

# A Review on Developments in Manufacturing Process and Mechanical Properties of Natural Fiber Composites

*Md. Maruf Billah, M S Rabbi\*, Afnan Hasan*

Department of Mechanical Engineering, Chittagong University of Engineering & Technology, Chattogram-4349, Bangladesh

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## ABSTRACT

From the last few decades, the study of natural fiber composite materials has been gaining strong attention among researchers, scientists, and engineers. Natural fiber composite materials are becoming good alternatives to conventional materials because of their lightweight, high specific strength, low thermal expansion, eco-friendly, low manufacturing cost, nonabrasive and bio-degradable characteristics. It is proven that natural fiber is a great alternative to synthetic fiber in the sector of automobiles, railway, and aerospace. Researchers are developing various types of natural fiber-reinforced composites by combining different types of natural fiber such as jute, sisal, coir, hemp, abaca, bamboo, sugar cane, kenaf, banana, etc. with various polymers such as polypropylene, epoxy resin, etc. as matrix material. Based on the application and required mechanical and thermal properties, numerous natural fiber-based composite manufacturing processes are available such as injection molding, compression molding, resin transfer molding, hand lay-up, filament winding, pultrusion, autoclave molding, additive manufacturing, etc. The aim of the paper is to present the developments of various manufacturing processes of natural fiber-based composites and obtained mechanical properties.

Keywords: Natural Fiber Composites, Manufacturing Processes, Mechanical Properties.



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## 1 Introduction

The research field of Natural Fiber Composites (NFC) has been increased due to its higher prospectus and are considering nowadays as the alternatives of carbon or glass fiber composites. Among extensive applicable fields, the demand for NFC, especially in the automotive industry is increasing comprehensively because of sound attenuation capability and lightweight, results in better fuel efficiency. NFC does not only reduce the weight of the vehicle but also lower the cost and energy needed for its production by 80% [1]. NFC can also be used to fabricate furniture, tiles, and marine piers [2]. However, the natural fiber composites have some distinct disadvantages over glass fiber composites such as lower load capability, higher moisture absorption, and lower processing temperature [2],[3].

Between plant and animal fiber, the former one gives more strength and stiffness rather than the later one though silk, a plant fiber is relatively expensive [4]. The cellulose-based natural fiber such as ramie, flax, hemp can give higher mechanical properties than other. The selection of fiber for NFC depends on geography, for example, jute, flax fiber, kenaf, whereas hemp and ramie have more interest in Europe, and in Asia, sisal fiber gets the large interest. The mechanical properties of natural fiber vary with the chemical composition and chemical structure of the fiber, usually related to the fiber harvesting time, growing conditions, storage procedures, extraction method, and the chemical treatment prior to the product fabrication. Mechanical strength may be reduced by 15% when it is harvested 5 days later of optimum harvesting time [5]. In case of the extraction process, manually extracted fiber can show 20% higher strength than mechanically extracted [6]. To establish as alternatives of glass fiber, natural fiber should be collected as an optimum way in terms of time and process that can give closer strength to glass fiber.

Apart from the fiber, one of the distinctive constituents of composites is the matrix, used as the binder in the laminate.

Various thermoplastic materials such as polyvinyl chloride (PVC), polypropylene (PP), polyethylene, and polyolefin are being used in NFC [7]. Thermoset polymer materials such as epoxy resin, unsaturated polyester, VE resins, and phenol-formaldehyde are used as matrices material as well though on small scale [8],[9]. Thermoset plastic exhibits better physical properties under the operating temperature of 200°C, the reason makes thermoplastics as matrices material more suitable [9].

Surface modification of fiber by coupling agent and compatibilizer is an important step for producing NFC [10]. It enhances the interfacial strength between fiber and matrices. Coupling agent creates strong bond in the interface by reacting with fiber and matrices simultaneously during processing time. Besides, polymeric compatibilizer is interfacial agent which grafts fiber and matrices onto the chain of polymer [11],[12]. The mechanical properties of NFC significantly depend on which coupling agent or compatibilizer is adhered [13],[14].

