure 1 SEM micrographs of the impact failure surfaces of Kenaf specimen.

Source : Sareh Aiman Hilmi Abu Seman, Roslan Ahmad, Hazizan Md Akil, Meso-scale modelling and failure analysis of kenaf fiber reinforced composites under high strain rate compression loading, Composites Part B: Engineering, Volume 163, 2019, Pages 403-412, ISSN 1359-8368, https://doi.org/10.1016/j.compositesb.2019.01.037. (https://www.sciencedirect.com/science/article/pii/S1359836818316226)

Figure 1 image shows pictures of shattered specimens that were put through a dynamic compressive test. The impact damage appears to have extended throughout the specimen on the upper surface. These failure modes include matrix fractures, fibre splitting, and degradation of the fiber/matrix bond strength, which together cause the composite's overall strength and stiffness to decline. Numerous loading circumstances may potentially result in the matrix material failing. In all cases, if the local strength of the matrix or interface is exceeded by the corresponding loading condition of normal stresses or shear stresses, cracks start or spread inside the matrix or at the interface between the matrix and the fibre. Fiber splitting is possible, especially if the fibre is weak in the transverse direction and the unidirectional composite is particularly coordinated in the transverse direction, even if the majority of failures involve matrix cracking or interface debonding. [33]

In the field of studying relation of fiber misalignment and failure mechanism, fibre breakage and fiber-matrix debonding when loaded are two additional effects of fibre misalignment on composite materials [34]. When specimen sustain under higher fibre misalignment and strain rates, the specimen gradually developed fibre plastic microbuckling, fibre breaking, fibre splitting, and fibre matrix debonding [33] under static loading.

CHAPTER 3
METHODOLOGY

3.1 Panel preparation

In the forming step of the wet moulding process, jute and kevlar fibre are cut into pieces of 25 cm x 25 cm from the fabric roll in order to lay on a clean flat surface, then the materials are transferred layer by layer. Epoxy resin with a hardener of a 3:1 ratio based on the fibre materials weighted. In a 3:1 ratio, epoxy resin is blended with hardener. Mixed resin is applied layer upon layer to make sure the resin covers the whole surface of the fibers. The thickness of the panel is controlled at about 8mm to 9mm. During layering process, pressure is put on every layer of woven fabric to make sure it absorbed resin in every surface. Next single layer of fabric is placed in parallel direction following the previous fabric, so fiber alignment during layers can be standardize. After the hand lay-up process, the porous release ply is covered on top first, followed by the breather ply. A vacuum bagging technique is used to pressurize, unseal, and take out the product. Heavy flat metal sheet is placed onto the panel to squeeze extra resin out from centre of panel. To ensure the epoxy resin is fully cured, curing time with 24 hours is used to make sure the resin is completely cured. The panel were then placed into drying oven to eliminate the stresses and air bubbles during the layering process.

Figure 2 Panel specimen of jute/epoxy composite

3.2 Specimen preparation

From the panel that was prepared both for jute and kevlar, which controlled to about 8 mm to 9 mm, 9 layers of jute and 25 layers of kevlar in total, respectively.

As a result, the thickness of jute is 8.3mm and the thickness of kevlar is 8.6mm, measured by vernier caliper.

In order to create the specimen with a fibre misalignment of 5 non-identical fibre misalignment angles, which are 0°, 1°, 2°, 3°, and 4°, grinding manually onto each small specimen with sandpaper sheets with 240 grit. From Figures 2 and 3, description of variables are stated :

X = Thickness of panel (8.3mm for jute, 8.6 mm for kevlar)

θ = misalignment angle (0°, 1°, 2°, 3°, and 4°)

x = trimmed length

L = Length of specimen after trimming

The slight angle which indicates by variable titah, θ of the fibre misalignment is measured onto the variable, L by using micrometer with the theory of trigonometry from edge to edge of the specimen which shown in the Figures 2 and 3. Equation of the trimmed length, $x = X\tan^{-1}(\theta)$.Variable L is the deduction of panel thickness X(mm) to trimmed length, x(mm). Final calculation of trimmed length and length of specimen after trimming are shown in Table 3 and Table 4.

