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Sustainable Biocomposite Its Manufaturing Processes and Applications

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THE biocomposite materials which serve for present nation or civilization without affecting our future generation is called as sustainable biocomposite i.e., it does not affect our environment and save our environment from toxic and hazardous effect. The sources and production of the raw materials, material Processing, the service-life of the product and waste management should be evaluated in terms of energy, chemical consumption, emissions of gaseous materials, toxicology upon use and disposal of a biocomposite are considered as sustainable bio-composites. This can be formed by different manufacturing process like filament winding, lay up method, extrusion moulding, Injection moulding, compression moulding, Resin transfer moulding, Sheet moulding compound etc. Sustainable biocomposite has several advantages like light weight, high specific stiffness, high strength, low electrical conductivity, easily bondable, good fatigue resistance, internal energy storage and release, low thermal expansion, easily moulded to complex and design flexibility etc. These biocomposites have huge applications in several fields like in the field of domestic sector, building materials, aerospace industry, circuit boards and automobile applications. It supports our sustainable environment by using natural fibres like jute, hemp, sisal, knead, flax etc. which is the cause of biodegradation and can also be used in the industrial scale. It not only saves our environment but also made our life easier and more comfortable.

Keywords: Bio composites, Sustainable bio composites, Green Polymer, Natural fibres, Bio fibres.

Introduction

Nowadays the whole world is in an alarming situation due to addition of huge amount of non-biodegradable polymeric materials and composites in our environment which not only threaten us but also threaten existence of life within the universe and degrades the quality of the soil and reduces the soil fertility and production efficiency. Hence, scientists are searching for a new material, which is biodegradable and environmental friendly. To save our earth from dangerous non-biodegradable polymeric material and composites, alternative materials known as bio- composites should be considered which not only saves our problem but also it is environmental friendly.

In this paper, we are discussing recyclable processes, its consequences of designing and applications of sustainable bio-composites. This satisfies the following requirements:

- In the manufacturing process the renewable and recycled resources are utilized.
- The synthetic management and processes having effective energy are to be considered.
- During any phases of their life cycle and their use, no hazardous environmental materials or toxicological effects should arise.
- Sustainable bio-composite should be measured by the exposure in the direction of degradation, which includes abiotic properties like water adsorption, thermal and photochemical oxidation by creation of biofilm by biodegradation. [1]

The composite consists of two phases. First

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one is the base phase or matrix phase of the compound which is regarded as matrix whereas other constituents are discussed as reinforcing material or fillers and the composites are classified as following.

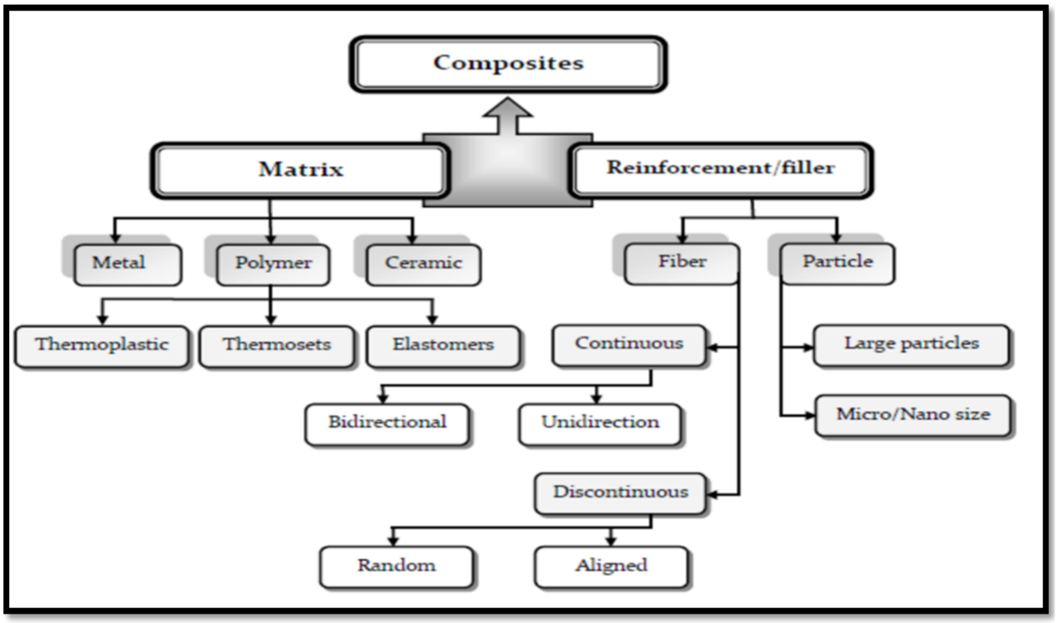

Fig. 1. (Classification of composite).

Classification of bio-composite materials

Biodegradable polymer is mixed with biodegradable fillers called as bio-fibres and causes the formation of bio-composite. The term bio-composite has three main assemblies as follows:

(a) Bio composites -1 : The renewable properties undergo several processes to form raw materials.

(b) Bio composites -2 : These are carried out by taking bio composites-1 where the waste may be accomplished economically i.e. by the process of composting, biomethanation, recycling etc.

(c) Bio composite -3 : In this method there is the applications of biocomposite-2 which undergoes sequential processes and the conversion of raw material to the finishing product are found suitable for environment and finally are formed. [2]

Sustainable biocomposite

This term is described by "the energetic and dynamic life style of human being that is treated carefully, but it cannot work together for the capability to come across their own needs for future generation". The key contents having more significance are suggested by Commission of European by the establishment of sustainability, are: (i) The change of climate; (ii) Passage of Sustainable material; (iii) Sustainability depletion by fabrication; (iv) Natural resources management and maintenance; (v) Regarding strength issue in community (vi) Demography relocation and (vii) Inclusive scarcity and challenges for improving sustainability. [3]

Sustainable bio -composites materials are made from biopolymers and this bio-composites which is the reverse of traditional synthetic polymers composites secured by several raw materials usage of inorganic synthetic fibres of low eco-toxicity and biodegradability. The design of sustainable bio composites is addressed in this review by applying resource consequences, where chemical modifications are done for the case of matrix material by emphasising the chemistry point of view. To form product and processing of materials by life cycle management or by LCA (life cycle assessment) studies (Fig- 2) are supportive method for production, convention and the waste materials are managed for evaluation of environmental influences. [4] Sustainability inferences should also be recognized by including rare tools selection, the artificial routes by component designing, consumption through lifecycle and then finally the study of waste management process in polymeric materials. The word like "biodegradable", "bio-composite", "sustainable biocompatible", "green bio-based composite", "renewable", "environmentally friendly", "eco-friendly", and "biopolymers" are

