To study the effect of curing temperature on mechanical properties of PLA/Natural Fiber based green composites

Dissertation-II

Submitted in partial fulfillment of the requirement for the award of degree

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MECHANICAL ENGINEERING

By

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Under the guidance of

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Final Topic Approved by PAC: **To Study the effect of curing temperature on mechanical properties of PLA/Natural Fiber based Green Composites.**

Overall Remarks: Approved

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CERTIFICATE

I hereby certify that the work being presented in the dissertation entitled **“To study the effect of curing temperature on mechanical properties of PLA/Natural Fiber based green composites.”** In partial fulfillment of the requirement of the award of the Degree of **MASTER OF TECHNOLOGY** and submitted to the Department of Mechanical Engineering of Lovely Professional University, Phagwara, is an authentic record of my own work carried out under the supervision of **Mr. Jai Inderpreet Singh**, Assistant Professor, Department of Mechanical Engineering, Lovely Professional University. The matter embodied in this 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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"Do not wait; the time will never be 'just right.' Start where you stand, and work with whatever tools you may have at your command, and better tools will be found as you go along."

—George Herbert

I feel immense pleasure in expressing my profound sense of gratitude to my thesis Supervisor **Mr. Jai Inderpreet Singh** under whose supervision and inspiring guidance, I have the privilege to carry out my research work. I am indebted to them for their constant and ungrudging encouragement, valuable suggestions and ingenious ideas.

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Harpreet Singh

DECLARATION

I hereby declare that the report of Post Graduate Thesis entitled **"To study the effect of curing temperature on mechanical properties of PLA/Natural Fiber based green composites"** which is being submitted to Lovely Professional University, Phagwara, in partial fulfillment of requirements for the award of the Degree of **MASTER OF TECHNOLOGY**, Department of Mechanical Engineering, is a bonafide report of the work carried out by me. The material contained in this report has not been submitted to any university or institution for the award of any degree or diploma.

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ABSTRACT

The vexation shown by the environment, increase in fuel prices, depletion of fossil fuels, global warming are the major concerns which force the researchers to work in the area of green composites because of its biodegradable nature. Green composites are the materials which are made up of natural fibers and biodegradable matrix materials, which have the ability to replace the non-biodegradable, petroleum-based products. In this study, focus is to develop the fully biodegradable green composites in which matrix material is selected as poly lactic acid (PLA) which is derived from the corn starch and different natural fibers as reinforcement. The method used to develop the composite is compression molding technique. This study leads to find the best curing temperature ranging from 160ºC to 180ºC which shows maximum mechanical properties. In this study, composites are developing with different volume fraction from 30% to 55% fiber volume fraction by weight. Different mechanical characterization test will be done to find tensile, flexural and impact strength as per ASTM standards. This study will also find the effect of environmental condition on degradability of developed composites. Furthermore study of failure mechanism of the tested specimens would be done with the help of SEM.

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Chapter-1

1 INTRODUCTION

Composite material also can be found in our households. E.g. concrete is made up of cement, sand, and gravel. It can also be reinforced with steel which improves around 10000BC the houses were made up of straw bricks, and then in around 4000BC the writing material was fabricated from the papyrus plant. The writing material was prepared in the form of laminates by arranging the fibers of the fabulous plant in a particular direction. Egyptians also made fibers by heat treating the glass material to very high temperature. In an around 1200BC Mongols develop the first modern composite bow. The bow was made from various materials such as wood, leather, bamboo, horn, antler and tendon. The horn and antler were used to create the main body of the bow because it has good flexibility. Tendon was used to follow and cover the horn and antler. All the pieces are joined together to used glue which is obtained from the bladder of the fish. The string of the bow had prepared from horse hair, silk along with tendon. The bow was very powerful which shoot within a range of 1.5km.the modern composite can develop after world war-2 because the world war-2 was mostly fought with fighter planes, which requires material to be lightweight and strong. Therefore phenolic resin was 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 fiber reinforced plastics which were used to make the covering of radar equipment. Modern-day the strength of concrete is high. Another example is wood which is made up of cellulose and lignin. Plywood is also a form of good composite used for making furniture. Our bone is also a composite material containing collagen fiber and hydroxyl appetite matrix.

1.1 COMPOSITE

Composite material is nothing but two or more fundamental materials with different physical or chemical properties combine together to make a new material, but the individual material process individual properties. The novel material may be chosen for various reasons: common examples contain materials which are stronger, lighter, or less luxurious as compared to traditional materials.

1.1.1 TYPES OF COMPOSITE

1.1.1.1 Fibrous Composite

In fibrous composite is mainly consists of fiber as a reinforcement in the matrix. This fiber can be continues fiber or discontinues fiber. Long fibers in several forms are characteristically much stiffer and stronger than the same material in the bulk form. For example, ordinary plate glass breaks at stresses of only a few thousand pounds per square inch, in material that have displacements the fiber form has less dislocation than the bulk form.

1.1.1.2 Laminated Composite

Laminated composite is mainly made up of at least two or more layer of different materials that are stuck together. The single layer is called Lamina the best example is plywood in this we can easily identify the laminas are arranged layer by layer to create lamina. The properties that can be highlighted by lamination are strength, stiffness, low weight, corrosion resistance, wear resistance, beauty, thermal insulation and acoustical insulation etc. These are mainly classified into three categories:

a) Bimetals
b) Clad metals
c) Fiberglass (or) safety glass

a) Bimetals

These are the laminates of two different metals that having different coefficient of thermal expansion. The different metals have different thermal coefficient and they heated, binding and warping take place. Under change in temperature, bimetals warp or divert a probable amount, therefore used in temperature measuring devices. These are mainly used to make thermostats.

b) Clad metals

These are the materials they combine the properties of two or more metals. In this process of cladding or sheathing, one metal is covered by another to obtain the best properties of both. E.g. Aluminum alloy has high strength but it is prone to corrosion but pure aluminum is corrosion resistant so pure aluminum is coated above the surface of the aluminum alloy to get the best properties.

c) Fiberglass or safety glass

It is a layer of polyvinyl butyl which is a sandwich between two layers of glass. Therefore the brittle behavior of the material is reduced because of the plastic layer in between the layer. The glass in the composite material defends the plastic from rubbing and gives its stiffness. The impact strength is very high.

1.1.1.3 Particulate Composite

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

a) Non-metallic particle in a metallic matrix
b) Metallic particles in a non-metallic matrix
c) Metallic particles in a metallic matrix
d) Non-metallic particles in metallic matrix
e) Cremates

Examples:

a) Concrete, it's a particulate composite in which sand and gravel particles are combined with mixture of cement and water. The strength of concrete is usually that of the grit because the cement matrix is tougher than the gravel.

b) Aluminum paint in which Al-particles are suspended in polymer resin when aluminum paint is applied on a surface the Al-particles align themselves giving a good surface finish.

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

d) Tool steels are generally made from a combination of oxide particles on metal matrix. The oxide particles such as uranium oxide are used in stainless steel to make nuclear reactor fuel elements

e) Ceramics + metals=Cremates

Ceramics such as tungsten carbide, boron carbide, titanium oxide etc. are used in a metallic matrix such as cobalt, nickel and copper is frequently used in highest temperature applications such as turbine parts. This has high hardness.

1.1.1.4 Hybrid Composite

In the case of concrete it has both particulate and fibrous. Concrete contains gravel in cement paste and because of steel reinforcement it is fibrous. Laminated fiber reinforced composites are also coming under hybrid composite in which layers of fibers reinforced material are attached organized with different fiber direction in each layer. Examples are rocket motor cases. Hybrid composites are used in Boat hulls, aircraft wing panels and body sections, tennis rackets, golf club shafts etc.

1.2 CLASSIFICATION OF COMPOSITE

Composite is classified based on the types of reinforcement and the types of matrix used.