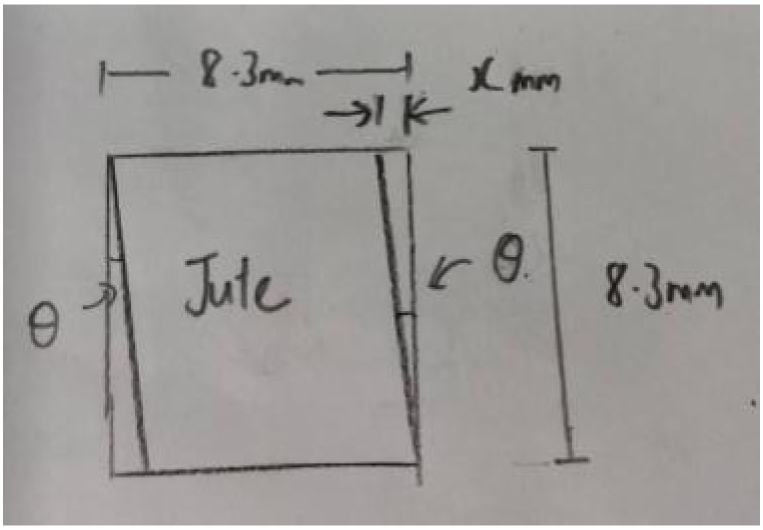


Figure 3 Jute specimen measurement and variables

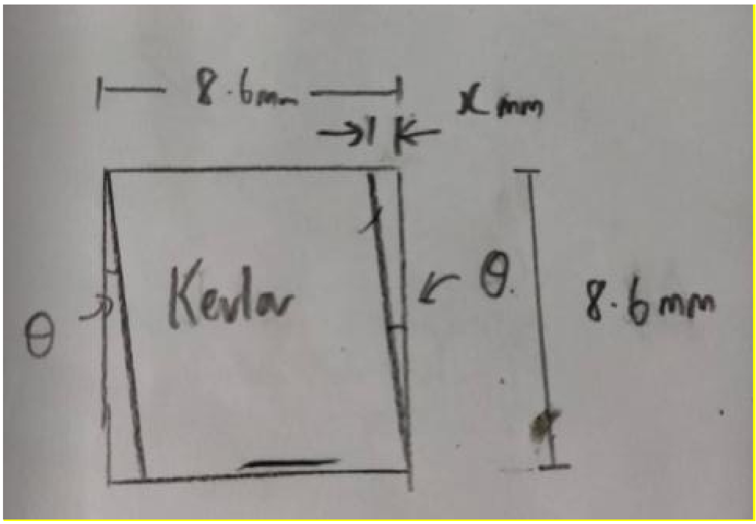


Figure 4 Kevlar specimen measurement and variables

Table 3 Measured length of jute specimen with different misalignment angle.

θ (°)	x (mm)	X (mm)	L (mm)
0	0.0	8.30	8.30
1	0.15	8.30	8.15
2	0.29	8.30	8.01
3	0.44	8.30	7.86
4	0.58	8.30	7.72

Table 4 Measured length of kevlar specimen with different misalignment angle.

θ (°)	x (mm)	X (mm)	L (mm)
0	0.00	8.60	8.60
1	0.15	8.60	8.45
2	0.30	8.60	8.30
3	0.45	8.60	8.15
4	0.60	8.60	8.00

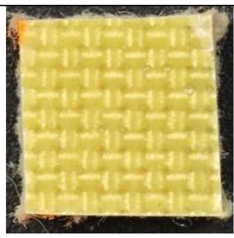
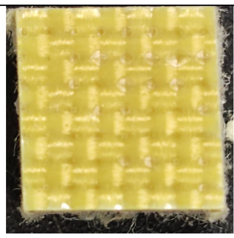
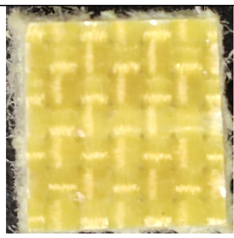
3.3 Jute specimen cutting

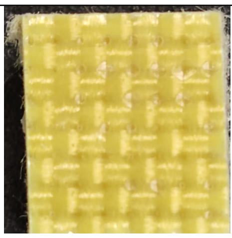
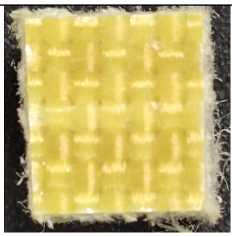
The jute panel is cut into cubes using a circular bench saw, then metallurgical cutting machine is used to cut the specimen from bar shape further into a cubic shape of about 9 mm. Thinning of the specimen's surface into required dimensions is done by the grinding method.

3.4 Kevlar specimen cutting

The kevlar panel is cut into a square shape separately using a hydraulic shearing machine before being cut into cube size. The specimens are then further cut using a metallurgical cutting machine from a square shape into a cubic shape with a thickness of about 9 mm. The specimen is then further thinned using a grinding technique in order to fulfil the required dimensions. Table 3.2 shows the specimens which are ready to be tested.

Table 3.3 Specimens' macroscopic image with different fiber misalignment angle

Fiber type / Fiber misalignment angle (°)	Jute Specimen	Kevlar specimen
0		
1		
2		

3		
4		

3.5 Mechanical testing

Impact loading is done by using SHPB with 3 loading rates of 1.0 bar, 1.25 bar, and 1.5 bar. In the direction of fill orientation, a specimen is placed between the incident and transmitted bars. Vaseline is applied to the two collided surfaces to keep the specimen from slipping between the bars. Both jute and kevlar composite specimens with 5 fibre misalignment angles are done thrice. Then graphs and data are extracted from the software. For every parameter 3rd impact loading test, HSC is used to record the slow motion of the impact test, reviewing the failure mechanism of each different parameter.