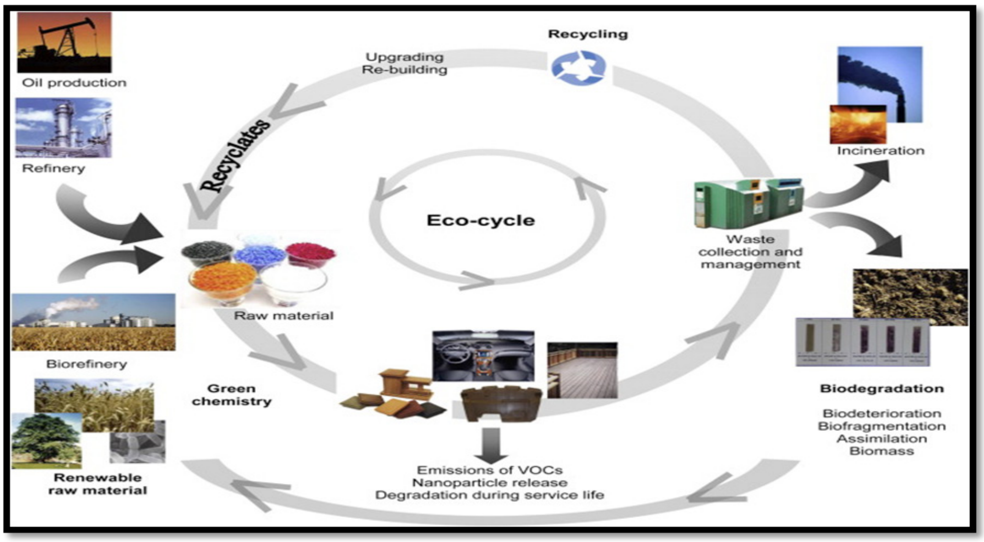

Fig. 2. Life Cycle of Sustainable Bio-composite.

related with the sustainable bio- composites and green bio-composite materials.

1. Natural fibres are reinforcing by non-biodegradable fuel established polymeric material.
2. Biologically active polymers are strengthened by naturally occurring fibres.
3. Biopolymers highlighting by manmade glass fibres. [5]

The composites may be described as green bio-composite materials which are sustainable and at least one of the components is from natural resources. Natural fibres which are formed by the reinforcement of petroleum derived polymer and biopolymer reinforced synthetic fibres are not ecologically sociable. The biopolymers that are reinforced by natural fibres are categorised as "green bio-composites" which are globally sustainable. The term is described as biodegradable bio-composites if the polymer having the matrix is biodegradable that contains bio-based and petroleum-based of two dissimilar kinds.

Fibres reinforced with the matrix material are derived through sustainable resources, which impactless toxic and hazardous influence on environment. The term 'natural fibre composites' are considered by taking the composites from natural fibres as reinforcing materials. "Hybrid"

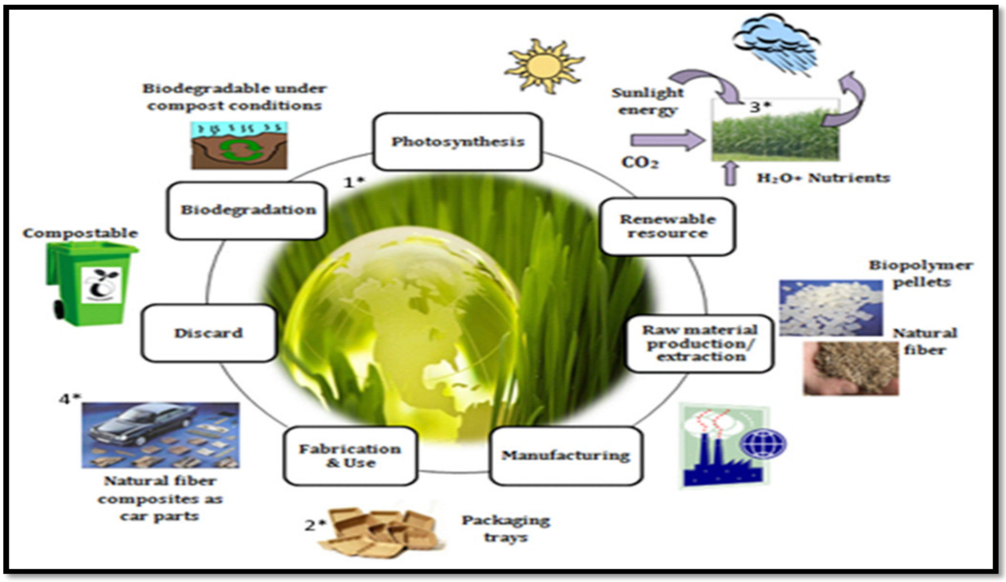

Fig. 3. Schematic representation of bio-based life cycle.

biocomposites are formed by the grouping of more than one fibre inside the polymeric matrix atmosphere. Bio-composite resulting from these assets have attractive properties like easily recyclable, biodegradable, compostable, with appropriate sustainably viable are regarded to be ecologically bio-based yields. For the appreciation of bio- based life cycle is posturized by a diagram regarding the bio-based term is given in Fig. 3. [6]

Green Polymer

Nowadays to save our environment and protection of fossil materials present in the nature we require the appropriate modern design and development of new generated biodegradable polymeric materials and composites. The composites design should be made from bio materials or biomass and is said to be as green composite. To save our earth from the toxic effect of polymeric materials and plastic nowadays this green bio-composite materials is an advanced research material in many countries of the world. The materials are said to be green materials if these are biodegradable, renewable and also environmental friendly in nature. The major properties and attraction of the sustainable composite are due to it is fully biodegradability, environmentally suitable and sustainable in every respect. It has good polishness properties, light weight and durable, therefore can be used for manufacturing of many machinery parts and automobile parts. Due to light weight it mostly used in aerospace engineering and after completion of its life cycle these materials are readily biodegraded and converted into compost by suitable micro-organism without damaging our environment. Nowadays there is a challenge to prepare, design and production of polymer based sustainable bio-composite in which the polymeric material is used as the base phase. [7]

Constituents of Sustainable Composite

During fabrication process of sustainable composites the natural fibres are used as reinforcing material which is in the discontinuous phase over the continuous phase of biodegradable polymeric materials. It brings the applied load, stress and updates better mechanical properties that include tenacity, hardness and high value of load bearing capacity. The base phase provides strength and challenging properties of the sustainable composites whereas the discontinuous phase provides the properties of the composites and on combining these two phases the stress of load applied is transferred and is distributed in these two phases. [8]

Reinforcing Bio-Fibres

Bio-fibres are renewable fibres that can be obtained from plants, animals and mineral resources and can be used as reinforcing materials in manufacturing process of green composite in the same way as the synthetic fibres. The classification of bio-fibres based on their origin is shown in Table 1.

