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Development of Natural Fibre/PLA based Green Composite and Investigation of the Effect of Curing Temperature and Surface Treatment on its Mechanical Properties

Submitted by

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To

School of Mechanical Engineering
In partial fulfilment of requirement for the award of degree
Master of Technology

In

Mechanical Engineering

Under the Guidance of

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TOPIC APPROVAL PERFORMA

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Qualitative Assessment of Proposed Topic by PAC		
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2	Project Feasibility: Project can be timely carried out in-house with low-cost and available resources in the University by the students.	8.00
3	Project Academic Inputs: Project topic is relevant and makes extensive use of academic inputs in UG program and serves as a culminating effort for core study area of the degree program.	8.40
4	Project Supervision: Project supervisor's is technically competent to guide students, resolve any issues, and impart necessary skills.	8.40
5	Social Applicability: Project work intends to solve a practical problem.	8.60
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PAC Co mmittee Members		
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Final Topic Approved by PAC: **Development of Natural Fibre/PLA based Green Composites and investigation the effect of curing temperature and surface treatment on its mechanical properties.**

Overall Remarks: Approved

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CERTIFICATE

I hereby certify that the work being presented that in the dissertation entitled. "Development of Natural Fibre/PLA based Green Composites and Investigation the Effect of Curing Temperature and Surface Treatment on its Mechanical Properties." In partial fulfilment of the requirement for the award of the degree **MASTER OF TECHNOLOGY** submitted to the school of Mechanical Engineering in Lovely Professional University, Phagwara is an authentic record of my work carried out under the supervision of **Mr Jai Inder Preet Singh**, Assistant Professor, School of Mechanical Engineering, and Lovely Professional University. The matter embodied in the dissertation has not been submitted in part or full to any other University or Institute for the award of any degree.

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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The external viva-voce examination of the student was held on successfully______________________________

Signature of Examiner

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ABSTRACT

Green composites are comprised of natural fibres and biodegradable matrix material. The environmental friendly nature and good mechanical properties of green composites could be able to replace the conventional petroleum products and other non-biodegradable materials. In this thesis, research has done on green composite with jute fibre as reinforcement and PLA (poly lactic acid) as matrix. Initially, the composite has developed using film stacking technique and compression moulding. Secondly, a new novel approach has been proposed and named the technique as sprinkling method. The new method has shown far better results comparatively. Furthermore, the second method has optimised with curing time and load. It has also observed that fibres treated with 5% NAOH solution has shown the same tensile and flexural strength but reduced impact strength.

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Chapter-1

1 INTRODUCTION

Composite materials are those materials in which two or more material combine together to form a new one but it shows the distinctive properties. As per the definition it is not restricted to any particular field in the sense any material can combine if it is possible and create a Composite. The best example is concrete; it is made up of cement, sand, and gravel. It can also be reinforced with steel which improves the strength. The use of composite has started from long back when consider the fact that around 10000BC the houses were made up of straw bricks, and around 4000BC the writing material had fabricated from the papyrus plant. The writing material prepared in the form of laminates by arranging the fibres of the fabulous plant in a particular direction. The Egyptians also made fibres by heat treating the glass material to very high temperature. People believe that, modern composite is made by Mongols in the form of a bow around 1200BC. The bow made from various materials such as wood, leather, bamboo, horn, antler and tendon. The horn and antler were used to make the main body of the bow because it has good flexibility. Tendon used to adhere and cover the horn and antler. All the pieces are joined together by using glue which is obtained from fish’s bladder. The string of the bow made from horse hair, silk along with tendon. The bow was very powerful which shoot within a range of 1.5km. But serious development in this field happened after world war-2 because the world war-2 was mostly fought with fighter planes, ships and automobiles, which require material to be lightweight and strong. Therefore phenolic resin used for the first time in the fighter planes by The British royal air force in its mosquito bomber aircraft. Further, the use of radar technology resulted in the development of glass fibre reinforced plastics which used to make the covering of radar equipment. Modern-day the strength of concrete is also high due to the reinforcements. Another example is wood which is made up of cellulose and lignin. Plywood is also a form of good composite used for furniture production. Finally our bone is also a composite material containing collagen fibres and hydroxyl appetite matrix.

1.1 COMPOSITE

As said earlier Composite material is nothing but two or more constituent materials with different physical or chemical properties combine together to make a new material, but the individual material process individual properties. Combining different materials are with different reason such as improving strength, light weight and less expensive when compared with traditional materials.

1.2 TYPES OF COMPOSITE

1. Fibrous Composite

2. Laminated Composite

3. Particulate Composite

4. Hybrid Composite

- Fibrous Composite

In fibrous composite it mainly consists of fibres as reinforcement in the matrix. This fibre can be continues or discontinues according to the application or the required property. In concreate beams the metal rods are considered as fibres.

- Laminated Composite

Laminated composite is made up of at least two or more layer of different materials that are stuck together. In this single layer is called Lamina, the best example is plywood, in this we can easily identify single layers or laminas are arranged layer by layer to create laminate. These are again classified into three categories.

(a) Biometals

(b)Clad metals

(c)Fibreglass (or) safety glass

(a) Biometals

These are the laminates of two different metals that are having different coefficient of thermal expansion. The different metals have different thermal coefficient when they heated binding and warping take places. These are mainly used for thermostat production.

(b) Clad metals

These are the materials they combine the properties of two or more metals. This process of cladding or sheathing one metal is covered by another to obtain the best properties of both. For example Aluminium alloy has high strength but it is prone to corrosion but pure

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aluminium is corrosion resistant so pure aluminium coated above the surface of aluminium alloy to get the best properties of both.

(c) Fibreglass or safety glass

It is a layer of polyvinyl butyl which is made like a sandwich in between two layer of glass. Therefore the brittle behaviour of the glass is reduced and the impact strength is increased to a higher limit.

- Particulate Composite

It contains particles of metals or non-metals suspended in a matrix of another material which can be metallic or non-metallic depend up on the particles and matrix which used in the matrix. This is mainly classified into four types

(1) Non-metallic particle in a metallic matrix

(2) Metallic particles in a non-metallic matrix

(3) Metallic particles in a metallic matrix

(4) Non-metallic particles in metallic matrix

The examples are,

1. Concreate, which is a particulate composite in which sand and gravel particles are combined with mixture of cement and water, which even gives an incredible strength to show that non-metallic particle in non-metallic matrix is also good.

2. Aluminium paint in which Al-particles are suspended in polymer resin. When aluminium paint is applied on a surface the Al-particles align themselves to give a good surface finish.

3. Lead particles used in copper alloys and steel to improve machinability. Lead is a natural lubricant which is used in bearings made from copper alloy.

4. Tool steels are generally made from a combination of oxide particles on metal matrix. The oxide particle such as uranium oxide is used in stainless steel to make nuclear reactor fuel elements. Even in the machining of the metals the tool steels are used because the after mixing with oxide particles the metal showing very good properties.

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5. Ceramics + metals=cremates

Ceramics such as tungsten carbide, boron carbide, titanium oxide etc. are used in metallic matrixes like cobalt, nical and copper to make machine parts. This kind of machine parts are showing good mechanical properties and the life of the parts also increased in a drastic level.

- Hybrid Composite

In the case of concreate it has both particulate and fibrous. Concreate contains gravel in cement paste and add steel as reinforcement it become fibrous. Laminated fibre reinforced composites are also coming under hybrid composite in which layers of fibres reinforced material are bonded together with different fibre direction in each layer.

1.3 CLASSIFICATION OF COMPOSITE

Composite is classified based on the types of reinforcement and matrix

Reinforcement

- Fibre reinforced
- Whiskers reinforced
- Particulate reinforced
- Flakes reinforced

Matrix

- Polymer matrix
- Metal matrix
- Ceramic matrix
- Carbon matrix

1.3.1 Reinforcement

Reinforcements are considered as the main load carrying constituent .So It should have significantly higher properties in comparison to matrix and here the matrix acts as binding agent. The reinforcement also further classified as follows.

Fibre reinforcement composite

The composite material which consists of fibre as the reinforcement here in this type of reinforcement’s fibres will carry the total load and matrix materials play as binding agents. Fibres can be classified into two categories

a) Continues fibre (l/d > 100)

b) Discontinues fibre (l/d < 100)

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Continues fibre again classified into two types

1) Unidirectional

2) Woven

Discontinues fibre are also classified into two types

1) Random orientation

2) Preferred orientation

Whiskers

It is also a fibre but it is very short and rigid in nature when compared with fibre. These are single crystals having very short length.

Flakes

Flakes are spheroidal in shape and they can be packed more densely in comparison with fibres but because of surface defects flake reinforced composites have less strength.

1.3.2 Matrixes

Matrix usually considered as binding agent but some of the cases matrix also plays an important role in delivering high strength composite. The different types of matrixes are explained below

Polymer matrix

The Polymer is defined as the substance which has a molecular structure made from a large number of similar units bonded together. These are mainly classified into two types

- Thermoplastics
- Thermosetting plastics

Thermoplastics are the material which has a linear and branch chain and has the capability to form different shapes by reheating. Especially they can be reheated number of times. Nylon, Polypropylene and Polyethene are the few example for this.

Thermosetting plastics are crossed linked chain polymers which has a property that once heated it forms a permanent shape by destroys their cross-linked structure so reheating is not possible. For e.g. epoxy, polyimides, phenolic etc.

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Metal matrix

In metal matrixes metals are used as matrixes. Metal matrixes are used for specific applications like the conducting properties are required. The common types of metal matrixes are Al, titanium and nickel-chromium alloys. These are heavier than that of polymer matrixes and are expensive as well.

Ceramic matrix

Ceramic matrixes are the one which uses ceramics as matrix material. These are used where the heat resistant properties are required. Common types of ceramic matrices are silicon carbide, boron carbide, tungsten carbide etc. These are even applicable at temperature above 1000°C where polymers and metals are not.

Carbon matrixes

Carbon matrixes are used along with the carbon fibres for higher temperature applicaton.Now adays carbon fibres are considered one of the strongest fibre for multiple applications. They are generally preferred in a temperature range of 1000°C to 2000°C and high strength applications.

1.4 GREEN COMPOSITE

In green composite the green stands for environment. The constituents are natural fibres as reinforcement and polymer as matrix material. It is an area where the researchers have been trying to develop eco-friendly materials which are biodegradable. So that most of the environmental problems can be eliminated. Under Green Composite Bio-composite are also considered, they are nothing but partially bio-degradable. In this report also deals with Green composite by considering biodegradable materials for the development of composite.

Fibre reinforced polymers are very common especially in the engineering applications. But most of the common composites are hazardous to the environment. There comes the application of green composite, in this the matrix as well as the fibres also bio-degradable. Most common fibres are the plant fibres used to develop green composite. Because not only the environmental friendly nature it also has no negative health hazard and the strength acquired from natural fibres are amazing. One of the main attraction is it is very easy to fit into any size and shape according to the requirement and it has wide range applications. The challenge in this field is the difficulty to find bio degradable matrix, where number of matrix are available but they are limited in quantity and quality. The PLA (poly lactic acid) is most

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widely used as bio-degradable matrix. This made a great interest in PLA, about this material it a fully bio degradable material and eco-friendly. The research has been going on this material and researchers have not found any health hazard about PLA. It is basically made from starch and corn starch found more suitable for it. Even corn starch based polymers are showing good properties[1]. PLA is produced from lactic acid by fermentation process. PLA can be made from two methods, first is condensation and second is ring opening polymerisation. The diagram is shown below.

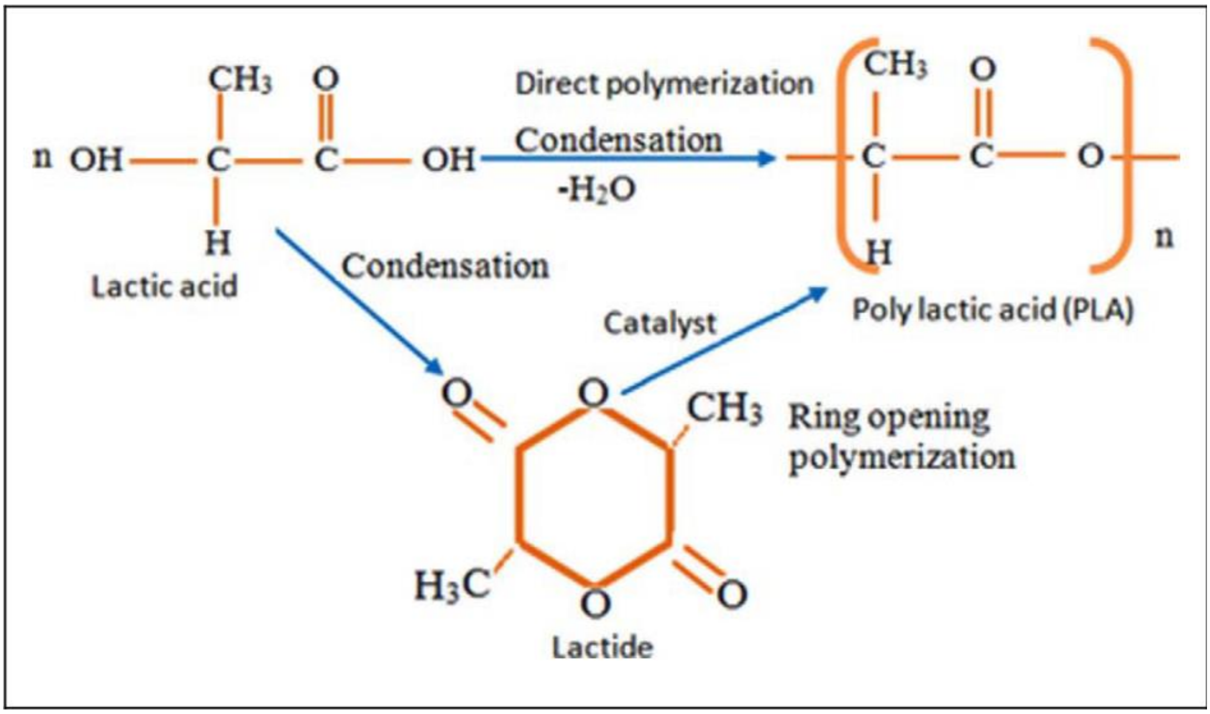

Figure 1 Polymerisation of PLA [2]

Discussing more about PLA, as said earlier it is naturally derived from the starch. In this case, starch can be from any of the plant's outcome like starch from potato, tapioca, rice and corn etc. Earlier statement had given justification about the corn starch's benefits and the processing is also not difficult. Even the availability of corn in our country taken in to consideration the processing of starch to develop PLA is not going to harm any human being in case of food and it can create the availability and market. So it can be a boon to the agricultural field. This kind of industrial application makes sure that the excess productions are not going to be wasted as well as the growth of the country in a wealthy manner. The processing of PLA in diagram has given below.

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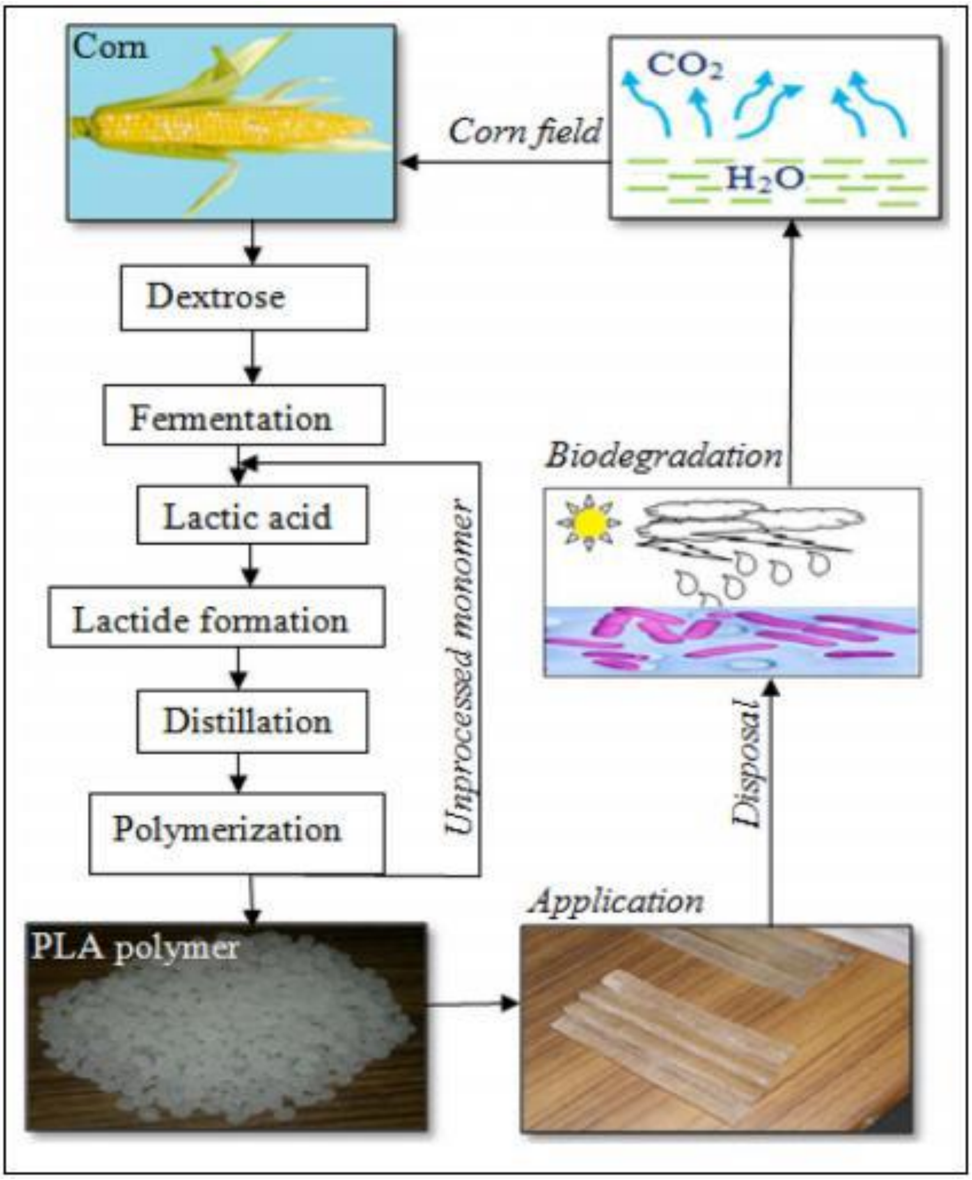

Figure 2: Process of PLA synthesis and its closed life cycle [2]

In the above figure clearly mentioned the process and how the life cycle is completing this once again indicating the importance of bio-degradable materials. Especially in the case of PLA it could easily replace plastic materials and it is a great leap forward for the environment.

1.5 CLASSIFICATION OF FIBRE

In the case of fibres vivid options are available and are mainly classified into two categories, natural and synthetic, the classification is given below fig 3. Nowadays the extraction of fibres also comes under studies[3] and has a wide range of scope in it. This thesis uses Jute fibre as reinforcement because it is easily availability and economical so the production cost can be reduced from the reinforcement part.

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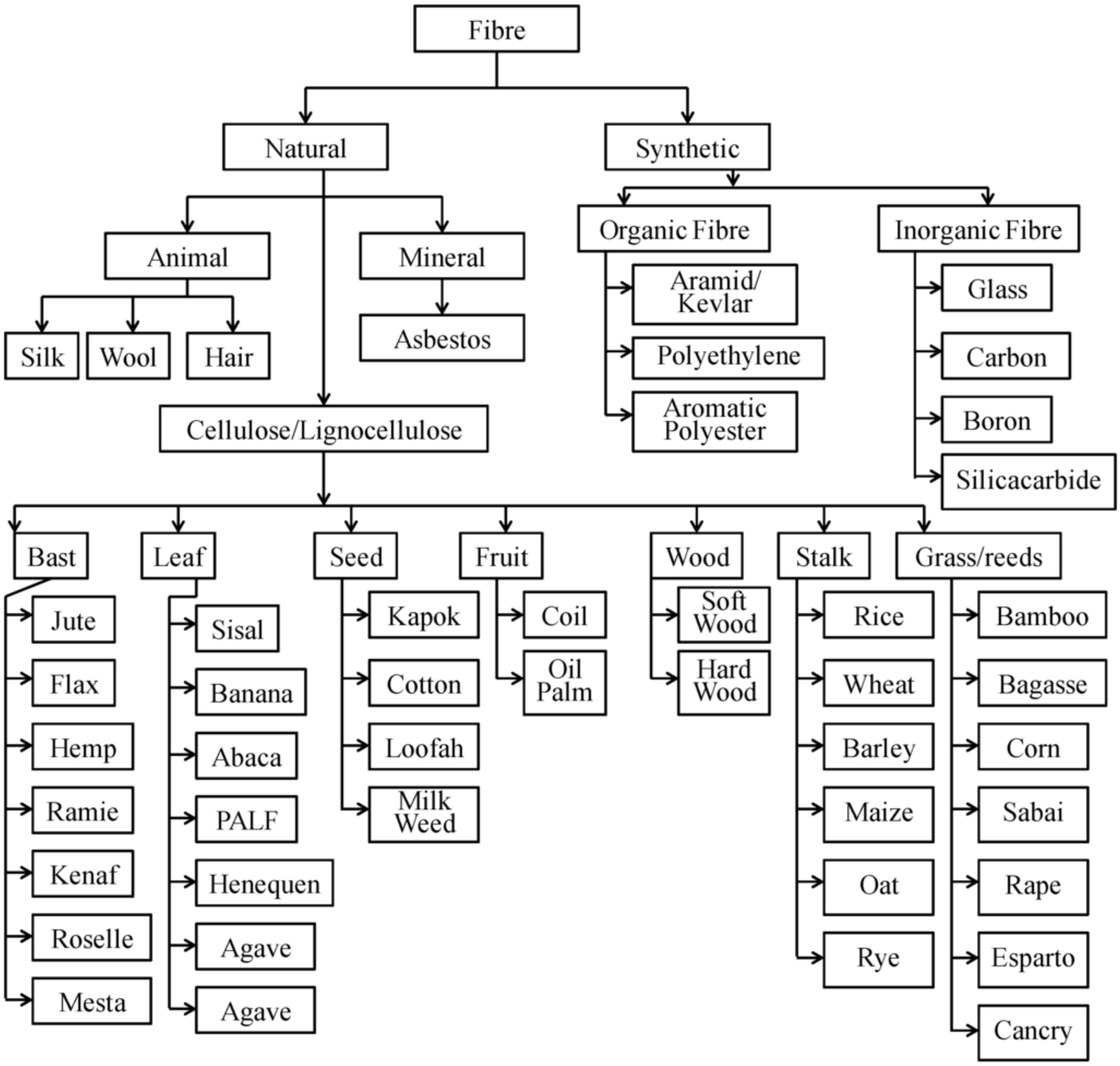

Figure 3 Classification of fibres[2]

The classification has given a wide variety of options to work on it from that a few commonly used fibres are discussed below in detail.