The manufacturing process plays an important role on the property of NFC [15]-[17]. Fiber lengths, product size, chemical treatment of fiber are the main parameters for selecting the manufacturing process associated with NFC [18]-[20]. Long fiber and large-size products follow open mold manufacturing processes like hand lay-up, automated tape laying, etc. for better mechanical and thermal properties [1],[21]. Relatively complex and small-scale NFC product made from short fiber through closed mold process such as injection molding, compression molding, transfer molding [19],[21]. Exceptionally short fiber is used in spray up open mold processing [22]. Strong fiber dispersion provides better interfacial bonding between fiber and matrices by reducing the void at this interface [23]. For overcoming this reason higher intensive mixing process like single screw extruder and twin-screw extruder are used [24]-[26].

In this article, the developments in the manufacturing process associated with NFC are reviewed. Conventional

\*Corresponding Author Email Address: [rabbi@cuet.ac.bd](mailto:rabbi@cuet.ac.bd)

manufacturing processes for NFCs are discussed in Section 2. Section 3 depicted the comparisons of selected mechanical properties from mentioned processes. Future research work is mentioned in Section 4. Finally conclusions are drawn in Section 5.

## 2 Manufacturing Processes

Earlier, composite materials were produced directly by human hand [27],[28]. With the advancement of technology and increasing demand, it goes through semi-automated to automated processes like additive manufacturing. The closed mold processes are being famous in the current century because of higher precision, accuracy, and productivity [29],[30]. Injection molding, Compression molding, Resin transfer molding are the most commonly used manufacturing method of NFC material in recent days. Hand lay-up, autoclave, Pultruded, Filament wound, etc. are the special method for specific type products manufacturing. The hand lay-up process is substituted by automated tape laying process for its technological benefits [31]-[33]. In this section of the report, various manufacturing processes of NFCs are upheld with manufactured composite's mechanical properties.

### 2.1 Injection Molding

In injection molding process, a specific amount of fiber and molten polymer is mixed into a mold cavity by sufficient force. Various studies have been done on the injection molding process [34]-[39]. In the injection molding process, both thermosets and thermoplastics polymer are used, but the process included with thermoset is difficult to execute [40],[41]. The process parameter of thermosets such as curing time, curing temperature, injection pressure, and injection torque were investigated by Deringer et al. [42] for epoxy-based natural fiber composite. An schematic setup of injection molding process is given in Fig. 1.

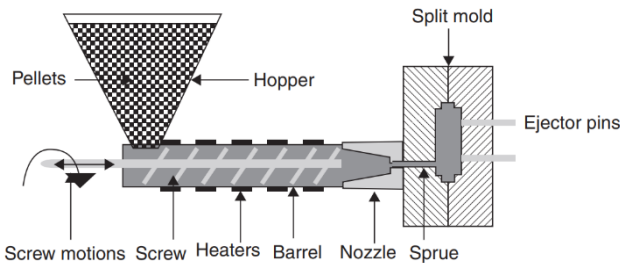


Fig. 1 Schematic setup of injection molding process [43].

In a contrast, thermoplastic polymer-based natural fiber composites production is quite easier in the injection molding process [44]. The small pellets of the thermoplastic polymer are mixed with chopped fiber and feed into a hopper. The material thus passes through high temperature and high-pressure melting section by rotating screw (single screw extruder or twin-screw extruder). High temperature is responsible for melting the material and made it viscous fluid. Finally, it goes through the sprue nozzle into mold cavities due to the above-mentioned high pressure. After solidifying, the product ejects from the mold cavities. The screw-type extruder generates the required share force for the following purpose:

- (1) Generates heat to melt the pellets and reduced the friction between barrel, pellet, and screw [39],
- (2) Ensures better mixing of polymer matrices and fiber [11],

- (3) Push the mixture into the sprue nozzle through the mold cavities with sufficient force [11].

It has been found that the increase of temperature reduced the share viscosity of biodegradable polymers [45].

In the injection molding process, fiber length should be appropriate to transfer entire stress from matrices to fiber and better performance by following the formula [46]:

$$I_c = \frac{\sigma_{fu} d}{2\tau} \quad (1)$$

where,  $I_c$ ,  $d$ ,  $\tau$  and  $\sigma_{fu}$  are critical fiber length, fiber diameter, shear stress at the interface of fiber and matrix and ultimate tensile strength of fiber respectively.

It is reported that the mechanical property of NFC is maximum at an optimum fiber length. Due to the imperfect interfacial bonding between fiber surface and matrix, the property might not reach its highest value though the critical fiber length has been obtained from equation (1) [11]. Thus, it is mandatory to choose optimum fiber length for the injection molding process. Otherwise, a predetermined critical fiber length may cause fracture in matrices.