Natural fibers

The resources collected from plants, animals and some minerals are used to manufacture natural fibers. Classification is shown in Fig. 4. The primary evidence for human utilizing the fiber material are wool, coloured fibers of flax, which is obtained by using fibers is the prehistorically cave of the Republic of Georgia. [9]

Plant Fibers

Natural fibers from plant origin are divided into two categories i.e. primary fibers and

TABLE 1. Classification of bio-fibres based on their origin.

Bio-fibers	Examples
Animal fiber	a) Wool/hair-sheep, camel, rabbit hair, yak, horse hair b) Silk-mulberry silk. coarse silk
Mineral fiber	Asbestos, wollastonite
Plant fiber	a) Wood fiber-hardwood, softwood b) Non-wood Stalk fiber-bamboo, wheat, rice, grass, barley, corn, maize Fruit fiber-coconut Seed fiber-cotton, oil palm, alfalfa Leaf fiber-sisal, banana, palm, pineapple, henequen Bastfiber-hemp, jute, banana, flax, kenafsugarecane

secondary fibers depending upon its utility. The primary plants fibers are those fibers in which the fiber content is more. [10] These are mainly jute, hemp, kenaf, sisal and the secondary plant fiber contains less percentages of polymeric material and these are mainly oil palm, coir. Comparison between synthetic fiber and natural fiber are shown in Table 2.

Green composite

The composite which is completely biodegradable or recyclable and manufactured from renewable natural resources such as natural fibres and natural resins are considered as green composite or more appropriately said to be as sustainable composites. The two major components of green composite are

1. Biodegradable matrix resin
2. Fibers from natural resources

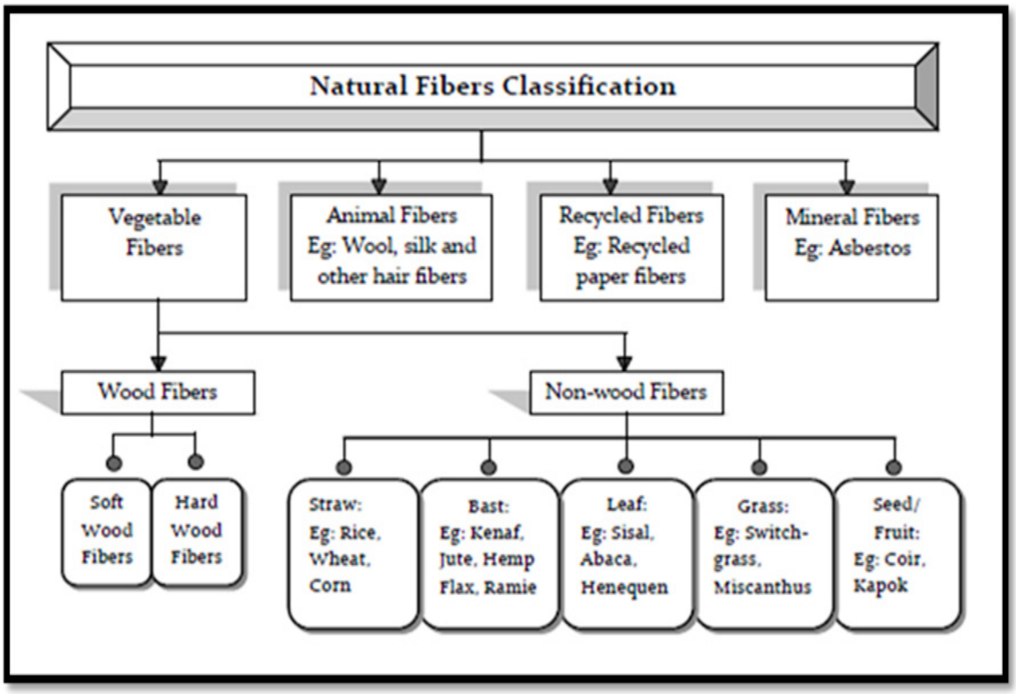

Fig. 4. Schematics representation of classification of natural fibers.

TABLE 2. Distinction between synthetic fibers and natural fiber.

Sources	Synthetic fibers	Natural fibers
Renewability	Non-renewable	Renewable
Resource	Infinite	Limited
CO_2 neutral	No	Yes
Bio-degradability	Bio-degradable	Non-biodegradable
Recyclability	Moderate	Good
Nature of abrasiveness	High	Low
Mechanical property	High	Moderate
Thermally sensitive	Low	High
Moisture sensitive	High	Low
Density	High	Low
Consumption of energy	High	Low
Cost	Higher than natural fibre	Lower
Toxicity	Toxic	Non-toxic

The traditional composites are many hazardous environmental impacts and to overcome these new eco-friendly bio-composites are manufactured from waste material and plant resources and commonly known as green composite. For manufacture of this composite, the materials like natural organic fibres, wood flour and fibres of low cost are used which have more dimensional stability and also high modulous of elasticity. The green composites have different industrial applications, but it has some drawbacks such as these are mainly ductile, less dimensional stability and also less processability. The green composite when combines with plant fibre it forms natural bio-composites. A number of bio based fibres are used in manufacturing of green composite, which are classified into two categories i.e. wood fibres and non-wood fibres. The different natural fibres used for manufacturing green composites are flax, kenaf, jute, sisal, hemp, coconut fibre, bamboo fibre, pineapple fibre and rani fiber.