Types of fibres

1. Natural fibre
2. Advanced fibre

1.5.1 Natural fibre

It is again classified into three categories

1. Plant (or) vegetable fibres

2. Animal fibre

3 Mineral fibres

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1.5.1.1 PLANT (or) VEGETABLE FIBRES

Start with examples Cotton, Jute, Hemp, Raffia Palm, Maize/Corn, Abaca fibre, Kenaf fibre, Bamboo fibre, Sisal fibre, Banana, Kapok, Coir, flax, Sugar cane and Ramie fibre

- Cotton

It is obtained from seeds of cotton plant and it contains cellulose. America is the largest exporter of cotton, while china is the largest producer. Worldwide production of cotton is 25 million tonnes per year. Cotton is used to make jeans, shirt, Towels, undergarments, Bedsheets etc. It has a density of 1.5µm and it contains 90% cellulose 8%water and the rest is combination of fatty substance and waxes

- Jute fibre

It is produced from the phloem of the plant and used as the second most commonly used fibre after cotton. It is 100% biodegradable and recyclable and having high tensile strength, also used for making Jute bags, Doormats etc.

- Hemp fibre

It is obtained from Cannabis plant. Hemp is refined into various products such as oil, wax, cloth, paper, fuel etc. It has properties similar to silk and is used as soil canvas.

- Sisal fibre

It is obtained from sisal plant by using a process called decortication. In this process, the leaves are crushed and beaten by a rotating wheel which has glut knives attached to it. Only fibres remain after this process. It is mainly used for making Carpets, Papers, Mattresses and Dartboards

- Bamboo fibre

This obtained from Bamboo tree. This is highly durable and has high breaking strength. It is obtained from steam explosion process in which bamboo is injected with steam at a high pressure. When it is exposed to atmosphere small explosion takes place within the bamboo due to steam release and fibres are obtained.

- Banana fibre

Banana fibre is obtained from a banana tree. The stem of the banana tree is the main source of these fibres. It is very easily available and it is used for manufacturing Carry bags, Table mats etc.

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- Abacas fibre

Abaca fibre also known as Manila hemp, it is extracted from leaves and stem of Manila hemp plant. It is used for making ropes, tea bags, bank notes, filter paper etc. It is found in Philippines, Ecuador and Costa Rica and is similar to banana fibre

1.6 Fabrication Techniques of composite

Composite can be fabricated by different techniques those are listed below

- Hand layup method
- Spray layup method
- Autoclave curing method
- Filament winding
- Pultrusion resin method
- Vacuum bagging
- Resin transfer moulding
- Compression Moulding

1.6.1 Hand layup method

Initially the fibres are place in the mould for that any type of fibre form can be used like in the form of woven mats, fabric, stitched fibres etc. Second step is to impregnate the resin for that roller, brushes or nip-roller type impregnators are used. This helps the epoxy or resin to completely drench the fibres. The laminates fabricated by this process are then cured under standard atmospheric conditions. The materials that can be used have, in general, no restrictions but it should be in liquid form. One can use combination of resins like epoxy, polyester, vinyl ester, phenolic and any fibre material.

Advantages

- The process results in low cost tooling with the use of room-temperature cure resins.
- The process is simple to use.
- Any combination of fibres and matrix materials can be used.
- Higher fibre contents and longer fibres on comparison with other process.

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Disadvantages

- The resin needs to be less viscous so that it can be easily worked by hands.
- Product quality highly depends on the labour skills.
- Uniform distribution of resin inside the fabric is not possible. It leads to voids in the laminates.
- Possibility of diluting the contents.
- Safety and precautions must be taken as the work is performed by hands.

Applications: Fabrication of wind-turbine blades, boats and architectural mouldings, bonnet of cars is suitable for this process.

1.6.2 Spray layup method

It consists of two guns; one sprays the catalysed resin directly to the mould and other sprays chopped fibres. After that, the deposited layers of fibre and resin are allowed to cure at the standard atmospheric conditions as per the requirement of resin. The polyester resins can be used with glass roving is best suited for this process.

Advantages

- Small and medium size components can be fabricated easily.
- Low maintenance and tooling cost.
- Economical for fabrication of small and medium size components.

Disadvantages

- It similar to hand-layup process, low viscosity resin is required for easy spray.
- Highly precise geometries cannot be formed.
- Since, pressurized resin is used the laminates tend to be very resin-rich.
- Parameters like fibre volume fraction and thickness cannot be easily controlled; it depends on skills and experience of worker.
- Only short length fibres can be used.
- Fabrication at open mould causes emission of styrene, precautions must be taken.
- Cores are inserted manually only.
- Gives good surface finish on one side and rough surface finish on the other side.

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Applications: This method is appropriate for the fabrication of bath tubs, shower-trays, small components of automobile body, panels etc.

1.6.3 Autoclave Curing Method

In autoclave method a closed vessel is used for curing of the PMC. The composite is fabricated by hand-layup and is placed in the vessel which is maintained at high pressure and temperature. Even the individual lamina in the form of fibre tape which has been impregnated with resin whole apparatus can be placed. A cycle of temperature and pressure is given for the curing of resin until the solidification occurs. We can use fibres like carbon, glass, aramid etc. along with any resin.

Advantages

- Large components can be fabricated.
- Since, the curing of matrix material is carried out under controlled environment the resin distribution was better.
- Less possibility of dilution with foreign particles.
- Better surface finish.

Disadvantages

- Initial cost of tooling is high.
- Running and maintenance cost is high.
- Not suitable for small products.

Applications: The process is suitable for aerospace, automobile parts like wing box, chassis, bumpers, etc.

1.6.4 Filament Winding Method

Filament winding is the fabrication process for circular or spherical hollow geometries. This is an automated process in which structures are made using flexible fibres. In this process, lot of fibre tows are used which are passed through the resin bath before being wound on the mandrel. The winding of fibre takes place in a variety of orientations and the whole mechanism, feed rate of fibre and rotation of mandrel is controlled through mechanism. The wound component is then cured in an oven or autoclave. One can use resins like epoxy,

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polyester, vinyl ester and phenolic along with any fibre. The fibre can be directly from creel, non-woven or stitched into a fabric form.

Advantages

- Resin content is controlled by nips or dies.
- The process can be very fast.
- The process is economic.
- Complex fibre patterns can be attained for better load bearing of the structure.

Disadvantages

- Only convex shapes can be processed.
- Resins with low viscosity are needed.
- Cost increases with increase in the mandrel size.
- Fibres cannot be laid parallel to length of the component.
- Smooth external surface is not obtained.

Applications: Breathing tanks, Chemical storing components, Pressure bottles, Gas cylinders, rocket motor casing etc.

1.6.5 Pultrution Resin Method

It is a continuous process in which composites in the form of fibres and fabrics are pulled through a bath of liquid resin. Then the fibres wetted with resin are pulled through a heated die. The die plays important roles like completing the impregnation and controlling the resin. Further, the material is cured to its final shape. The die shape used in this process is nothing the replica of the final product. Finally, the finished product is cut to length. In this process, the fabric is allowed into the die. The fabric allows a 0° fibre direction. Further, a variant of this method to produce a profile with some variation in the cross-section is available. This is known as pulforming. The resins like epoxy, polyester, vinylester and phenolic can be used with any fibre.

Advantages

- The process is suitable for mass production.
- The process is fast and economic.

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- Amount of resin can be controlled easily.
- Cost of fibre is minimized as it can be taken directly from a creel.
- The surface finish of the product is good.
- The straight fibre gives very high properties of structure.

Disadvantages

- Limited to constant or near constant cross-section components.
- Heated die costs can be high.
- Products with small cross-sections alone can be fabricated.

Application: Beams and girders used in roof structures, bridges, ladders, frameworks etc.

1.6.6 V**acuum Bagging Method**

This process is similar to wet-layup process. In this process, the fibres are in the form of mat or fabric is placed in the geometry with a bleeder beneath. The layup is covered with upper mould and sealing is done to create perfect vacuum. Through one opening high vacuum is applied which uniformly distributes the resin in the geometry. It is then allowed to cure. Extra rein is absorbed by bleeder.

Advantages

- Development of low voids.
- High fibre fraction is achieved.
- Safe and easy to handle.
- Perfect wetting of fibre with extra resin is absorbed by bleeders.

Disadvantages

- High skilled worker is required.
- High cost due to extra added materials.

Applications: Components of boats and racing cars.

1.6.7 Resin Transfer Moulding Method

In this process the fibre or fabric is arranged in the mould as per requirement. The fibres are then pressed to fix their place this is done by using binder. After that a matching tool mould

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is placed over it and pressure is given to inject the resin into the mould. Sometimes vacuum is also applied to assist the resin to flow out of the mould and proper wetting of the fibre this called Vacuum Assisted Resin Transfer Moulding (VARTM). Then the resin is allowed to cure at room or high temperatures. This process is suitable for epoxy, polyester, vinylester and phenolic. For reinforcing material any type of fibre can be used because fibre binder works well with every fibre.

Advantages

- The process is very efficient.
- Suitable for complex shapes.
- Low void content and high fibre fraction can be obtained.
- Safe and environmental friendly.
- Lesser labour is required.
- Both the surface of the component have very good surface finish.
- Better reproducibility.
- Relatively low clamping pressure and ability to induce inserts.

Disadvantages

- Perfect tool matching is hard to generate, expensive and heavy pressure bearing is not possible.
- Limited to the manufacturing of small components.
- Wastage is high.

1.6.8 Compression Moulding Technique

Compression moulding is a very famous technique for the fabrication of composite materials. In this process there is a mould consisting of upper part and lower part both are designed as per the requirement of the geometry. Mainly the metallic mould is taken into use because the mould undergoes high pressure for the safety factor purpose metals are used. In the mould assembly the lower part is called base plate which remains stationary and aligned with the upper part or plate with the help of guide pins, the upper plate is movable. The reinforcing material and matrix material are placed in the cavity of the mould and gradually pressure is applied, the pressure may vary from 100KPa to 50MPa depending upon the need the pressure is applied. Generally heating elements are also installed into the mould because the matrix

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material may be cold working and hot working. On the application of the pressure the extra resin flows out of the mould leaving behind the reinforcing material with proper amount of matrix. It is then allowed to cure under same temperature and pressure for some time required for curing of the matrix. After curing the temperature is cut off and pressure is removed to lift the upper plate, fabricated component is taken out of the mould. Generally hydraulic system is applied to give pressure to the mould. For some material anti-stick surface is developed for the proper removal of the component and to avoid sticking of the matrix with the plates.

Advantages

- High production rate due to less curing time.
- Good surface finish with different styles and geometries can be achieved.
- High part uniformity can be achieved with compression moulding process.
- Flexibility in part design is possible.
- Extra features like inserts, bosses and attachment can be moulded in during the processing.
- Minimum wastage of raw material.
- Low maintenance cost.
- Minimum or negligible residual stresses.
- No twisting and shrinking gives perfect dimensional accuracy.

Disadvantages

- Due to expensive machinery and parts, the initial capital investment associated with compression moulding is high.
- Suitable for high production rate not for prototyping.
- It is a labour intensive process.
- Sometimes secondary processing (trimming, machining) of product is required after compression moulding.
- Sometimes uneven parting lines are there.
- There is limitation on mould depth.

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Chapter-2

2 REVIEW OF LITERATURE

As a beginner, to start or understand the research had been a pain. Even the areas are very broad and it really felt difficult to cope up with the things. This is the moment were the literature review helped to overcome the difficulties trough sharing different aspects of the research and given continuity between the past and present even prediction of future scope also possible. The understanding of literature review helped to find an area of interest as well as the work which can be carrying forward. Few of the research papers are listed below.

David Plackett et.al (2003) [4]explains about the l-poly lactic acid to make a bio-degradable composite here he used film stacking technique to make composite by combining jute fibre as reinforcement. Furthermore the mechanical properties are evaluated and found good properties which can replace conventional petroleum products.

Amar K. Mohanty et.al (2005) [5] Green composite from soy-based plastic and pineapple leaf fibre has studied. In these scientists derived a composite and analysed the properties before going through the properties they identified that the increase in the fibre content is effective only along with the compatibilizer. The properties whichever induced in it is related to the hydroxyl group involved in the leaf and epoxy group in PEA. The fabrication of the material is done by an extrusion process and injection moulding. In this material mechanical and physical properties are appreciable and by adding PEA-g-GMA have improved the mechanical properties. Also, improve the adhesion between the fibre and the matrix because of that stress can be easily transferred from matrix to the fibre and hence the mechanical properties of the material also get increased.

Anil N. Netravali (2006) [6] the properties of the ramie fibre were investigated (surface topology, tensile properties, thermal properties).Mechanical testing values are noted in the paper. The specific tensile properties of the ramie fibre calculated and compared with glass fibre. Ramie fibres exhibited good thermal stability after ageing up to 1600C with no decrease in tensile strength or Young’s modulus, Temperature greater than 1600C causes a decrease in tensile property. S E M micrographs revealed that ramie fibres have a fibrillary structure and irregular cross-section.

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Alexander Gomes et.al (2007) [7] studied the effect of alkali treatment on tensile properties of Curaua fibres and he identified the optimum amount of alkali percentage needs for the maximum tensile strength. It is clearly mentioned the difference in strength between treated and non-treated curaua fibre

Maya Jacob John et.al (2008) [8] had studied two different fibres by comparing their properties as well as the effect of fibre ratio on mechanical properties. More over the swelling behaviour of the composite also comes under the study. Study has given the sisal fibre has better properties with the respective matrix than oil palm tree fibre but the hybrid composite made by these two shown a positive outcome.

Yan Li et.al (2008) [9] study of green hemp fibre reinforced composites using bag reting and white rot fungal treatment. Here discovered the importance of the interfacial bonding between the fibres, for improving the bonding use White rot fungi. This fungus consumed the non-cellulosic compounds from the fibre and improves the bonding between the fibre and matrix. The bag retting process is an environmental friendly process and helped the growth of the fungi and bacteria. By doing all these studies helped to find out that rot fungi and bag retting process successfully removed the non-cellulosic particle such as wax, pectin, hemicellulose and lignin. Removing this helped to improve the surface roughness and results in the interfacial bonding, through increased the composite strength.

Narendra Reddy (2009) [3] The respected author discussed the extraction of the fibres from the milkweed plants for that he adopted some measures and succeeded in the extraction of the fibres. Chemical treatment of the plant was the first step and after that, he performed the experiments by changing the time and temperature. By performing several experiments he was able to achieve the optimum solution for the problem.

Behjat et.al (2009) [10] studied the bio-degradability of kenaf cellulose and effect of poly ethylene glycol this several blends are prepared by acquiring the cellulose from different kenaf plant. The bio-degradability test conducted in 120 days span. Here the addition of 5% poly ethylene Glycol shows a better result than any other combination.

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P.K Das et.al (2010) [11] described an elaborative study on how the natural fibres are been extracted and the spinning of fibres. From this it is easy to identify that for accruing the fibres from the different plants are also different; it is according to the nature of the plant and properties of the fibres. Because of this study we can easily come into a conclusion that, the process of getting fibre is also an important and difficult task also it can vary the results of an experiment which uses fibre.

M. Thriuchitrambalam et.al (2010) [12] depicts the use of Roselle fibre as the reinforcement with polymer matrix material. They done a thorough study on the mechanical properties of the final output and comparison have given a great confidence to the researchers to move with new fibres. They also did a thorough study in the alkali treatment of the fibres. They concluded that the Roselle fibre polymer composite is a success and it can be used for many applications.

Chin-San Wu (2010) [13] Study of polyester bioplastic based green renewable composite has taken the biodegradability, morphology and mechanical properties of the materials consisting of acrylic acid-grafted poly and agriculture residues are in considerations. Poly butylene succinate adipate (PBSA) is the focus of this papers her in this, the use of the material is very vast and it will degrade within few years but the limitation plays a negative role. The limitation is the production is both complicated and expensive, limiting its usefulness. But which can overcome by blending few natural materials in it and the study has carried on this way. The experiments done on the modified material has given an output in such a way that the mechanical properties are not affected that much but the degradation rate has increased. The increase in the degradation rate has its own preferences while consideringinto the practical applications.

B.S. Kaith et.al (2010) [1] studied about the development of corn starch based bio-polymer and evaluation of its properties. This study is a clear cut indication of the credibility of using corn starch derived polymer. Even the thermal stability is appreciable more over it shown resistance to water and acid.

Kenichi Takemura (2010) [14] evaluated the effect of water absorption in hemp fibre and the effect in the mechanical properties. He found that with higher content of the fibre the

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water absorption is high and in initial days the absorption rate is very high and later after 30 days the rate starts to be in the stagnant position.

Narendra Reddy (2011) [15] illustrates making of the green composite by using Zein as the matrix material and jute fibre as the reinforcement. Zein is a bio-degradable material, which helped to make a green composite. After completion of the product manufacturing, they had undergone a series of testing processes. Paper concludes that the new matrix material can replace the polypropylene.

Mohammad K. Hossain el.al (2011) [16] discussed the surface modified jute fibre by the help of some chemical treatments. They concluded that the surface treatment helped in the removal of materials in the material and it helped to improve the particular properties of the material. This study improved the surface adhere property of the fibre and matrix.

Pramendra Kumar Bajpai et.al (2012) [17] describes the making of complete bio-degradable material with PLA as matrix material as well as non-bio-degradable material as polypropylene. And compared the properties of both composite while comparison shows numerous results which favour the final outcome as well as given new outcomes.

Maya Jacob John et.al (2012) [18] In this paper discussed about the various bio- degradable polymers that can be used to produce bio-degradable composite. In this review mentions a clear study in green composite and mentions the difficulties facing in this field. There after the support given by the biotechnology field to improve the yield of the plant to provide better quality fibres.

Goichi Ben et.al (2012) [19] studied the heat resistant tensile properties on green composite. For that he selected kenaf fibre and PLA resin. The tensile strength found varying according to the arrangement of the fibre in some found better strength than the matrix alone. The ethanol as a solvent used to wash the fibre, after ethanol treatment the adhesion between the matrix and reinforcement has improved.

Nurul Fazita Mohammad Rawi et.al (2013) [20] given the clear-cut study of bamboo fabric in PLA matrix. He used film sacking technique to make the composite material. Taguchi

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method has successfully integrated to find out the optimum pressure and temperature produce the composite. The mechanical testing has also done as the results are discussed in this paper.

Vikas Dhawan et.al (2013) [21] studied the effect of natural fillers in the green composite to make it more economical for the ever-growing demand. He did research with three different filler material and studied the effect in mechanical characterisation. The mechanical properties have increased and he concluded that coconut coir fillers are the better filler material than any other.

Kuruvilla Joseph et.al (2013) [22] deals the thermal, calorimetric and crystallization behaviour of polypropylene. The jute fibre has taken as reinforcement and chemical treatment also performed. By the help of chemical treatment thermal stability has improved marginally.

Pramendra Kumar Bajpai et.al (2014) [2] provides an idea completely based on the processing of bio-degradable Green Composite. For this, they have used film stacking techniques. In this paper, PLA used as the matrix material and different types of natural fibres as reinforcement.A number of mechanical testing had been conducted and the results are been discussed.

Warunee Ariyawiriyanan et.al (2014) [23] deals with the effect of modified jute fibre and, its mechanical properties in green rubber composite. Here the rubber compounding was prepared by using two roll mills and then moulded by hot compression moulding techniques. The filler content was used in the research shows increase in modulus and hardness but decreased tensile strength. Again comparison carried on the basis of treated and non-treated jute fibre from this jute treated with DPNR latex can improve the mechanical properties of composite more than jute treated with HANR.

I.M. Low et.al (2014) [24] discussed the effect of fabric orientation on mechanical properties of cotton fabric reinforced geopolymer composites. In recent years the generation of aluminosilicate polymers also known as geopolymers this material can reduce the use of Portland cement which is obviously a fact of global warming. Here cotton fibres used as reinforcement in geopolymer matrix and the mechanical properties are greatly affected by the direction of the applied load. In the case of vertical orientation results low strength of the

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composite, whereas the horizontally oriented fabric composite with respect to applied load shows a higher load carrying capacity and resistance to the deformation.

Keikhosro Karimi et.al (2014) [25] Talking about the castor plant, it is the most useful and bit dangerous plant in the Indian history because this plant has the healing powers so it is used in the Ayurveda for treating diseases. Apart from that, this is the best source of oil i.e., Castor oil which is used in the automotive industry along with that it also has poison. Considering all these facts into consideration a thorough study carried on the paper. It helped to identify that not only the seed but also the total plant is capable of delivering components which are useful for the human race.

