Development of Low Velocity Bullet Proof Vest for Cops Using Glass Fabric

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Abstract:
Bulletproof vest is a vest which can protect wearer's body from the impact of bullet. Soft vests are made of many layers of woven are laminated fibers and can protect the wearer from small caliber, hand gun and shot gun projectiles.Fiber reinforced composite materials have become important engineering materials used such as marine bodies, air craft structures and light weight body armor for ballistic protection in military applications. Composite body armor is an item or piece of clothing that is designed to protect the wearer against a variety of attacks. The most useful properties of composites are high specific strength and specific stiffness, good corrosion resistance and good fatigue resistance. Advanced composite materials, typically consisting of reinforced fibers in a resin matrix.So that we have construct the composite using glass and sisal with resin matrix.

Keywords: armor, resin matrix, caliber, ballistic, composite

Introduction

Glass Fabric is an ideal material to be used in the bullet proof vest as compared to other materials. Ballistic impacts are generated by 9mm Parabellum ammunition. The objective is to access the characteristics of high speed ballistic penetration into a combination of a glass fabric and resin with the capabilities of glass of different and multiple layers.

LITERATURE REVIEW

GLASSFABRIC

The S-glass fabric is a type of fiber reinforced plastic. The glass fiber is also called as "glass reinforced plastic". The plastic matrix may be a thermoset polymer matrix most often based on thermosetting polymer such as Epoxy, polyester, resin or thermoplastic. The glass fabric is strong light weight material and is used for many products. Its bulk strength and weight are also better than many metals and it can be molded into complex shape [4].

The S-glass fabric has outstanding ballistic protection and structural performance for hardcomposite armor application due to high inherent tensile and compressive strength of the fiber and its composite applications. The structural performance against the fire, smoke and toxicity reduced cost and weight. When compare to E-glass, S-glass provides about 40% higher tensile and flexural strength about 10% to 20% higher compressive strength and flexural modulus and greater abrasion resistance. The glass fiber has excellent heat resistance at relatively low cost. Glass fabric retains approximately 50% of room temperature tensile strength at 700oF (371oC) and a melting point of 2075oF (1121oc).

DIFFERENT TYPES OF GLASS

The glass fibers are classified into different types. They are,

- A-glass
- AR-glass
- C-glass
- D-glass
- E-glass
- ECR-glass
- R-glass
- S-glass
- S-2 glass

A-glass

Alkali glass made with soda lime silicate used where electrical resistivity of E-glass is not needed. A-glass or soda lime glass is the predominate glass used for containers and windowpanes.

AR-glass

Alkali resistant glass made with zirconium silicate used in Portland cement substrates

C-glass

Corrosive resistant glass made with calcium borosilicate's used in acid corrosive environments.

D-glass

Low dielectric constant glass made with borosilicate's used in electrical application.

E-glass

Alkali free highly electrically resistive glass made with alumina- calcium borosilicate. E-glass is known in the industry as a general purpose fiber for its strength and electrical resistance. It is most commonly used fiber in the fiber reinforced polymer composite industry [5].

ECR-glass

An E-glass with higher acid corrosive resistance made with calcium aluminosilicates used where strength electrical conductivity and acid corrosion resistance is needed.

R-glass

A reinforcement glass made with calcium aluminosilicates used where higher strength and acid corrosion resistance is needed.

S-glass

Higher strength glass made with magnesium aluminosilicates used where high strength, high stiffness, extreme temperature resistance, and corrosive resistance is needed.

S-2 glass

Glass similar with S-glass, and the properties are improved is called as S-2 glass.

PROPERTIES OF GLASS

The properties of glass fabric are

1. Incombustibility.
2. Corrosive resistance.
3. High strength at low densities.

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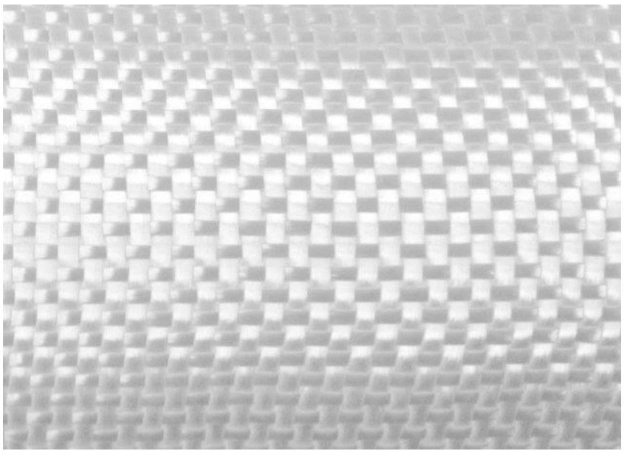
4. Good thermal resistant.
5. Sound insulation.
6. Special electrical properties.

APPLICATIONS OF GLASS FIBER

The applications of glass fibers are

1. Aircraft and aerospace
2. Appliances and equipment's
3. Constructions works
4. Corrosion resistant product
5. Electrical rods, tubes and components
6. Marin and Marin accessories
7. Miscellaneous (protective gears, framing, industrial tools S-glass
8. Higher strength glass made with magnesium aluminosilicates used where high strength, high stiffness, extreme temperature resistance, and corrosive resistance is needed.
9. S-glass ("S" for "Strength") is used when high tensile strength (modulus) is important, and is thus an important building and aircraft epoxy composite.
10. S-glass feels exactly the same to the touch as E glass but it is about 30% stronger.
11. The S-glass has typical nominal composition of Sio2 65wt%, Al2o3 25wt%, MgO 10wt%.
12. The S-glass provides about 40% higher tensile and flexural strength, about 10 to 20% higher compressive strength and flexural modulus and greater abrasion resistance [5].
13. S-Glass is generally used for polymer matrix composites that require improved mechanical properties compared to E-glass based composites. This is often the case when the material is operated under more extreme conditions.