Bio-polyester based green composites

1. Advanced bio-polyester based composites have higher strength than green composites. PHBV are certainly taking place by eco-friendly polymers obtaining from an inclusive range of microbes. PHBV polymers have the major relating properties with traditional thermoplastic i.e the mechanical properties of PP and PE. PHBV polymers characterise biodegradable polymers of new groups, their applications are limited due to their high cost. [11]
2. Combination of fibers or fillers can not only create them reasonable but also undergoes progress in their mechanical properties. Fillers are used in case of clay, $CaCO_3$ and PHBV resins belongings are altered by fiber made of wood. Cellulose fibres have biodegradable fillers, which is not only delivered reinforcement for PHBVs but also retain recyclability advantages.

Green composites based on soy-protein resin

1. The materials are available commercially by soy protein resin which is not much exclusive and are available substantially in the world. The bio-decomposable resins like PLA, PHA etc. are hydrophobic in nature and cannot bind with fibers obtained from plant and soy based resins and are associated with polar groups having good connection to them and undergo the production of composites of respectable mechanical assets.
2. There are several advantages of soy-protein linked with traditional polymer based on petroleum. It is used in the artifacts of computer, wrapping and in case of auto inner panels.
3. This resin has mechanical properties almost equivalent to the epoxy resins. These SPC resins are revised and strengthened by highly strengthen liquid crystalline (LC) fibers made from cellulosic to construct 'advanced green composites'. By using E-glass the same modified resins were reinforced to fabricate composites. Fully bio-degradable, environment-friendly green composites were fabricated by using ramie fibers and SPC resin whose mechanical properties were studied. [12]

Cellulose-Based green Nano-composites

1. Cellulose is a crystalline, high molecular mass polymer and infusible in nature. Due to this infusibility, highly valuable ester of cellulose and ethers of cellulose are transferred to its by-products. Cellulose acetate is used in high capacity requests from fibers to flicks during the process of injection moulding.
2. Now day's bio -nanocomposites are industrialized by cellulosic materials because of good thermal and mechanical properties. Green nano-composites manufactured by using cellulose acetate have good inflammable characteristics which are again amplified by adding Suitable plasticizer. [13]
3. In current days, the development of biodegradable composites by using plant origin is known as "green" composites. In "green" composites, some natural fibers are combined with resin of biodegradability property like PLA and starch.
4. Natural fibers, like cotton, jute are obtained from plant or animal foundations having absence of several appearances in synthetic fibers. Five different arrangements of fiber include: (1) stem fibers (2) leaf fibers (3) seed-hair fibers (4) core, pith or stick fibers (5) all other plant fibers not included above. Examples of stem fibers are jute, flax, hemp, kenaf, ramie, roselle and urena. Leaf fibers include banana, sisal, henequen, abaca, pineapple, cantala, caroa, Mauritius and phormium. [14].

Polylactic acid based bio-composite

1. PLA is obtained from lactic acid and is a thermoplastic polymer. It is used for the

formation of decomposable materials, like bags and cups made up of plastic in which PLA is used as a matrix phase for the formation of biodegradable and eco-friendly composites.

2. PLA is inelastic in behaviour and addition of triacetin is established as plasticizers to expand the impact strength in the composites of flax or PLA.
3. The power and strength of composites are 50% improved in comparison to composite of polypropylene and is applicable in automotive boards.

Hybrid Composites

The composite in which a number of different kinds of fibres or fillers used as reinforcing material in a single matrix phase is called as hybrid composite. If the fibres or materials are from natural resources then it is said to be as bio-hybrid composites. The properties of hybrid composites generally depend upon the amount of fibre materials used, length of fibres, aspect ratio, orientation, bonding in between fibre and matrix, the arrangement of fibre within the matrix phase. Strength of the hybrid composite mainly depends upon the failure strain of the fibres used during the manufacturing of the composite [15]. The hybrid composites are designed by mixing a synthetic fibre and a natural fibre in a matrix phase or may also the combination of two natural fibres or bio fibres in a single matrix phase. The hybrid composite if hybridised with glass fibre then the mechanical properties of the prepared bio hybrid composite is enhanced [16]. The oil palm fibres if hybridized with glass fibres during the manufacturing of the composite, then their tensile strength and young's modulus of elasticity was changed .The negative effect was also observed in the young's modulus of elasticity whereas positive effect was observed for elongation at the break point of the hybrid composite. By addition of glass fibres as one of the reinforcing material, the impact strength of hybrid composite is again increased [17, 18].

Bio-degradable polymers

1. Natural fibers are described as bio-based fibers derived from sources of vegetable and animal origin. Plant fibers like cotton, hemp, jute etc. and fibers based on protein are silk, wool etc. Depending upon the constituents natural fibers are termed into three kinds: seed hair i.e. cotton, leaf fibersi.e abaca, sisal and bastfibersi.e jute, hemp. [19]
2. Depending on the reinforcement, fibers from plants are categorised into two kinds as short fiber and long fiber. These are known by taking their aspect ratio; if l/d >100, it becomes long fibers achieved by producing high amount of composites from origins of plant for several applications and if l/d < 100 is short fibers and is obtained from plant origins that undergoes the formation of composites reinforcing of natural fiber.
3. Several advantages of natural fibers are good mechanical properties, higher strength, cost effective and better thermal stability. Due to explicit modulus of natural fibers, it is found to be better than fibers made of glass or glass fiber. [20]
4. The composites of natural fibers having substantial prospective in the market of construction as well as automobile industry. Hemi -cellulose is accountable for biologically compostable, immersion through moisture and also thermally degradable. Ligninfibers when contact with UV lights it undergoes degradation but it is generally thermally stable.

Factors Influencingprocessing of sustainable Biocomposite

The problems arising in the processing of sustainable biocomposites having natural fibres are hydrophilic and hygroscopic in nature, which is regarded by reinforcing the natural fiber. At low temperature and high glass transition temperature the natural fibre composites are tested by using limits of polymer as resin in matrix for sustainable composites. [21]

The fibres having hydrophilic and hygroscopic in nature have lower compatibility with hydrophobic polymer matrix, which is the reason of reinforcing of natural fibre polymer composites. Interfacial adhesion of fibre or matrix needs development by using fibre in composites and other limitations is the high moisture absorbing capacity of fibres in sustainable composites. In composites swelling occurs in fibres due to the moisture, which disturbs the stability of the composite. During processing of sustainable composites, existence of moisture converted into water vapour which causes some difficulties in injection moulding process.[22]

Manufacturing Processes of Sustainable Biocomposites

Hand Laminating Process

➢ This method is more flexible and low capital outlay found in moulds and equipment.