K Senthil Kumar et.al (2014) [26] deals with three types of testing on hybrid composite and how the effect of stacking sequence affects the mechanical properties. Compression moulding techniques are used along with chemically treated conditions. It concludes with optimum stacking sequence for better properties and better damping factor value is also is observed.

Samson Rwawiire et.al (2015) [27] Development of natural cellulose fabric (bark cloth) is the main motto of this paper. The application focus is on the automotive instrumental panel. At present most of the vehicles has a mere share of 14% green composite in it. In the coming future it should increase for that as an initiation or an approach to achieve the goal. Here the researchers had gone through the bark cloth applications and use from the yesteryears and on that basis they have developed a biodegradable bark cloth reinforced green epoxy bio-composite. The properties which were analysed has given a clear cut idea that this we can use as the best alternative.

Ignaas Verpoest et.al (2015) [28] the area of interest in the green composite shows an inclination on the flax and hemp fibre composites. Here by the study clarified that these two fibres composite has technical and non-technical application and more importantly it has the mechanical properties such as specific stiffness, strength and high vibration damping capacity. The applications are also impressive e.g. are for sporting goods, musical instruments, in automobiles etc. When considering the low cost of production, durability and nature-friendly there is no need of a second thought for the scientists to go for these two fibres for the research and optimisation of the quality of the fibres.

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A. J. Kinloch et.al (2015) [29] Flax fibre and cellulose fibre were studied to achieve a natural fibre reinforced polymer to achieve are latively high value of the interlaminar fracture energy. For an increase in the toughness of the epoxy material they added silica nanoparticles, rubber nanoparticles and the combination of both and compared with glass fibre reinforced composite. Resin infusion flexible tooling process was firstly used to make the composite but the problem with the moisture content in the fibre is not suitable for this process so introduced a modified RIFT process and which helped to reduce the moisture content from 9-10wt% to 1% and the further process carried on.

Minna Hakkarainen (2015) [30] studied the recycling of PLA by artificially by using thermal treatment. One-Pot procedure is used to speed up the bio-degradability process. The thermal treatment is done in the polymer chain to increase the speed of action.They effectively improved the compatibility of mechanical pRoperties irrespective of the thermal treatment done on the material.

Ismaeil Ghasemi et.al (2016) [31]considering the green composite the PLA has an important role. This is made up of natural materials such as corn, starch, sugar etc. PLA is thermoplastic polyester with stiffness, tensile strength and gas permeability. However, low degradation rate, relatively high cost and high inherent brittleness are the limitations for its applications. Here a new compatibilizer is synthesised to improve the compatibility of the poly (lactic acid)/thermoplastic starch blends. For canalising the ability of the new material several samples were made and checked the different mechanical properties. The study has given a positive feedback about the newly derived material.

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Chapter-3

3 RATIONAL AND SCOPE OF THE STUDY

Nowadays as far as the life is concerned the development and changes are inevitable. As we talk about the technological development a common man is unable to update the advancement, that quick it is. The evolutions are creating an impact in the environment as well but the question is; the environmental impact is boon or bane? The changes which are evident in the environment are a clear cut indication that not only human beings but all the organisms in the planet are going to suffer. The main problems are created by waste contamination, as waste is concerned they are also in different types but the non-bio-degradable materials causing a big trouble to the environment. These facts are taken in to consideration found that the green composite can have a positive approach towards this concern. So this is the main reason to choose Green Composite for research.

Scope of the study

When we become more technologically advanced, we produce materials that can withstand extreme temperatures, highly durable and easy to use. Plastic bags, synthetics, plastic bottles, tin cans and computer hardware- these are few things make the life easy for everyone. But these products do not break down naturally. When we dispose them in a garbage pile, the environmental conditions are unable to break them down naturally so it would not dissolve. These are non-biodegradables

Common issues because of non-biodegradable materials

1. Climate change

2. Environmental degradation

3. Environmental health

4. Pollution

    a) Air pollution

    b) Water pollution

    c) Soil pollution

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5. Resource depletion

6. Toxicants and Waste

Considering all these problems we need something instead of non-biodegradables.

This is the point where the green composites come into the picture. The use of green composite is the best alternative for the problems created by the non-biodegradable materials

Needs of composite

- The resin and fibres are used in the green composite are biodegradable, when they dumped, decomposed by the action of microorganisms.
- They are converted into the form of H_2O and CO_2. The H_2O and CO_2 are absorbed in to the plant system
- Less expensive
- Reduced weight
- Increased flexibility
- Renewable energy resource
- Thermal recycling is possible
- Friendly processing
- Low embodied energy and CO_2 emission
- Non-toxicity
- Biomedical applications

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Chapter-4

4 OBJECTIVES OF THE STUDY

- To develop a fully biodegradable Green composite.
- To Study the effect of curing temperature on mechanical properties of developed composite.
- Study the effect of surface treatment on the properties of developed composite.
- Study the effect of bio-degradability on soil.
- Study about the water absorption of green composite.

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Chapter-5

5 MATERIALS AND RESEARCH METHODOLOGY

5.1 Materials Used

There are mainly two components used to develop the composite. They are Natural Fibre and Matrix material. The details are given below.

5.1.1 Natural fibre

The natural fibre is Jute, which is easily available and very economical in nature. In market there are different types or quality of the fibre is available but for the convenience the easily available and common fibre is used. The natural fibre is obtained from the local market. The diagram of the specimen is given below

Figure 4 Natural fibre used

5.1.2 Matrix Material

To maintain the status of green PLA is used as matrix material. This is purchased from Nature Works, USA. The grade mentioned is 4042D. The selection of the material is done by observing the applications such as Candy twist wrap, Salad and vegetable bags, Window Envelop Film, Lidding Film, Label film and other packing applications. The former line describes the application shows the 4042D is an ideal product for practical application. The density of the material is 1.24g/cc. The diagram is shown below.

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Figure 5 PLA Pallets

5.1.3 Releasing Agent

The Teflon sheet is used as releasing agent. It is having a good non sticking property which utilised in the development of composite.

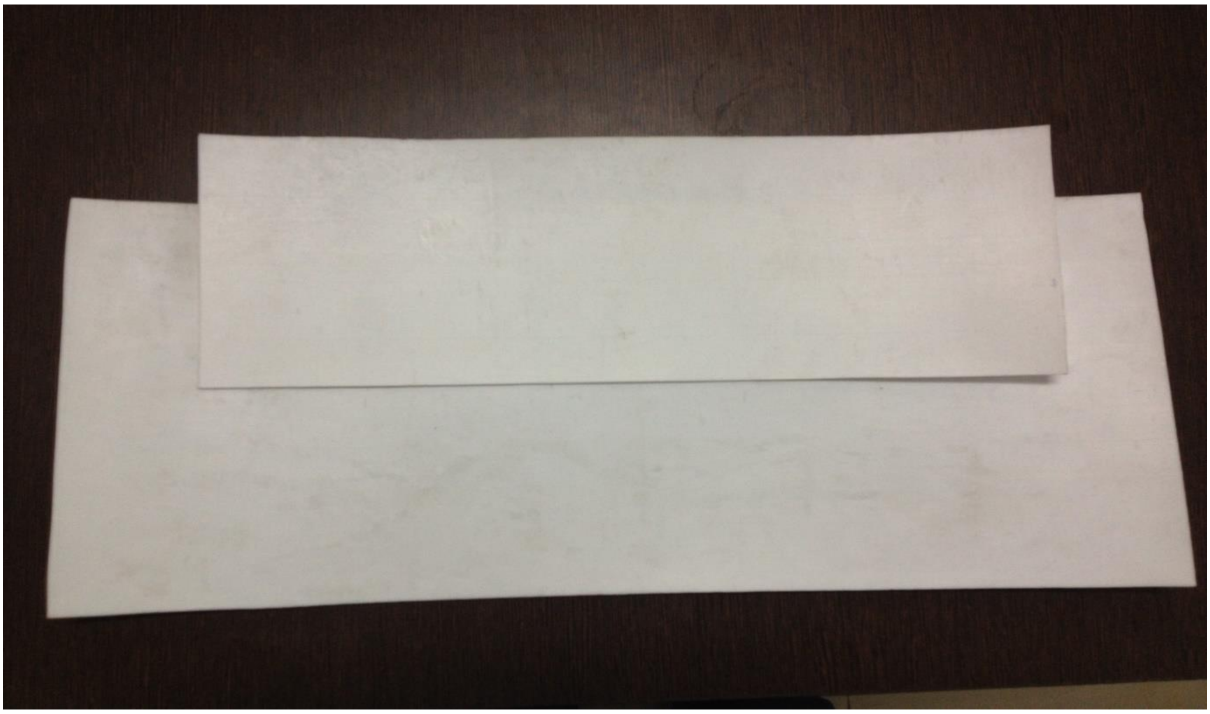

Figure 6 Teflon sheet

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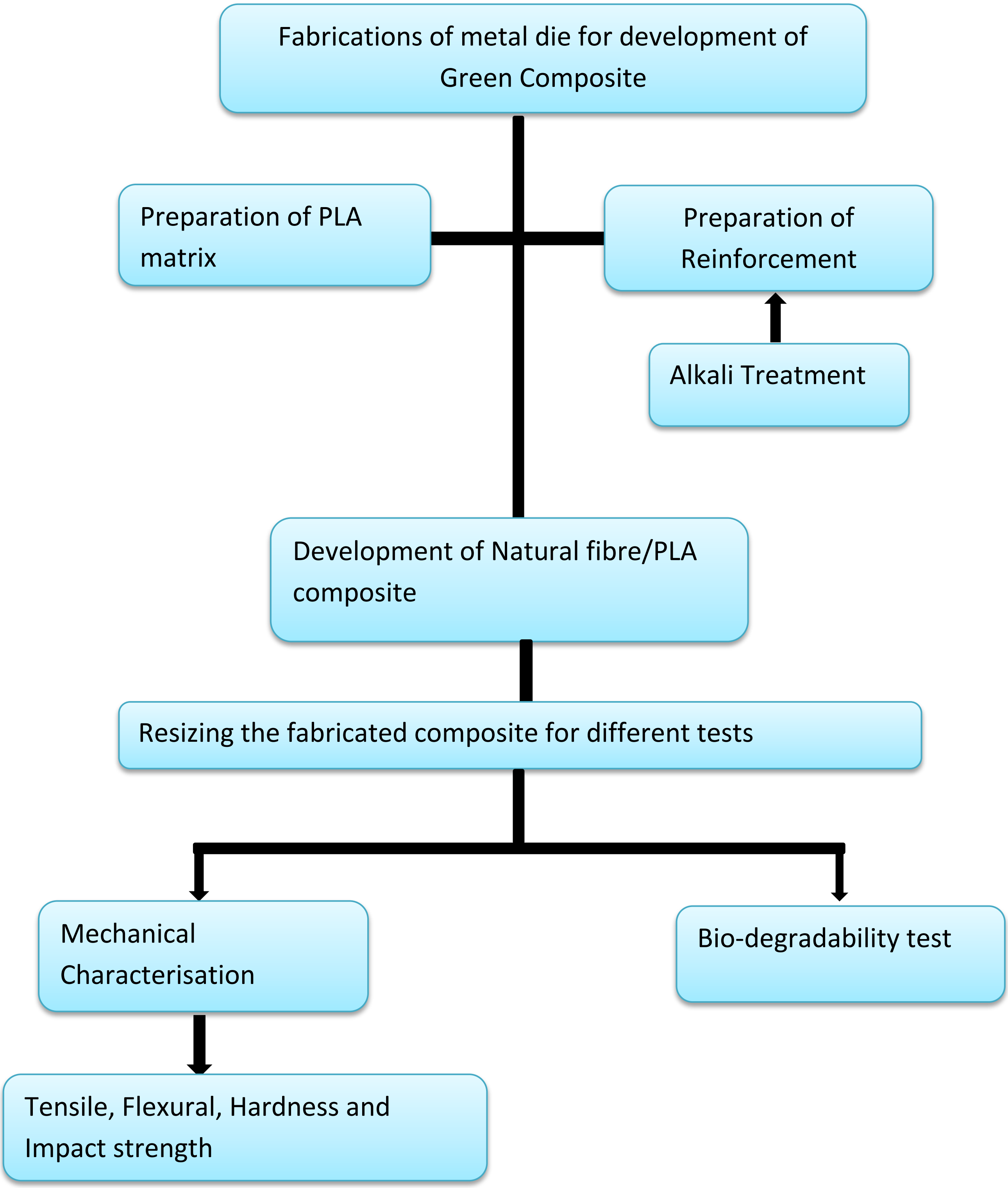
5.2 Research Methodology

FLOW CHART



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Chapter-6

6 EXPERIMENTAL WORK

For the experimental purpose Film stacking technique with the help of compression moulding has adopted through Literature Review. According to the selection of experiment the working procedure changed for the convenience of the work, it is divided in to several steps.

1. Selection of Die
2. Compression Machine
3. Heating element
4. Electrical control panel unit
5. Development of Releasing Agent
6. Development of PLA sheets
7. Treatment of fibre
8. Development of Composite

6.1 Development of Die

First and foremost consideration is the ASTM standard, for that the thickness of the composite maintained at 4mm and the dimension of the die is 320*120 and thickness can be varied with the help of strips used in the die. The maintained thickness are 4mm and 1mm, 1mm is for the development of sheets.

Figure 7 Image of die with upper and lower parts

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Secondary the Die is made up of EN 31steel and a provision is given in the die to accommodate the heaters in the upper as well as the lower plate. Before starting the experiment the Die washed with diesel.

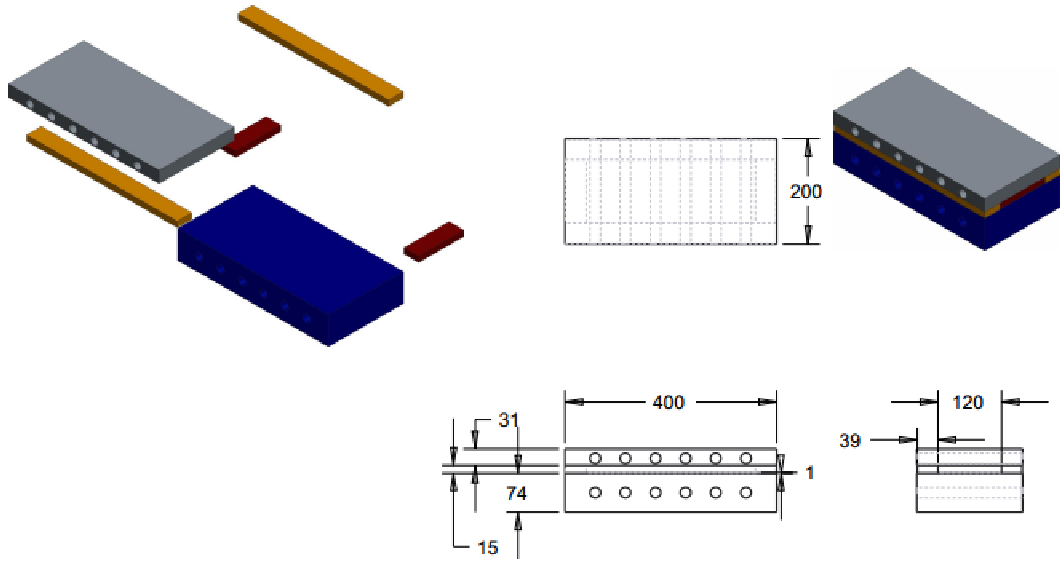

Figure 8 Detail diagram of die

6.2 Compression Machine

In the field of compression testing machine, HEICO's machine is used. The capacityof the machine is 1000KN (fig.5). This machine consists of loading unit as well as pumping unit. At the base of the loading unit, a hydraulic jack is fitted and a load display unit is attached to the upper end of loading unit which is used to operate the pumping unit and controls the load. Specification: motorised pump (200V, single phase AC), maximum load (1000KN), and Hydraulic oil servo system ENKL 68.

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Figure 9 Image of compression machine

6.3 Heating Element

The setup was heated by commercial heating rod elements as shown in fig 8. Total nine heater rods used to heat the setup. The wattage of each rod heater is 750W with single phase. The controller was used to cut off the supply of heater when Temperature reaches required value.

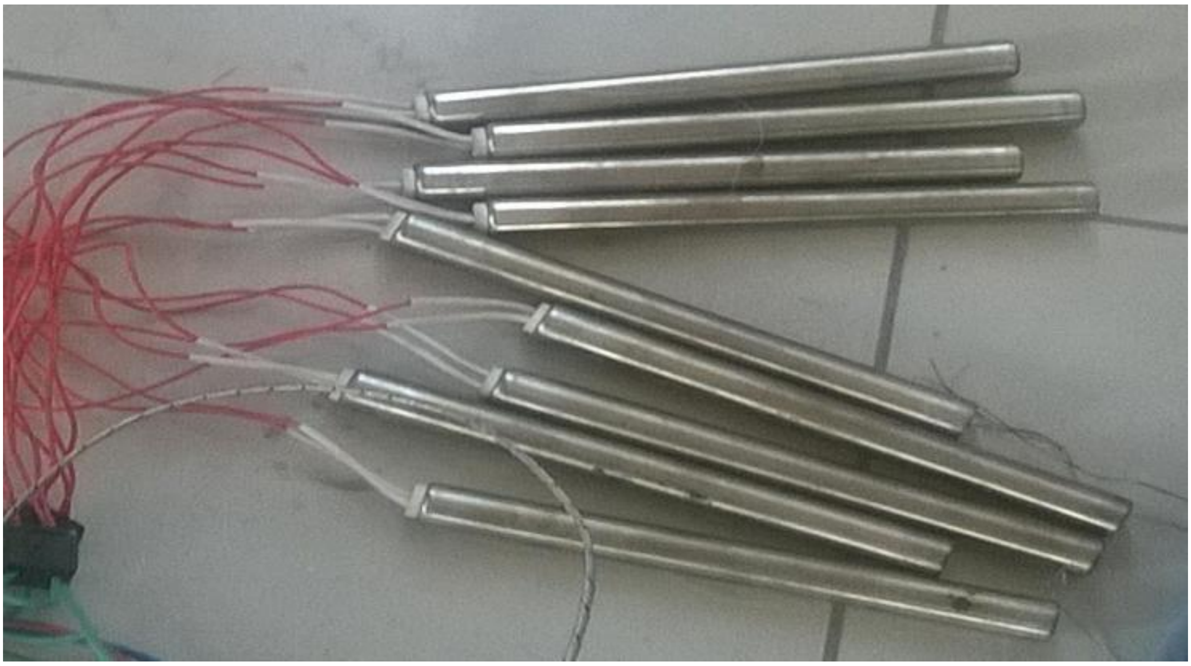

Figure 10 Image of heating rods

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6.4 Electrical control panel unit

The electrical control panel unit consists following Components:

1. Thermocouple
2. Controller

6.4.1 Thermocouple:

It is a device which consists of two wires made of different metals for the measurement of temperature. J-type thermocouple (fig.5.6) is used in the electrical control panel to measure the temperature of the die. The range of J-type thermocouple is -40 ˚C to 750 ˚C.

Figure 11: Image of J-type thermocouple

6.4.2 Calibration of thermocouple

Calibration means whether instrument gives a correct reading or not. It is basically a process that helps to calibrate the instrument. The calibration of the thermocouple is done with the help of a thermometer. In this process, first water is heated up to 80°C by an electric heater and 80°C temperature of hot water is kept for few minutes. Thereafter both thermometer and thermocouple are immersed into the hot water. Both thermocouple and thermometer gave the same reading. This helped to identify the accuracy of the material.

6.4.3 Controller

The main target of this setup is to maintain the die temperature at a required value. So that a controller is used in control panel to control the temperature of the die with the help of relays cut off. To begin with, set the temperature value on the display screen (fig. 8). Once the die attained the set value controller cuts off its supply by sensing the temperature of the die with the help of thermocouple.

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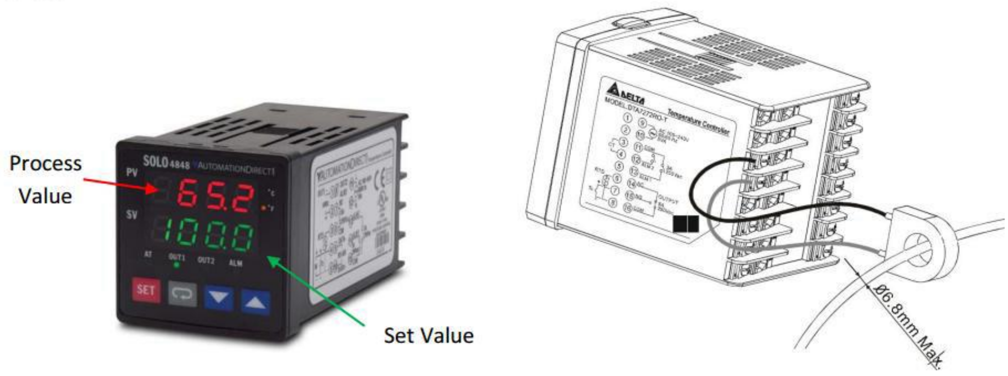

Figure 12: Image of the controller showing front and back sides

6.5 Development of Releasing Agent

This was one of the hurdles found in the experiment earlier. The former experience with the epoxy and resin compelled to consider PVA as the releasing agent. The combination used is

PVA granules 20gms+ 80ml of water+ 20ml of glycerine

This combination was mixed together manually and the outcome was a thick paste. Once started applying found that it's very difficult to cope up with the higher temperature. So by the help of Literature [4], [17], [19] identified Teflon sheets are good to go with experiment.

6.5.1 Development of PLA sheets

PLA sheets are the backbone in film stacking technique and it made in the die itself the steps are given below.

Step: 1

Preheat the required amount of PLA granules (82gm) in the oven at 80°C temperature for duration of 4hrs as per the data sheet given by the firm.