Fiber orientation and residual stress in NFC are also important issues for unequal modulus distribution. Improper mixing, insufficient heating after injection may cause irregular fiber orientation and rapid cooling of molten polymer, excessive pressure at the mold section is accountable for growing residual stress [47]. This unexpected residual stress causes tensile stress at external surface of the product and compressive stress at intermediate region which is called injection-molded characteristic residual stress distribution<sup>49</sup>. Various studies have been performed in residual stress development factors [45],[48]-[50]. It has been found that non-uniform temperature distribution along with whole molten polymer, higher pressure gradient, polymer chain orientation, unequal thermal expansion coefficient between fiber and matrices are major causes of building residual stress in NFC. The geometrical parameters like mold cavities, mold shape, mold size, mold vents which help to escape air bubble, and injection gate location are also responsible for stress concentration [11]. On the other hand, non-uniform fiber orientation developed due to unequal thickness of mold which causes variation in properties through the final product. For more fiber concentrated region shows fiber dominating properties and molten polymer generates a complex flow geometry on upstream [51]. Mechanical properties of NFCs which are made by injection molding process from previous literatures are listed in Table 1.

### 2.2 Compression Molding

Compression molding (CM) is the oldest manufacturing process among all of them. Plastic products are produced at a very early stage by CM process. In the composite manufacturing industry, it achieves huge scopes parallelly for glass fiber and natural fiber [59],[60]. Both thermoplastic and thermoset matrix natural fiber composites can be produced by CM [61]. There are two mold sections, upper and lower, in the CM process. The charge is placed at the lower section of mold and during the molding time the upper section press with sufficient pressure and temperature to get the shape inside the mold cavity. The CM process can be called the combination of autoclave and hot press process. Both short and long fiber composite can be produced by this process. Prepregs of thermoplastic material are laid in a

proper sequence on mold in autoclave process. Then the laminate is bagged in negative pressure and placed inside the autoclave. The laminate goes through heat and pressure cycle and after curing the desired composite is formed [62]. On the other hand,

it is not necessary of closed the mold in hot press process [63]. In close mold, precut and measured amount of natural fiber are stacked with each other and placed in the mold cavity (see Fig. 2).

Table 1 Mechanical Properties of NFC prepared by Injection molding process

Matrices	Fiber	Fiber percentage (%) mass)	Tensile strength (MPa)	Flexural strength (MPa)	Young's modulus (GPa)	Flexural modulus (GPa)	Reference
PP	Hemp	40	52	86	4	4	[52]
PP	Newsprint	40	53	94	3	4	[52]
PP	Kraft	40	52	90	3	4	[52]
PP	Flax	30	52	60	5	5	[53]
PP*	Flax	30	-	70	-	6	[54]
PP	Wood BKP	40	50	78	3	3	[55]
PP	Jute	60	74	112	11	12	[56]
PA	Cordenka	30	120	-	6	-	[57]
PLA	Cordenka	25	108	-	4	-	[58]
PP	Cordenka	42	90	-	4	-	[58]

PP = Polypropylene, BKP = Bleached Kraft Pulp, PA = Polyamide, PLA = Polylactide Acid

\*High molecular weightmaleic acid anhydride modified PP.

Table 2 Mechanical Properties of NFC prepared by Compression molding process

Matrices	Fiber	Fiber percentage (%) mass)	Tensile strength (MPa)	Flexural strength (MPa)	Young's modulus (GPa)	Flexural modulus (GPa)	Reference
PP	Kenaf	30	46	58	5	4	[10]
UP	PALF	30	53	80	2	3	[65]
Epoxy	Harakeke	45	136	155	11	10	[66]
Epoxy	Hemp	50	105	126	9	8	[66]
Epoxy	Hemp	65	113	145	18	10	[67]
Epoxy	Hemp	65	165	180	17	9	[67]
PP	Hemp	46	-	127	-	11	[68]
PLA	Hemp	30	83	143	11	7	[67]
PLA	Kenaf	40	82	126	8	7	[69]
PHB	Kenaf	40	70	101	6	7	[69]
PLA	Hemp	30	77	101	10	7	[69]
PLA	Kenaf	80	223	254	23	22	[70]
Epoxy	Sisal	73	410	320	6	27	[71]
Epoxy	Sisal	77	330	290	10	22	[71]
Epoxy	Harakeke	55	223	223	17	14	[72]
Epoxy	Harakeke	52	211	-	15	-	[73]
PLA	Harakeke	30	102	-	8	-	[66]
Epoxy	Flax	50	290	248	24	22	[42]
Epoxy	Flax	40	34	90	-	-	[74]
Epoxy	Bamboo	40	23	58	-	-	[74]
UP	Flax	58	304	-	30	-	[75]
PP	Flax	50	40	-	7	-	[76]
UP	PALF	30	53	80	2	3	[65]
PHB	Lyocell	30	66	105	5	5	[69]