Comparison of materials

Materials	Density (g/cm^3)	Tensile Strength (MPa)	Young modulus (GPa)
E-Glass	2.55	2000	80
S-Glass	2.49	4750	89
Alumina	3.28	1950	297
Carbon	2.00	2900	525

Kevlar 29	1.44	2860	64
Kevlar 49	1.44	3750	136

SISAL FABRIC

Sisal fiber is one of the most widely used natural fiber and is very easily cultivated. These plants produce rosettes of sword-shaped leaves. In general, a sisal plant will produce 200 to 300 commercially usable leaves in its life-time and each leaf contains an average of around 1000 fibers.

Each leaves contains a number of long, strength fibers which can be removed in a process known as decortication. During decortication the leaves are beaten to remove the pulp and plant materials, leaving the tough fiber behind.

The fibers can be spun into thread for twine and textile production, or pulped to make paper products. About 10g of dried fibers having an approximate length of 50mm is taken for the water absorption examination [4].

Conclusion

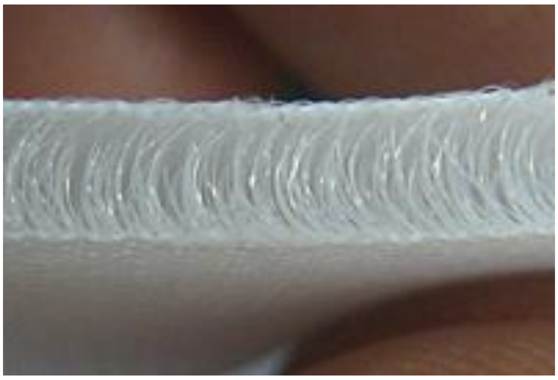
In this study the herbal extracts recommended have been applied to the cotton fabric by dip and dye process. Herbs have been used for foods and medicinal purpose for centuries various herbs that poses many properties that may be useful in helping reduce the risk of skin diseases.Textile materials.

SPACER FABRIC

Spacer fabric are 3D fabric that comprise of two outer textile substrates that are joined together and kept apart by an insert of spacer yarns, mostly monofilaments. This creates a ventilated layer of air, allowing heat and moisture to escape.

The spacer **fabric** in standard width of 1.4 m - 1.7 m.This fabric is available in heights from 1mm to 10mm and with different elasticity. Air permeability and thermal conductivity of spacer fabric are closely related to the fabric density [2].

The thermal–mechanical properties determined by TMA revealed that the optimal molding conditions and compressive strain of molded spacer fabrics are closely related to the material used as spacer yarn, the density of spacer yarn, and the elongation and recovery of the spacer fabric. Air permeability and thermal conductivity of spacer fabric are closely related to the fabric density.



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CHARACTERISTICS OF SPACER FABRIC

- Dimensional stability
- Conformability
- Mold ability
- Withstand multi-directional mechanical stress

2.3.2. APPLICATIONS OF SPACER FABRIC

- Automotive engineering
- Home textile
- Cycle helmets
- Boot soles
- Composites
- Medical products
- Neoprene replacement
- Fire men’s clothing
- Seating
- Ballistic and various industrial uses.

2.3.3. ADVANTAGE OF SPACER FABRIC

- Lightweight,
- Hypoallergenic,
- Natural protection against mold,
- The antibacterial properties,
- Breathable,
- Easy to clean,
- Easy decontamination,
- Wide range of hardness and elasticity,
- Easy to recycle,
- Very durable,
- Resistant to crushing

2.3.4. PHYSICAL PROPERTIES OF SPACER FABRIC

- Excellent compression elasticity
- Breathability /air permeability
- Cushioning
- Insulation
- Good bending performance
- Drapabilty
- Adjustable vapor transport

2.4. TENSILE TEST (ASTM D-638)

The ability to resist breaking under tensile stress is one of the most important and widely measured properties of materials used in structural applications. The force per unit area (MPa or psi) required to break a material in such a manner is the ultimate tensile strength or tensile strength at break [9]. Tensile properties indicate how the material will react to forces being applied in tension. A tensile test is a fundamental mechanical test where a carefully prepared specimen is loaded in a very controlled manner while measuring the applied load and the elongation of the specimen over some distance. Tensile tests are used to determine the modulus of elasticity, elastic limit, elongation, proportional limit, and reduction in area, tensile strength, yield point, yield strength and other tensile properties

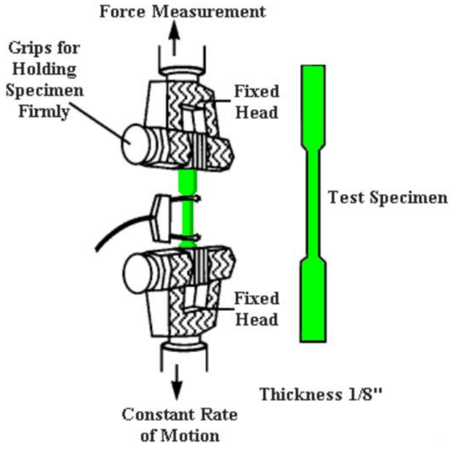


Fig no.2.4 Tensile teste

FLEXURAL STRENGTH (ASTM D-790)

Flexural strength, also known as modulus of rupture, bend strength, or fracture strength a mechanical parameter for brittle material, is defined as a material'sability to resist deformation under load.

The transverse bending test is most frequently employed, in which a rod specimen having either a circular or rectangular cross section is bent until fracture using a three point flexural test technique. The flexural strength represents the highest stress experienced within the material at its moment of rupture. It is measured in terms of stress, here given the symbol .

When an object formed of a single material, like a wooden beam or a steel rod, is bending, it experiences a range of stresses across its depth. At the edge of the object on the inside of the bend (concave face) the stress will be at its maximum compressive stress value. At the outside of the bend (convex face) the stress will be at its maximum tensile value [5].

These inner and outer edges of the beam or rod are known as the 'extreme fibers'. Most materials fail under tensile stress before they fail under compressive stress, so the maximum tensile stress value that can be sustained before the beam or rod fails is its flexural strength.