Step: 2

Clean the die and heat it up to the required temperature at which the sheet is going to be made

Step: 3

Once it reaches the required temperature fix the Teflon sheet and the strips. Finally the granules spread in the cavity and spread it uniformly. Once it's over the die is closed and loaded in the CTM machine

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Step: 4

The temperature is maintained as per the requirement and load starts to apply. Initially 0.5MPA Pressure has applied in the Die and waited for 3min later the pressure has increased up to 1MPA and waited for 2min by maintaining the same temperature. Later the power supply has switched off and die kept under the same load for cooling in room temperature.

Step: 5

Cooling time has limited to 80°C to open the die. Finally the Sheet has made with a thickness of 1mm. The diagram of the sheet has shown below

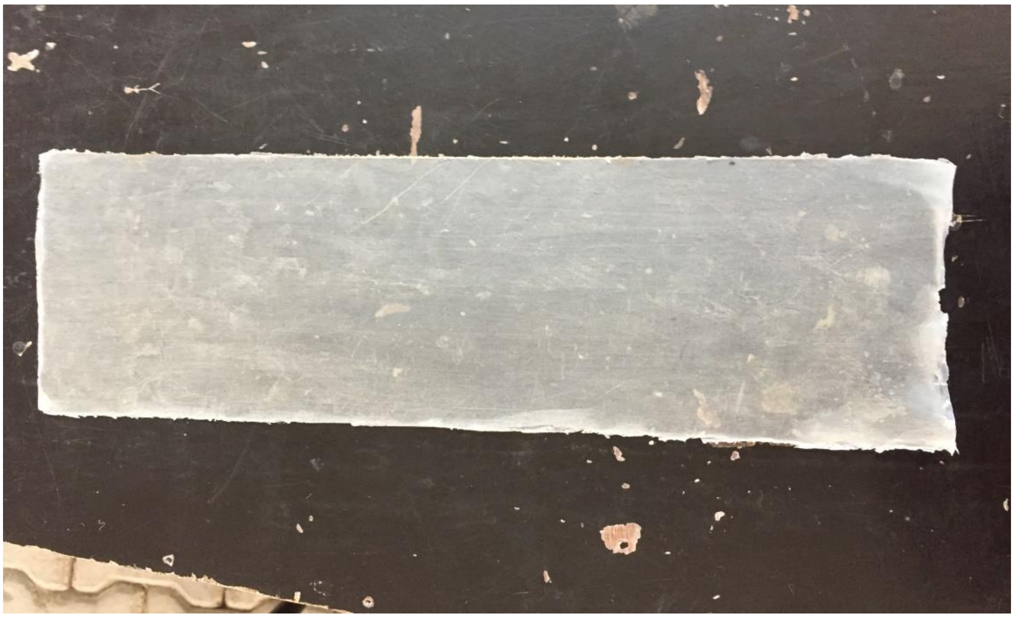

Figure 13 PLA sheet

6.6 Treatment of Fibre

The purchased fibres are directly kept it in 5% NAOH solution. The solution has prepared by adding 50gm of NAOH pellets in 950ml of distilled water. After dissolving NAOH the solution looks thick. The fibres are immersed in the solution at room temperature and kept it for 24hrs finally the fibre washed with distilled water itself to remove the alkali content from it. Later it is dried in the oven for 4hrs for removing the water content from the fibre. Finally it is ready for the experiment.

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Figure 14 NAOH pellets

Figure 15 Alkali solution

6.7 Development of Composite

The composite developed by using Film Stacking technique for this 4 layer of PLA sheet with 1mm thickness and 3 layer of jute fibre stack in between each other and form a sandwich structure. The development is explained step by step given below.

Step: 1

Initially the PLA films kept in the oven for pre-heating at a temperature of 70°C for 4hrs. Along with that 3 layer of jute fibre cut according to the dimension of the cavity and kept it fin the oven along with the sheets to remove the moisture content.

Step: 2

Once the temperature of the die has reached in to a required level the sandwich structure arranged with sheet and jute has kept in the cavity. Later the die has closed and loaded in the CTM machine

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Step: 3

Then a load of 0.5MPA is applied initially and waited for 3min after 1MPA load is applied for 2min at a constant temperature and the power supply has switched off. The cooling has done at room temperature in load condition

Step: 4

Finally the die opened at 80°C and the composite has removed manually.

The diagrams given below could give a better idea.

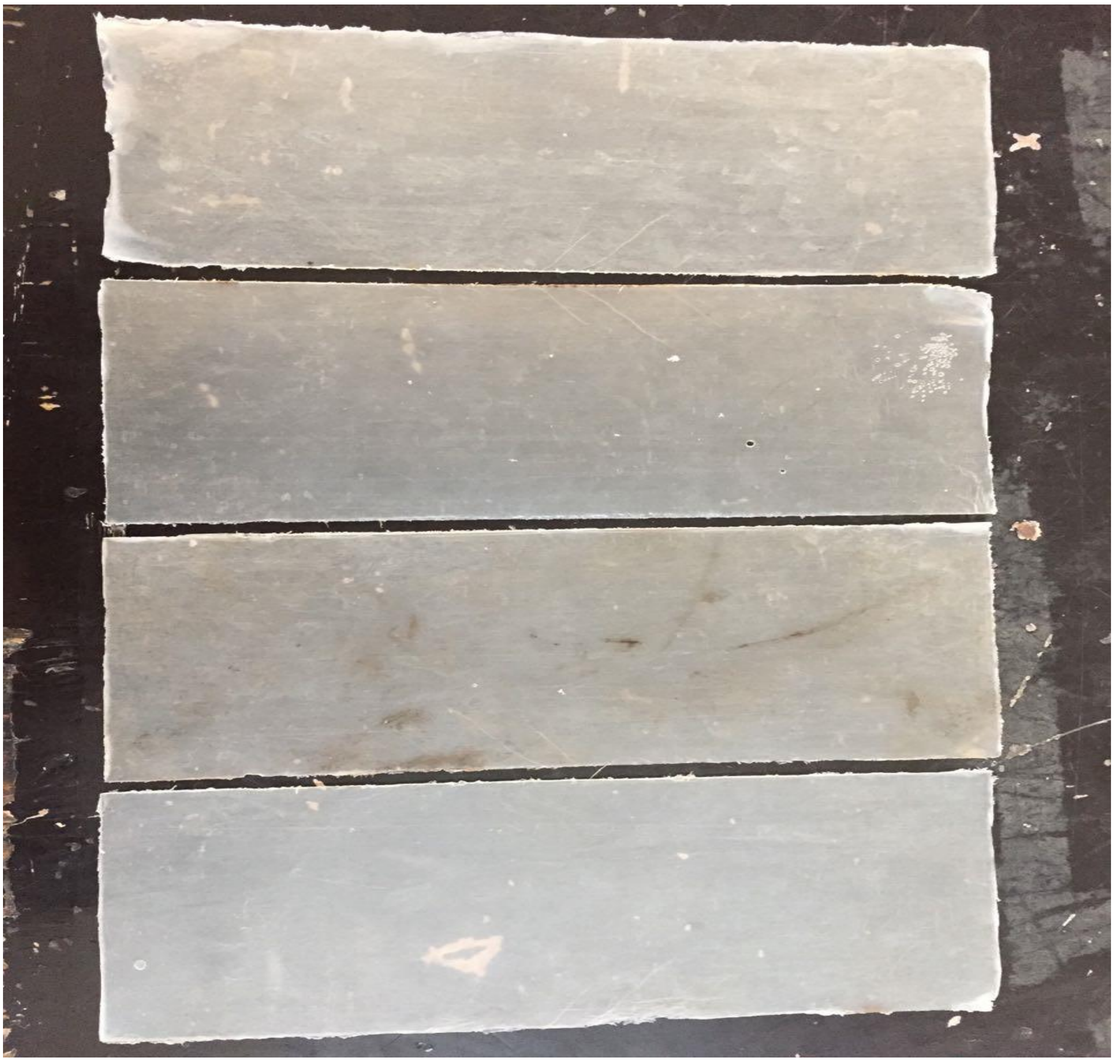

Figure 16 PLA sheets

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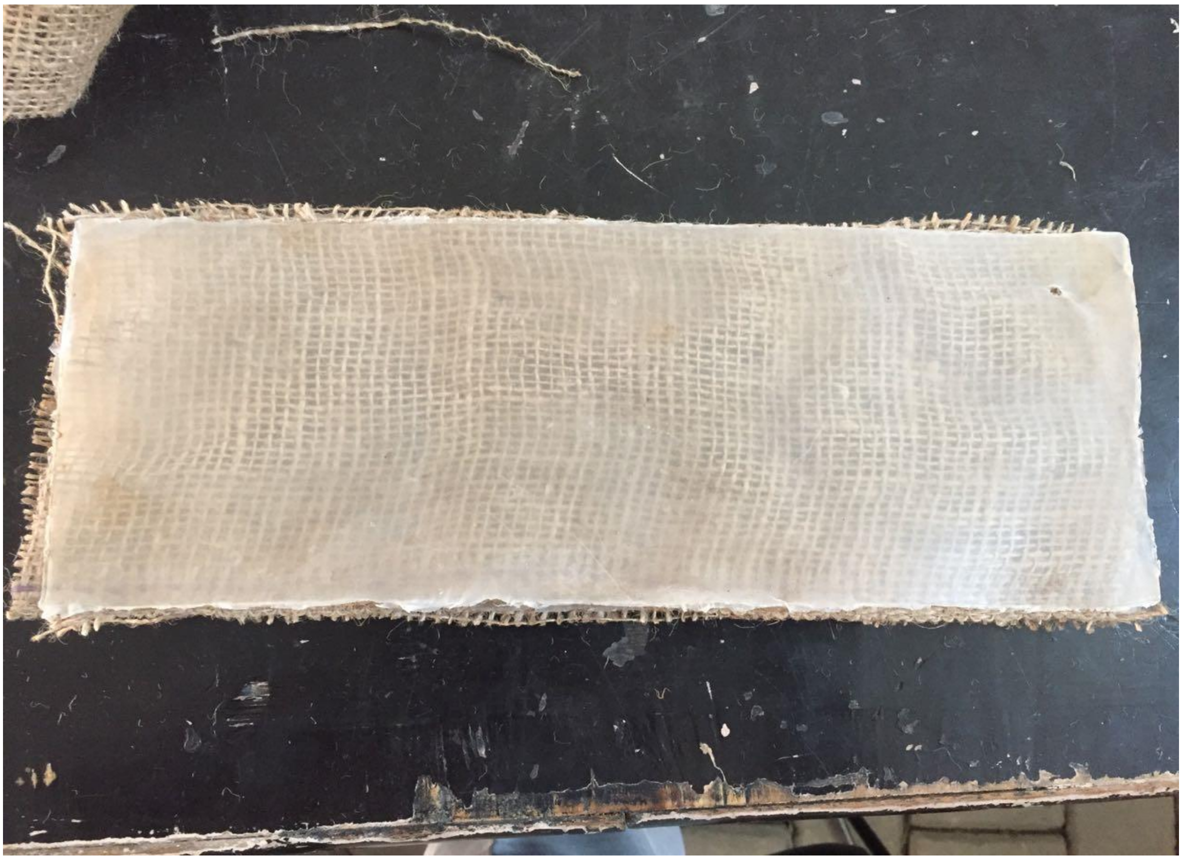

Figure 17 Sandwich structure

The diagram given below shows 4 specimens made by different temperature by using film stacking technique. The temperatures are 160°C, 170°C, 180°Cand 190°C. The different samples made by using PLA sheets of different temperature and made a four set s of sandwich structure. Later the die temperature is maintained respective of the sheets temperature and further process carried on.

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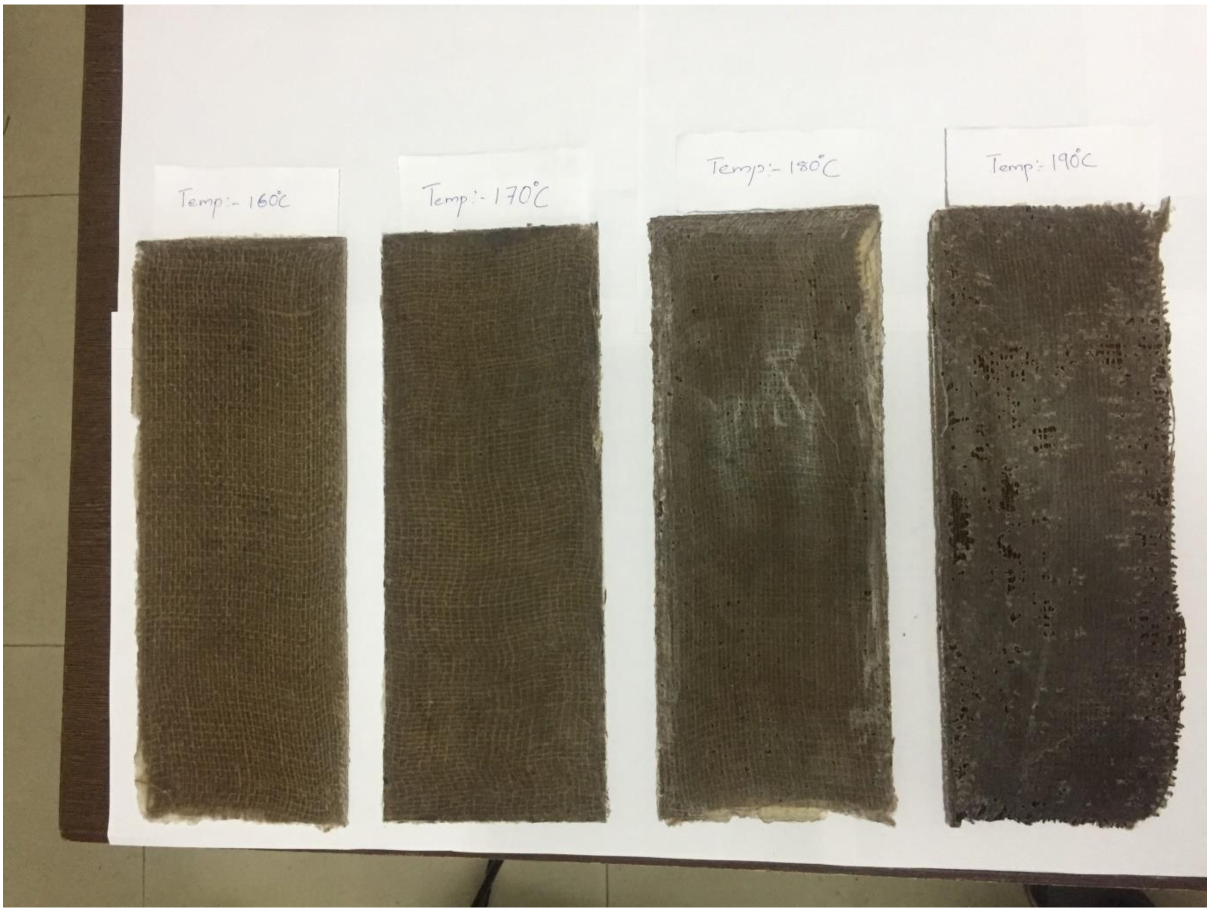

Figure 18 Different Samples with varing temperature

6.8 Calculation of Fibre Volume Fraction

Fibre volume fraction means the amount of fibre present in the composite material. The Fibre volume fraction is calculated by using the formula [7] given below.

$$V_f = 1 - \frac{W - W_f}{\rho m^V} \quad (1)$$

V_f =Volume fraction of fibre

W = weight of fabricated composite

ρm = density of matrix used

V = volume of fabricated composite

CHAPTER-7

7 RESULTS AND DISCUSSION

7.1 TESTING AND CALCULATIONS

7.1.1 Tensile Test

The tensile testing is conducted on Computerised Twin Screw UTM machine as per ASTM D3039 standard. The dimension of the specimen is 250x25x4mm. The model number of the machine is LSU-13 having a maximum load limit of 1000KG. The specimen is fixed between two jaws and axially load is applied by the machine which is parallel to the fibre direction. The longitudinal unidirectional fibre embed in the matrix experiences the axial load and fracture takes place when material loses its elastic nature and extends plastically.

Figure 19 UTM Machine

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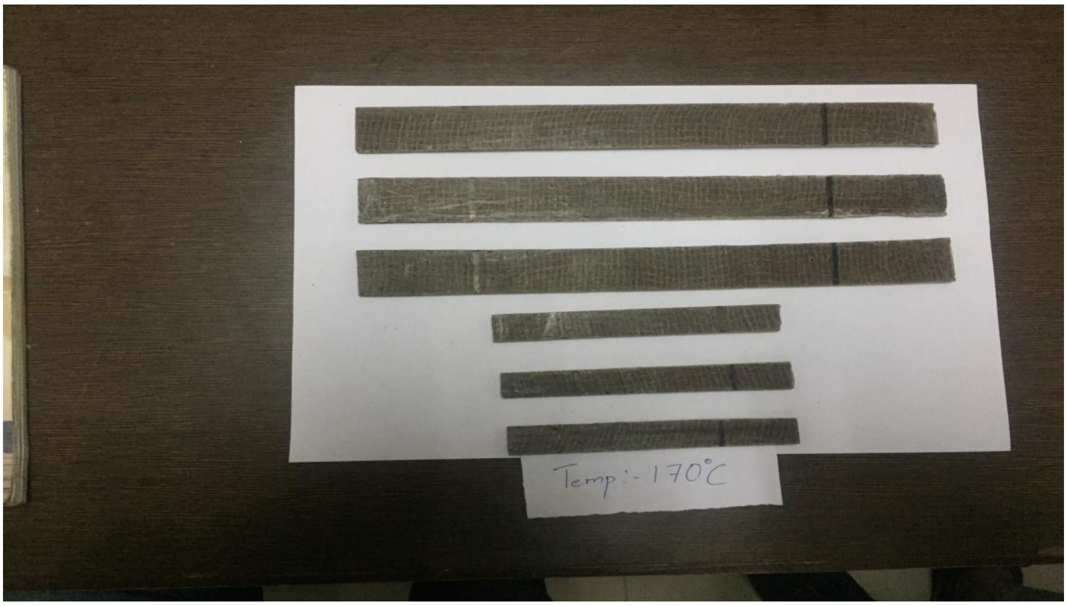

Figure 20 Samples for Tensile and Flexural

7.1.2 Flexural Test

The flexural test is also done in the same UTM machine according to the ASTM standard D790-02. It is a three point bending test. The specification of samples for flexure test is as per the ASTM standard is 120x15x4mm.

Figure 21 Flexural Test

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7.1.3 Impact Test

It is the amount of energy absorbed by the material during fracture. Izod test is conducted on each specimen of composite material. The ASTM D256-02 is used for Izod testing. The dimension of samples for impact test is 62.7x12.7x4mm.

Figure 22 Izod Impact Test Machine

Figure 23 Izod test samples

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Barcol Hardness Test

This is especially meant for the soft materials and Polymer material. It uses ASTM D2583 Standard. This is a manually operated machine and readings are given by the needle shown in the meter below.

Figure 24 Barcol Hardness Apparatus

7.1.4 Water Absorption Test

The water absorption test is done according to the Indian standard IS: 1998-1962 [21]. The test specimen is 38mm square with a 0.5mm clearance. The specimen is shown below.

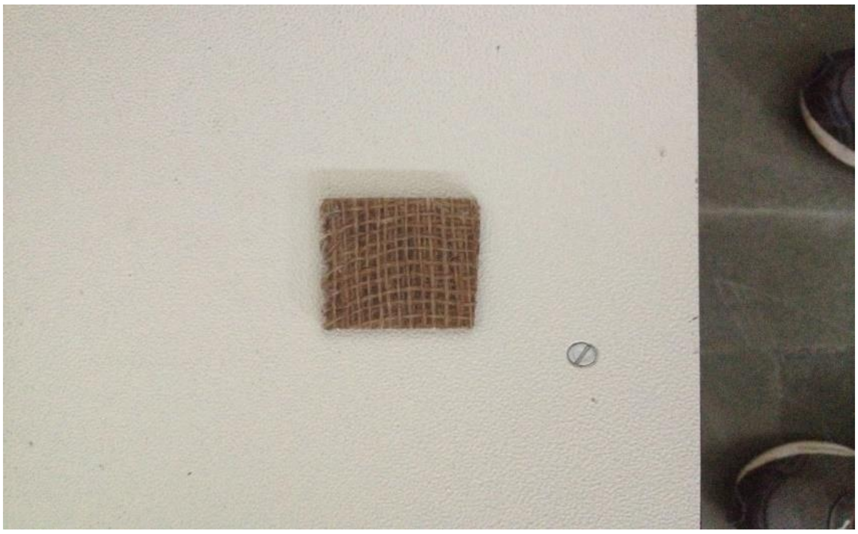

Figure 25 Water absorption test specimen

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7.1.5 Bio-degradability Test

For bio- degradability considered three samples from film stacking technique with temperature consists of 160,170 and 180 are considered with a dimension 150*25*4. The specimen has shown below.

Figure 26 Degradability Samples

7.2 MECHANICAL TEST RESULTS

The results of Mechanical Properties are given below in the table 1. All of the experiment the volume fraction of fibre is maintained in a range of 20-25%.