For obtaining composite of big size and multipart shape product hand laminating process is used. In this method sailing craft, motor boats and canoes products are formed.

- It involves the application of a well-ordered resin layer, 'coat associated with gel', in a

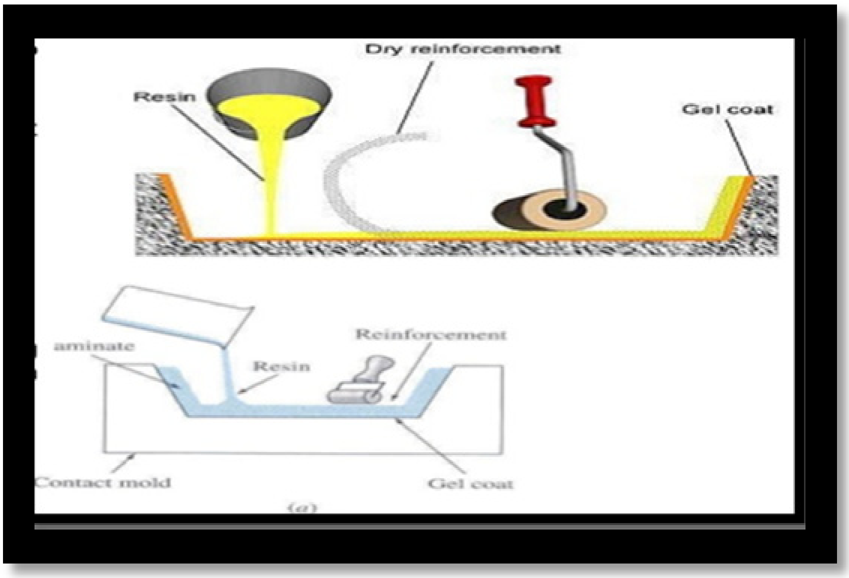

Fig. 5. Hand laminating process.

mould that can cover by the releasing instrument to form easier release of the completed elements.

When gel coat ones solidified, reinforcement and other resin coatings are functionalise for achievement of wideness. By the applications of resin to confirm impregnation of the reinforcement, a ribbed roller is used. Safety equipment is used due to the VOCs emission.

- To confirm impregnation of the reinforcement, a ribbed roller is used. Safety equipment is used due to the VOCs emission.
- Base resin are mixed with catalysts are

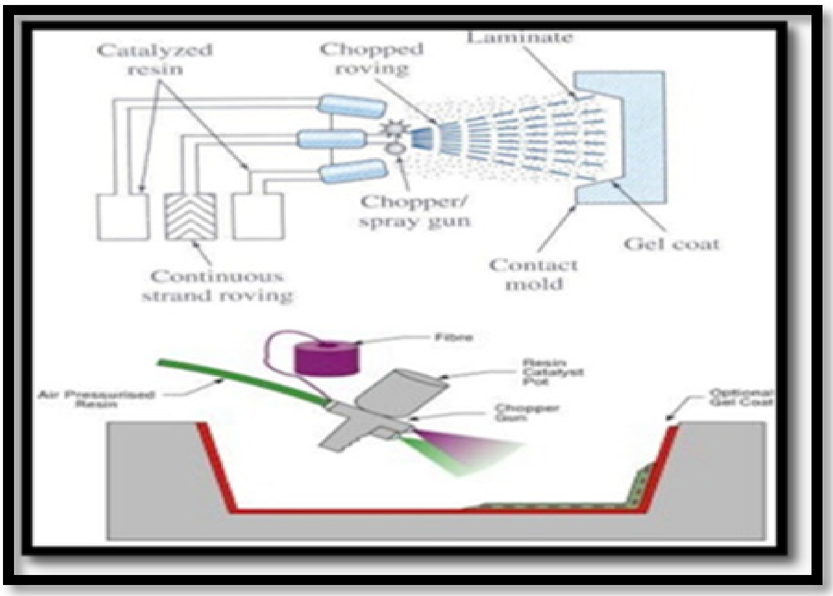

Fig. 6. Spray up process.

applicable in brushing and pouring.[23]

Spray-up Process

➢ Both resin and fibres are delivered together into the mould in spray up process. Filaments of continuous reinforcing are sliced by an entity of chopper into short length, then passed into the mould surface through a stream of catalysts.

➢ The applications of this method are lightly loaded structural panel e.g. Caravan bodies, Truck, fairings, bath tubs, small boats etc.

Filament winding Process

➢ Resin bath are used to feed the continuous fibre strands. The attachment of resin bath and fibre fed found in a criss-crossing heat. The achievement of comparative speed in case of navigating head and the alternation speed of the previous and twisting angle are preferably observed. The applications of this are the construction of pipes, pressure vessels, rocket

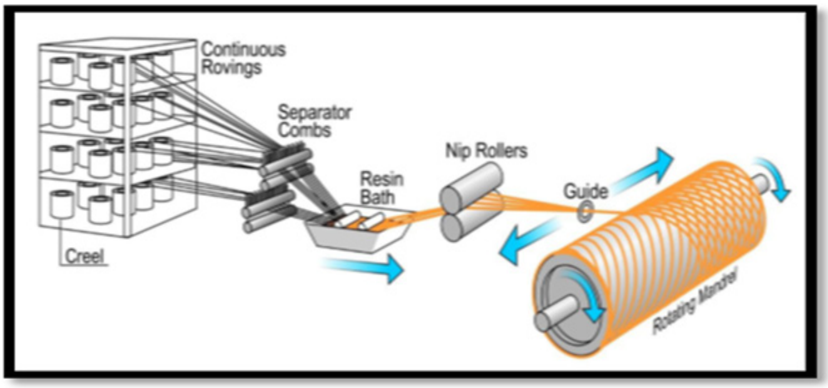

Fig. 7. The filament winding process

motors and gas bottles etc.

Pultrusion Process

➢ Filaments of uninterrupted fibres are fed by heater die through resin bath that preserves the resin.

➢ This is a useful method for the formation of long beams and other continuous sections.