UP = Unsaturated Polyester, PLAF = Pineapple Leaf Fiber, PHB = Poly (3-Hydroxybutyrate).

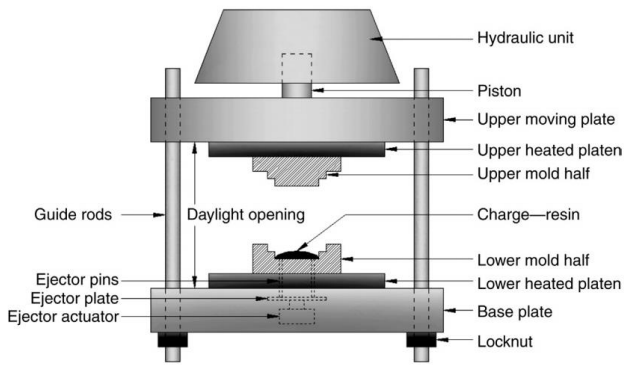


Fig. 2 Schematic setup of compression molding process [64].

In the CM process, BMCs and SMCs are the consecutive initial charge of this molding process. Around 30 to 70% of the lower mold cavity is filled up by this initial charge [62]. Sufficient pressure is applied before getting high temperature. In that case, some fiber may fracture when excessive pressure is applied before molten of matrices. After applying heat, it gets cool and removed from the mold cavity. Lots of studies had been done to find out the prospects of using renewable polymer and natural fiber composite as a new form of bio-composite by compression molding process [34]-[37]. Zero shear stress, proper placing of fiber in the mold cavity, unwanted motion during processing ensure minimum fiber damage. To make large volume fraction of fiber, long fiber can be used. And for better reinforcement and lower shrinkage of molten material, short fiber and compound should be mixed with each other<sup>11</sup>. Mechanical properties of NFCs which are made by the CM process from previous literatures are listed in Table 2.

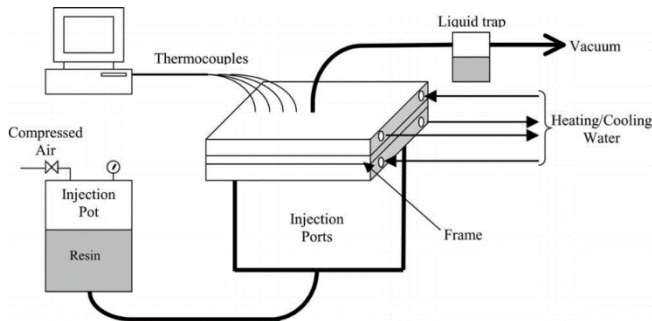


Fig. 3 Schematic setup of resin transfer molding process [84].

## 2.3 Resin Transfer Molding

Table 3.

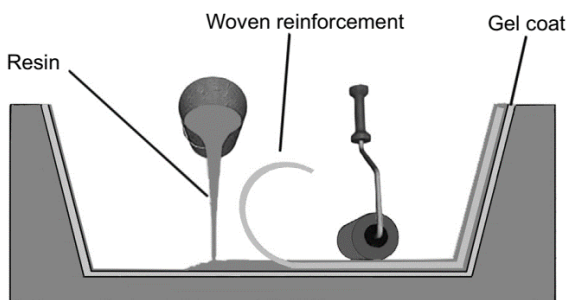


Fig. 4 Schematic setup of hand lay-up process [96].