With UTM, static loading is carried out at about 8 mm/s, which is based on each specimen thickness. The specimen is also positioned in the direction of fill orientation before being pressed.

3.6 Microscopic and macroscopic

The damage behaviour of kenaf and jute composites was then determined using microscopic scale under a Hitachi S-3700 scanning electron microscope (HSC) with the most damaged part, to discover various post-compression failures with a resolution of up to 500m. Macroscopic photographs of the whole damaged specimens were taken using a phone camera.

CHAPTER 4
RESULTS AND DISCUSSIONS

4.1 Results & Discussions

4.1.1 Impact loading

4.1.1(a) SHPB

The impact loading test were done by using SHPB. Each parameter was tested three times, but the dataset with the smoothest and least fluctuating values is chosen and compared to other parameters. The stress readings are in unit of mega pascal (MPa). Comparison of stress-strain curves using jute and kevlar specimens with five distinct fibre misalignment angles, which are 0°, 1°, 2°, 3°, and 4° under constant pressure bar, 1.0 bar, 1.25 bar, and 1.5 bar consecutively, is shown below.

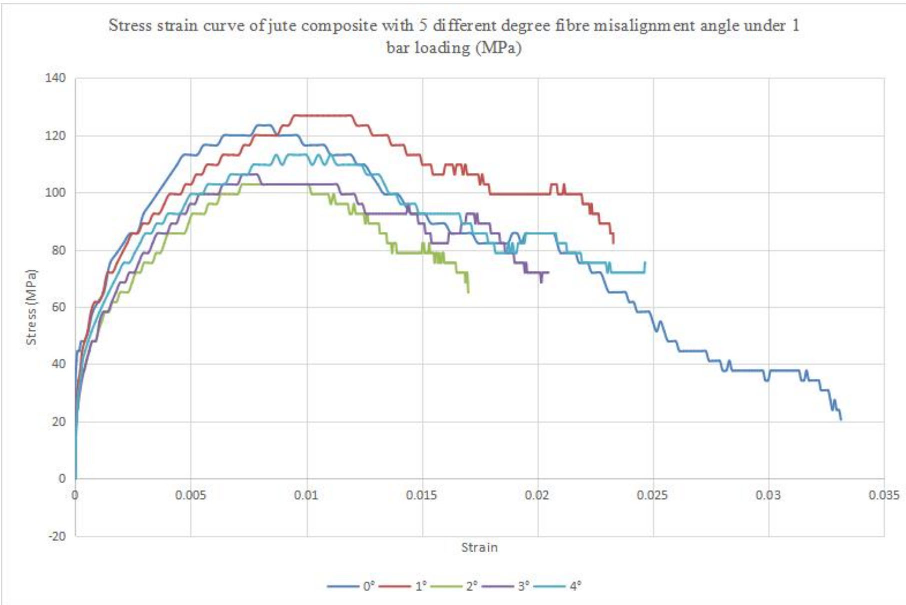


Figure 5 Stress-strain curves of jute composite with 5 different fiber misalignment angles under 1.0 bar loading

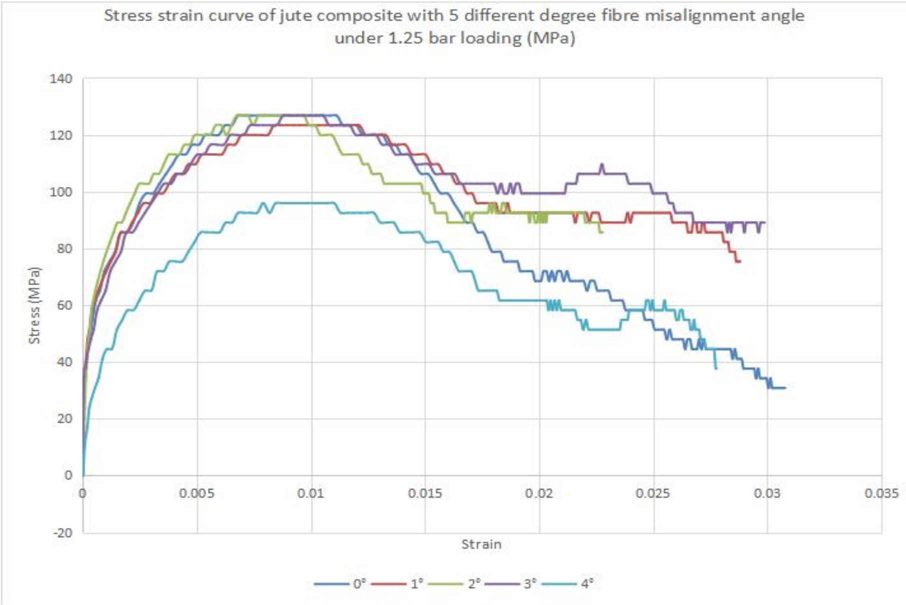


Figure 6 Stress-strain curves of jute composite with 5 different fiber misalignment angles under 1.25 bar loading