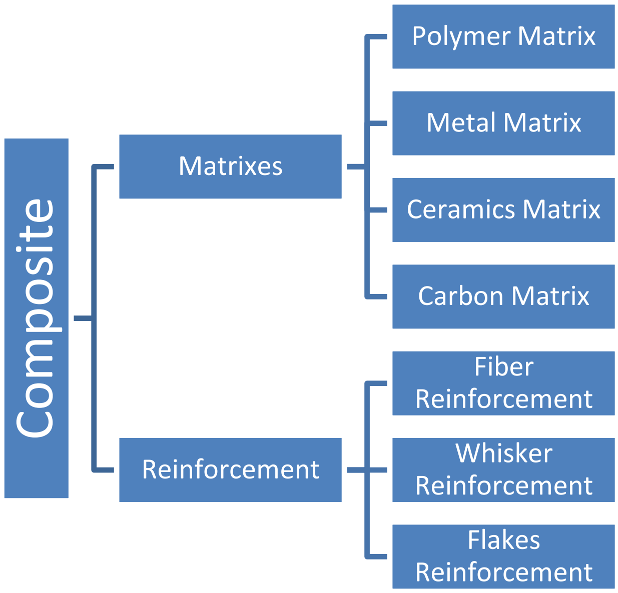


Figure 1 Classification of composites

1.2.1 Matrixes

Matrix acts as a binding agent and different types of matrixes are given below:

a) Polymer

The Polymers are the substance which has a molecular structure builds from a large number of similar units attached together. These are mainly classified into two types:

- Thermoplastics Polymers

Thermoplastics are the material which has a linear and branch chain and this can be given different shape by reheating. These polymers can easily soften repeatedly once heated and hardened after cooled with little change in their properties. Especially they can be reheated number of times. For e.g. Nylon, Polypropylene, Polythene, Polyvinylchloride, Teflon, etc.

- Thermosetting Polymers

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. These are the polymers which undergoes permanent change on heating. For e.g. epoxy, polyimides, phenolic, Bakelite, melamine formaldehyde, etc.

b) Metal matrixes

Metal matrixes are nothing but the metals which are used as matrixes. Metal matrixes are used where the conducting properties are required. The common types of metal matrixes are Aluminum, titanium and nickel-chromium alloys. These are heavier than that of polymer matrixes and they are expensive.

c) Ceramic matrixes

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 can be used at temperature above 1000°C where polymers and metals cannot be used.

d) Carbon matrixes

Carbon matrixes are used along with the carbon fibers for higher temperature applications are required generally in the range of 1000°C to 2000°C.

1.2.2 Reinforcement

Reinforcement is the main load carrying constituent. It should have significantly higher properties in comparison to matrix because it carries most of the load.

a) Fiber reinforcement composite

The composite material which consists of fiber as the reinforcement here in this type of reinforcement's fiber will carry the total load and matrix materials play as binding agents. Fibers can be classified into two categories:

- Continues fiber (l/d > 100)

  Continues fiber again classified into two types:

  - Unidirectional
  - Woven

- Discontinues fiber (l/d < 100)

  Discontinues fiber also classified into two types:

  - Random orientation
  - Preferred orientation

b) Whiskers

It is also a fiber but it is very short, stubby and rigid in nature when compared with fiber. These are single crystals having very short length. Whiskers are more perfect than a fiber and therefore reveal higher properties.

c) Flakes

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

1.3 ADVANTAGES/DISADVANTAGES OF COMPOSITE MATERIAL

Advantages:

- ✓ Light Weight - Combinations are light in weight as compared to most metals. Their lightness is vital in aircraft, where a smaller amount weight means improved fuel efficiency.
- ✓ Strength Related to Weight – Strength to weight ratio is a material’s strength in relation to how greatly it weighs. Few materials are very strong and heavy, like steel.
- ✓ Corrosion Resistance - Composites resist loss from the weather and from harsh chemicals that can eat gone at other materials. They stand up to severe weather and wide change in temperature.
- ✓ Design Flexibility - Composites can be formed into complicated profiles more simple than other materials.
- ✓ Part Consolidation - A single piece builds of composite materials can change an whole assembly of metal parts. Decreasing the number of parts in a machine saves time and cuts down on the maintenance required throughout the life of the product.
- ✓ Dimensional Stability - Composites maintain their shape and size when they hot/cool, wet/dry. And are used in aircraft wings because wing shape and size do not change as the plane gains or loses altitude.
- ✓ Radar Transparent - Radar signals pass through composites, a property that makes composites perfect materials for use anywhere radar equipment is operating. Composites play very important role in stealth aircraft.
- ✓ Durable - Structures builds of composites have a higher life and need small maintenance. We have no idea how many long composites last, because we have not go through to the end of the life of many original composites.

Disadvantages:

- ✓ Delamination - Composites are mostly built of different ply layers into a laminate structure, they can "delaminate" between layers where they are fragile.
- ✓ High Cost - They are a reasonably new material therefore they are more expensive.
- ✓ Complex Fabrication - The fabrication process is usually labor concentrated and complex, which further growths in cost.
- ✓ Damage inspection - The cracks in composites are mostly internal.
- ✓ Composite to metal joining - Metals grow and contract more on variations in temperature as compared to composites.

1.4 GREEN COMPOSITE

This thesis report mainly deals with the green composite. The green composite is nothing but the composite material which is made up of green materials in the sense environment-friendly. In this case, it can be bio-degradable or non-bio degradable according to the matrix we are using. Green composites are those composites that are made from natural occurring resin and fiber matric interface. There are various fiber matrix are obtain from the nature that are jute, flax, hemp, cotton, kenaf, coir, abaca, remie, wool, silk, pineapple, coconut, banana and sisal. Natural fibers are grouped into the three type's seed hair (cotton, coir), bast fibers (hemp, flax, jute, kenaf) and leaf fibers (sisal, abaca). The properties of natural fiber have low cost, high specific mechanical property, good thermal, acoustic insulation and bio degradability.

Fiber reinforced polymers are very common especially in the engineering applications. But most of the normal composites are hazardous to the environment. There comes the application of green composite, in this the matrix as well as the fibers also bio-degradable. Most common fibers are plant fibers used to make a green composite. Because not only it is environmental friendly but also no negative health hazard made this as very interesting now a days for the researchers. The beauty of green composite is it is very easy to fit into any size and shape according to the requirement and wide range applications. In the meantime, it is very difficult to find bio degradable resins and epoxy materials. This made a great interest in PLA (poly lactic acid), 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 produced from lactic acid by fermentation process. PLA can be made from two methods, first is condensation and second is ring opening polymerization. The diagram is shown below:

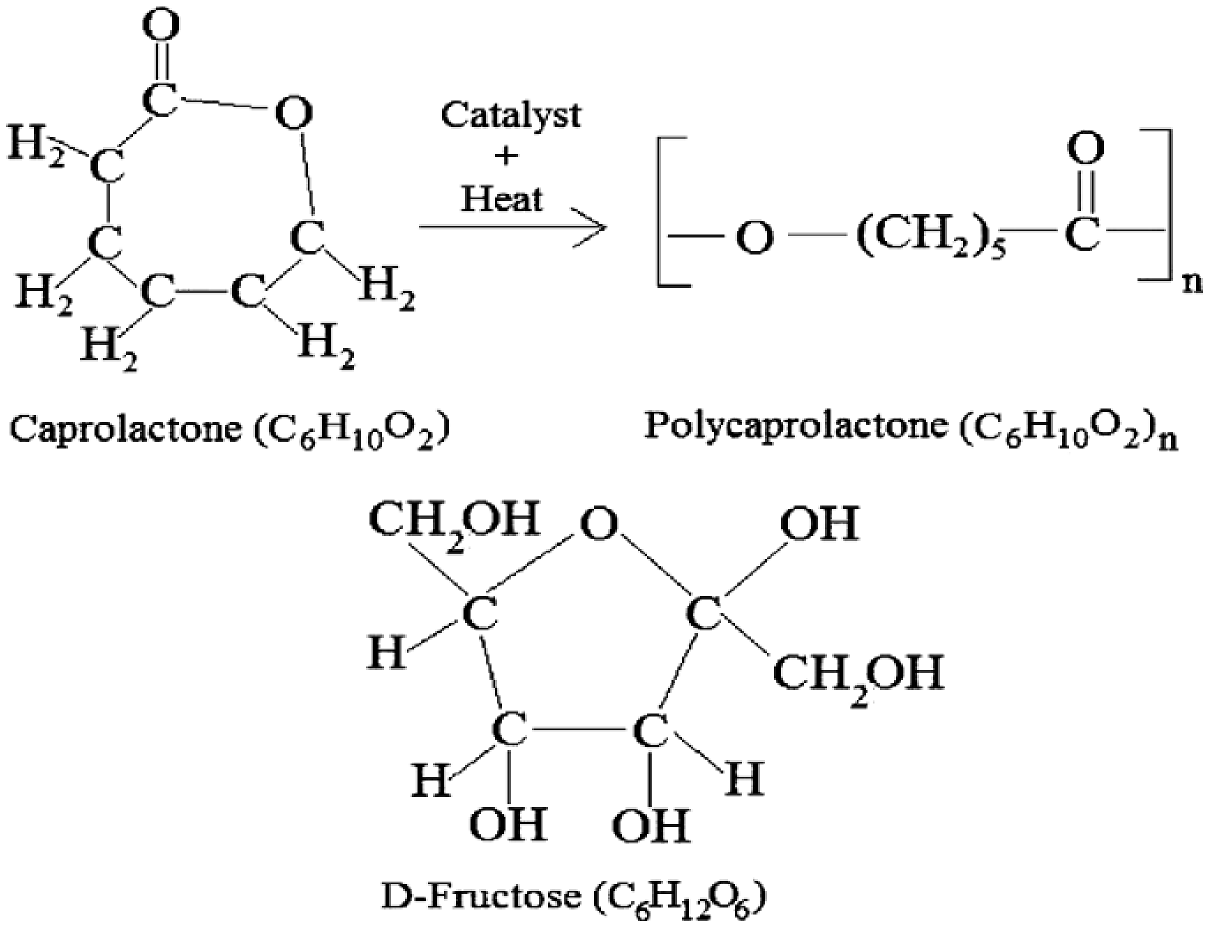


Figure 2 Polymerisation of PLA [2]

Talking more about PLA, it is a derived naturally from the starch. In this case, starch can be from any of the plants outcomes for example starch from potato, tapioca, rice, corn etc. But the most suitable material to make PLA is corn starch. The PLA which is made from corn starch is showing very good properties.

The synthesis of PLA from corn starch is shown below:

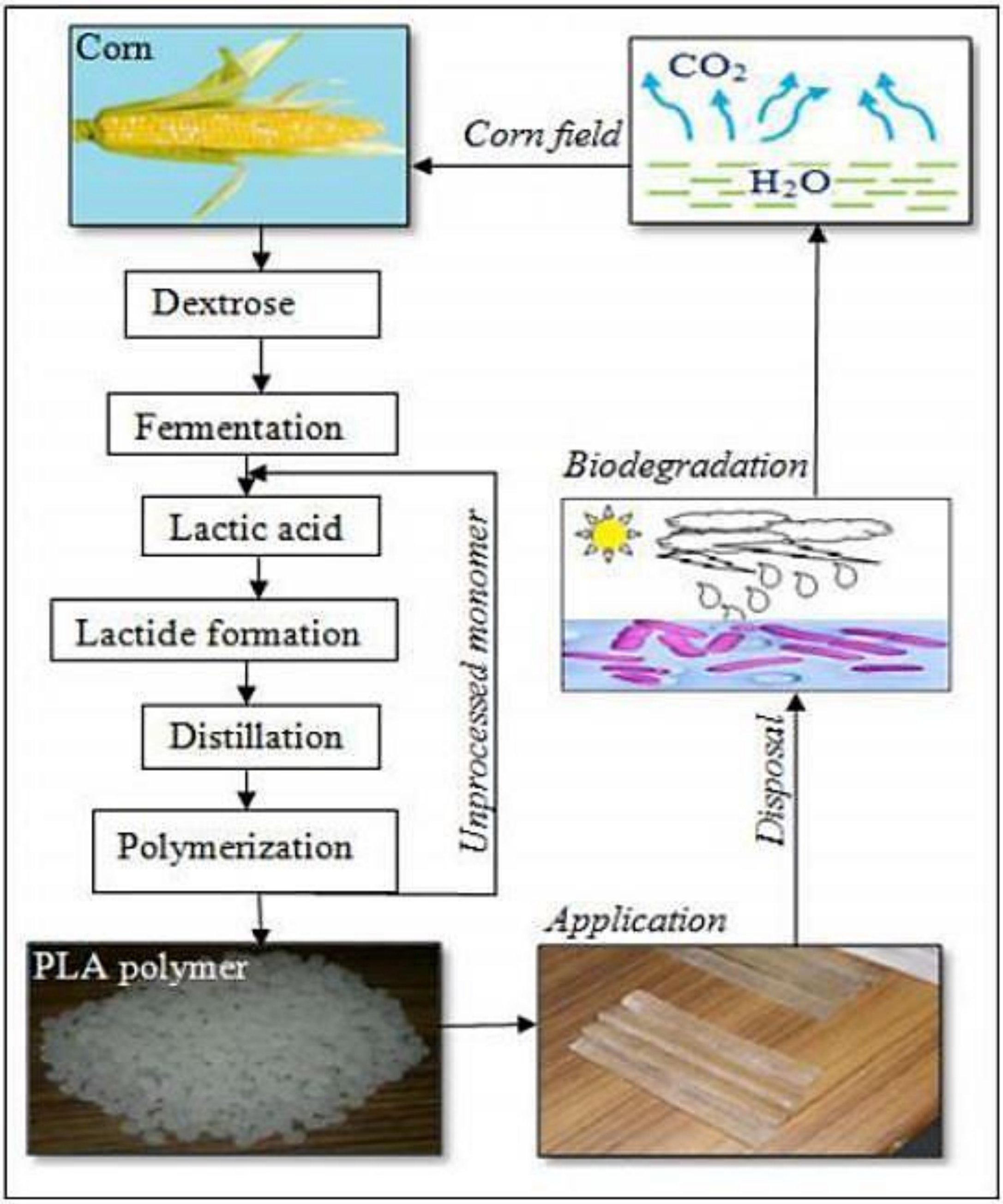


Figure 3 Process of PLA synthesis and its closed life cycle [2]

This is a short description of the process of the PLA in this we can easily identify the making process of the PLA. But in the further making of the Green composite with natural fibers along with PLA is still facing difficulties.

1.4.1 Constituents of Green Composites

a) Biodegradable Matrix

With the increasing use of polymers/matrix, the problems of disposal of waste of these polymers are also posing alarming causes regarding environment and health issues. So are main concerns to go the biodegradable polymers which can be broken rapidly by soil micro-organisms and do not cause any serious effects on the environment. Biopolymers degrade mainly by enzymatic hydrolysis and to some extent by oxidation. The disposal problems of polymer waste and for developed polymers for other safe uses in human system. Few examples of biodegradable polymers are:

- Polyhydroxy butyrate (PHB)
- Polyhydroxy butyrate-co-β-hydroxy valerate (PHBV)
- Polyglycolic acid (PGA)
- Poly lactic acid (PLA)
- Poly(ε-caprolavtone) (PCL)

b) Biodegradable Fibers

In the case of fibers, we have many options but they are mainly classified into two types natural and synthetic a classification is given below fig 1.3. Talking about the fibers there are vast varieties are already available in the market as well as in some of the papers researchers tried to extract the fibers from the plants. This made an interest to think about a new direction to extract fiber from the Castor Plant. The methods which we used different molar values of varied temperature this has given a positive feedback for the further processing. The jute fiber also has taken for consideration.