➢ Pultrution is automatic, highly productive fabrication process of Polymer matrix composites of long product of constant cross-section.

Vacuum bag

➢ Both resin and reinforcing materials are allowed in the techniques of hand laminating to a mould. Then laminate is covered by a release film and a rubber bag and is fixed to the edges of the mould which is placed over the laminate. The air

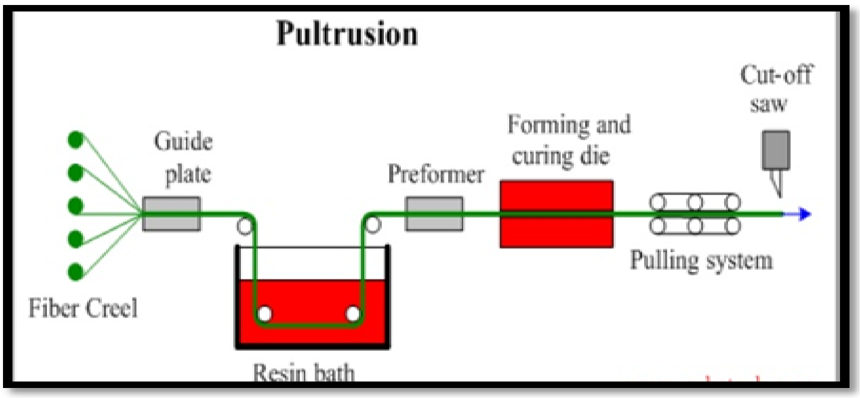

Fig. 8. Pultrution process

can be evacuated in the space between the bag and the laminate so that the atmospheric pressure is applied over the surface of the composite, serving alliances of the laminate and impregnation of the fibre by the resin. To confirm the full penetration of the fibres external hand rolling is required.

➢ The variation found in vacuum bag is regarded as mould of pressure bag in which pressure of positive amount are added than the pressure found in atmosphere, that undergoes well

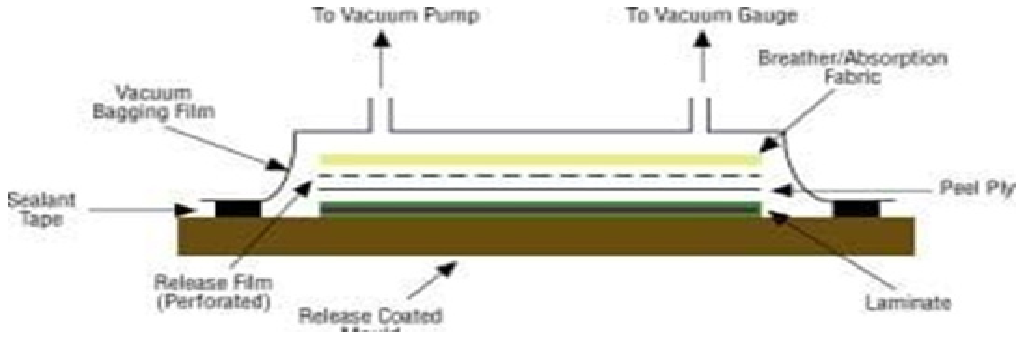

Fig. 9. Vacuum bag

association and fraction of high volume fiber are obtained. [24]

Compression moulding process

➢ The fibers having good dispersion and impregnation by the resin are achieved by using high pressures in rigid moulds attached in hydraulic presses.

➢ The mould is loaded by dry reinforcement and resins are discharged on the upper part. Then mould undergoes closing by the application of pressure, resins are scattered causing reinforcement impregnation. When the resin once becomes hard, then there is the release

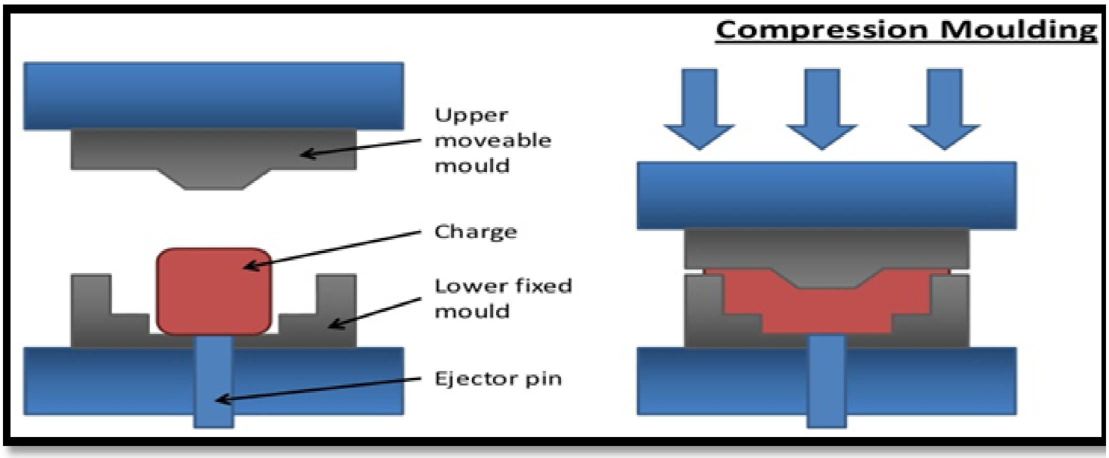

Fig. 10. Compression moulding process.

of pressure then the removal of component from the mould is observed.

Resin transfer moulding process (RTM)

➢ This process is related with the cold pressing, in which the reinforcing of load is taken in a batch mould.

➢ The resin is pumped into the mould before the closing of mould through injection ports. [25]

Pre-pregs

➢ SMC (Sheet Moulding Compound): First sheet is formed by combined mixture of fibre, resin, fillers & catalyst, which forms the final product by compression moulding.