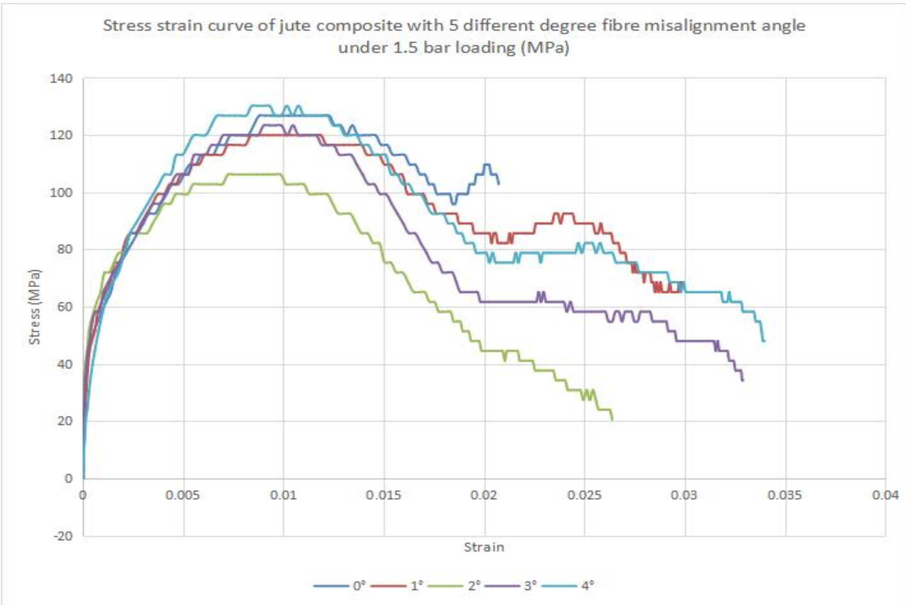


Figure 7 Stress-strain curves of jute composite with 5 different fiber misalignment angles under 1.5 bar loading

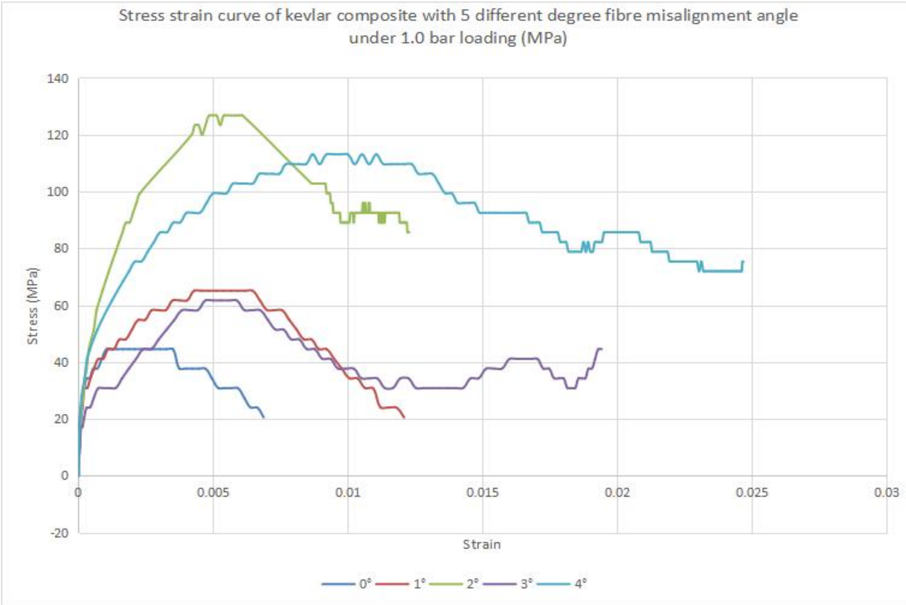


Figure 8 Stress-strain curves of kevlar composite with 5 different fiber misalignment angles under 1.0 bar loading