CHAPTER - 3

3.METHODOLOGY:

Sourcing of materials
Preparation of composite
Development of vest
Testing properties
Analyze the impact resistance
Costing of product
Result and discussion
Fig 3.1 Flow Chart for methodology

3.1. Sourcing of materials:

There are many materials which are used in ballistic protection. But the materials which we are using are slightly different from normal materials; we have selected the fabrics based on their end uses, characteristics, and objectives. The material which we are using is

- S glass fabric
- Sisal
- Spacer fabric

3.1.1. S-Glass:

- S-glass, magnesium alumino silicate glasses used for textile substrates.
- Mainly for reinforcement in composite structural applications.
- It has high strength, Modulus and stability under extreme temperature and corrosive environments.

3.1.2. Sisal fabric:

- It is grouped under the broad heading of the “hard fibres”.
- Among which sisal is placed second to manila in durability and strength .
- Due to the low density and high specific properties of sisal fibres, composites based on these fibres

may have very good implications in the automotive and transportation industry

3.1.3. Spacer fabric:

- It has excellent compression elasticity
- Breathability
- Cushioning
- Insulation
- Good bending performance
- Recyclable.

3.1.4. Chemicals used:

To bind the fabrics and to make composite more effective we have used some chemicals such as

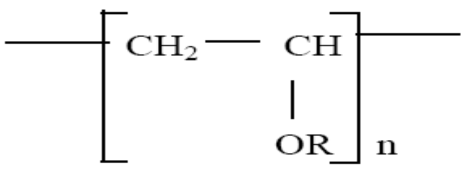
- Isophthalic resin.
- Poly vinyl alcohol

3.1.5. Isophthalic resin:

Unsaturated resin such as polyester resins, are thermo set, capable of being cured under the proper condition. There are two types of resin such as isophthalic and orthophthalic resin, in which isophthalic resin has higher formation of bond between s2glass and resin. It has 10%higher flexural and 20%higher tensile properties than orthophthalic resin; hence we chose isophthalic resin for making composites

3.1.6. Poly vinyl alcohol (PVA):

- Polyvinyl alcohol for food use is an odorless and tasteless, translucent, white cream colored granular powder.
- Typically a 5% solution of polyvinyl alcohol exhibits a pH in the range of 5.0 to 6.5.
- •Polyvinyl alcohol has a melting point of 180 to 190°C.
- •Molecular structure of PVA is



where R = H or $COCH_3$

3.2. Preparation of composite:

3.2.1 Composite

Composite are defined as any material containing two or more substances which significantly displays the properties of all constitute parts in order to create a whole with a better combination of properties [7].

Composite are made of two materials :

- The matrix, which is the main and continous material.

The dispersed phase, which is suspending with in the matrix and doesnot have to be continuous.

3.2.1.1 Types of composite

There are three main categories of composite materials

- Particle-reinforced composite
- Fiber- reinforced composite
- Structural composite

Particle –reinforced composite:

Particles-reinforced composite use small particles as the dispersed phase.

Fiber-reinforced composite:

Fiber-reinforced composite use fibers with large strength to weight ratios as the dispersed phase.Eg: composite containing carbon fibre or glass fiber in an epoxy resin.

Structural composite:

Structural composite are made up of layers of materials that have direction specific strength [7].

From all the above composites, here we are prepared the fiber-reinforced composite according to our requirement.

3.2.3 Moulding

Moulding is the process of manufacturing by shaping liquid or pliable raw material using a rigid frame called mold.

Types of moulding:

- Blow moulding
- Power metallurgy
- Compression moulding
- Extrusion moulding
- Injection moulding
- Laminating moulding

Here we are using compression moulding technique.

3.2.3 Compressive moulding

Compression is one of the well-known and one of the oldest technique tdevelop variety of composite products. It is a completely manual process in which pressure is applied. It is a closed moulding process and its applies a high pressure application.

The composite processing method performs forming, the product along with simultaneous curing [3].

Fig no.3.1 compressive moulding machine

- Steps involved during preparation of composite:
- The first process is to apply the (PVA) on the frame and the plates used for preparing composites.
- Then the isophthalic resin is applied on the plate and 4layers of glass is placed in an alternate manner as resin and s2 glass fabric.
- After the 4 layers of glass, 4sisal and 3glass fabrics are placed alternatively by isophthalic to create a strong bond between them, and to make a composite stronger.
- Then at an end again 4 layers of glass are placed by using polyester resin.
- Then the mold is left under the compression machine to extract the excess resin and to make the composite size to reduce.
- Then the mold is kept in sunlight to make it stronger.


3.3. Development of vest:

Development of vest comprises of three processes such as

- Cutting the panels
- Sewing the panels
- Finishing the vest.

3.3.1. Cutting the panels:

- The fabric is first unrolled onto a cutting table that must be long enough to allow several panels to be cut out at a time; sometimes it can be as long as 32.79 yards (30 meters).
- As many layers of the material as needed (as few as eight layers, or as many as 25, depending on the level of protection desired) are laid out on the cutting table.
- A cut sheet, similar to pattern pieces used for home sewing, is then placed on the layers of cloth.
- For maximum use of the material, some manufacturers use computer graphics systems to determine the optimal placement of the cut sheets.
- Using a hand-held machine that performs like a jigsaw except that instead of a cutting wire it has a 5.91-inch (15-centimeter) cutting wheel similar to that on the
- End of a pizza cutter, a worker cuts around the cut sheets to form panels, which are then placed in precise stacks.

3.3.2. Sewing the panels:

- To sew the layers together, workers place a stencil on top of the layers and rub chalk on the exposed areas of the panel, after the cloth is made, it must be cut into the proper pattern pieces.
- These pieces are then sewn together with accessories (such as straps) to form the finished vest.
- Marking a dotted line on the cloth.
- A sewer then stitches the layers together, following the pattern made by the chalk.
- Next, a size label is sewn onto the panel.

3.3.3. Finishing the vest:

- The shells for the panels are sewn together in the same factory using standard industrial sewing machines and standard sewing practices.

The panels are then slipped inside the shells, and the accessories—such as the straps—are sewn on.

Fig. 3.3 Finished vest

3.4. Testing properties:

- The mechanical testing of composite structures to obtain parameters such as strength and stiff less is a time consuming and often difficult process.
- It is, however, an essential process, and can be somewhat simplified by the testing of simple structures, such as flat coupons.
- The data obtained from these tests can then be directly related with varying degrees of simplicity and accuracy to any structural shape.
- flexural strength
- Short beam shear strength.
- compression strength
- Tensile strength.