In resin transfer molding (RTM), thermoset resin is used as matrices which is injected in mold cavity containing fiber (see Fig. 3). To avoid leakage, two halves of matching molds are clamped together with sufficient pressure. Generally, continuous or long fiber is used in the RTM process [30],[77]. Various studies have been done to find out the prospects of resin transfer molding process [29],[78]-[82]. The process parameter of thermosets such as curing time, curing temperature, heat flow, and degree of cure were investigated by Rouison et al. [30] for unsaturated polyester resin-based natural fiber composite. Dominating criteria of RTM are injection pressure, temperature, perform architecture of fiber, resin viscosity, fiber mat permeability, and mold configuration [11]. The main advantages of RTM over the other processes are requirement of lower temperature and abstinence of thermomechanical degradation [83]. Natural fibers have lower compaction than glass fibers which made an effect on the NFC properties of low density in the RTM process [83]. RTM is suitable for large volume production which is also cost-effective compared to other manufacturing processes [11]. Higher injection temperature and pressure reduces the RTM manufacturing cycle time. Though excessive pressure may deform the mold shape and excessive temperature may cause premature resin formation.

In the RTM process, little clearance should be maintained between mold edges and fiber which adjust the fiber perform deformation. At the beginning stage of injection process, higher velocity difference exists which is reduced with respect to the time difference. The flow resistance is accountable for reducing this velocity difference [60]. Without increasing injection pressure, resin flow can be faster by using multiple injection gates. But, a large number of gates creates the process more complex and creates numerous bubbles in the meet point of flow fronts [85]. This void content area reduces the mechanical properties remarkably. To reduce the void in the product, the injection pot and mold need to remain vacuum before starting injection process.

Besides, higher flow resistance creates an obstacle in flow path and flow goes into lower resistance channel for injection pressure hence the effect is escalated. Therefore, the required time at edge flow of bottom is increased which creates adverse effect to format spillage and dry spots [86]. The average velocity field of resin flow may look smooth but the local velocity field can be varied point to point at microscopic scale. Local capillary pressure, permeability, non-uniform microstructures are the main reason for local velocity field roughness [87]. Mechanical properties of NFCs which are made by resin transfer molding process from previous literatures are listed in

Mechanical properties of NFCs which are made by resin transfer molding process from previous literatures are listed in Table 4.

## 2.4 Hand Lay-up

Hand lay-up is older open mold manufacturing technic of natural fiber reinforcement composites compared to others [93]. Long and continuous natural, glass or carbon fiber composite materials can be prepared easily by this process for wide range size of products [27]. Hand lay-up has wide variation to orient fiber in different directions such as unidirectional, inclined or woven. Hybrid composites are made step by step in this process that types of composite gains strong attention in composites industry because of its less directional dependency and resistance to multiple types of stress [94].



In this process, antiadhesive agent is treated at mold surface to prevent polymer sticking and to release it easily [95]. In bottom and top section of the mold plate, a plastic sheet is placed to get smooth surface [96]. Then gel coat of matrix material is applied to the lower mold surface and the fiber which is in various orientation and chemically treated, is kept immediately

on coat as shown in Fig. 4. Then, little amount of pressure is created by roller to removed trapped air bubbles from it. Fiber, matrix or both need to mix with ingredients which ensure stronger interfacial bond on this different material [97]. After fully cured of base material the hardened product is removed from mold cavity [78].

Table 3 Mechanical Properties of NFC prepared by Resin transfer molding process

Matrices	Fiber	Fiber percentage (% mass)	Tensile strength (MPa)	Flexural strength (MPa)	Young's modulus (GPa)	Flexural modulus (GPa)	Reference
UP	Flax	39	61	91	6	5	[88]
UP	Jute	35	50	103	8	7	[88]
Bio-epoxy	Cellulose	-	92	727	9	27	[89]
VE	Flax yarn	35	111	128	10	10	[89]
VE	Flax yarn	24	248	-	24	-	[90]
UP	Flax yarn	34	143	198	14	17	[90]
Epoxy	Flax	37	132	-	15	-	[91]
Epoxy	Flax	46	280	-	35	-	[92]
Epoxy	Flax	54	279	-	39	-	[92]
Epoxy	Sisal	48	211	-	20	-	[91]
Epoxy	Sisal	37	183	-	15	-	[91]