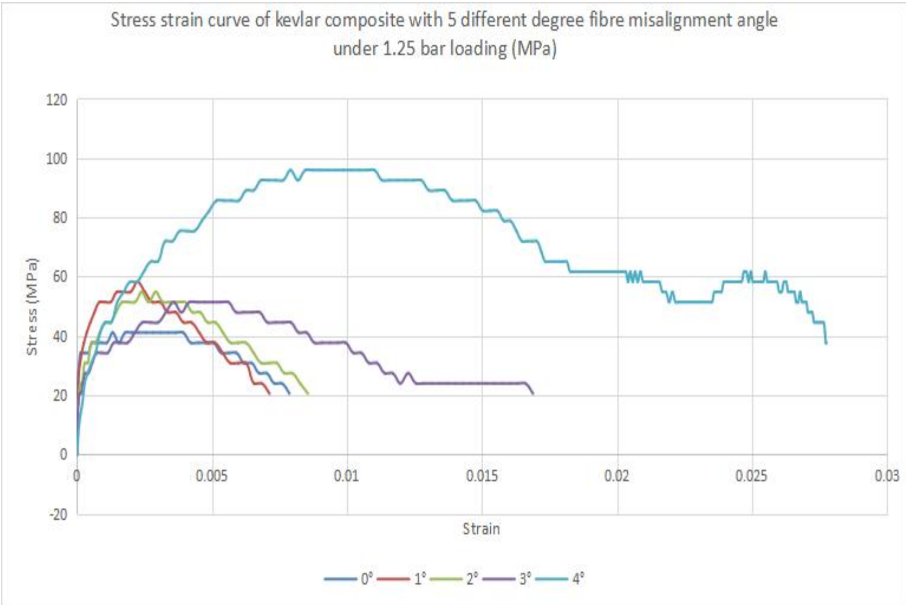


Figure 9 Stress-strain curves of kevlar composite with 5 different fiber misalignment angles under 1.25 bar loading

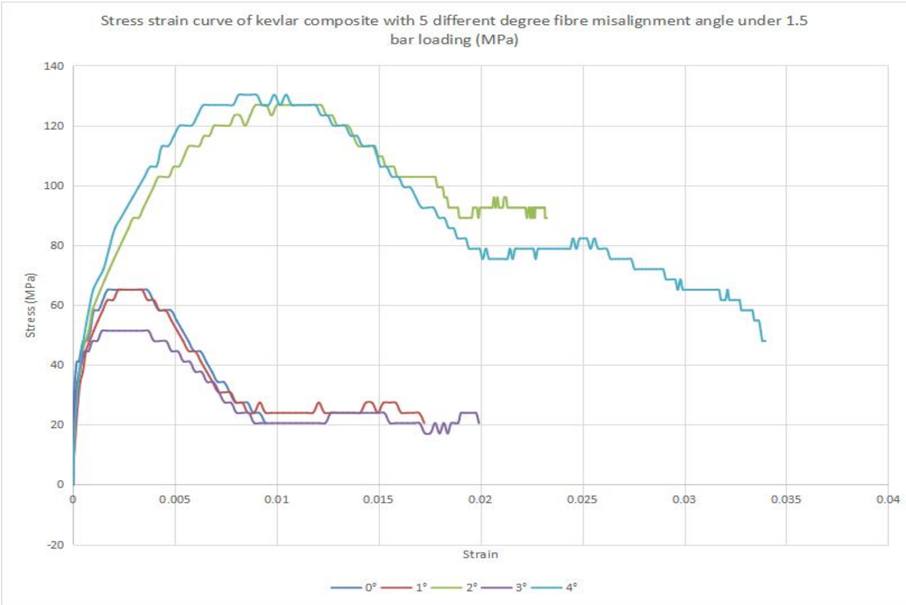


Figure 10 Stress-strain curves of kevlar composite with 5 different fiber misalignment angles under 1.5 bar loading

The comparison of stress-strain curves between jute and kevlar specimens, where fibre misalignment is compared under constant pressure bar, 1.0 bar, 1.25 bar, and 1.5 bar consecutively, are shown below. The dataset with the smoothest and least fluctuating values is chosen and compared to other parameters. The stress readings are in units of megapascal (MPa).

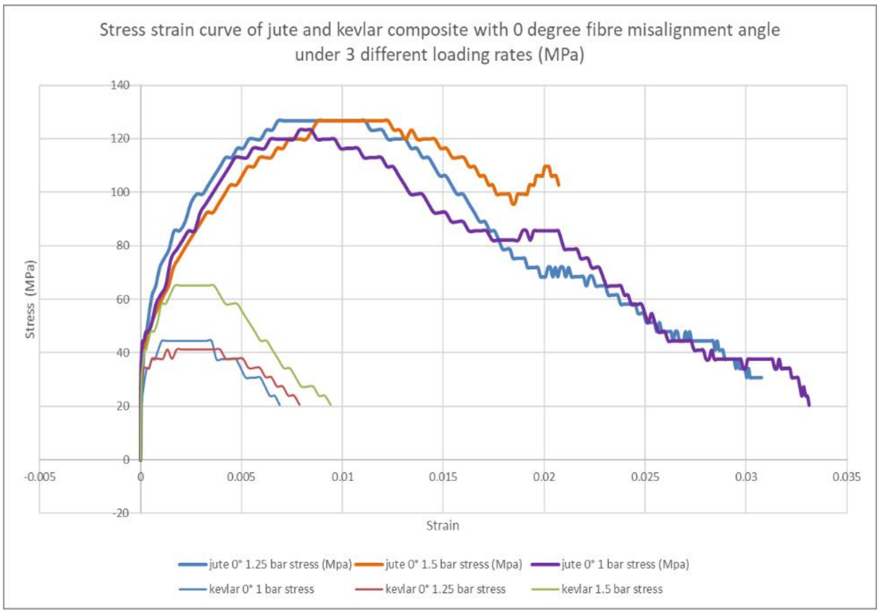


Figure 11 Stress-strain curves of composite at 0° fiber misalignment.