Table no.3.1 Test methods and ASTM specification [8]

TEST	SPECIFICATION NO
Tensile strength	ASTM-D638[5]

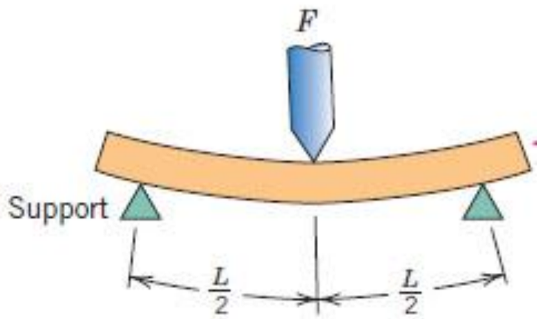
Flexural strength	ASTM-D790[7]
Compressive strength	ASTM-D695[6]
Short beam shear strength	ASTM-D2344[8]

3.4.1. Flexural strength:

- Composite material is a material consisting of two or more physically and (or) chemically distinct phase, suitably arranged or distributed.
- A composite material usually has characteristics that are not depicted by any of its components in isolation.
- The flexure test method measures behavior of materials subjected to simple beam loading.
- It is also called a transverse beam test with some materials.
- Maximum fiber stress and maximum strain are calculated for increments of load.
- Results are plotted in a stress-strain diagram. Flexural strength is defined as the maximum stress in the outermost fiber .
- This is calculated at the surface of the specimen on the convex or tension side.
- Flexural modulus is calculated from the slope of the stress vs. deflection curve. If the curve has no linear region, a secant line is fitted to the curve to determine slope.
- The 3-point flexure test is the most common for polymers. Specimen
- Deflection is usually measured by the crosshead position.
- Test results include flexural strength and flexural modulus [6].
- Flexural strength can be obtained from the following formula:
- Where,

$$\sigma = F \times S = \frac{3PS}{2bt^2}$$

σ = flexural strength (N/m2)
P = maximum test load (N)
S = dimension between load points (mm)
b = sample width (mm)
t = sample thickness (mm)



3.4.2. Short beam shear test:

- Test specimens were placed on the two 3.0 mm diameter supports, with care taken to align the center of the specimen in the center of the span.
- Loading supports were free to rotate, allowing free lateral motion of the specimen.
- Load was applied in the center of the specimen at the rate described above through the use of a 6.0 mm diameter steel dowel.
- The beam was loaded until fracture, and the fracture load was taken as a measure of the apparent shear strength of the material.
- Displacement was measured from the relative movement of the loading head through the use of the integrated MTS linear displacement gauge [6].

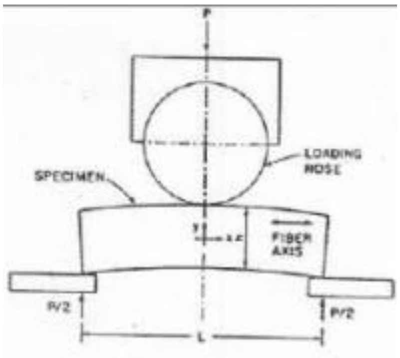


Fig.no.3.5 Short beam shear tester

Displacement and load data were automatically logged by computer through the use of the MTS Test Star software package.
A predicted load-displacement curve was observed for each specimen.
As load was applied, a linear deflection response was observed until a maximum load was achieved.
At this point, the applied force drops dramatically indicating the specimen has failed.
This maximum load was taken as a measure of the apparent shear strength of each specimen.
Five specimens of each configuration were tested. Short beam shear strength was calculated for each specimen based on the formula

Fsbs = 0.75 X Pm / (b X h)
Where:
Fsbs = short-beam strength, MPa
Pm = maximum load observed during the test, N
b = measured specimen width, mm
h = measured specimen thickness, mm

3.4.3. Compressive Testing

The results tined are essentially dependent on the type of compression fixture used.
Also, the gauge length is conical, as if it is too long, the specimen will buckle and flex, resulting in premature failure.
If it is too short, then the proximity of the tabs will adversely affect the stress state, resulting in

artificially high values.
□The most widely used compressive test technique is the Celanese fixture, shown below.
□Cylindrical in design, a small specimen sits within a set of trapezoidal grips, encased in collars and an alignment shell.
The gauge length depends on the type of test material and varies between 12.7mm for longitudinal specimens and 6mm for transverse specimens. Again, it is a good idea to tab the specimens [9]

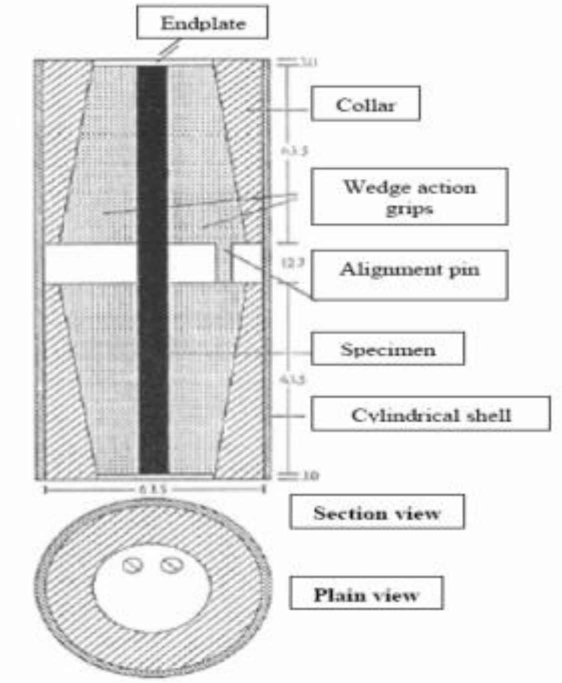


Fig no.3.6 Compressive tester

3.4.4. Tensile strength:

□Tensile testing utilizes the classical coupon test geometry as shown below and consists of two regions: a central region called the gauge length, within which failure is expected to occur, and the two end regions which are clamped into a grip mechanism connected to a test machine.
□These ends are usually tabbed with a material such as aluminum, to protect the specimen from being crushed by thegrips.
□This test specimen can be used for longitudinal, transverse, cross. Ply and angle- ply testing. It is a good idea to polish those specimen sides to remove surfaceflaws [9].