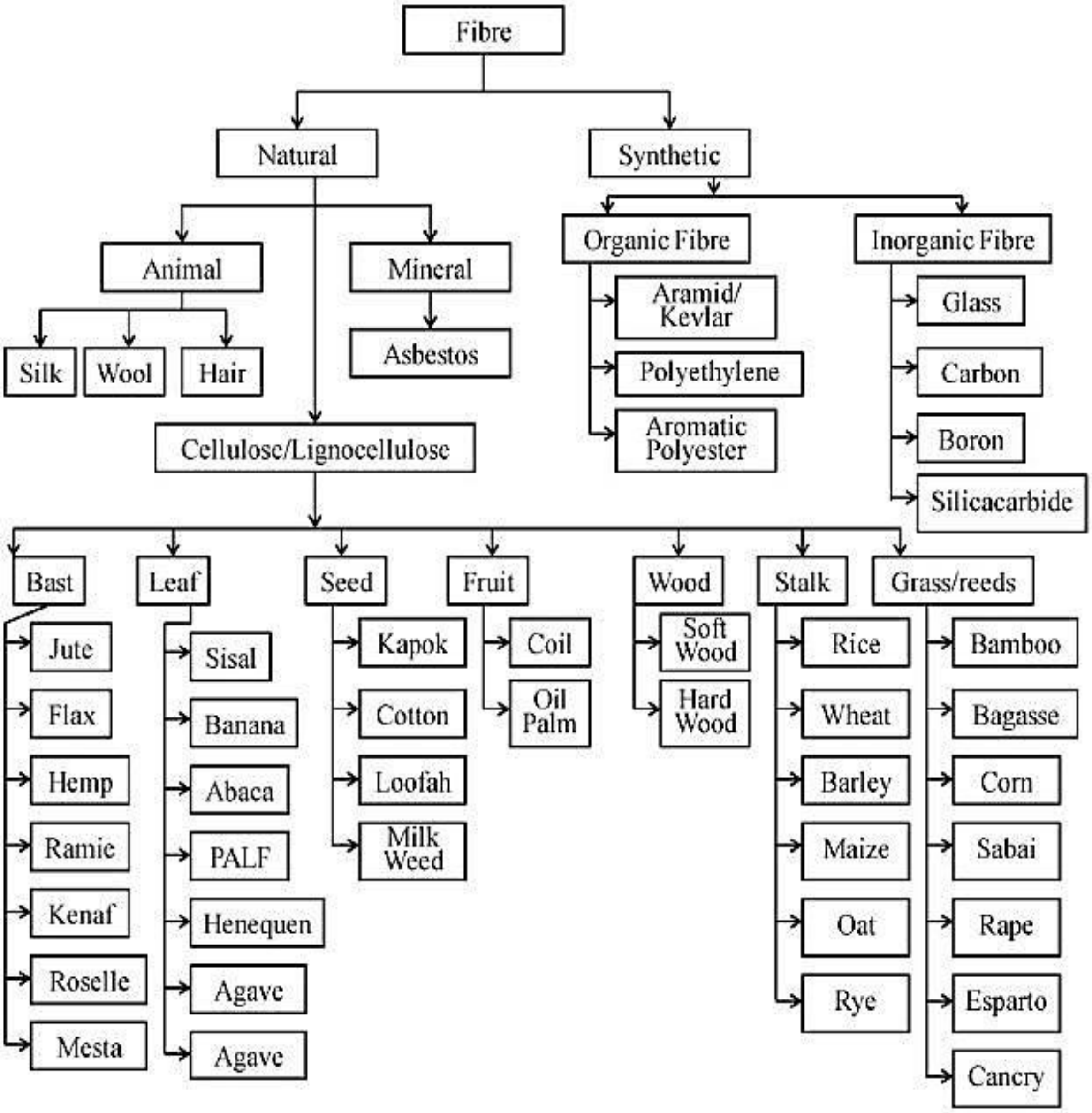


Figure 4 Classification of fibers [2]

The classification has given a wide variety of options to work on it from that a few commonly used fibers are discussed below:

Types of fibers:

Natural fiber

Advanced fiber

- **Natural Fiber**

It is again classified into three categories:

a) Plant (or) vegetable fibers

b) Animal fibers

c) Mineral fibers

a) Plant (or) Vegetable Fibers

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

- 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 tons per year. Cotton is used to make jeans, shirt, Towels, undergarments, Bed sheets etc. It has a density of 1.5μm. It contains 90% cellulose 8% water and the rest is combination of fatty substance and waxes.

- Jute fiber

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

- Hemp fiber

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 to soil canvas.

- Sisal fiber

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

- Bamboo fiber

This obtained from Bamboo tree. It is highly durable and 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 fibers are obtained.

- Banana fiber

Banana fiber is obtained from a banana tree. The stem of the banana tree is the main source of these fibers. It is used for making Carry bags, Table mats etc.

- Abacas fiber

It is 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. It is similar to banana fiber.

The above-given fibers except cotton fiber are the area of interest along with Castor plant for the research. The Castor plant is mostly available in India and India is the second largest producers in the world. This plant is most commonly used for extracting oil.

Castor bean is a flowering plant that belongs to the spurge family. It originates from eastern Africa, but it can be found in warm, tropical areas around the world today. Castor bean grows on fertile, well-drained soil in areas that provide sufficient moisture and sun (usually along the river banks). People cultivate castor bean as a source of oil that has application in various industries. Several varieties of castor bean are cultivated for ornamental purposes.

1.5 FABRICATION PROCESS OF GREEN COMPOSITE

1.5.1 Hand Lay-Up with compression molding

This method is the simplest and oldest open molding process of the fabrication process of composite materials. This method has a low volume, labor intensive method suitable for especially for large modules, such as boat hulls. Glass reinforcing mat is located manually in the open mold and resin is poured consistently. Caught air is removed by hand with help of scrapers or rollers to complete the laminates structure. Room temperature remedial polyesters and epoxies are the commonly used matrix resins. Remedial is initiated by a catalyst in the resin system, which stabilizes the fiber reinforced resin composite without external warmness. For a high quality part surface, a pigmented lotion coat is first applied to the mold surface.

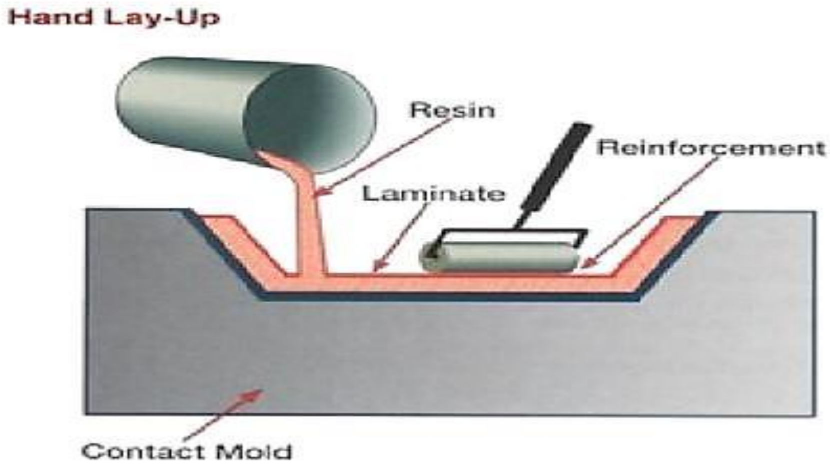


Figure 5 Hand Lay-Up with compression molding process

1.5.2 Spray Lay-up method

This method is similar to hand lay-up method in its suitability for making boats, tanks. A sliced laminate has good conformability and is sometimes faster to produce than a part made with hand lay-up when molding complex shapes. As with hand lay-up, lotion coat is first applied to the mold and allowed to cure. Continuous element glass roving and initiated resin are then fed through a chopper gun, which deposits the resin-saturated chop on the mold. The laminate is rolled to systematically saturate the glass strands and compact the chop. Other layers of chop laminate are added as required for thickness.

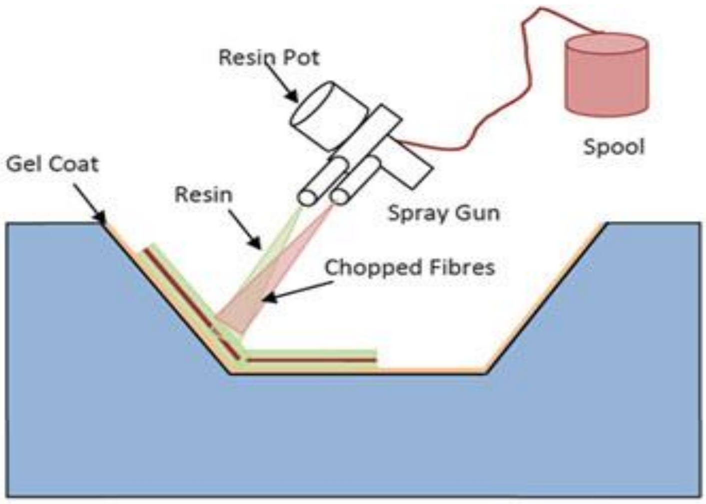


Figure 6 Spray lay-up process

1.5.3 Compression Molding

Compression molding is a high-volume thermoset molding process that employs expensive but very long-lasting metal dies. It is suitable choice when production quantities exceed so many parts. Several parts can be twisted out on a set of forged steel dies, by sheet molding compound, a composite sheet material formed by sandwiching chopped fiberglass between two layers of thick resin paste. To build the sheet, the resin paste transfers from a metering device onto a moving film carrier. Chopped glass fibers drop on the paste, and a second film carrier placed on another layer of resin on top of the glass.