Table 1 Readings of Mechanical Tests on Film Stacking Technique specimen

SR No	Temp	Tensile (MPA)	Flexural (MPA)	Impact (J)	Barcol Hardness
1	**160°C**	**7.382**	**13.538**	**2**	**21.5**
2	**170°C**	**8.902**	**18.835**	**1**	**23**
3	**180°C**	**9.766**	**20.354**	**0.5**	**18**
4	**190°C**	**4.532**	**8.427**	**0.2**	**6**

The graphical representation of the results are given below

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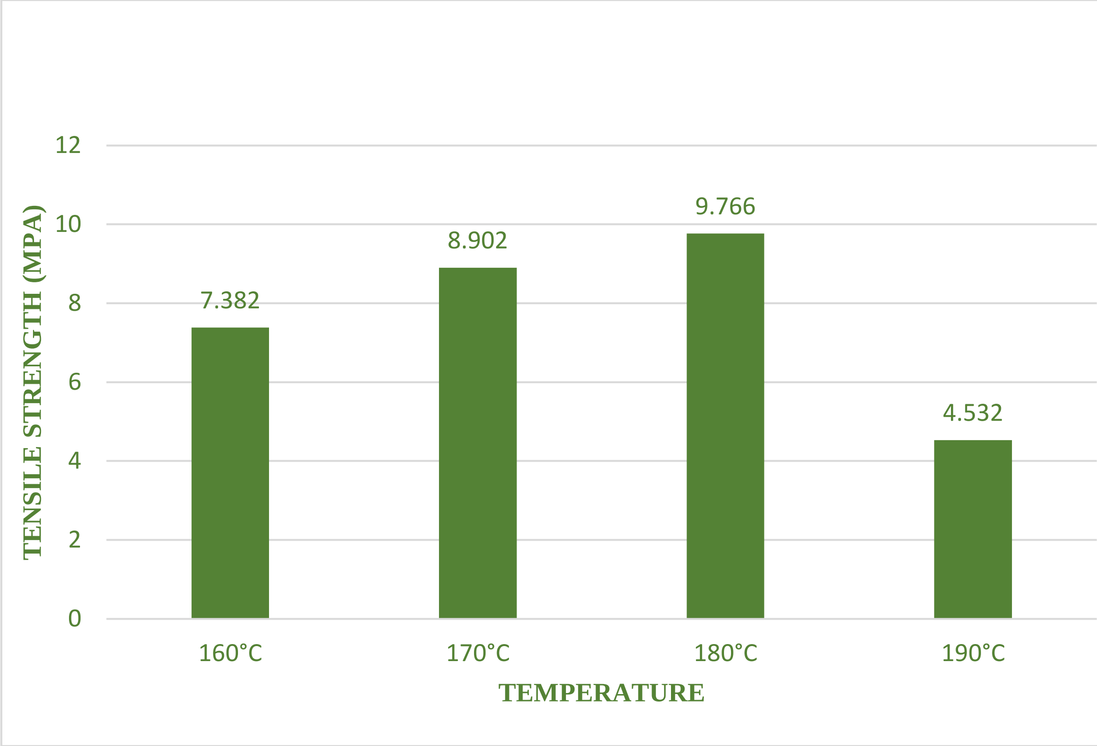

Figure 27 Tensile strength

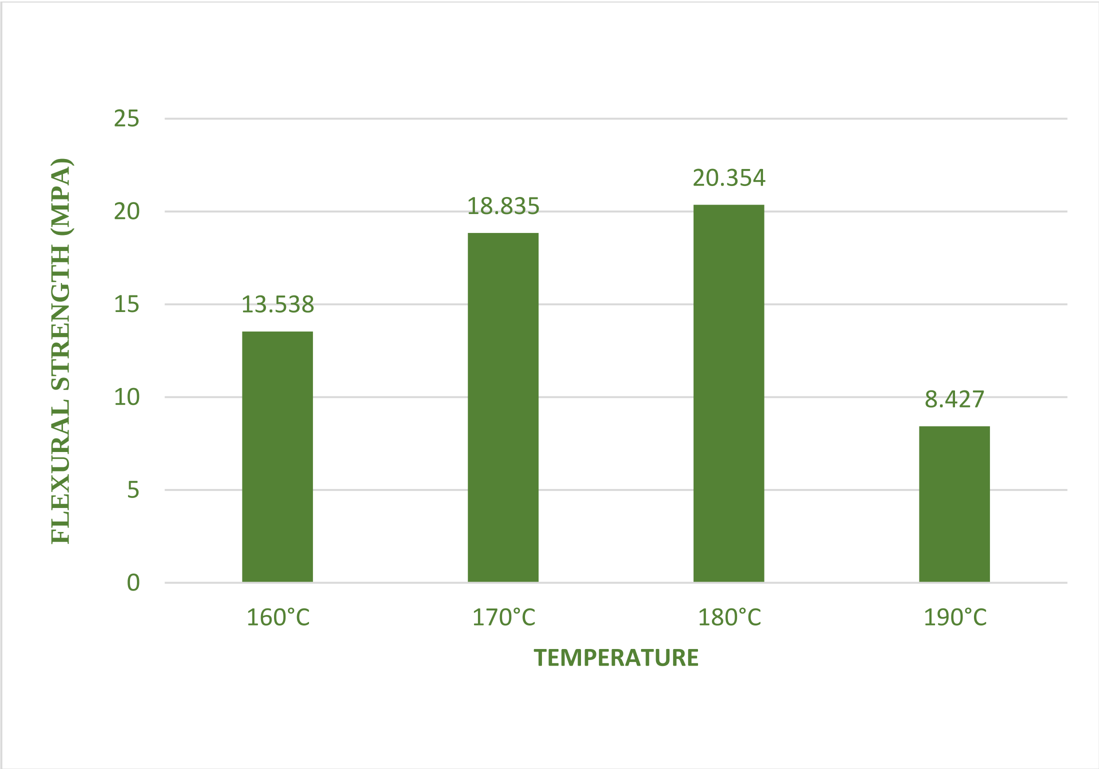

Fig: Flexural strength

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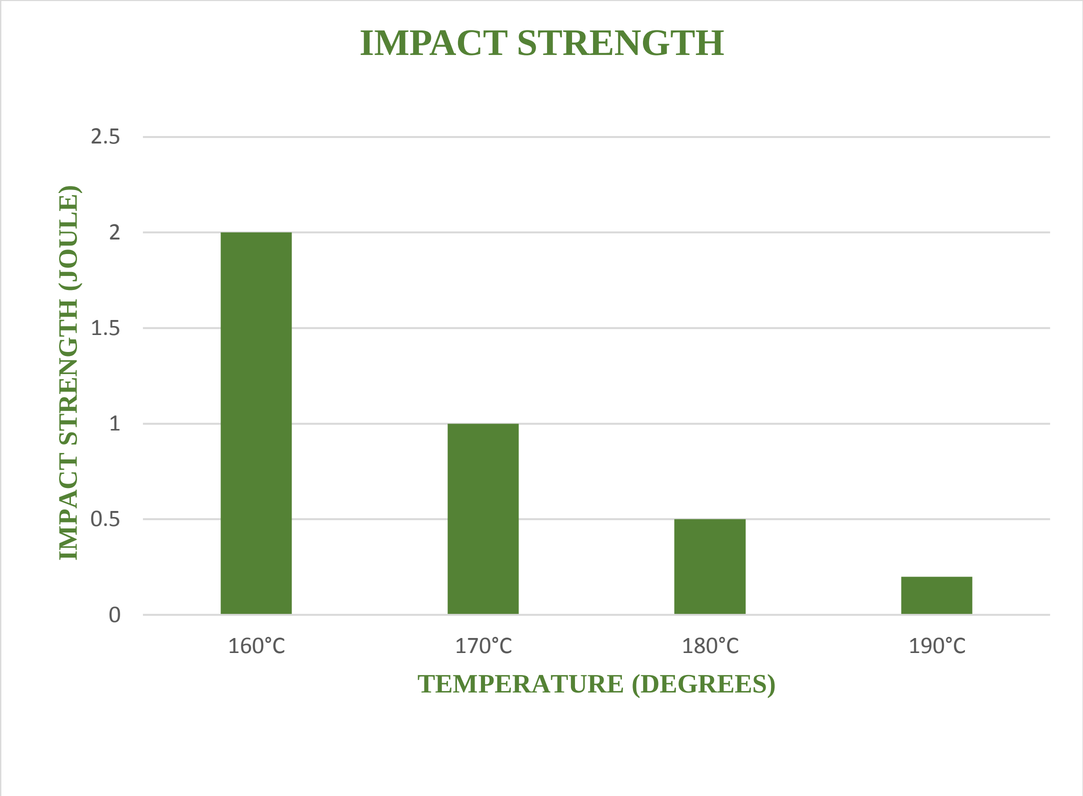

Figure 28 Impact Strength

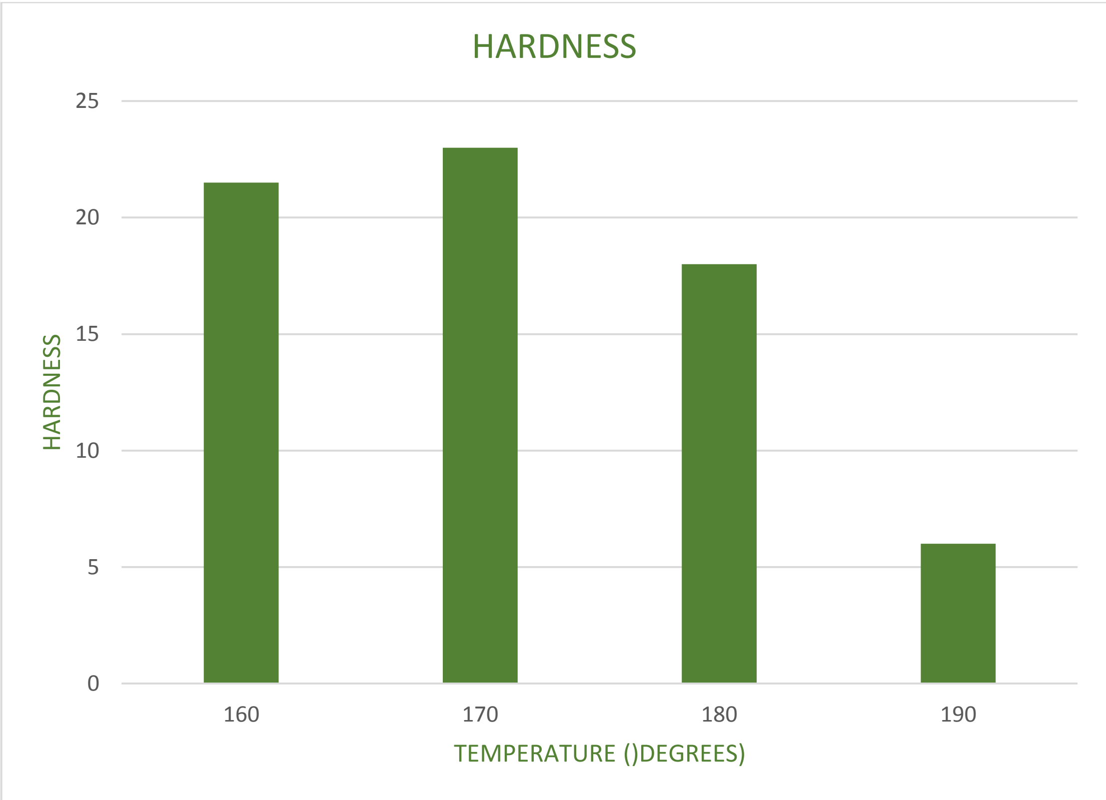

Figure 29 Barcol hardness

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7.2.1 Water Absorption Test Result

It calculated by keeping the specimen for 24hrs in water.

Initial Weight =6.5gm

Final Weight = 7gm

The percentage of water absorbed is 7%

7.2.2 Bio degradability Test Results

Table 2 Bio degradable results

Temperature	Initial Weight (gm)	Final Weight (gm)
160°C	17gm	16gm
170°C	17gm	17gm
180°C	17gm	16gm

The specimens were kept in soil for 23days and the change is clearly visible in the picture given above in this. Initially plan is to study the degrading according to the weight reduction but once the specimen experienced through naked eyes given a different feel that the weight might be same or small variation but the specimen damaged in a very bad manner. Even the 160°C specimen break automatically and 180°C also damaging in a fast manner and the 170°C is not that quick but the pace of damage is not bad as well. So I wish not to conclude anything from this irrespective of the understanding what explained earlier. The PH of the soil also checked and found out the value, it is 7.468, can say it is slightly acidic in nature.

7.3 NOVEL APPROACH

The Mechanical Characterisation results seems logically wrong, because when the results compared with the tested result of 1mm PLA sheet which made at a temperature of 160°C according to the ASTM standard D882 found a vast difference with a value of 89MPA. This variation is difficult to understand and leads to a conclusion that search for another method, if it is possible to achieve better results.

Figure 30 PLA sheet sample for testing

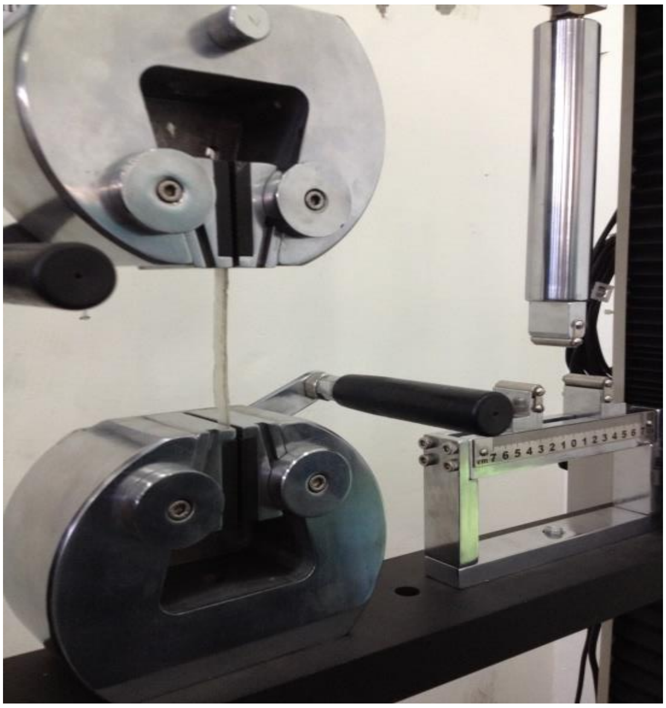

Figure 31 Tensile test of PLA sheet

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Before considering the second method two things taken in to consideration they are

1. Better quality

2. for mass production

For all previous experience taken in to account selected the second approach. It is **'SPETTERING METHOD'** It's not sure to call it as it is but named as it with regard the way the method has processed. At the beginning the method is an idea later it took forward to reality and finds a leap forward in the success. Detailing of the experiment is done in step wise down below.

Step: 1

An amount of 200gm PLA has taken and equally divided in two metal containers and kept in the oven for the preheating of the PLA at 80°C for 4hrs as did in the film stacking technique. The meantime 3 layer of fibres cut according to the dimension of the die and weighed later kept it in the oven for drying at same temperature for 3hrs to remove the moisture content from it.

Step: 2

Once the die has reached at a temperature of 180°C the first container which is having 100gm of PLA has taken out from the oven and poured it in to the cavity and levelled with the help of spatula. Once it accommodated in a uniform manner the three layer of jute fibre arranged above it and again the balance granules weigh 100gm is poured above the jute fibres and arranged it in a manner that it looks like a sandwich with 3 layer of jute in between the layers of PLA. Second time the arrangement of PLA was not that easy because of the waviness from the fibre In this case also the releasing agent is Teflon sheet. The pictures are shown below.

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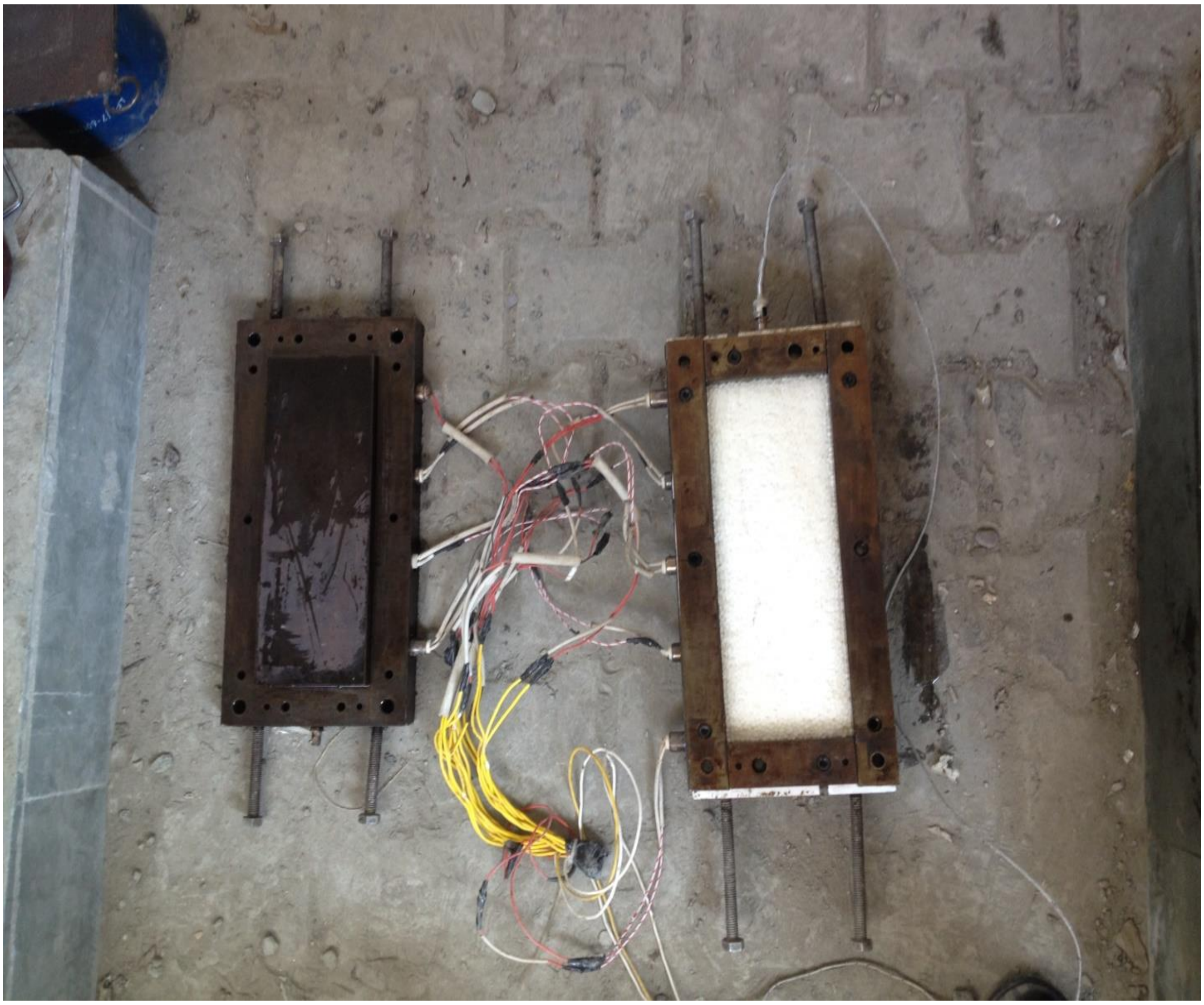

Figure 32 Sprinkling the PLA granules

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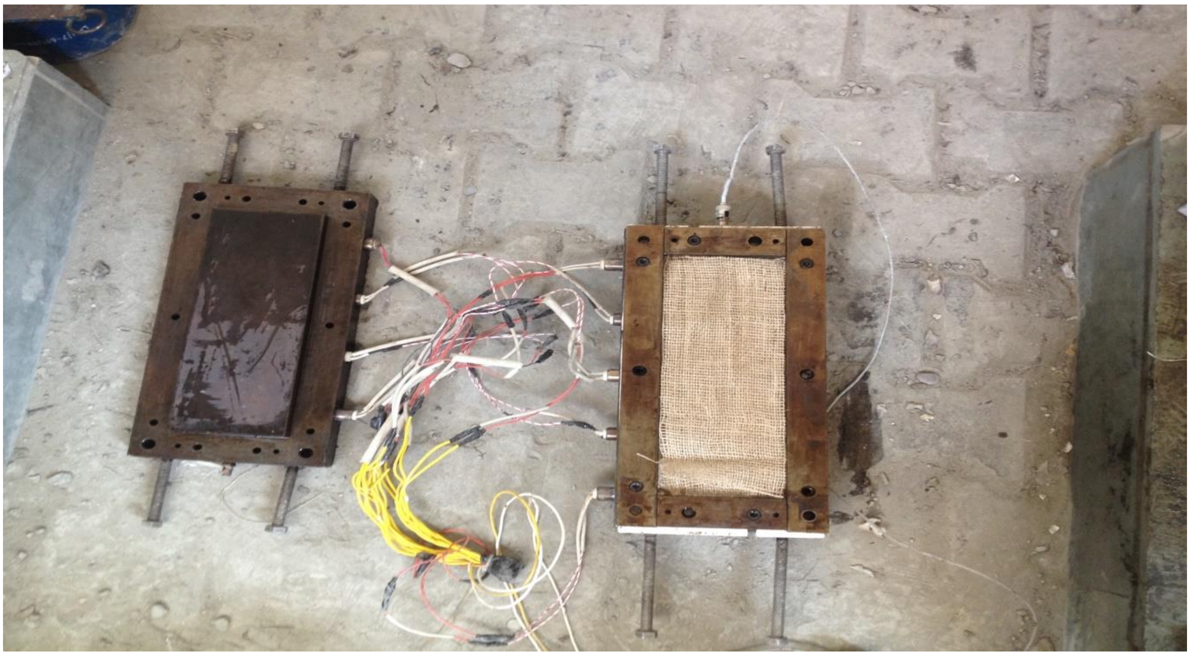

Figure 33 Arranging the Jute fibre

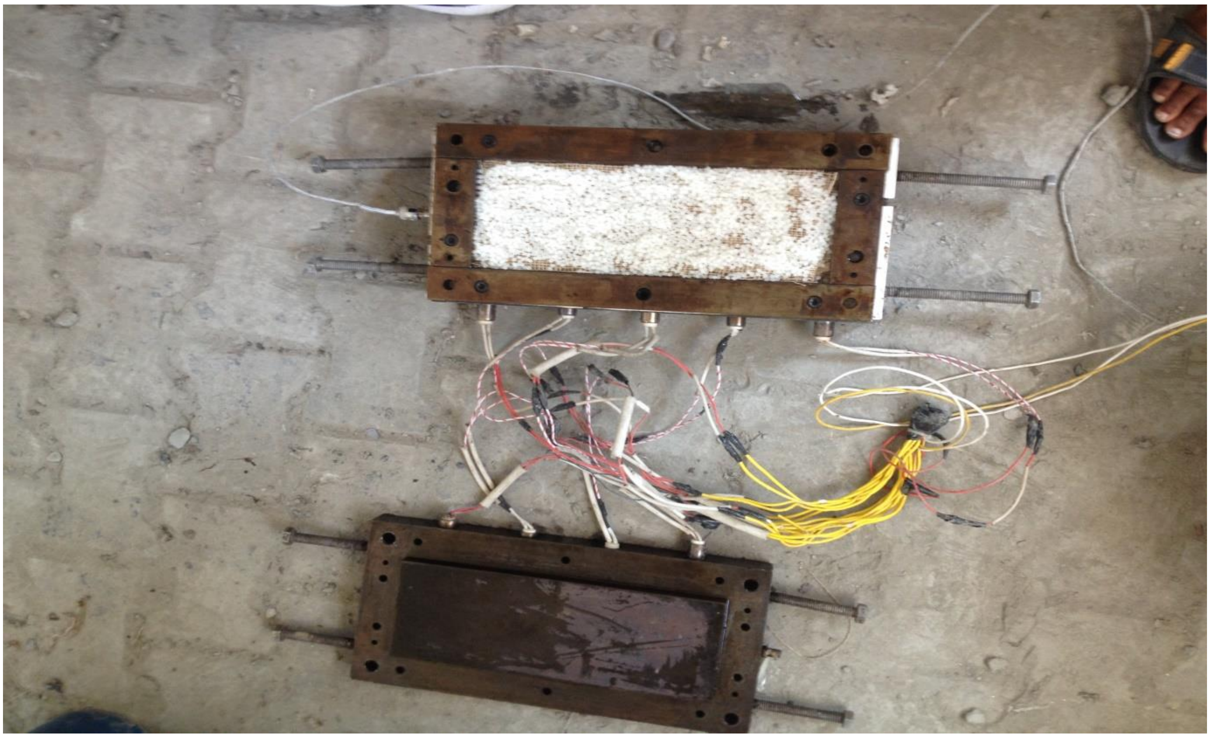

Figure 34 Sprinkling the second layer

In the above figures it clearly shows the procedure about the new technique. Here to mention that while arranging the jute fibre felt difficult to maintain a flat surface because of the

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waviness and that clearly affected the second layer of PLA as well. So the uniform distribution of the granules was not possible but tried to maintain a unity among all the sides. Finally the die closed by adjoins the Teflon sheet above PLA.