VE = Vinyl Ester

Table 4 Mechanical Properties of NFC prepared by Hand lay-up molding process

Matrices	Fiber	Fiber percentage (% mass)	Tensile strength (MPa)	Flexural strength (MPa)	Young's modulus (GPa)	Flexural modulus (GPa)	Reference
Epoxy	Jute	36	102	53	3.8	4	[98]
Polyester	Jute	20	36	64	-	-	[99]
Polyester	Jute	30	41	71	-	-	[99]
Polyester	Jute	40	46	82	-	-	[99]
UP	Jute	14	23	-	4	-	[100]
PLA	Bamboo	40	115	-	6	-	[101]
UP	Bamboo	15	22	-	4	-	[100]
UP	Kenaf	13	28	-	5	-	[100]
Epoxy	Banana	40	108	72	-	-	[102]
Epoxy	Banana	50	113	65	-	-	[102]
Epoxy	Banana	60	98	77	-	-	[102]
Epoxy	Banana	-	37	128	-	-	[103]
Epoxy	Coir	30	24	25	1	-	[104]
Epoxy	Coir	40	21	14	1	-	[104]
Epoxy	Coir	50	18	6	2	-	[104]
Polyester	Rattan	10	16	48	-	-	[105]
Polyester	Rattan	18	12	31	-	-	[105]
Epoxy	Rattan	13	13	131	-	-	[103]
Epoxy	Flax	31	160	190	15	15	[90]

## 2.5 Other Processes

Depends on shape of the products, different types of processes are used to produce NFCs. Pultrusion, Filament

winding, Autoclave molding, and Vacuum bag molding are the most popular among the numerous methods.

Pultrusion was developed at the middle of the twentieth century. The pulled fiber is impregnated by formulated resin in this process (see Fig. 5). Hollow cylindrical shape products are

mostly produced by pultrusion process. During the manufacturing process, the fiber experiencing high tension and thus results in higher production rate and great fiber orientation [106]. The long/continuous fibers are immersed in resin bath and goes through shaping die, here the curing of impregnated resin occurred [107]. Traditionally this process has higher consistency in quality, distribution, impregnation, and alignment of reinforcing fiber [108],[109]. Mechanical properties of NFCs which are made by pultrusion process from previous literatures are listed Table 5.

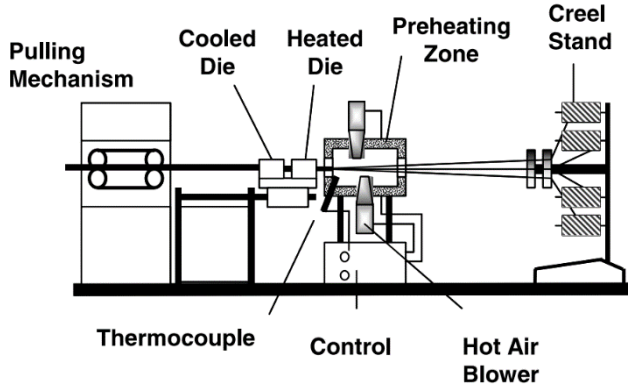


Fig. 5 Schematic setup of pultrusion process [110].

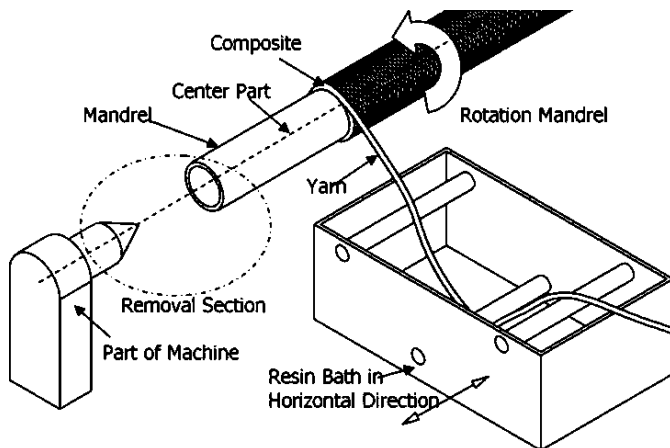


Fig. 6 Schematic setup of filament winding process [118].

Filament winding (see Fig. 6) is another open molded manufacturing process which is most preferable for rotationally symmetric products from continuous fiber composites. This process is mostly used for glass and carbon fiber. Recently various study conducted to prove the ability of natural fiber uses too [111]-[116]. Mechanical properties of NFCs which are made by filament winding process from previous literatures are listed in Table 5. A rotating mandril creates winding of fiber on it which may be simple or helical. Helical and cross filament winding provide better mechanical properties compared with simple one [117].