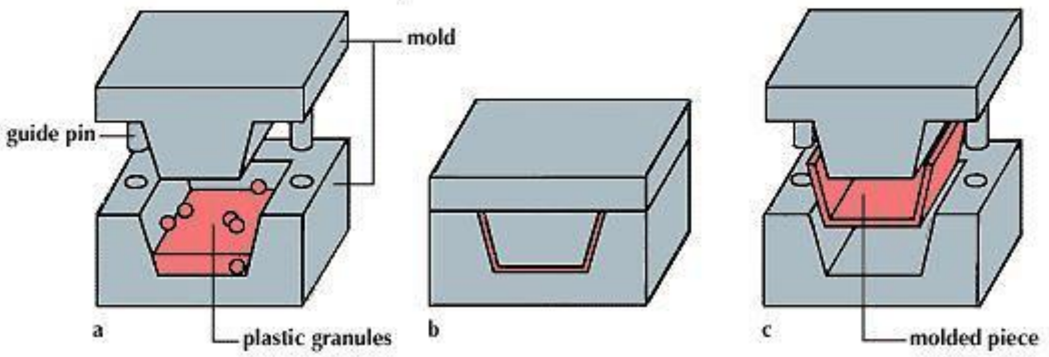


Figure 7 Compression molding process

There are the following classifications of compression molding techniques used to fabricate green composite:

a) Direct Method

b) Pre-forming Method

c) Pregpreg Sheet Method

a) Direct Method (DM)

In this method fibers are implanted into a metallic mold and resin is poured directly to them and after that material is going too pressed at temperature of 150 ◦C and then kept cool at room temperature.

b) Pre-forming method (PF)

The composites are formed by hot pressing the pre-forms of resin pasted fibers. Firstly the fibers are wounded and pushed around a metallic plate, then resin is poured on the fibers with the help of a small brush. Finally performs of fibers entrenched in the resin are dried at 30˚C for 24 hours. Afterwards dried performs are pressed at 150˚C for 1 hour. The heating process is then clogged and pressure is applied to it until the material attains the room temperature.

c) Preg-preg sheet method

In this method, fibers are positioned in the metallic mold, overextended and resin is applied to them. Then the preg-preg sheets are achieved to pressing slightly those resin pasted fibers one by one at 120ºC. Afterwards a set of five sheets, each with same fiber orientation is implanted in the mold and pushed by load at 150◦C for 1h and a pressure is also applied until the temperature methodologies at room temperature.

1.5.4 Resin Transfer molding (RTM)

RTM is a vacuum-assisted, resin transfer process with an elastic solid counter tool for the other side surface compression. This process yields enhanced laminate compression, a high glass-to-resin ratio, and unresolved strength-to-weight characteristics. RTM parts have two finished surfaces. Reinforcement mat is positioned in the mold, which is then closed and clamped. Catalyzed, low-viscosity resin is pumped under pressure, relocating the air and venting it at the edges, until the mold is filled.

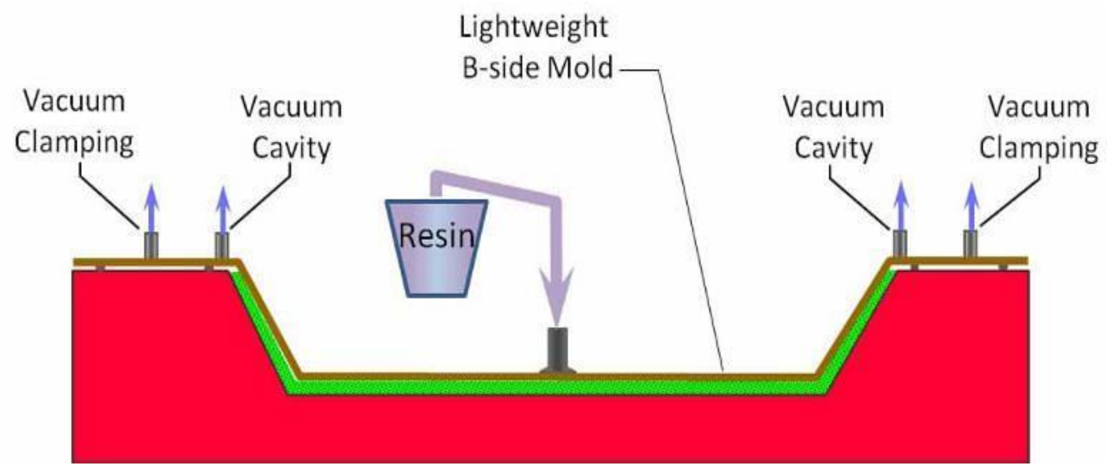


Figure 8 Resin Transfer molding process

Resin transfer molding further classified as:

a) **Vacuum assisted resin transfer molding (VARTM)**

This is like to RTM, it is usually an open-top mold composite fabricating technique that attaches a vacuum bag to the top of the mold tool and applies vacuum to support the nonstop flow of low-pressure infused resin from one side of the mold to the other side. Vacuum eliminates air from the preform and assists the VARTM machine on-ratio metered and mixed flow of degassed air-free resin through the compacted composite fiber preforms under the vacuum bag.

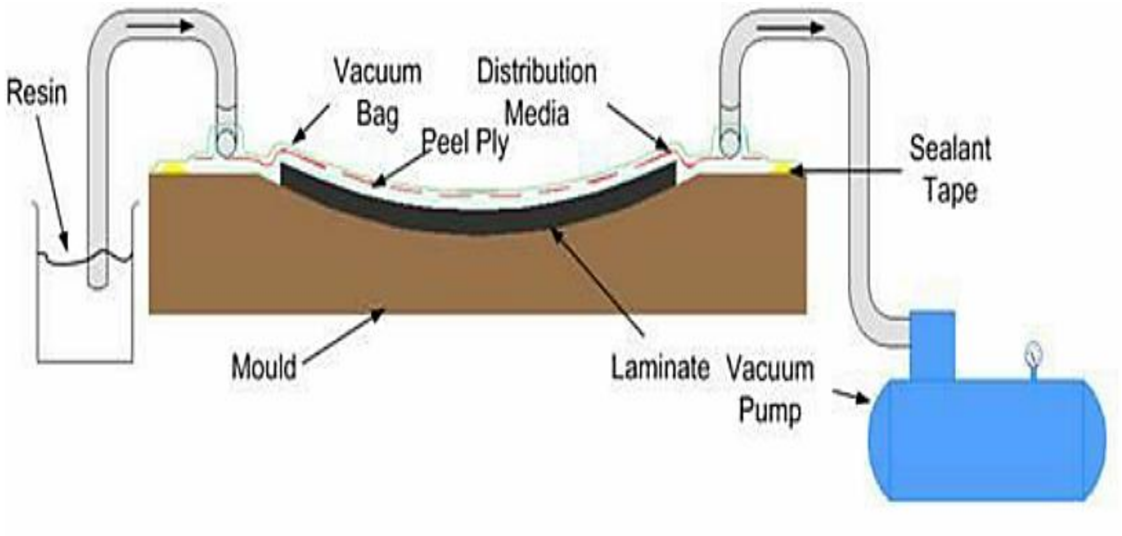


Figure 9 VARTM Molding Process

1.5.5 Injection molding process

Natural fibers are randomly oriented or short fibers were used as reinforcement and composites were developed with the help of Injection molding process. It is a fast, high-volume, closed process using maximum commonly, filled thermoplastics, such as nylon with axed glass fiber. It is the most commonly used manufacturing process for the fabrication of plastic parts. This process required the use of an injection molding machine. The plastic is melted in the injection molding machine and then inserted into the mold, where it cools and solidifies which gives the final product.