Step: 3

The die has moved to the CTM machine and given a 5min curing to the material later load has applied at a range of 40KN. But in this method few seconds later the needle shows the load as zero. It helps to identify the material has completely melted then again same load of 40KN has applied and wait for 2min to get everything settled at the same temperature. Finally the die subjected to cooling at room temperature with in the loading condition itself.

Step: 4

From the former experience the cooling of the die has limited up to 80°C to open the die. The final product seems unsatisfied with its surface finish here in this experiment the maximum temperature is 180°C

Figure 35 Specimen at 180°C

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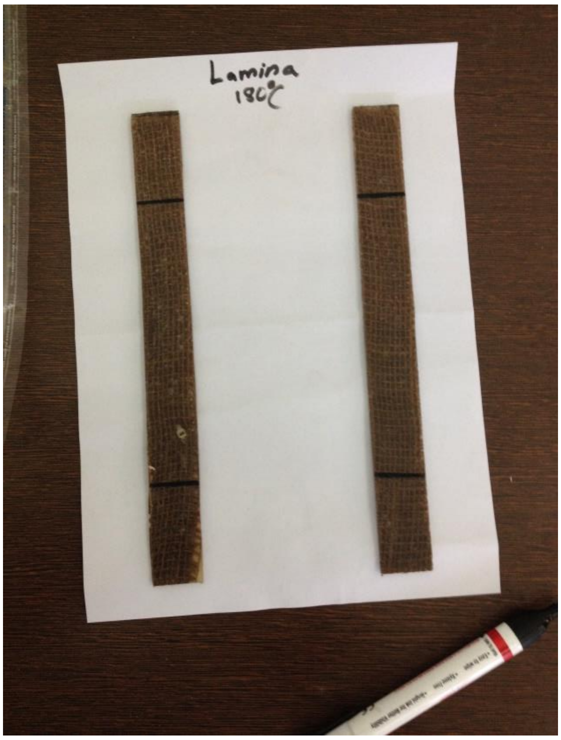

Figure 36 Tensile test specimen at 180°C

The testing for mechanical characterisation has shown an appreciable improvement with almost double the value when compared with film stacking technique irrespective of the surface finish. The values obtained are 17.206 MPA as tensile strength and 35.254 MPA as flexural strength. The table is given below to identify the values obtained from the first trial with new method.

Table 3 Mechanical properties at 180°C

SR NO	Temperature	Tensile strength (MPa)	Flexural strength (MPa)	Impact strength (MPa)	Barcol hardness No
1	180°C	17.206	35.254	1.5	12.5

For a better understanding the test results of Film stacking technique and spettering methods at which 180°C is compared with the help of graphs

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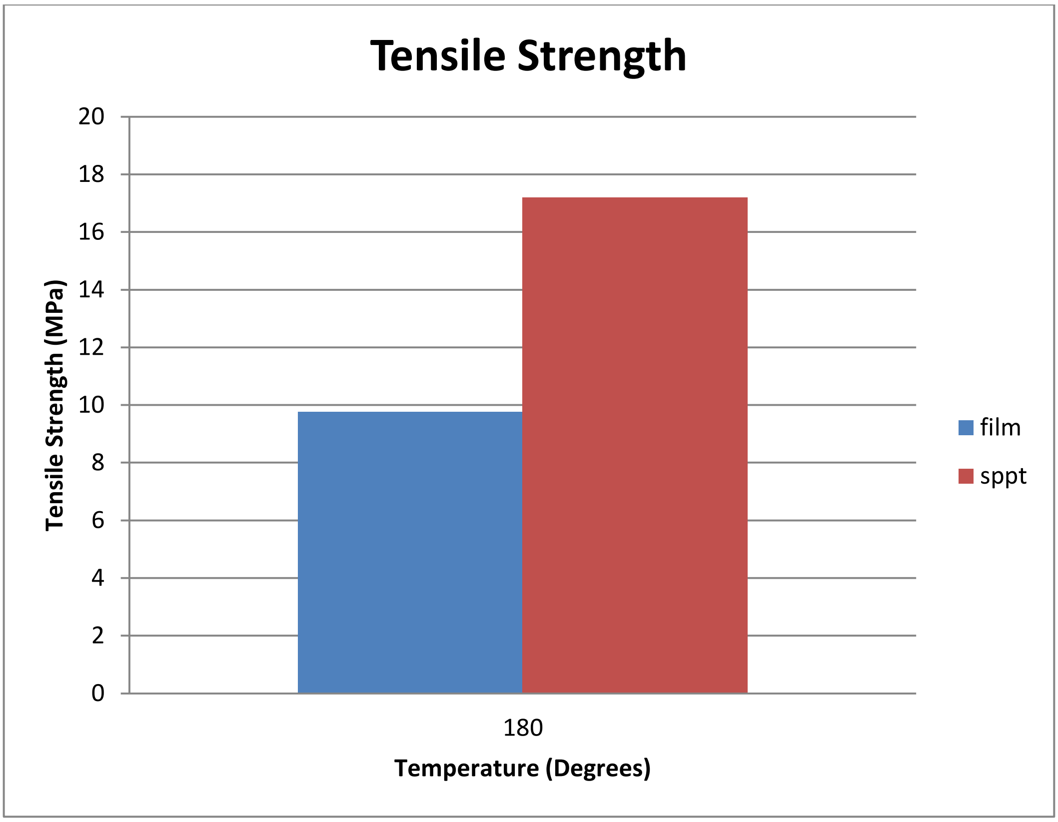

Figure 37 Tensile strength

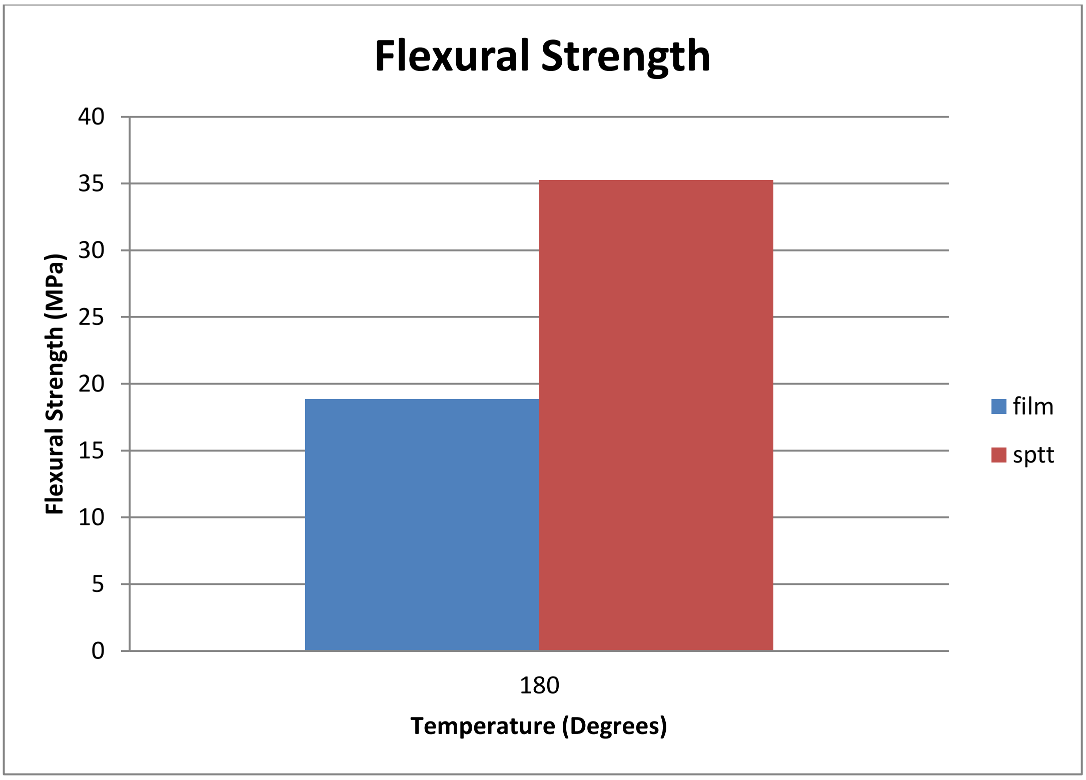

Figure 38 Flexural strength

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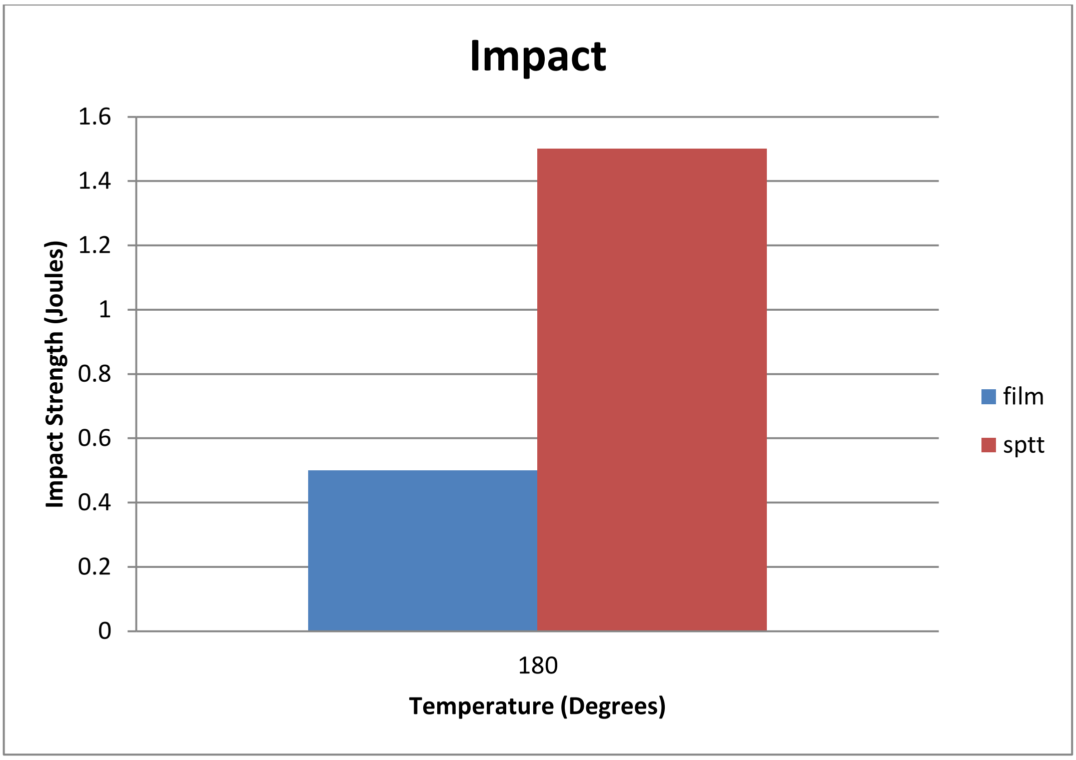

Figure 39 Impact strength

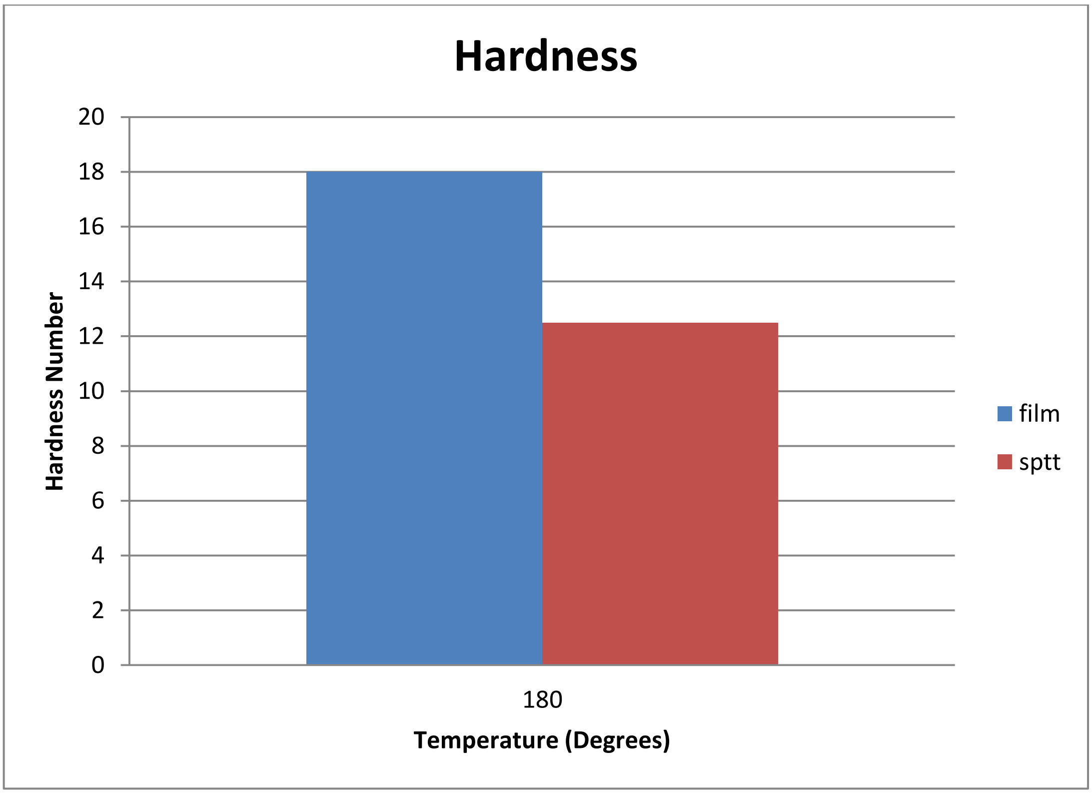

Figure 40 Hardness

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Step: 5

7.3.1 Effect of Curing

The second step was to find out the effect of curing temperature here the curing has considered the time taken after loading and before subjected to cooling which means the time in between these two. Initially the curing temperature study did with 180°C itself and the results are given in table below.

Table 4 Mechanical Characterisation at 180°C in different curing time

SR no	Temperature	Curing Time (min)	Tensile Strength (MPa)	Flexural Strength (MPa)	Impact Strength (J)	Barcol Hardness
1	180°C	5	17.206	32.257	1.5	12.5
2	180°C	15	26.752	72.372	2	22
3	180°C	30	16.805	15.735	3	21

The graphical representations are given below.

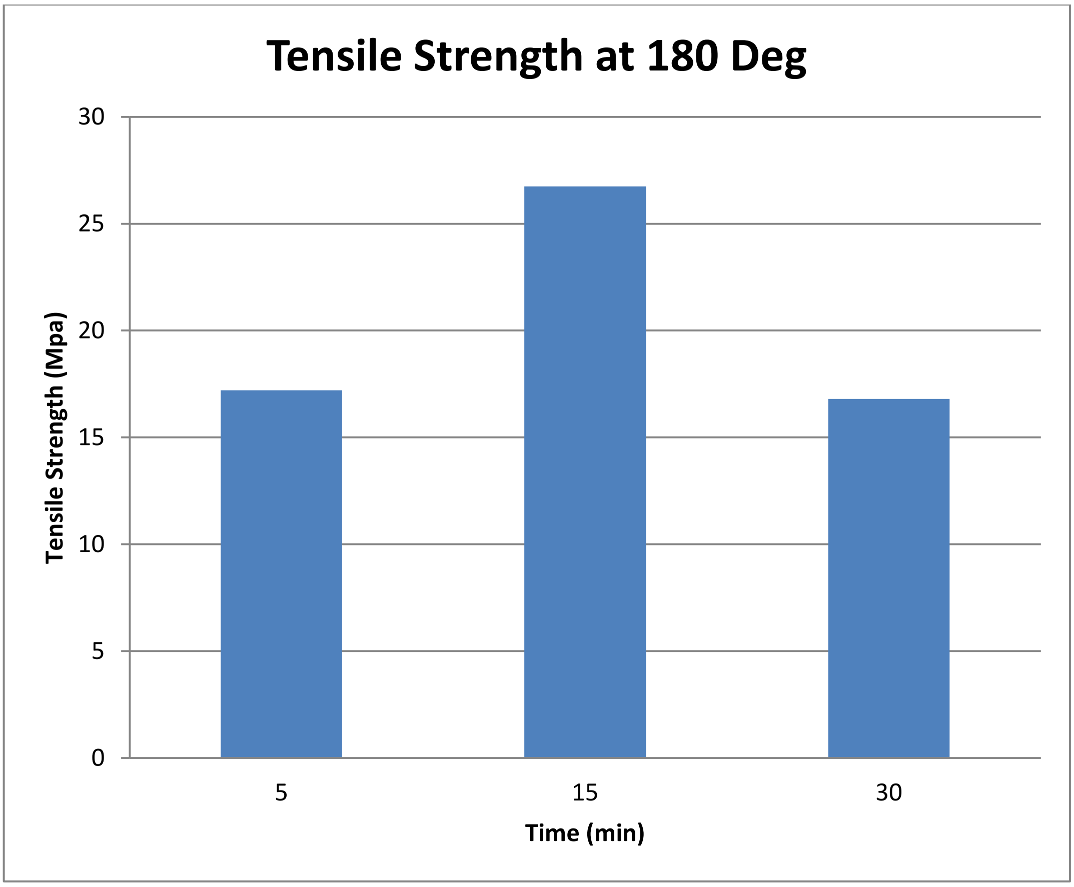

Figure 41 Tensile strength

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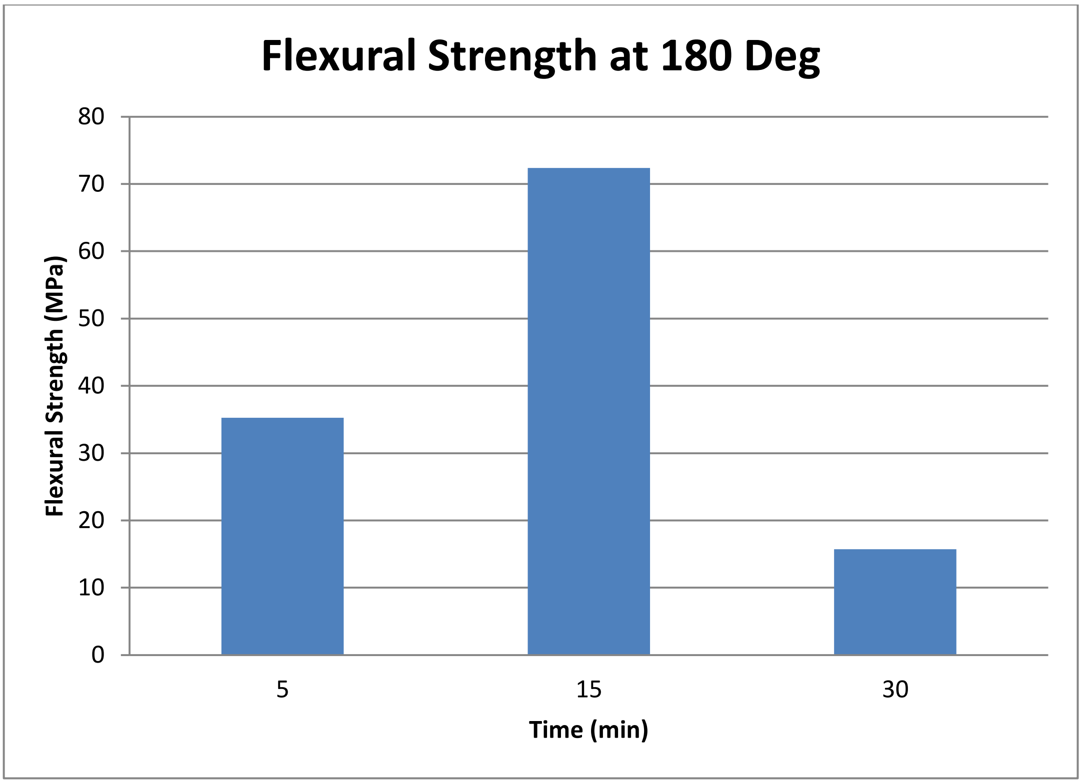