➢ DMC (Dough Moulding Compound): Dough is formed by mixing of fiber, resin, fillers and catalyst. Catalyst is activated by heat so the dough can be kept for some time before needed. Product formed by compression moulding or injection moulding. [26]

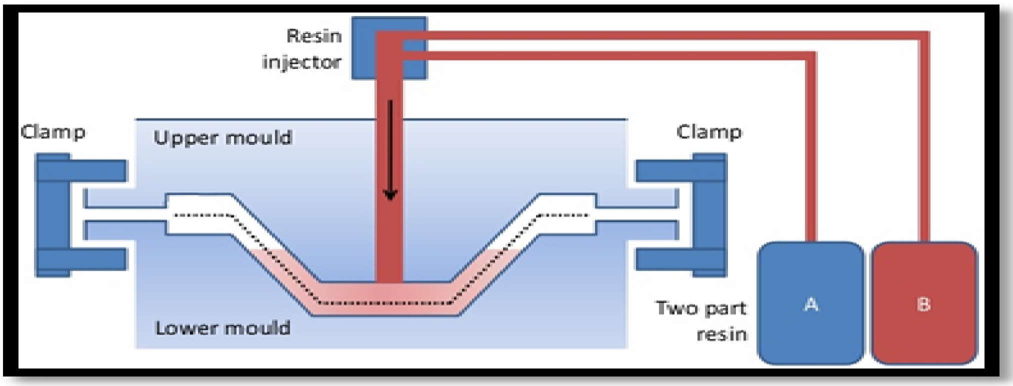

Fig. 11. Resin transfer moulding.

SMC Junction box
(Source: British Plastics Federation)

DMC Conduit box
(Source: British Plastics Federation)

Fig. 12. SMC and DMC.

Compounding and extrusion

➢ Extrusion process used from food industries to metals industries.

➢ Extrusion used in blend fibre with plastic (and additives) which can be extruded and pellet are formed. These pellets are used as the feedstock for the injection moulding process.

➢ Now manufacturers offer equipment for fabricating wood-plastic composite (WPC) product.

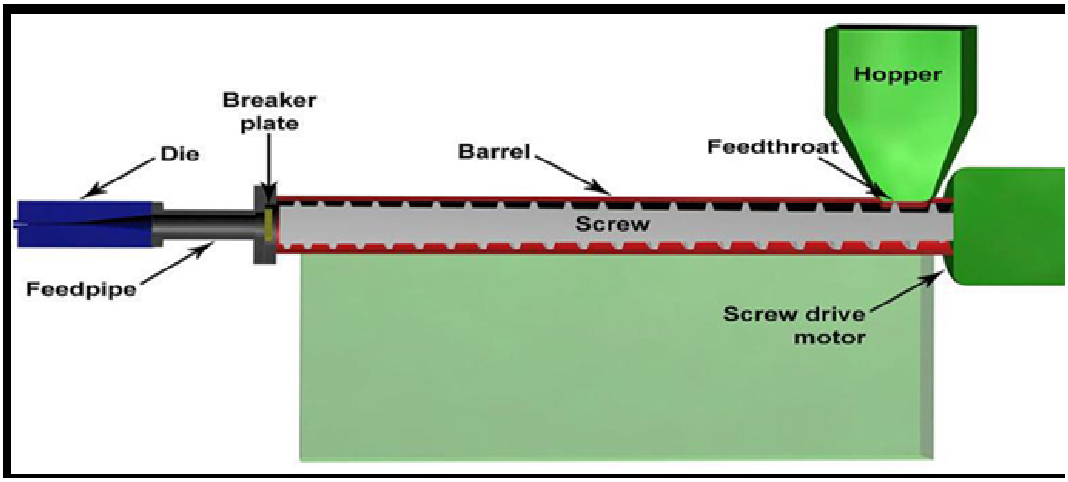

Fig. 13. Schematic diagram of extruder.

- *Injection moulding process*
- In closed mould molten polymer or fibre blend is forced.
- The mould is "split" so that the polymer or blend becomes cooled and solidified, then mould undergoes opening then injection moulded part can be removed. [27].

Application of Sustainable Bio-composites

1. In automobile industry

The sustainable bio composites are used to manufacture lighter, more fuel efficient and safer automobiles part like automobile engines, bodies, cylinder, pistons, connecting rod, bearing materials are made by sustainable bio-composite.

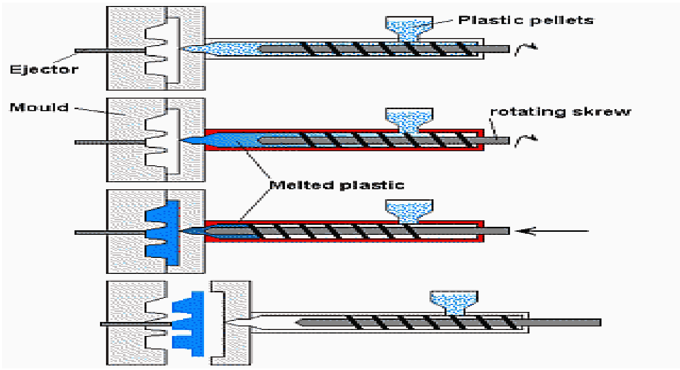

Fig. 14. Schamatic diagram of Injection Moulding.

2. In aerospace industry

Sustainable bio composites are used in the aerospace industry to manufacture aircraft parts because of light weight. The materials like fiber glass, carbon fiber, carbon epoxy and aramid fibers are used for the manufacturing of different parts of aircrafts like appliances of jet, turbine edges of turbine, cutting edge of compressor, airfoil surface, fly wheels, appliance inlet entrances, propeller craft in airliners, airplane spread assemblies.

3. Natural fiber composite applications

Used in organizational applications where the properties like cost effective, moderate strength is necessary. E-glass, car glasses are made from this composite materials. Mercedes, Audi and fords are manufactured in Germany by natural fibers composites.

4. Coir fiber-reinforced composites applications

It is also used in domestic sector for making of sofa bed, seat cover, some other automotive segment.

5.Kenaf fiber-reinforced composite applications

These are used in housing project because of better fire retardant property, light weight and are cost effective. Hybrid kenaf fiber composites show potential applications in the essential parts of car like profuse grins. [28]

6. Flax fiber-reinforcing applications of composites

It shows almost same performance as the glass fiber-reinforced composites.it is used the development of structural components having less cost. These composites used as raw materials for subdivision panel of an incomplete auxiliary of wood. Flax fibers composites like flax mat and foam are manufactured which are used for conventional wood structures in buildings.