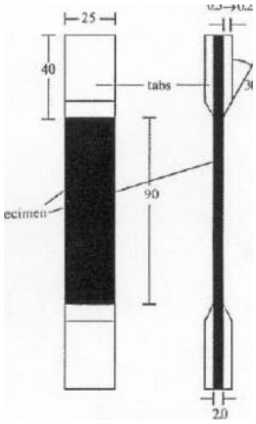


Fig no. 3.7Tensile test

3.4.4SEM analysis

SCANNING ELECTRON MICROSCOPE:

•A scanning electron microscope (SEM) is a type of electron microscope that produces images of a sample by scanning it with a focused beam of electrons.

• The morphological characterization of the composite surface is observed in scanning electron microscope of Model.

•The composite samples are cleaned properly; air dried.

• The fracture surface morphology of the composite specimens is observed by means of SEM [7].

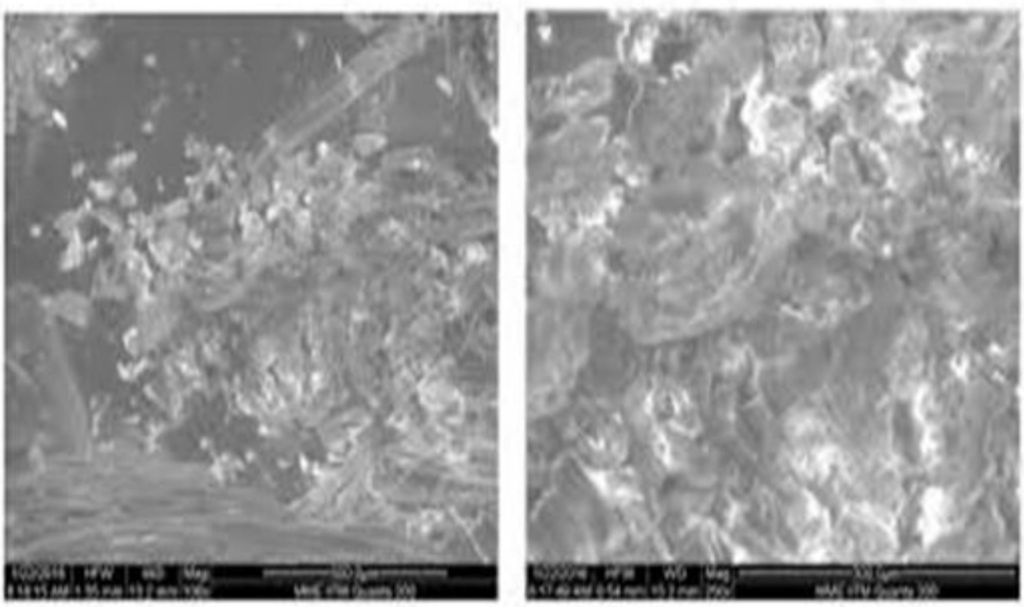


Fig no.3.8Internal structure of composite

3.6 COSTING

S.NO	MATERIAL	COST(in Rs)
1	Material sourcing	
	-Glass fabric	2450
	-Sisal fabric	1250
	-Spacer fabric	600
	-Grey fabric	195
	-Resin, catalyst.	7000
2	Mould preparation	1000
3	Composite preparation	500

4	Vest finishing	900
5	Testing	
	-Flexural test	518
	-Tensile test	1380
	-SEM test	1495
	TOTAL=	Rs.17288/-

NOTE:

The minimum cost of the bulletproof vest is about Rs.40,000. But we have developed our new ballistic vest of cost around Rs.17,300 approximately. By comparing the cost, we have obtained 52% of cost reduction for manufacturing.

CHAPTER-4

4. RESULTS AND DISCUSSION

This chapter deals with the physical and mechanical behavior of glass reinforced composite.
Physical and mechanical characteristics of composites
The existence of void content in the composites significantly reduces the mechanical and physical properties of the composites. Table shows the theoretical tensile strength, flexural strength and SEM analysis.
The difference in theoretical and experimental strength is mainly due to the presence of voids in the composite. Hence, it becomes essential to certain extent to determine the percentage of voids in the samples prepared. It can be seen that the void fraction in the composite increases with the woven glass mat loading. It is observed from the table that the strength of the composite significantly influenced by the woven mat loading.

Table no.4.1 Test results

NO	Begin Flexural-E-Modulus %Fmax	End flexural-E-Modulus %Fmax
1.1	10.00	40.00

CHAPTER-5

5. CONCLUSION:

In this study, the modeling and simulation of composite body armor that modeled from glass and sisal fabric with polyester resin were studied.

- It was found that 11 layers of glass and 3 layers of sisal with polyester resin (Isophthalic resin) can stand impact energy of * mm bullet type with a distance of meter with a muzzle velocity of m/s.
- The researched bullet resistant composite body armor weight of about 1kg, if back and front were to used at combat field it weight up to 2kg.
- The cost comparative study shows that for localization of body armor there is 52% cost reduction.

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APPENDIX-1

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PSGTECHS COE INDUTECH

Heading	: PSGTECHS COE INDUTECH	Tester	: BGL
Customer	: PRABHU	Machine data	: FLUXRAL TEAT
Test standard	: ASTM D790		