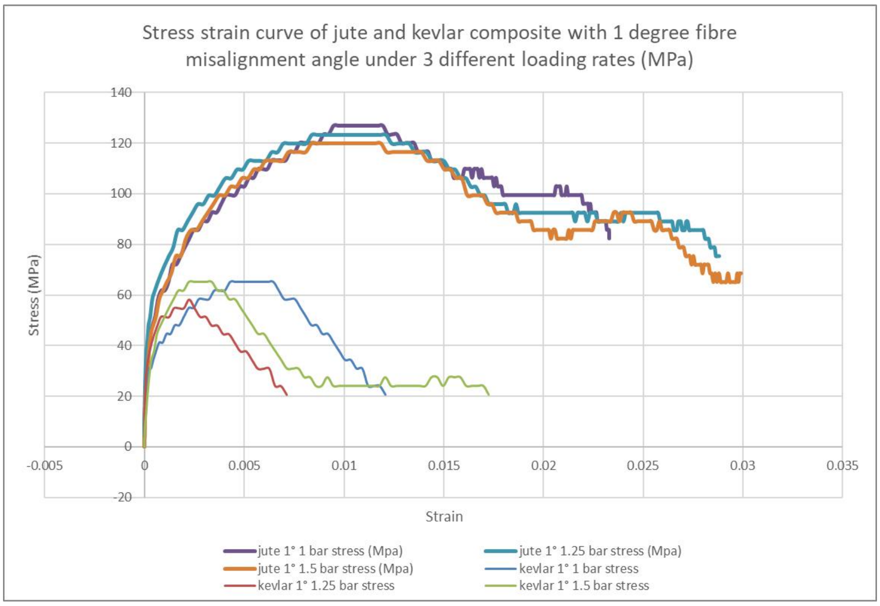


Figure 12 Stress-strain curves of composite at 1° fiber misalignment

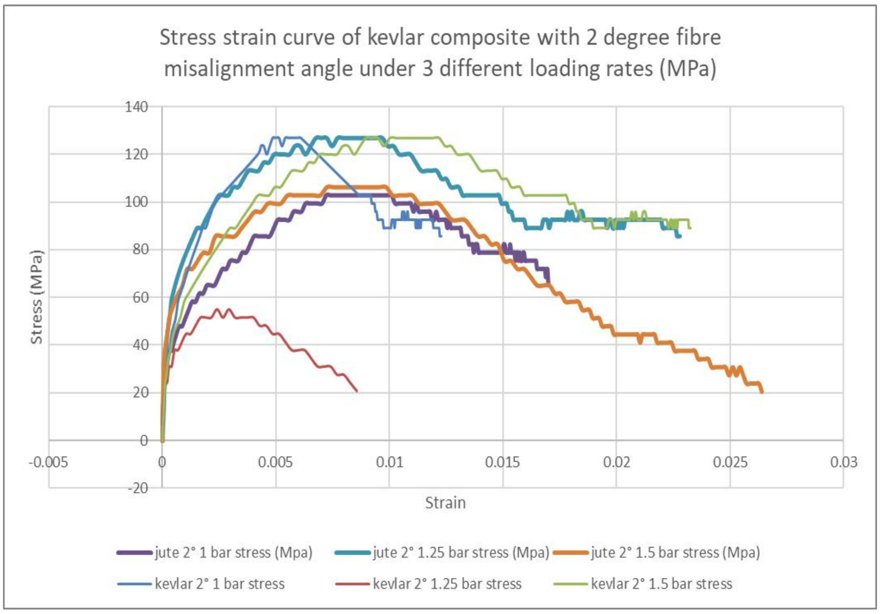


Figure 13 Stress-strain curves of composite at 2° fiber misalignment

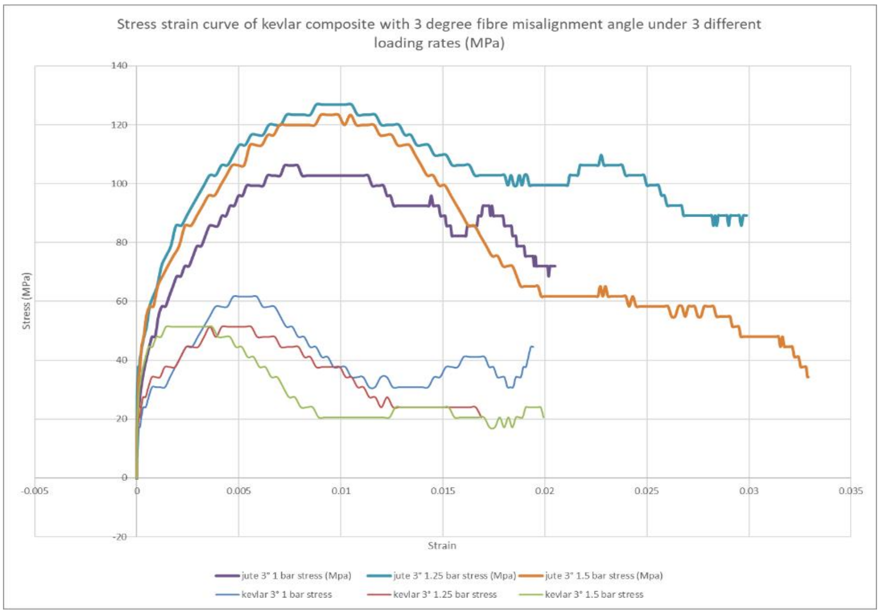


Figure 14 Stress-strain curves of composite at 3° fiber misalignment

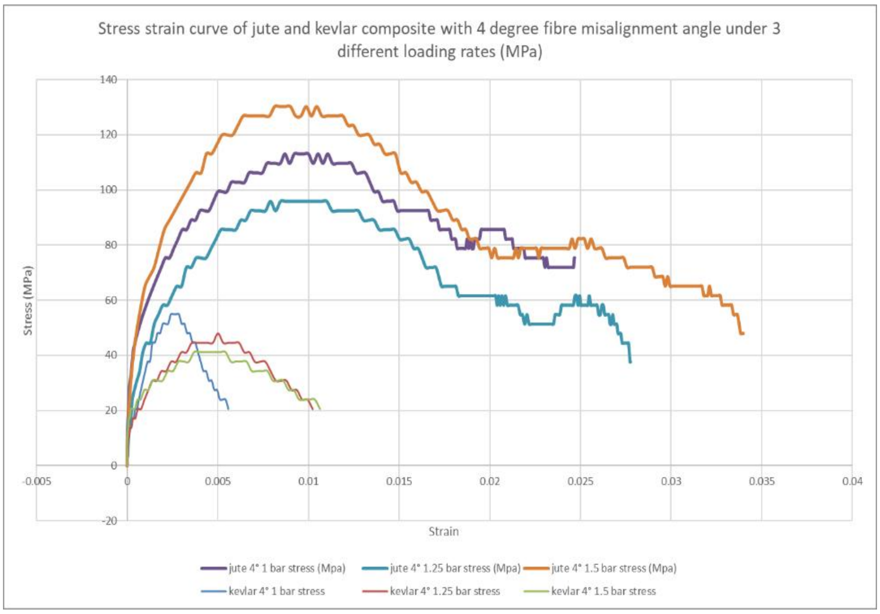


Figure 15 Stress-strain curves of composite at 4° fiber misalignment

From Figure 4 until Figure 10, different fiber misalignment angle does not affect the basic shapes of stress strain curves for both jute and kevlar. Shapes of stress strain curve presented by composites shows plastic properties. The elastic region and the plastic region, which are shown as two distinct regions for each specimen, are plainly visible. As jute epoxy materials