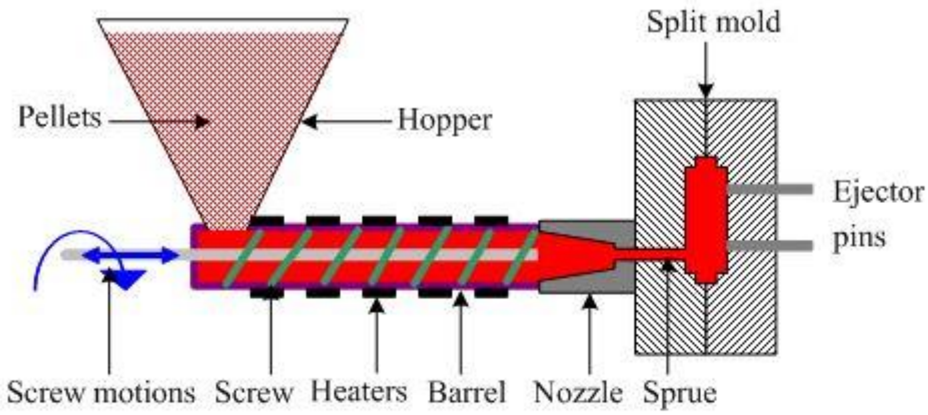


Figure 10 Injection molding process

1.5.6 Pultrusion

Its process is same as RTM, which is used for periods with glass fiber and polyester resins. In this simple, continuous process, the reinforcing fibers are typically pulled through a heated resin bath and then fashioned into specific shapes as it passes through one or more forming guides. The material is then moves through a heated die, where it takes its net shape and cures. A wide range of continuous, consistent, solid and hollow profiles are pultruded.

1.6 APPLICATINS OF GREEN COMPOSITES

Green composites are applied to different components with moderate and high strength such as cars, mobile phones. Numerous problems associated with green composites include effects of moisture and humidity, strength reliability. Furthermore, there are some concerns over natural fiber quality and constancy, fogging and relief and processing temperature (200 C).

Some other zones in which the green composites are used:

- ✓ False ceilings
- ✓ Partition purposes
- ✓ Doors panels
- ✓ Furniture
- ✓ Boxes for farming purposes

Other various applications:

- ✓ Rims
- ✓ Mobile panels
- ✓ Toys
- ✓ Aircraft
- ✓ Ships

1.7 ADVANTAGES/DISADVANTAGES OF GREEN COMPOSITE MATERIAL

Advantages:

- ✓ Less luxurious
- ✓ Abridged weight
- ✓ Better flexibility
- ✓ Renewable resource
- ✓ Sound insulation
- ✓ Thermal recovering is possible where glass poses problems.
- ✓ Friendly dispensation and no skin anger.

Disadvantages:

- ✓ Low strength properties.
- ✓ Better moisture absorption causing swelling of fibers.
- ✓ Low stability
- ✓ Poor fire resistance and irregular fiber lengths.

Chapter-2

2 SCOPE OF THE STUDY

Environmental problems are harmful to the human being. Now days increasing facilities and technologies made humans in a dream world. Because of that, the future generation is going to affect not only the human beings all the living organisms are going to extinct. While going through all the environmental issues the non-biodegradable materials are causing more damage. So the interest of research has taken into that direction.

When we become more technologically, we create materials that can withstand great temperatures, highly durable and easy to use. Plastic bags, synthetics, 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 place them in a garbage pile, the environmental conditions are unable to break them down naturally so it would not dissolve due to non-biodegradable nature.

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
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.

Chapter-3

3 REVIEW OF LITERATURE

The researchers have been working under green composite for a long time. We have gone through a number of research papers for the identification of the development, problem formulation and a complete understanding for the further processing of researches.

David Plackett et.al (2003) [3] evaluates the biodegradable polymer L-polylactide and natural jute fibers were used for fabrication of composites at different temperatures by film stacking technique. Tensile and flexural strengths were increased and SEM investigates the voids occurring between jute and polymer. Degradation of polymer was evaluated with size exclusion chromatography which gives the minimum changes in molecular weights.

Wanjun Liu et.al (2005) [4] studied the twin-screw extrusion and injection molding for determining thermal, mechanical properties and morphology of green composites from soy based plastic and pineapple leaf fibers with dynamic mechanical analyzer, united testing system and environmental microscopy.

Alexandre Gomes et.al (2007) [5] investigate the improvement and effect of alkali treatment on tensile properties of curaua fiber green composites. They used curaua fibers as reinforcement was treated with alkali sodium hydroxide and polycaprolactone and corn starch as matrix interface. This overall result shows that suitable alkali treatment was best technology for improving mechanical properties of cellulose based fiber composites.

Victoria L. Finkenstadt et.al (2007) [6] PLA is biodegradable polymers which is nontoxic to environment, has related mechanical properties like polypropylene and more expensive that other polymers. According to agriculture aspect oil is recovered before cuphea, lesquerella and milkweed. There are many levels of PLA are compounded by twin-screw extrusion and injection molding. As a result weight fraction of fibers increasing PLA-C and PLA-L are gradually reduced.

Shinji Ochi (2008) [7] describes the application of kenaf/an emulsion-type PLA biodegradable composites. It was noted that at 180ºC temperature fabricated composite gives the tensile strength was reduced. For that concern the composite was fabricated at 160ºC temperature. As a result tensile, flexural strengths and elastic moduli of composite increased. By using garbage-processing machine the biodegradability was investigated for four weeks which shows reduction in weight as well as tensile strength.

Maya Jacob John and Sabu Thomas (2008) [8] investigated the cellulosic fibers polymeric composite and their applications in many fields. The idea of bio based materials has now become the key point because of the need of secure our environment. The development dealing with the cellulose based nanocomposites and electrospinning has also been presented.

Chanakan Asasutjarit et.al (2009) [9] gives that, SEM was used to evaluate composite based coir fiber for the morphological and structural changes, which identifies the impurities on coir surface. The efficiency of composites based on coir fiber can be enhanced the interfacial adhesion between coir and matrix. It performs better as compared to untreated coir based green composites and having better mechanical properties due to increase in internal bonding between fibers/matrix and modulus of rupture.

Nina Graupner et.al (2009) [10] investigate the mechanical characteristics of composites made completely of renewable natural fibers like kenaf, cotton, hemp and human made cellulose fiber and PLA by compression molding technique. Hemp and kenaf/PLA gives high tensile strengths and young’s modulus values while, cotton/PLA gives good impact results.

J. Jayaramudu et.al (2009) [11] here Grewia tiliflia natural fibers were used for composites after treating with NaOH. Fourier transforms infrared spectroscopy, X-ray diffraction, thermogravimetric analysis, scanning electron microscopy and polarized optical microscopic methods were used. Due to the effect of alkali treatment the mechanical, thermal and morphological properties of the fibers were determined. Tensile properties like as maximum stress, Young’s modulus were evaluated, the percentage of α-cellulose increased whereas hemicellulose decreased and thermal stability & tensile properties of fibers were improved due to alkali treatment.

Ranjan Pardhan et.al (2010) [12] in this paper evaluate the degradation of PLA with untreated wheat and soy straw by using injection molding process. The composites are prepared with PLA pallets with wheat and soy straws at 190°C to 205°C. It has been noted that the composite samples were placed in mixture of compost and soil, pH tests and moisture were tested. As a result it has been found that CO2 released from the samples and samples were degrades 70% in 45 days.

Narendra Reddy (2011) [13] illustrates making of the green composite by using Zein as the matrix material and jute fiber 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.

Yeng-Fong Shih and Chien-Chung Huand (2011) [14] studied the PLA/Banana fiber composites were fabricated by melt blending technique. Tensile and flexural results shows the increment in strength but impact strength was reduced due to increased fiber content. Thermal stability was also assessed through the incorporation of banana fibers due to that cost of composites were reduced. Due to higher stress changes and to practical products under high temperature therefore, PLA/BF composites can be used for storing of hot food containers.

F.P. La Manita and M. Morreale (2011) [15] studied the brief review of environment friendly composites Due to its biodegradability nature. This paper is trying to describe the main ways and results about biodegradable polymers (polyethylene and polypropylene) and natural fibers such as cellulose, flax, cotton, kenaf, jute hemp etc. The tensile and flexural strengths were also be enhanced by using natural fibers and polymer matrixes.

Jun Young Jang et.al (2012) [16] in this paper the entire study observed the mechanical and thermo-physical behavior of green composites. Composite fabricated with Coconut fibers/PLA by using plasma treatment to improve the interfacial adhesion between the coconut fibers and PLA matrix. It was noted that the tensile strength and young's modulus was as increased with increasing the weight fraction. Plasma treatment can play an important role to enhance the mechanical and thermochemical properties of natural fiber reinforcement composites.

Pramendra Kumar Bajpai et.al (2012) [17] studied 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 favor the final outcome as well as given new outcomes.

Nurul Fazita et.al (2013) [18] given the clear-cut study of bamboo fabric in PLA matrix. He used film sacking technique to make the composite material. Taguchi 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.