Figure 42 Flexural strength

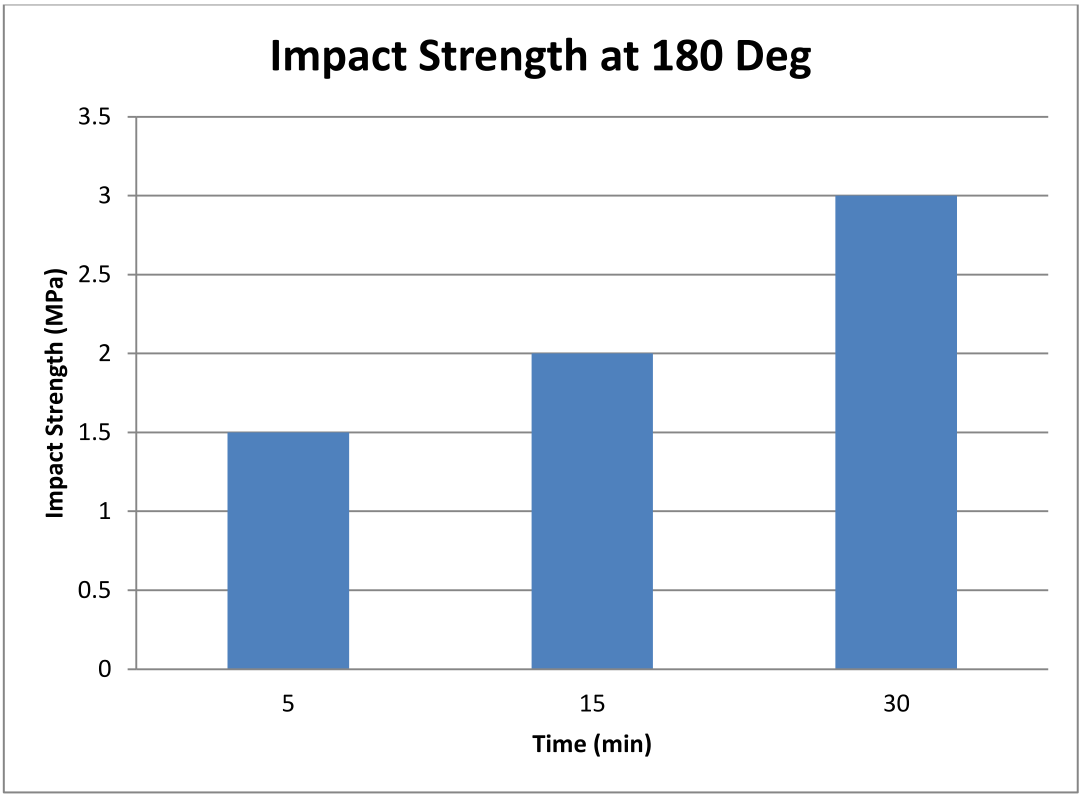

Figure 43 Impact strength

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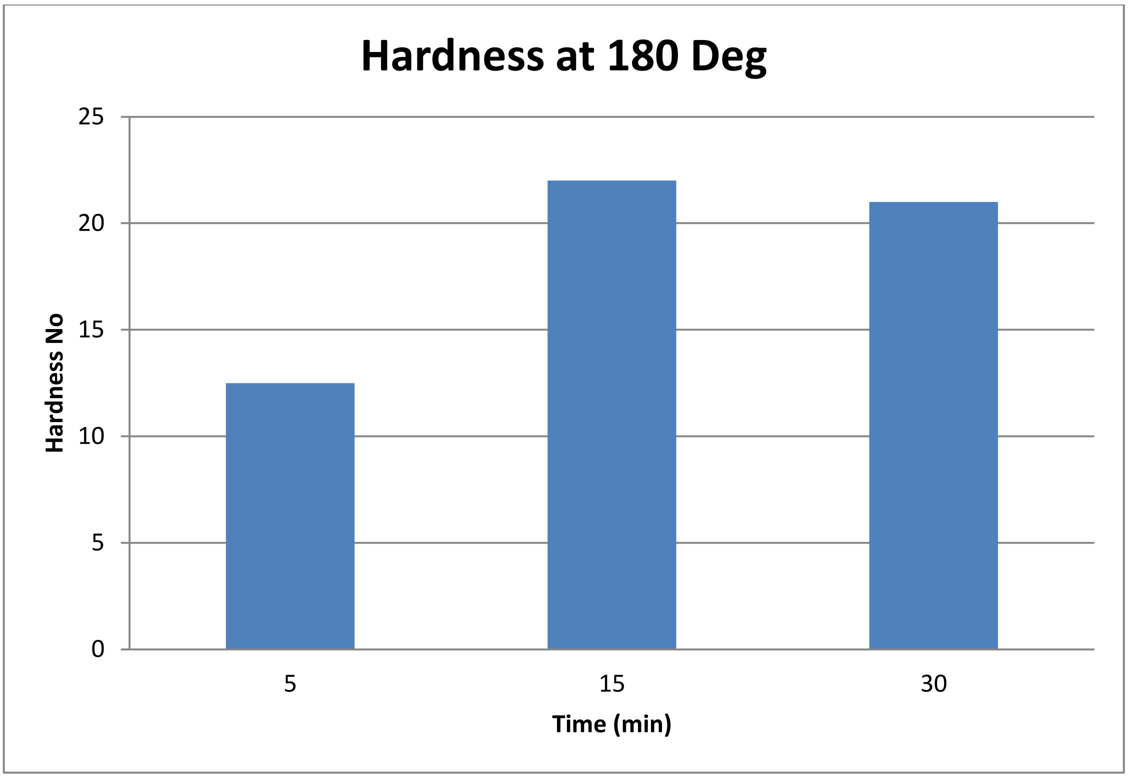

Figure 44 Hardness

In the above table and graph it is very clear that the 15min curing gives the better mechanical properties. After achieving a remarkable properties the next agenda concentrated on the surface finish

Step: 6

7.3.2 Optimizing the surface finish

To optimise the surface finish the temperature reduced to 160°C and the same procedure has followed the result is a good surface finish as well as the testing results shows a good improvement in the mechanical properties as well. The table given below shows the result for 160°C spettering method.

Table 5 Results of spettering method at 160°C

SR.NO	Temperature	Tensile strength (MPa)	Flexural strength (MPa)	Impact strength (MPa)	Barcol hardness
1	160°C	38.808	66.963	2.5	15

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Figure 45 Specimen at 160°C

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For better understanding of the betterment of result the spettering method results are compared with film stacking technique by maintaining the other parameters as same. The graphs are given below.

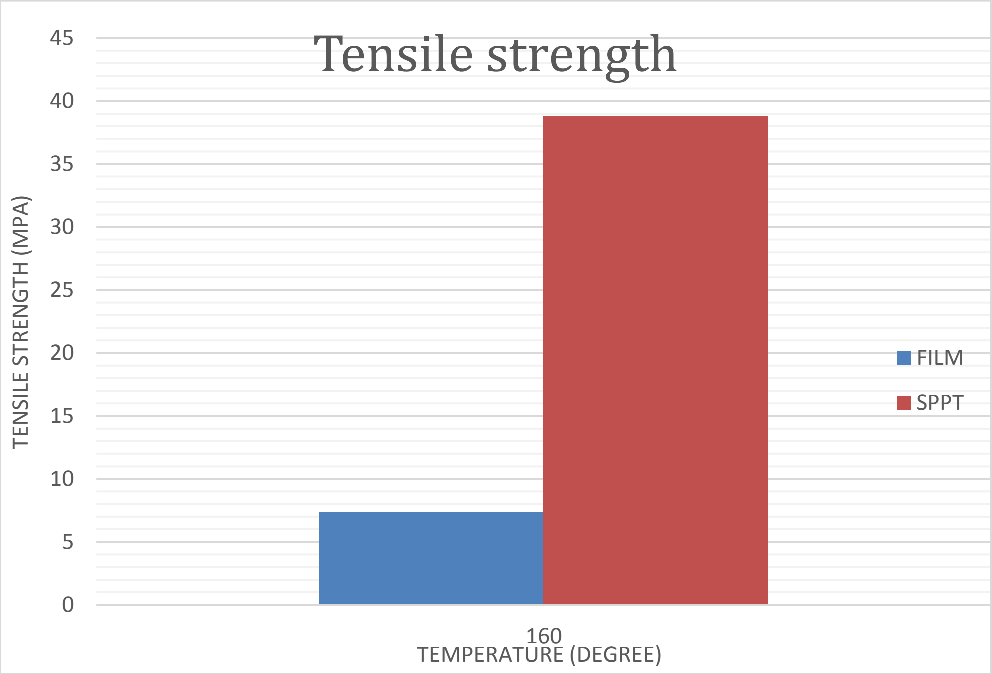

Figure 46 tensile strength

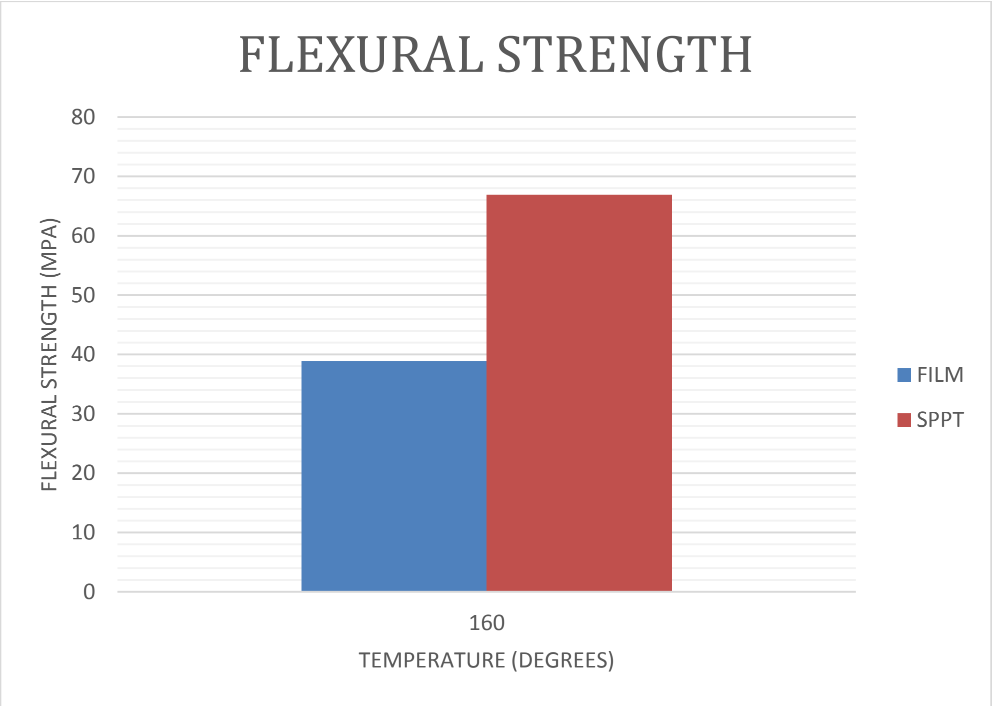

Figure 47 Flexural strength

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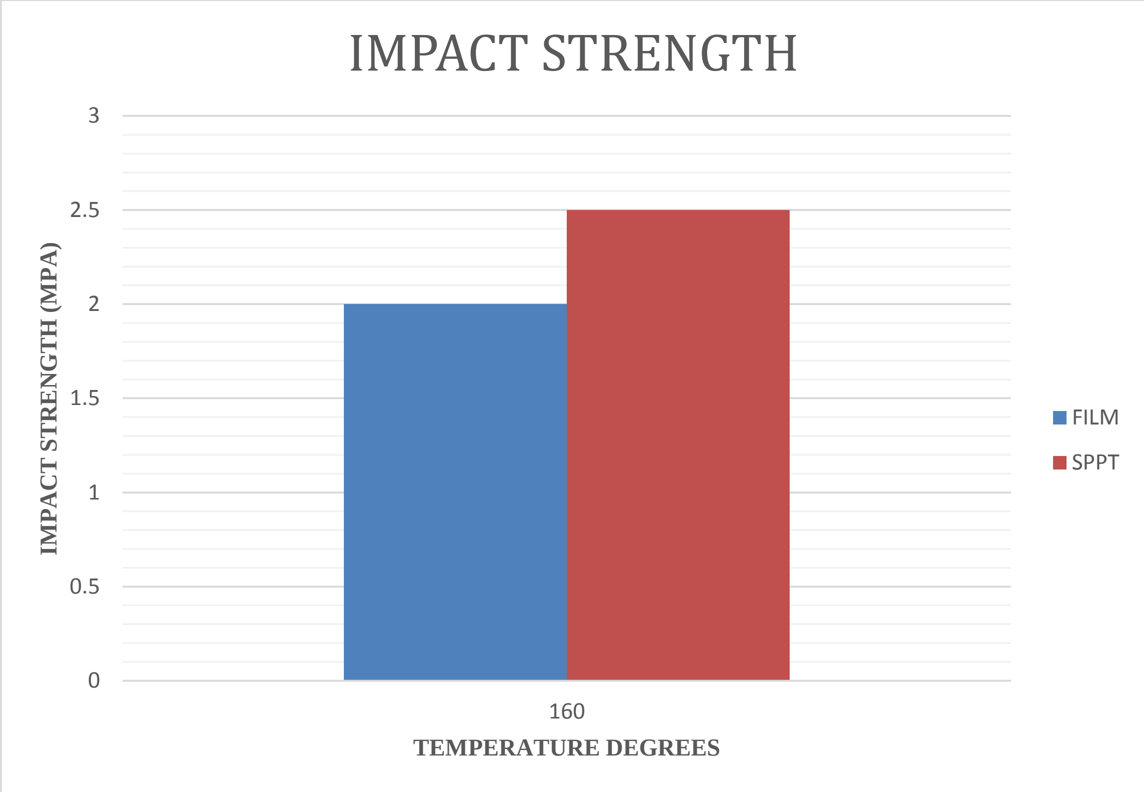

Figure 48 Impact strength

Figure 49 Hardness

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Step: 7

7.3.3 Surface Treatment

The next objective is to identify the effect of surface treatment on fibre. The NAOH solution is considered for the fibre treatment. Treated fibre composite developed at 160°C because of the better results obtained from the former experiments. And the value is compared with non-treated fibre developed in same temperature with same volume fraction and parameters. The results are discussed below

Table 6 Comparison of treated and non-treated composite

`	Temp	Treated/Non-treated	Tensile strength	Flexural strength	Impact strength	Barcol hardness
1	160°C	Treated	38.2	66.9	1.75	15
2	160°C	Non-treated	38.2	66.9	2	21.5

The comparison graphs are shown below

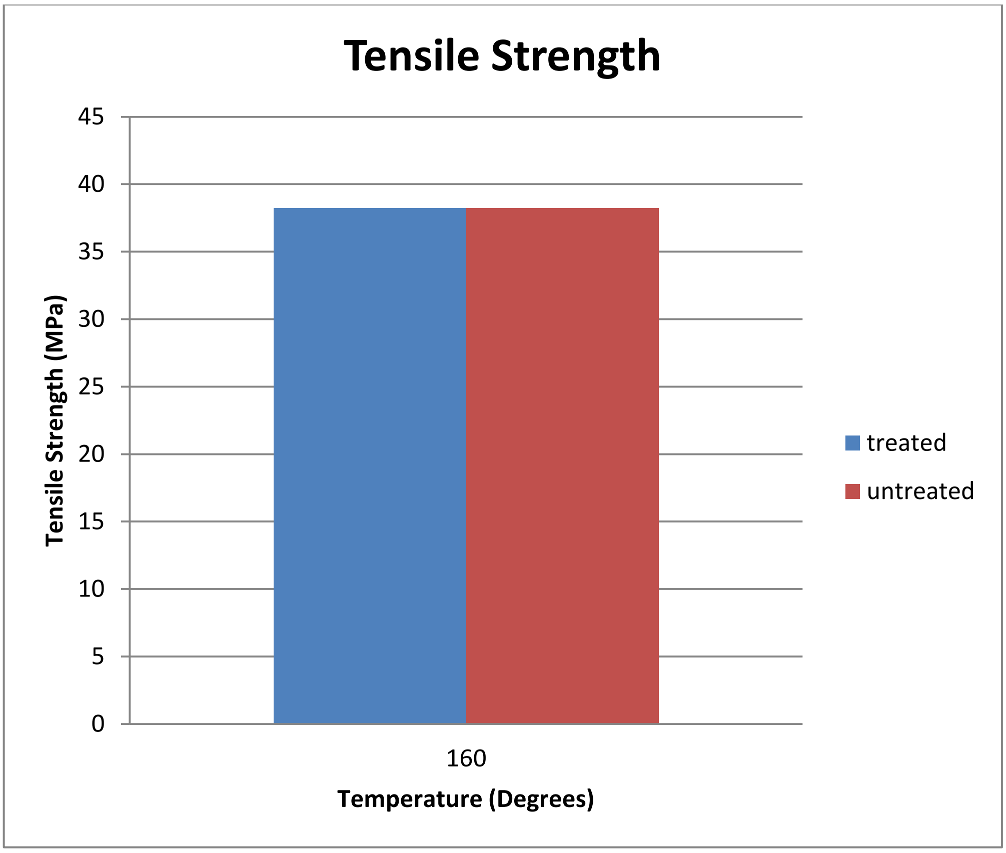

Figure 50 Tensile strength

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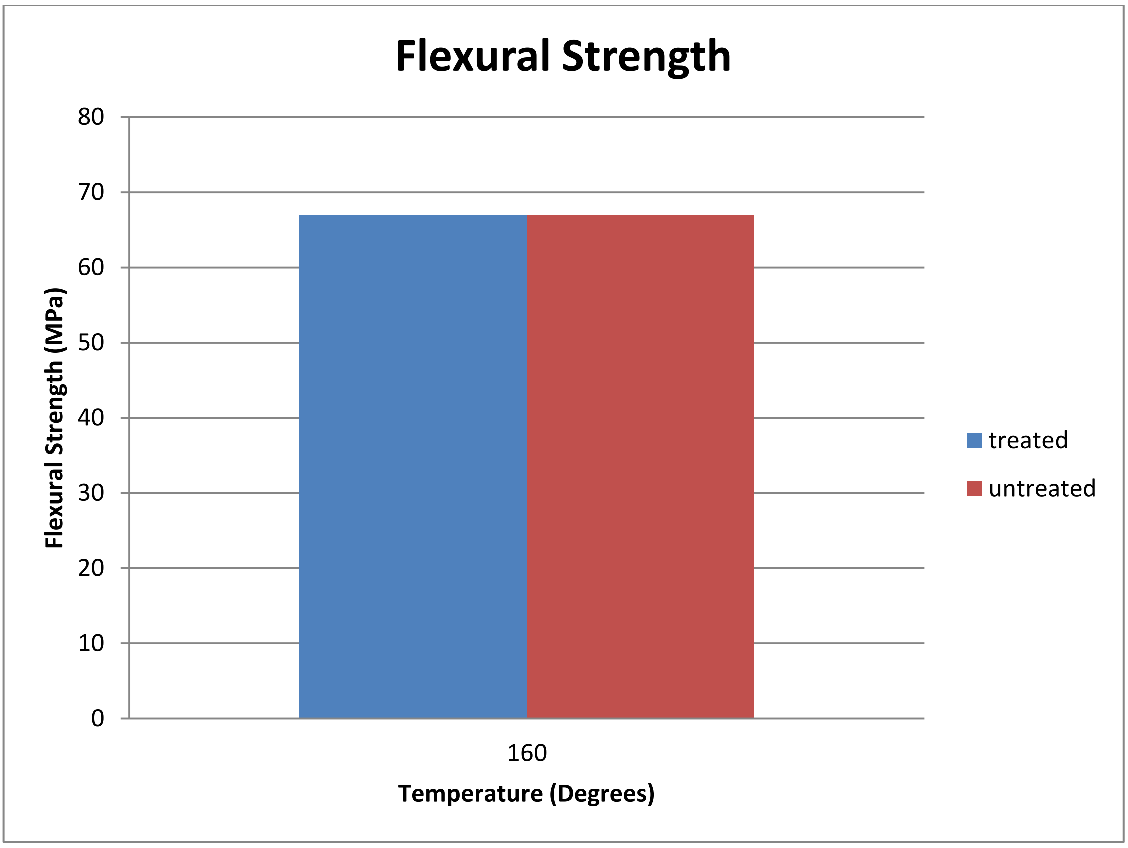