demonstrate their capacity for extensive plastic deformation before breakage, jute/epoxy composite and kevlar/epoxy composite demonstrate unmistakably that are a typical ductile material.

Figure 10 until Figure 14 prove that jute composite has larger maximum failure stress and greater failure strain in general. Kevlar should have better failure stress and failure strain as much research proven [2-12,18], that jute has only 393-

773MPa in tensile strength, however Kevlar has 3260MPa tensile strength. Poor failure strength in kevlar specimen during testing is mostly due to voids which shown in Figure 15, which frequently exist in kevlar panels.

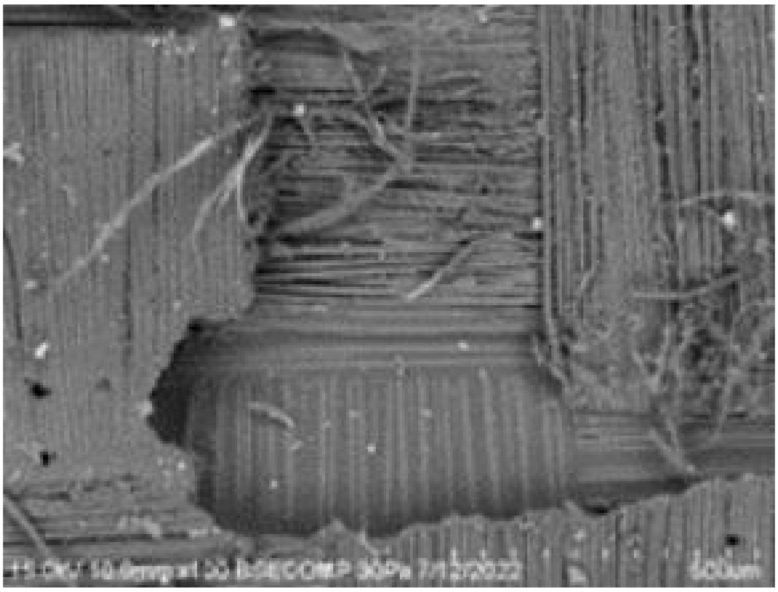


Figure 16 : Voids of kevlar under SEM

Table 4.1 Compressive failure stress and failure strain of jute/epoxy under impact loading