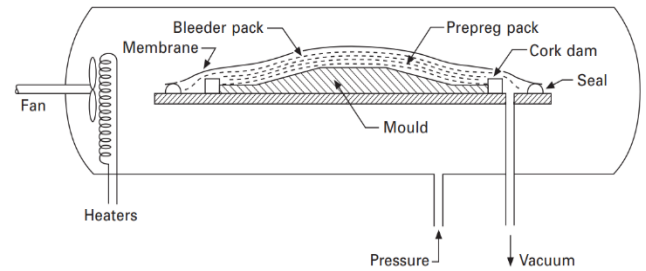


Fig. 7 Schematic setup of autoclave molding process [119].

Autoclave molding ensure higher accuracy and surface finish which is mostly used in aerospace industry from preregs. A smooth polyester ply covers the both sides of laminates which enhances the surface quality of products (see Fig. 7). A good sealing of whole assembly is provided by non-porous membrane where a porous film covers the top surface of laminate. To remove porosity and volatility of mold, vacuum pressure is crated inside membrane cover where temperature and pressure are controlled to provide exact cure and thermal equilibrium inside the mold. The process is cost intensive and slower compared to other process [119].

Mechanical properties of NFCs which are made by pultrusion, filament winding, and autoclave molding process from previous literatures are listed in Table 5.

Table 5 Mechanical Properties of NFC

Matrices	Fiber	Fiber percentage (% mass)	Tensile strength (MPa)	Flexural strength (MPa)	Young's modulus (GPa)	Flexural modulus (GPa)	Process	Reference
Polyurethane	Hemp	30	122	145	18	12	Pultrusion	[106]
Epoxy	Flax hackled	28	-	182	-	20	Pultrusion	[90]
PP	Flax yarn	30	89	-	7	-	Pultrusion	[110]
Epoxy	Flax	52	191	-	28	-	Filament winding	[112]
EpoBioX	Flax	48	152	-	2	-	Filament winding	[112]
PP	Flax yarn	72	321	-	29	-	Filament winding	[120]
Epoxy	Flax yarn	45	133	218	28	18	Autoclave	[121]

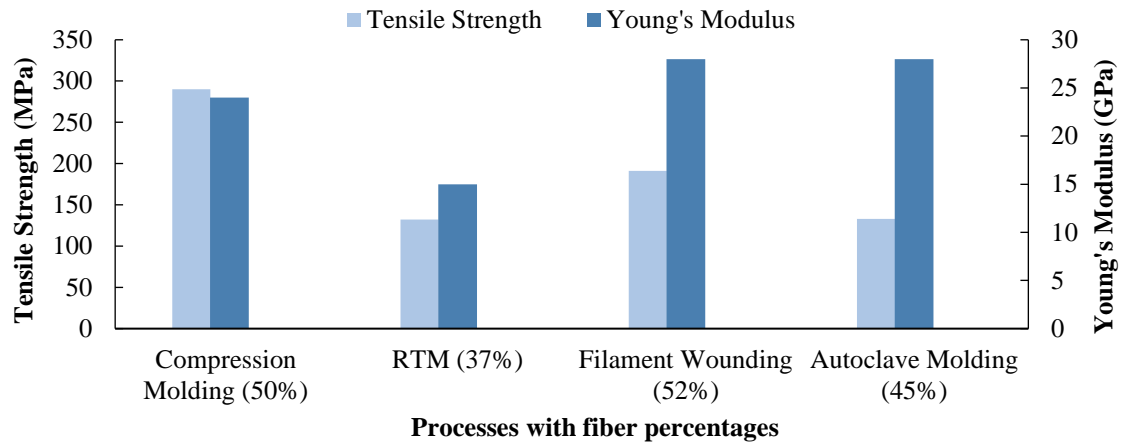


Fig. 8 Comparative Tensile strength and Young's Modulus of epoxy-flax composite from different processes.