7. Flax Application

This fiber is commonly known as linsed, and it is a membrane of the plant genus linum, which is a fiber crop bio- material and widely cultivated in the cooler regions of our globe. Flax based composites are mostly used for manufacturing of bed sheets, table cloth and undergarments. Nowadays highly developed sustainable materials are prepared by using flax fiber as reinforcing material. The flax fibers are low cost and show several specific essential mechanical properties and nontoxic in nature. The bio- composite materials and hybrid composites are prepared using flax fibers by taking thermo plastic, thermosetting resin and bio degradable polymers as matrix phase shows better mechanical properties. Flax based composites are nowdays used as household textile, material for interior furnishing of houses and also wall decorating and covering material. This composite don't deformed easily, retain its color and also luster for a longer period of time. It is used for manufacturing of tarpaulin, driving belts, soil cloths and fishing net, partly reduces the marine pollution load. Since it has good water proofing characteristics, therefore it is used for fabrication of roofing material. Flax bio- composites are generally hygroscopic, permeable to air and bioactive in nature, the textiles manufactured from it may be widely used in medicine packaging, manufacturing of combined bandages, a special surgical thread. It shows fire retardant properties and is applicable for manufacturing of heat insulating material and can be used successfully as construction materials. [29]

8. Curaua fiber-reinforcing applications of composites

The caraua fiber composites are widely applicable in manufacturing of different automobile parts and it is one of the step towards sustainability of automobile industry. It is more economical, eco-friendly, reduces the pollution load due to automobile industry and also highly beneficial to our society. [30]

9. Hemp fiber-reinforced composite applications

By taking thermoplastic polymeric material as matrix with hemp fiber as reinforcing material, the composite prepared is commercially comparable with the glass fiber reinforced composite. The emission of CO_2 is potentially reduced by using hemp fiber reinforced composite in automobile sector instead of glass fiber composite. If we compared the properties and application of hybrid glass fiber composite and hemp fiber reinforced composite for manufacturing of pipe, then it was found that the cost of production is reduced about 20% and the weight is reduced about 23% in case of hemp fiber composite[31].

10.Sisal fiber-reinforced composite application

The hybrid polymer composite made by using sisal and glass fiber or sisal and silk fiber as reinforcing material shows better chemical resistance, for which it is used for the manufacture of water and chemical storage tanks. The polymer composite of sisal and kapok fiber are used in low housing projects and also for the manufacture of components for interior designing of automobiles. It is also applicable in orthopedic both internal fixation and external fixation of the fractured bone and replaces the conventional metals such as stainless steel, zirconium. The composite of polypropylene matrix reinforced with sisal fiber has several applications and replaces glass fiber composites. [32]

11.Banana fiber-reinforced composite applications

The composite of epoxy resin reinforced with banana fiber is applicable in designing and fabrication of modern table of multipurpose use and telephone stand. The composite prepared by reinforcing banana fiber is used for household furniture application and nowadays it is going to replace wood, conventional plastics, metallic and non-metallic materials used for manufacturing of furniture and treated as good furniture material. [33]

12. Jute fiber bioactive materials application

The composite prepared from jute fiber and chitosan or alginate shows permanent bioactive properties. These composites show anti-bacterial properties towards E.coli and S.Aureus bacteria. Therefore more promising application of jute fiber is the manufacturing of food packaging materials. [34, 35]

It is used for the manufacturing of jute mat, composite doors and windows, door frames, fishing boats, natural fiber boats for recreation and tourism because of good electrical insulation, corrosion resistance and high fire retardant properties [36]. In addition to that, the major disadvantages of jute fibre are less compatibility between hydrophobic matrix phase of polymer with the hydrophilic reinforcing phase of the fibre, which creates a weak interface and causes poor mechanical properties of the composite material. Another disadvantage is more water absorption capacity and poor thermal stability [37, 38, 39].

13. Oil palm fiber-reinforced composite applications

Nowadays due to rapid population growth and deforestation, the forest coverage area from our globe gradually decreased, which resulted the acute shortage of wood. The researchers are now searching a new material which serves as the alternative of wood. The oil palm reinforced composite is one of the best alternative for manufacturing of plywood and can be used as alternative of wood [40].

14.Rice husk-reinforced composite applications

The composite prepared by reinforcing rice rusk by using high density polyethylene matrix by injection moulding process is used suitably for preparing window frames and also designing hollow instruments in low cost.[41]

15.Bamboo fiber-reinforced composite applications

The bamboo trees are widely available in different parts of the world, and bamboo fiber is a low cost natural fiber which is stable under different environmental conditions. The polymer composite prepared by reinforcing bamboo fiber is hard, light weight and fire resistance in nature, therefore these composite materials are used as building materials, packaging materials, automobile parts, storage devices, manufacturing of panels, ceilings and partition boards.[42]

Nobelity of The Use of Bio-Composite

The bio-composite materials are more sustainable, non-toxic, lightweight and environmental-friendly than the presently used materials like aluminum, steel, carbon-fibre etc. The use of bio-composite in the industry is now increasing day by day and industries like automobile, construction, consumer packaging use bio-composite materials with an increased rate. These materials generally lighter and more fuel efficient and require less energy in the meantime sustainable and greener, which is an important cause of commercial application of bio-composite in the automotive industry.

The demand for bio-composite materials in the world is increasing gradually (first world countries). It was estimated that the demand for bio-composite in Europe was 0.3 million tons in 2011 and in 2016 it was increased to 1.2 million ton. The North and South American countries (like the USA, Canada and Brazil) use bio-composite materials and the growth is almost around 41% per annum [43,44]. Hence it is expected that in future a new market may develop when a natural fibre composite product becomes more durable, dimensionally stable, moisture resistant and fire retardant.[45, 46].

Conclusion

Most of the polymeric materials and composites are not biodegradable in nature and its accumulation within the environment causes serious environmental hazards not only in the soil but also in the marine environment. If biofibers are used as fillers, the bio-fibre based green composites serves as basis for imparting sustainable material for bio-composite production. The life cycle assessment and life cycle management studies are also be done in bio-composite materials and green composite materials to improve not only general traditional properties but also improved environmental performance for biodegradation. Although sustainable bio-composites supports environmental performance but still it has some major disadvantages by using it in operational submissions. Hence investigation is required for designing sustainable bio-composite and green composites materials by enhancing its functionality, stability, processability and service life along with preserved biodegradability. However, it is our responsibility for the researchers to design and manufacture sustainable bio-composite materials and increasing or enhancing the desired properties of these materials for applications in different advanced fields and various sectors so that we can fulfil our material requirement and along with we can save our environment from dangerous conventional non-biodegradable synthetic plastic materials.

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