Pramendra Kumar Bajpai et.al (2013) [19] investigated tribological characteristics of natural fibers (nettle, grewia optiva and sisal)/PLA composite by hot compression technique. For investigation thermal stability of composite TGA analysis has been carried out, wear and frictional characteristics has also been found. As a result, it was found that wear behavior of developed composite was improved as well as friction coefficient reduction was found. For morphological characteristics SEM indicates the presence of abrasive wear.

Takian Fakhrul and M.A. Islam (2013) [20] investigates the enhancement in the biodegradability of polypropylene (PP) mixed with blended wood sawdust and wheat flour. Moisture of soil, water, brine solution and exposure to the open environment was observed for 15 weeks. After, the observation it was found that there were micro cracks and dislocation were observed by FTIR spectroscopy. As a result, the biodegradability of PP with saw dust and wheat flour improved due to high water absorption.

Weiwei Jia et.al (2014) [21] studied that the development of fully biodegradable PLA fibre reinforced and poly butylene succinate (PBS) matrix composites to reduce the environmental related issues. These two different kinds of matrix composites were fabricated by film stacking technique. As a result, it founded that higher tensile strength and young’s modulus gives by PLA/SRC than PLA/PBS composites because of more interfacial adhesion in PLA/SCR (self-reinforced polymer composite).

B.C. Mitra (2014) [1] Green composites are those composites that are made from natural occurring resin and fiber matric interface. There are various fiber matrix are obtain from the nature that are jute, flax, hemp, cotton, kenaf, coir, abaca, remie, wool, silk, pineapple, coconut, banana and sisal. Natural fibers are grouped into the three type's seed hair (cotton, coir), bast fibers (hemp, flax, jute, kenaf) and leaf fibers (sisal, abaca). The properties of natural fiber have low cost, high specific mechanical property, good thermal, acoustic insulation and bio degradability.

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 has been used as the matrix material and different types of natural fibers as reinforcement. A number of mechanical testing had been conducted and the results are been discussed.

Toshihiko HOJO et.al (2014) [22] studied that the natural fiber mat that are jute, kenaf and bamboo as reinforcement and polyester as matrix were invented by hand lay-up and compression molding method. Tensile properties were investigate for all the three fabricated composites and compared with glass/polyester composite. As a result, it was found that bamboo/polyester and jute/polyester gives similar tensile properties and ultimate modulus, while kenaf/polyester gives higher strengths. According to SEM results, kenaf/polyester gives better tensile properties as compare to other two fabricated composites because of higer interfacial adhesion to matrix.

A. Porras et.al (2016) [23] PLA having short time degradation, easy to dispose, good strengths and easy to use in conventional methods. Here PLA is being used with Manicaria Saccifera fibers with compression molding technique are optimized by Taguchi method. As a result it was found that chemical treatments increased surface roughness which is best fiber/PLA internal adhesion and better stress transfer capacity.

Marzieh Akrami et.al (2016) [24] deals with the blending of Polylactic acid and Thermoplastic starch blend. In this investigation has given a new opportunity to the people to blend other materials with PLA. Here they found fixed polyethylene glycol grafted starch (mPEG-g-St) was synthesized to increase the compatibility of the

PLA/thermoplastic starch blends. And several blends also tried to develop for the better adhesion of these two materials.

Rosni Binti Yusoff et.al (2016) [25] investigates to enhance the tensile and flexural properties of PLA with natural fibers kenaf, bamboo and coir fibers by hot-pressing molding method, SEM and optical microscopy were used to determine the microstructural failures. The optical microscopy technique identifies poor bonding between fibers and PLA due to insufficient matrix in BCF. As a result the KBCF/PLA shows highest tensile strength which is higher than of KCF/PLA and higher than BCF/PLA.

Chapter-4

4 OBJECTIVES OF THE STUDY

- Investigation on variation in curing temperature on mechanical properties of developed green composites.
- Morphological studies to find the failure mechanical of developed composites using SEM.
- Investigation on degradability of developed composite under soil.

Chapter-5

5 EXPERIMENTAL SETUP AND EQUIPMENT'S

5.1 EXPERIMENT SETUP

A setup had been made for the development of Green Composite. The complete setup of fabrication of green composites as gives below:

Figure 11 Complete view of setup

5.2 FABRICATION SETUP

The complete setup is basically consisting following items.

5.2.1 Compression testing machine

5.2.2 Compression molding die

5.2.3 Heating element

5.2.4 Releasing agent

5.2.5 Electrical control panel

5.2.1 Compression molding machine (CMM)

In the field of compression testing machine, HEICO's machine is used. The capacity of the machine is 1000KN figure 12. 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: motorized pump (200V, single phase AC), maximum load (1000KN), and Hydraulic oil servo system ENKL 68.

Figure 12 Compression molding machine

5.2.2 Compression molding die

It is a specialized tool used for the fabrication of composite by pressing it. Basically, it consists of an upper part (punch plate) and the lower part (die block) as shown in figure 13. There are different types of strips used for making the different samples. The die is made of EN31 steel material which achieves very high compressive strength with high hardness value.

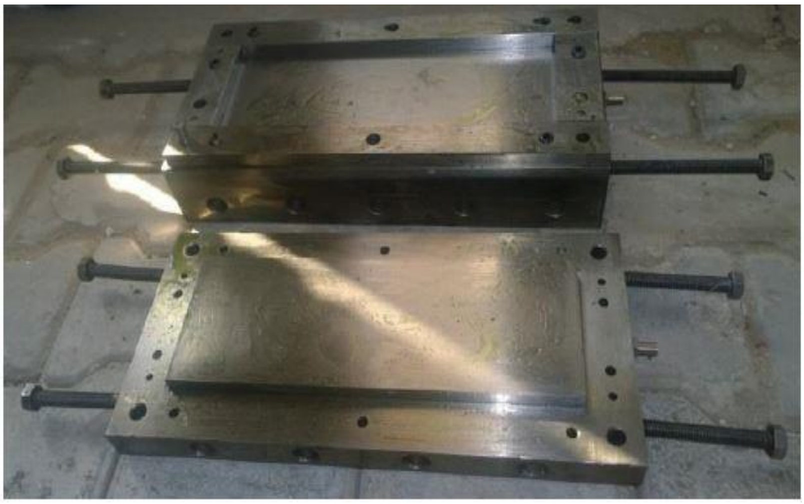


Figure 13 Die with upper and lower parts

5.2.3 Heating element

The setup was heated by commercial heating rod elements as shown in figure 14. Total nine heater rods used to heat the setup. The voltage of each rod heater is 750W with single phase. The controllers were used to cut off the supply of heater when temperature reaches required values.

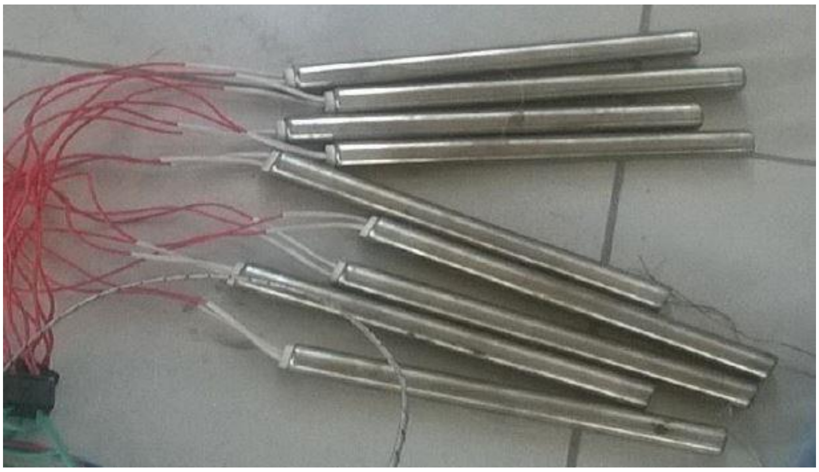


Figure 14 Heating rods

5.2.4 Releasing Agent

To reduce the sticking phenomena between metallic die and matrix material, we are using Teflon sheet as releasing agent so that metallic die can be easy open. Teflon sheet is placed on the upper face of lower die and lower face of upper die to prevent the metallic die and fabricated composite specimen also.