Figure 51 Flexural strength

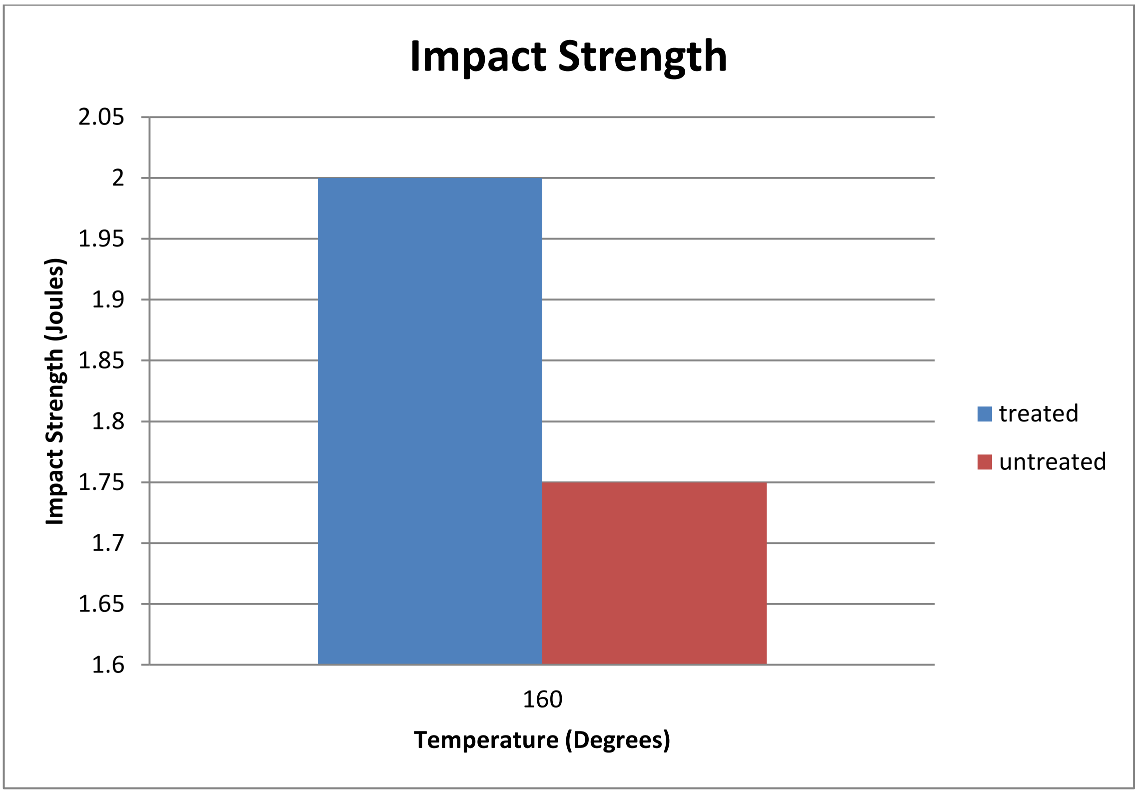

Figure 52 Impact strength

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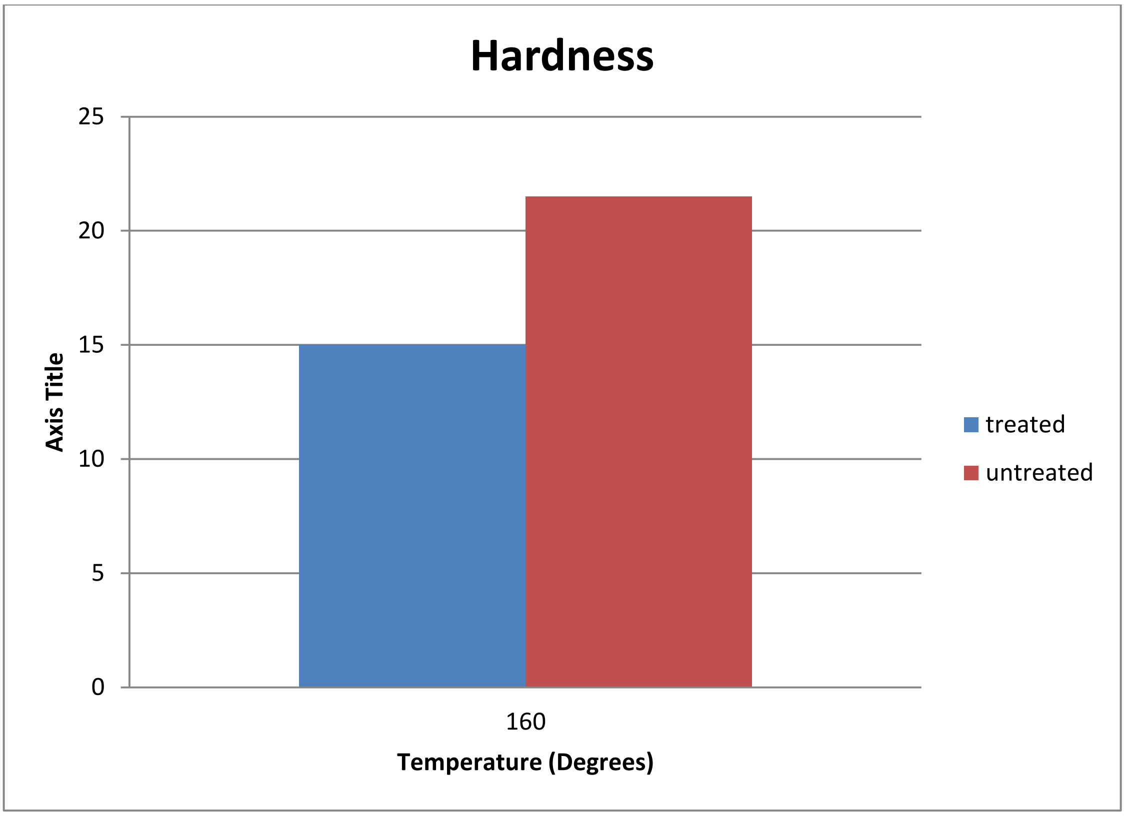

Figure 53 Hardness

The comparison results in the above depicts there is hardly any difference between the treated and non-treated with few of the properties. So it is unable to discuss about the alkali treatment. According to literature reviews it is clear that there is a good amount of variation in the properties. So that further study is important to finalise the effect.

Step: 8

7.3.4 Optimisation of Load

By maintaining the temperature as constant tried to optimise the load for the better strength. This was completely based on the work experience with the PLA and I am sure the load which applied seems bit fascinating by its procedure. Here three different sets of load has applied.

- First experiment maximum load is maintained up to 40KN but the procedure is initially after loading a load of 20KN is applied to settle the matrix once it got settled the needle comes to zero. This moment load has again increased up to 40KN and waited for curing. Here a trend has observed that the load is reducing gradually. This was the spark for the selection of second set of load.

- Second experiment started with 40KN load and once it came down again a load of 40KN has applied this process continued till 5 sets it shows the maximum load as 200KN but the material experience maximum load as 40KN. Later 2sets the load has

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not come up to zero but a far reduction was visible so the procedure of applying load up to 40KN has continued till 5sets

- Third experiment also follows the same procedure but the initial load was 30KN and the maximum gone up to 60KN for three sets so the total load applied is 210KN with 5sets.

As a novel approach wish to point out that the optimisation is not the ultimate still variation of load could make difference in the output. The output found by the outcome is much appreciable when compared with the former ones. The results are given in the table below.

Table 7 Impact of load variation in composite

SR. NO	Load(KN)	Tensile(KN)	Flexural(KN)	Impact(J)	Hardness
1	40	38.808	66.963	2.5	15
2	40-200	42.378	66.668	2	15
3	30-60-200	54.32	84.837	2	19.5

The graphical representation is given below in detail

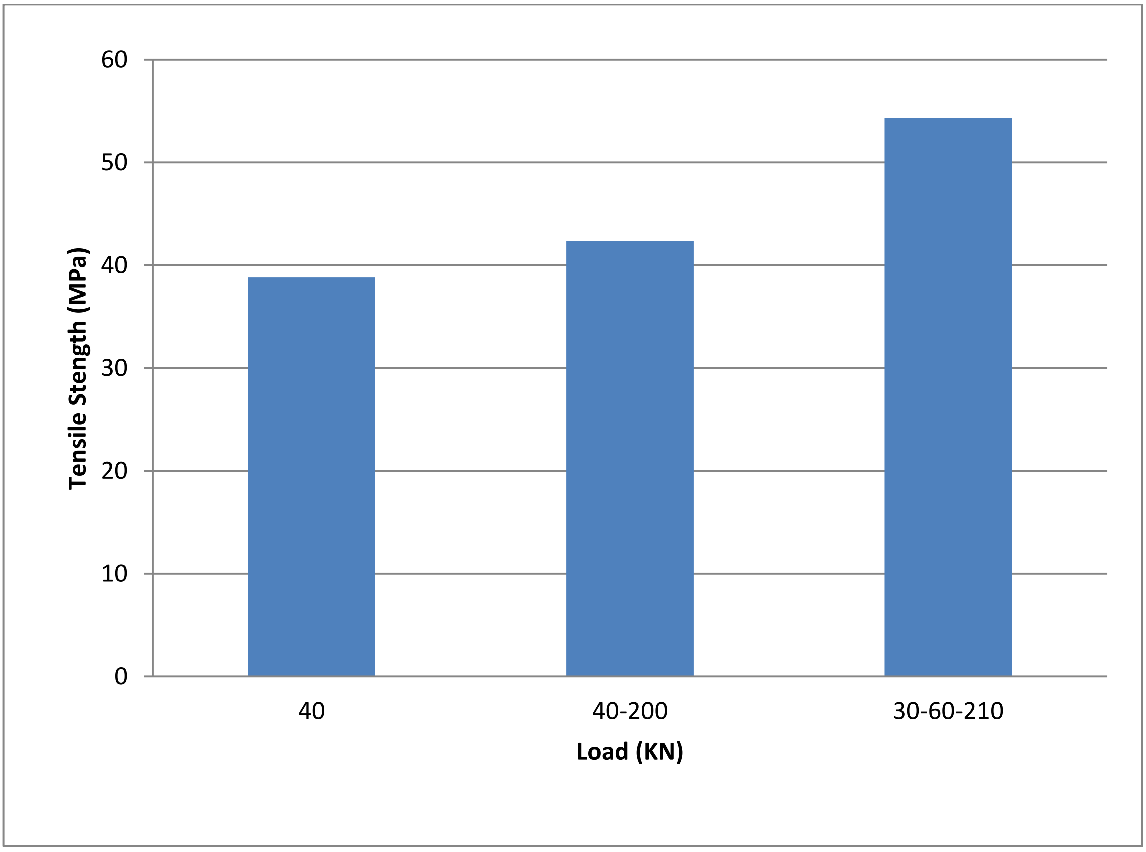

Figure 54 Tensile strength

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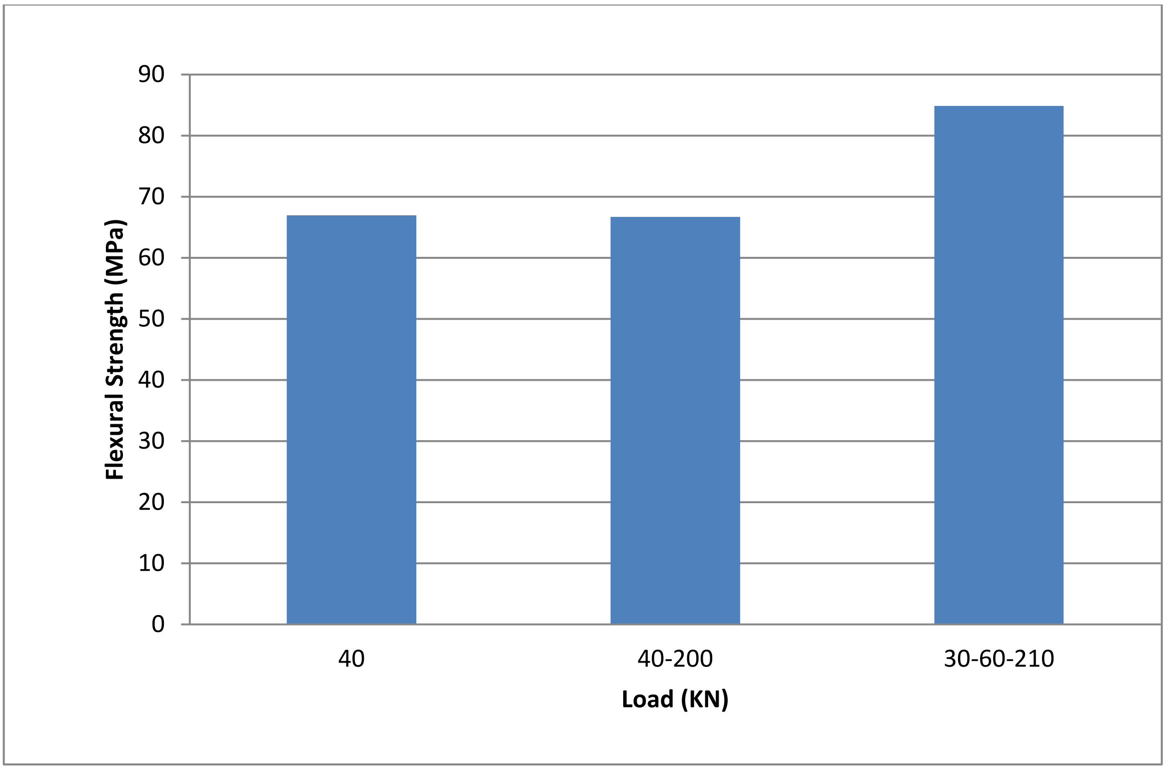

Figure 55 flexural strength

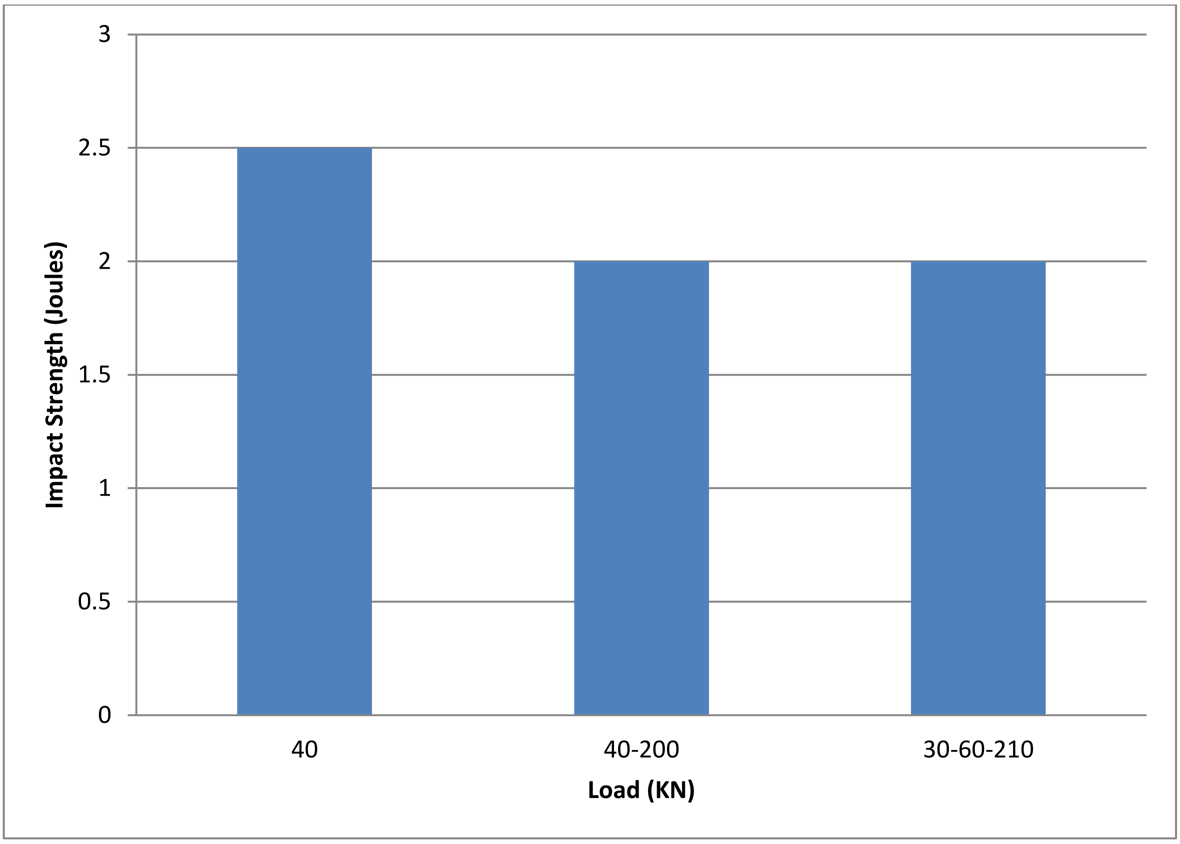

Figure 56 Impact strength

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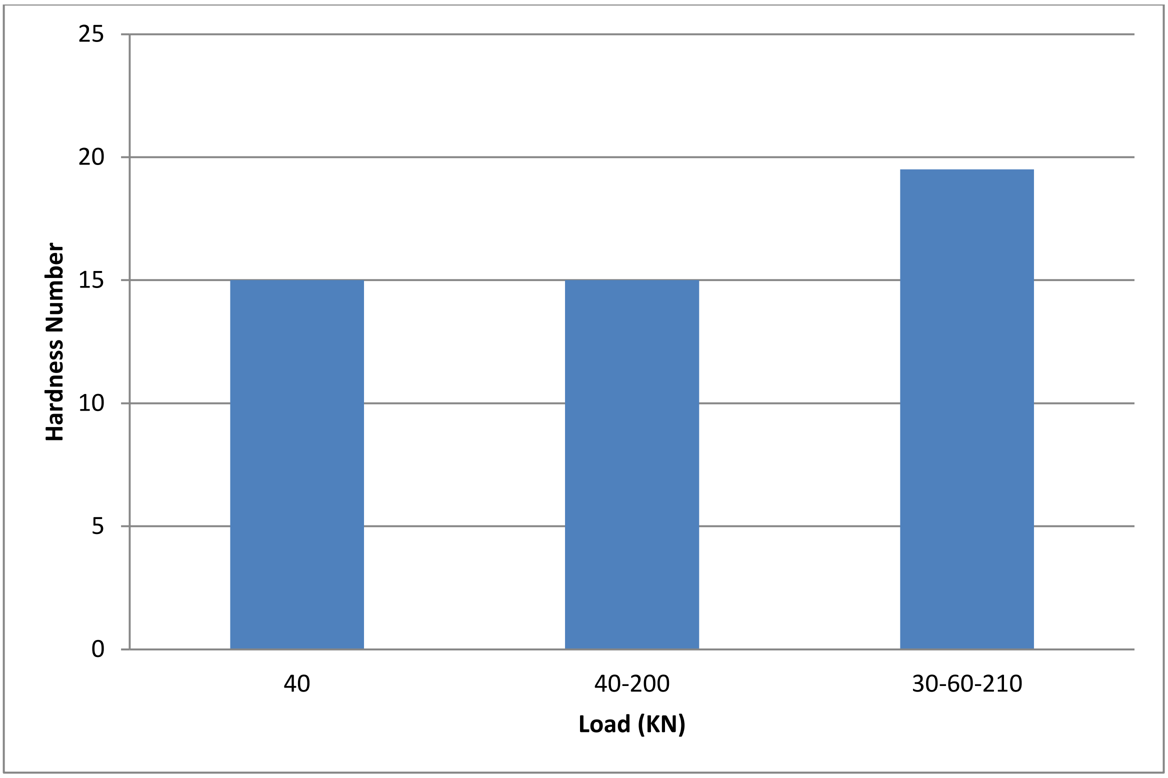

Figure 57 Hardness

In these results it is clear that the Tensile and Flexural strength has increased and the new method with this optimisations are referred.

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Chapter-8

8 CONCLUTION AND FUTURE SCOPE

This study is about the development of green composites with poly lactic acid as matrix material and natural fibres as reinforcement. Woven Jute fibers are used as reinforcement which is purchased from the local market. Two different techniques have been used for the development of green composites. This research throws the light on study the effect of curing temperature and surface treatment on mechanical properties of developed composites. Following are the conclusions drawn from the study as.

8.1 Conclusion

- Successfully able to developed the biodegradable green composites with the help of film stacking technique.
- Testing results shows that among different temperature ranges from 160° C to 190° C. 180° C curing temperature gives the maximum tensile (9.76 MPa) and flexural strength (20.35 MPa) with the help of film stacking technique.
- Novel Approach is being proposed for the development of green composites and found that maximum tensile and flexural strength is as 54 Mpa and 84.83 MPa respectively at 160° C with optimum parameters.
- Green composites are developed with the novel approach with variation in curing time with the range from 5 min to 30 minutes and it has been found that 5 min curing time shows 17.206 MPa as tensile strength and 15 min curing time shows 26.75 MPa as tensile strength and 30 min shows 16.80 MPa as tensile strength at 180°C with same operating conditions.
- 15 min curing time is the optimal for getting the maximum tensile and flexural strength.
- Maximum impact strength obtained is 2.5 J from novel approach at 160°C
- The alkali treatment of 5% concentration almost shows similar values of tensile and flexural with 38 and 66 MPa respectively. But in the case of impact non treated shows higher value of 2.5 J and treated shows only 2 J.
- The variation of impact strength in treated and non-treated, because the removal of lignin from the surface of the fibre after treating and this trend supports the literatures about the alkali treatment.

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- Optimisation of the load study gives maximum strength values of tensile and flexural with 54 MPa and 84.84 MPa respectively.

8.2 Future Scope

To talk about future scope it is clearly mentioned in the former chapters about the importance advantages but did not say about the disadvantage because there is no dis advantage in it. Put it in a nutshell the **Green Composite** is the future.

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Chapter-9

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