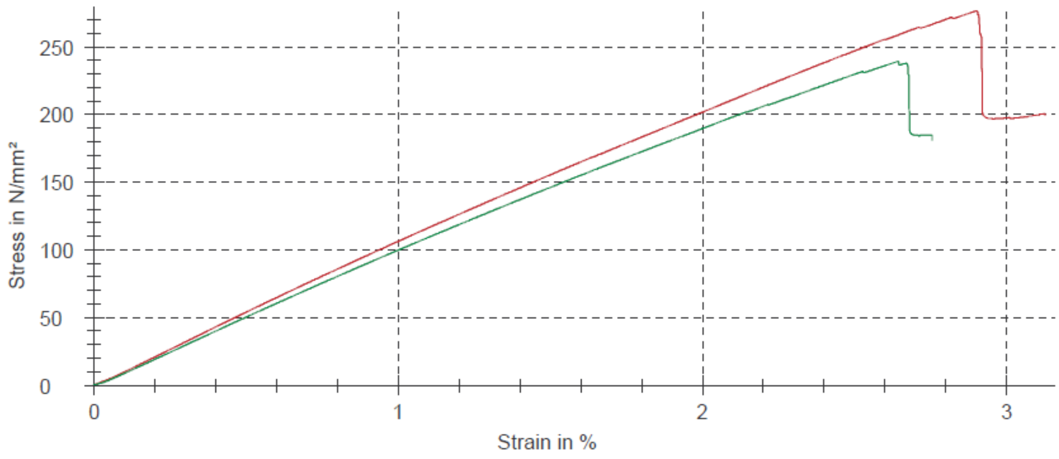
Pre-load : 1 kp/cm²
Test speed : 2.08 mm/min

Test results:

No.	Begin flexural-E-Modulus %Fmax	End flexural-E-Modulus %Fmax	Specimen ID	F_1 MPa	F_2 MPa	f_1 %	f_2 %	E_b MPa	P_{max} N
1.1	10.00	40.00	sample-1	27.7	110.7	0.26	1.04	10600	737
1.2			sample-2	23.9	95.7	0.25	0.96	10100	637

No.	σ_{bB} MPa	f_{Break} %	L_s mm	a mm	b mm
1.1	277	-	75	4.8	13
1.2	239	-	75	4.8	13

Series graph:



APPENDIX-2

Zwick Roell

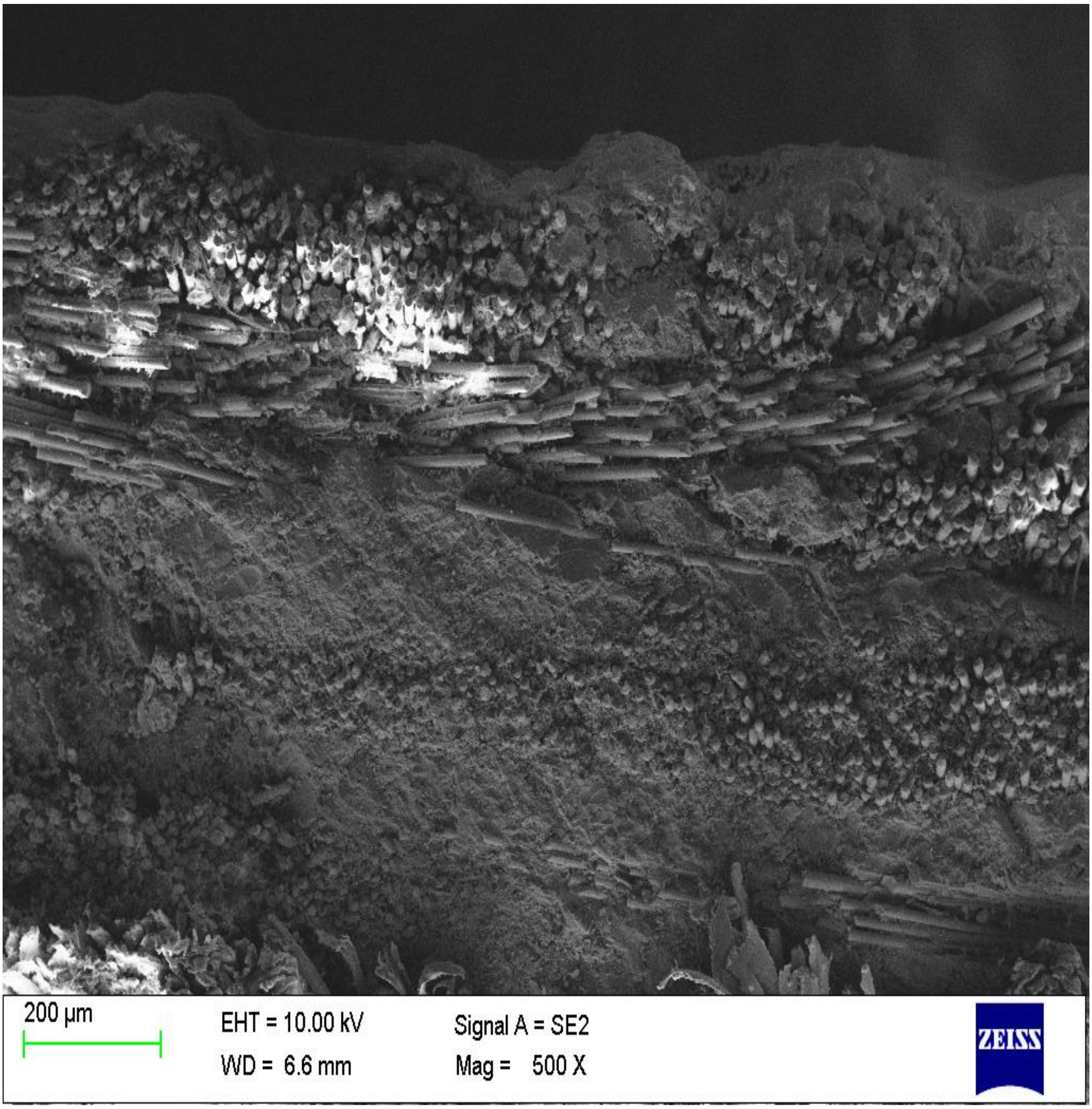
05.04.17

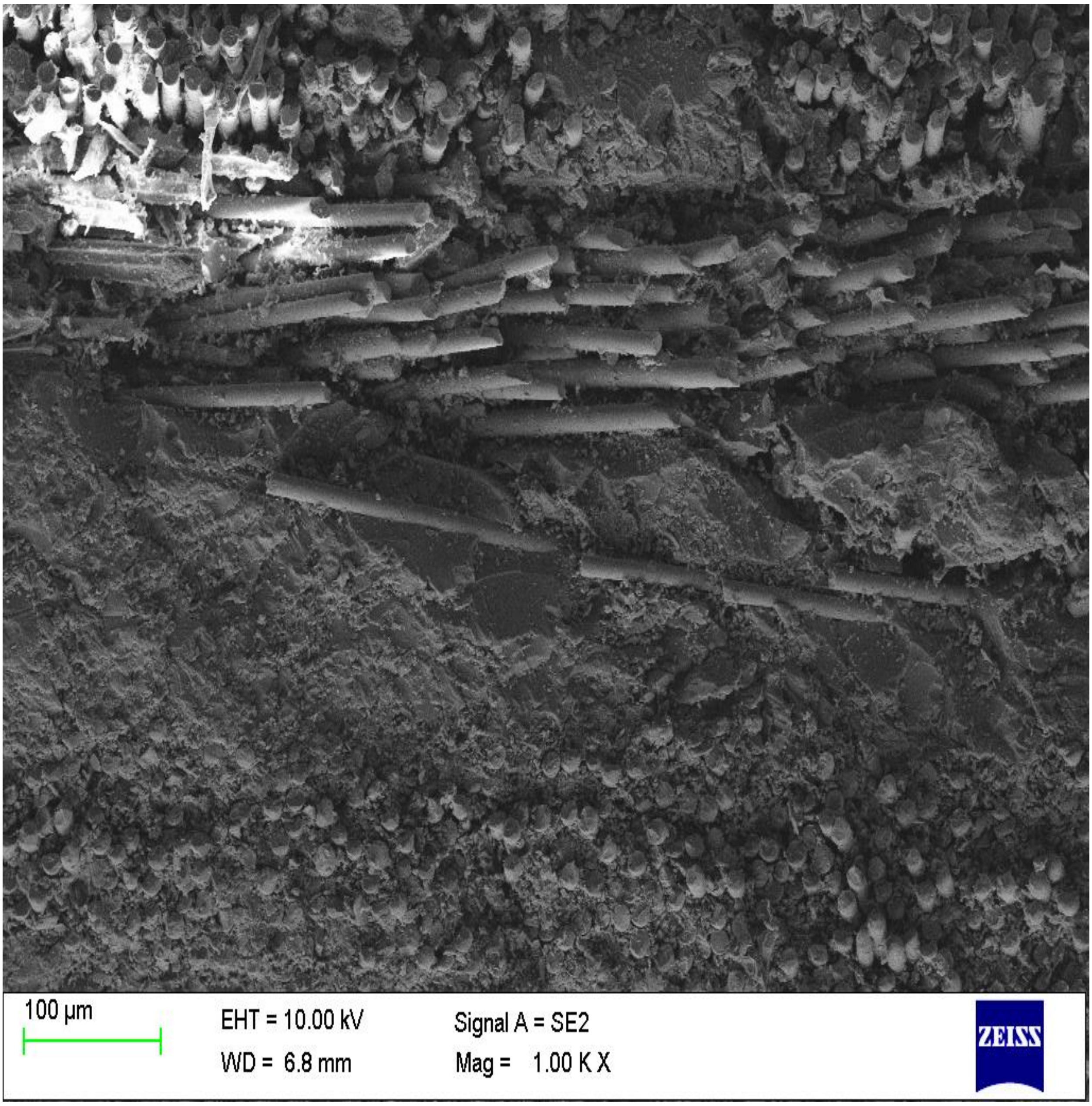
Statistics:

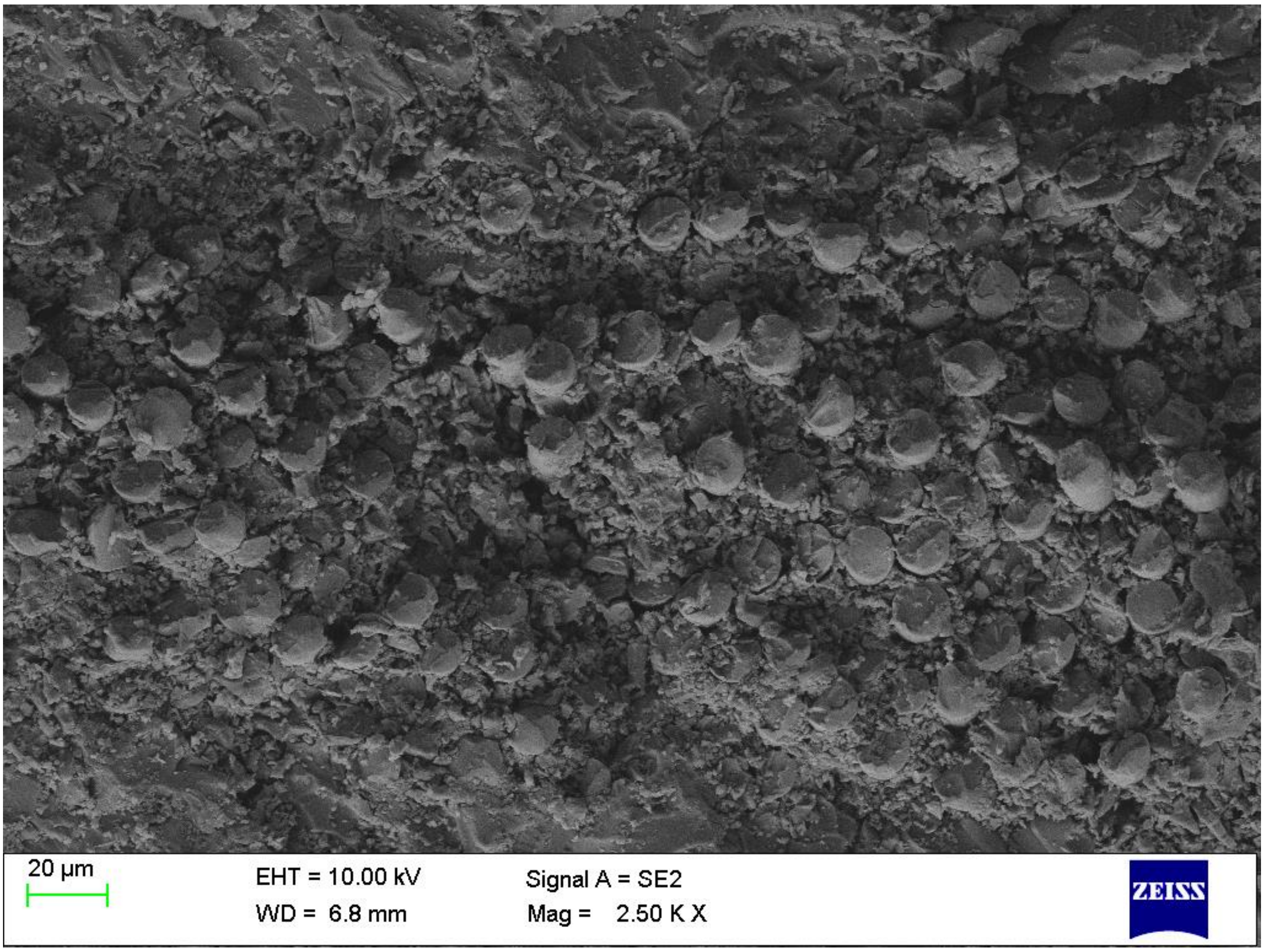
Longitudinal n = 2	F_1 MPa	F_2 MPa	f_1 %	f_2 %	E_b MPa	P_{max} N	σ_{bB} MPa	f_{Break} %	L_s mm	a mm	b mm
$\bar{x}$	25.8	103.2	0.25	1.00	10400	687	258	-	75	4.8	13
s	2.6	10.6	0.01	0.06	400	70.5	26	-	0.000	0.000	0.000
ν	10.26	10.26	4.20	6.07	3.51	10.26	10.26	-	0.00	0.00	0.00