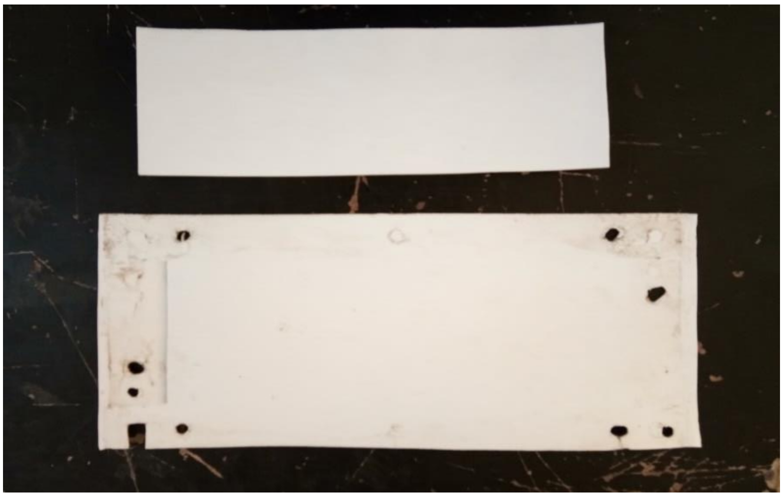


Figure 15 Releasing agent (Teflon sheet)

5.2.5 Electrical control panel

The electrical control panel unit consists following Components:

a) Thermocouple
b) Controller

a) Thermocouple

It is a device which consists of two wires made of different metals for the measurement of temperature. J-type thermocouple figure 16 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. 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.

Figure 16 J-type thermocouple

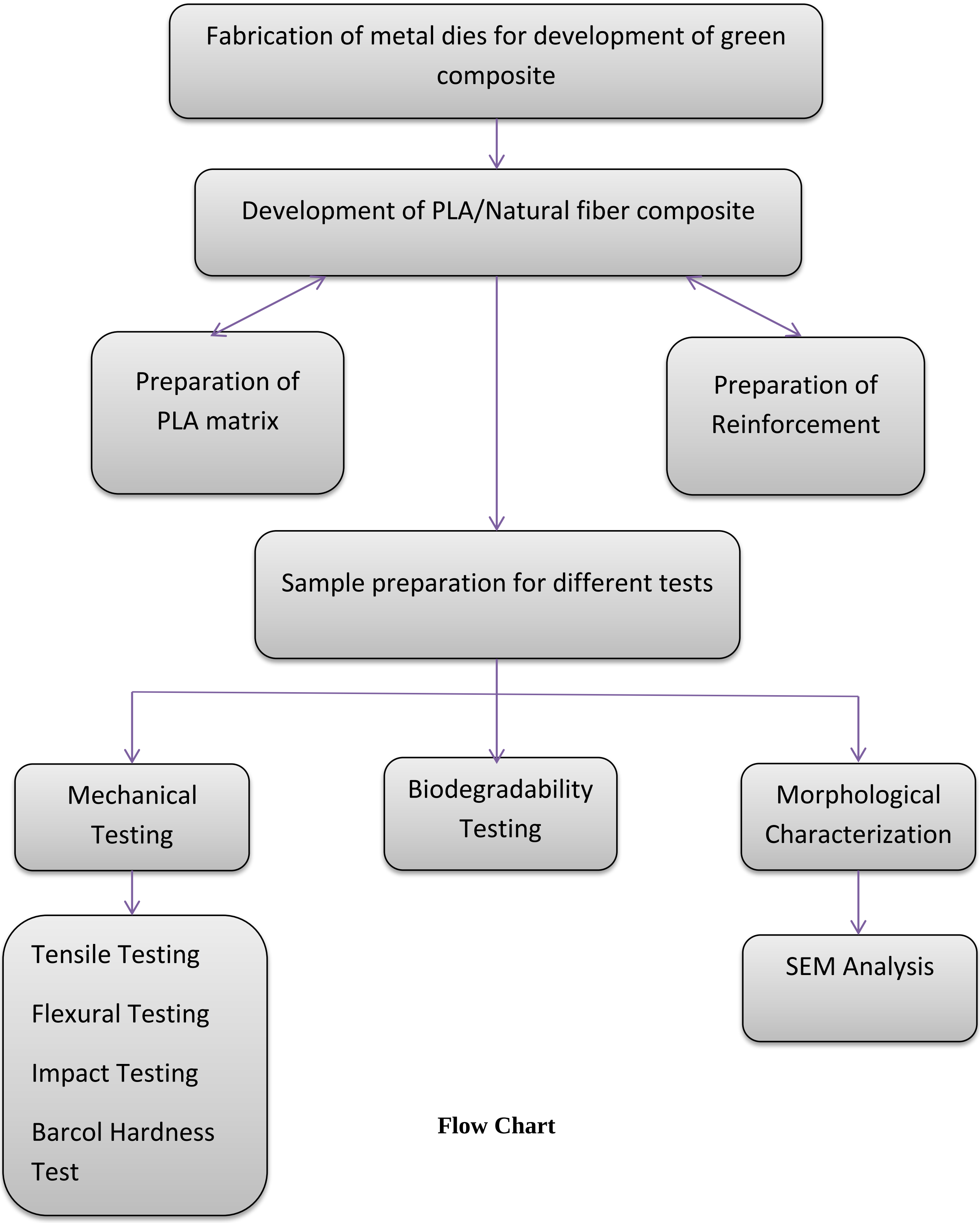
b) Controller

The main target of this setup is to maintain the die temperature at a required value. So that controllers are used in control panel to control the temperatures of the dies with the help of relays cut off. To begin with, set the temperature value on the display screen figure 17. Once the dies attained the set value controllers cut off its supply by sensing the temperatures of the dies with the help of thermocouples.

Figure 17 Controllers

Chapter-6

6 RESEARCH METHODOLOGY



Flow Chart

6.1 MATERIAL USED

Natural fiber used as the reinforcement and PLA is used as the matrix material to make the green composite.

6.1.1 Reinforcement

The reinforcement such as jute used is balanced and symmetrical jute fiber collected from the local source.

Figure 18 Jute fiber

6.1.2 Matrix

The matrix used PLA pallets are used according to ASTM standard 4043 D, collected from Natur-Tech India Pvt.Ltd. Chennai, India.

Figure 19 PLA pallets

6.2 CALCULATION OF VOLUME FRACTION

Fiber volume fraction incomes the quantity of fiber present in the composite material. The Fiber fraction obtained after fabrication of composite is cross verified with the formula [5]

$$V_f=1-(W-W_f/\rho_m V) \tag{1}$$

Where,

V_f=Volume fraction of fiber

W is weight of fabricated composite

ρ_m Is the density of resin

V is volume of fabricated composite

6.3 MECHANICAL CHARACTERISATION

6.3.1 Tensile Test

The tensile test will be done on the universal testing machine. It is load bearing capacity per unit area of cross section. Through this test decision of its application and site of using is, done easily by according to the ASTM standard D 3039. The specification of samples for the tensile test as per the ASTM standard is 250x25x4mm.

6.3.2 Flexural Test

The flexural testing will be done on the universal testing machine. 3 point bending test will be performed according to the ASTM standard D790-02.The results obtained showing the effects surface treatment on flexure strength. The specification of samples for flexure test as per the ASTM standard is 120x15x4mm.

6.3.3 Impact Test

It is the amount of energy immersed by the material during fracture. Izod V notch test is conducted on each specimen of composite material. The ASTM D256-02 is used for Izod testing. The specifications of samples for impact test are as per the ASTM standard is 62.7x12.7x4mm.

6.3.4 Barcol Hardness Test

The Barcol hardness test is used to identify the hardness of materials through the gravity of penetration of an indenter, which is loaded on a material sample and matched to the penetration in a reference material. The technique is frequently used for composite materials like reinforced thermosetting resins or to examine how much a resin has cured. The test matches the measurement of glass transition temperature, as secondary measure of the degree of cure of a composite.

Figure 20 Barcol hardener

6.3.5 Morphological Characterization

The structural analysis will be done by Scanning electron microscopy (SEM). The pictures of samples are produced with an electron microscope by keeping it in a focused electron beam. The surface of the test piece is firstly cleaned with acetone and kept in vacuum for approximately 15 minutes to completely dry the surface. After this, the piece is kept on the microscope for the proceedings for SEM. The SEM results are taken at different magnifications and then analyzed.

Chapter-7

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