Fibre misalignment angle (°)	Jute Composite					
	1.0 bar		1.25 bar		1.5 bar	
	Failure stress (MPa)	Failure strain	Failure stress (MPa)	Failure strain	Failure stress (MPa)	Failure strain
0	123.357946	0.008172159	127.012013	0.006529662	126.756487	0.012272391
1	126.784728	0.009479284	124.567046	0.008390865	119.93095	0.008382868
2	102.796826	0.007219504	127.700728	0.006757741	106.126683	0.007240804
3	106.223608	0.007234901	124.138455	0.00878776	123.394437	0.009020558
4	113.077386	0.008702271	95.943048	0.007911272	130.21151	0.008138419

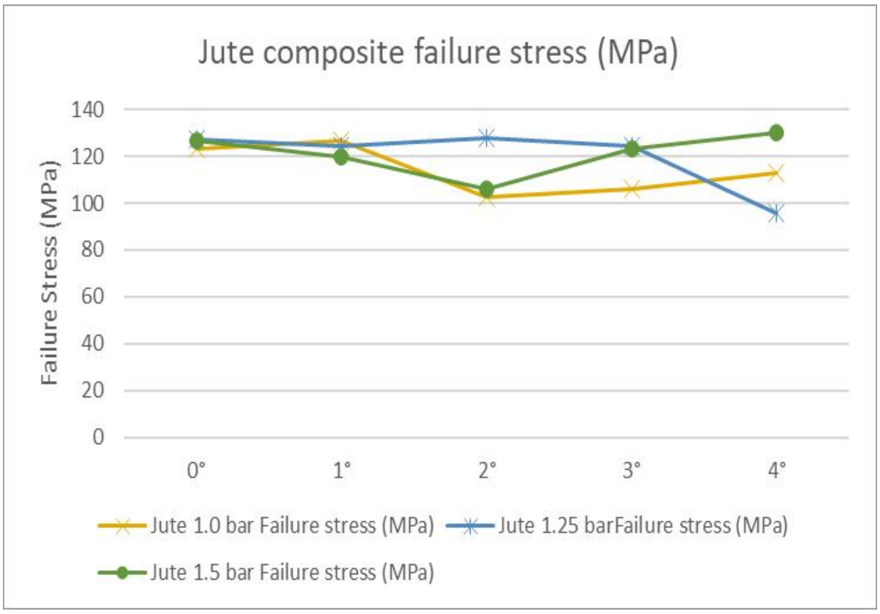


Figure 17 Jute/epoxy composite failure stress under impact loading (MPa).

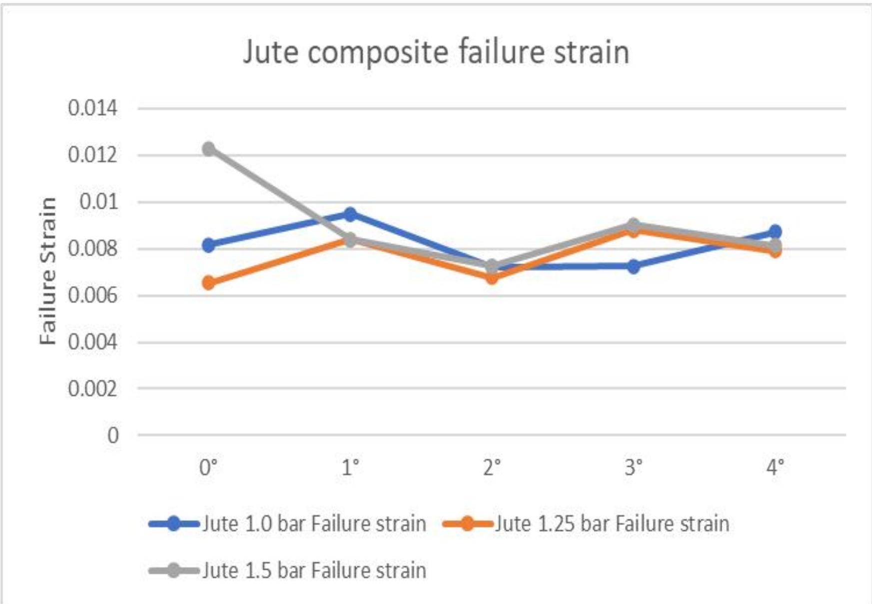


Figure 18 Jute/epoxy composite failure strain under impact loading

From Table 4.1 and Figure 16,17, jute composite show criteria with gradually decrease in maximum failure stress from 0° to 4° in 1 bar and 1.25 bar SHPB testing, with 8.1% and 24.3% respectively. However, small increment of 2.1% during 1.5 bar impact testing. In average, reduction with 10.1% of failure stress onto jute specimen as fiber misalignment increases. Besides, as fiber misalignment of jute specimen vary, the higher fluctuation phenomenon in failure stress occurs. At the same time, jute composite also shows an overall decrement of 2.1% of failure strain as fiber misalignment increase from Figure 16,17 and Table 4.1.