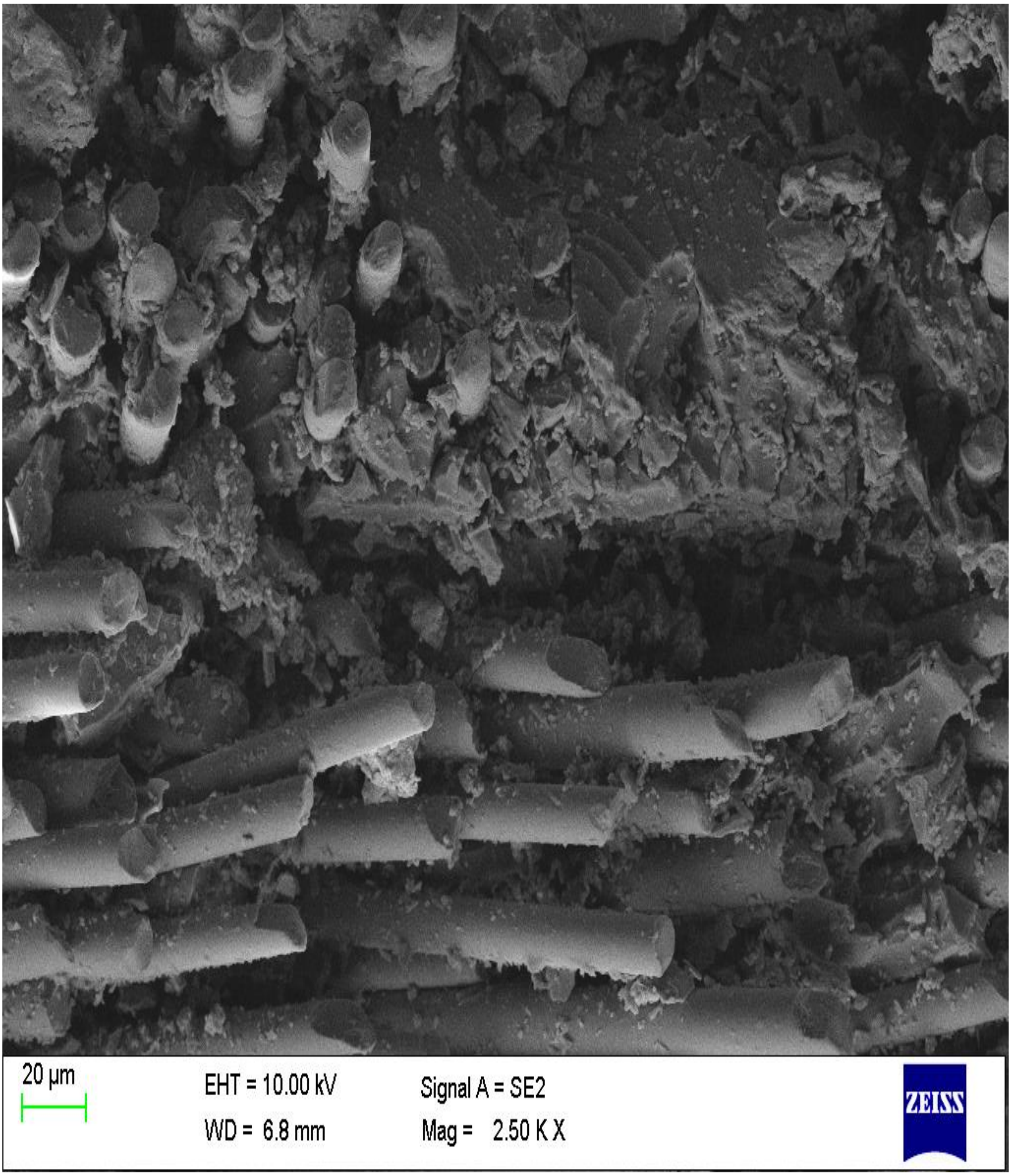
4

APPENDIX-3


200 µm
EHT = 10.00 kV
WD = 6.6 mm
Signal A = SE2
Mag = 500 X
ZEISS


100 µm
EHT = 10.00 kV
WD = 6.8 mm
Signal A = SE2
Mag = 1.00 K X
ZEISS


20 µm
EHT = 10.00 kV
WD = 6.8 mm
Signal A = SE2
Mag = 2.50 K X


20 µm
EHT = 10.00 kV
WD = 6.8 mm
Signal A = SE2
Mag = 2.50 K X
ZEISS

CHAPTER-6

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