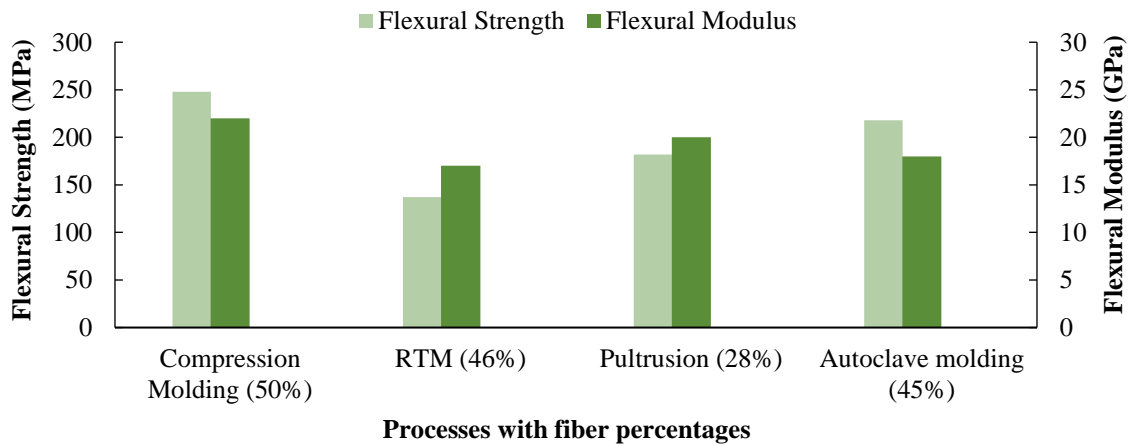


Fig. 9 Comparative Flexural strength and Flexural Modulus of Epoxy-Flax composite from different processes.

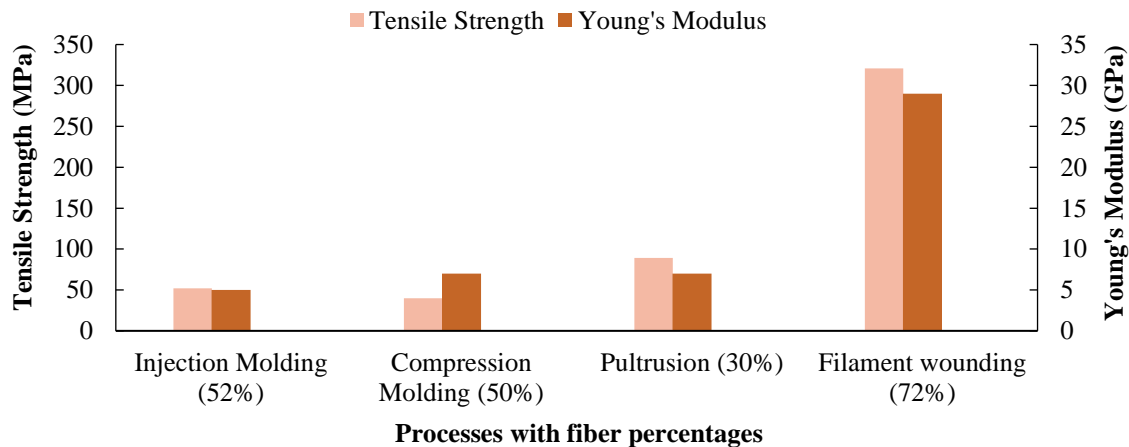


Fig. 10 Comparative Tensile strength and Young's Modulus of polypropylene-flax composite from different processes.

### 3 Comparisons of Mechanical Properties

Among all of the discussed natural fiber, flax fiber gives the highest mechanical properties. Consequently, the flax-based NFCs from various processes have more strength compared to others and utmost research has been done associated with it. In this article, adequate mechanical properties of flax-based NFCs with thermoplastics and thermosets binding have been upheld for comparison.

Epoxy as a thermoset has higher mechanical properties but the process associated with it is little complex than thermoplastics. The properties are shown in Fig. 8 and Fig. 9 of epoxy-flax composites with various fiber percentages which are

prepared from Compression Molding, Resin Transfer Molding, Filament Winding, and Autoclave Molding.

Short fiber composites behave like quasi-isotropic material additionally the mechanical properties in a random direction are slightly higher than long fiber composites. Contrastingly, long fiber composites have slightly lower mechanical properties with having strong directional dependency. As a result, compression molding short fiber composite has higher tensile strength than the other three processes. Pure epoxy has tensile strength of 82-115MPa [122] and flax fiber can show maximum 1500MPa tensile strength while the minimum is 88MPa [123]. The fiber percentage can play a tremendous effect where the higher

strength flax fibers are used. Approximately similar fiber percentages are used in compression molding, filament winding, and autoclave molding. Among all of them, compression molding gives the highest tensile strength which is 51% higher than filament winding. Contrastingly, Young's modulus remains near about similar at every process except Resin transfer molding because of its lower fiber percentage.

Besides, compression molding composite has comparative flexural strength with compared to others except pultrusion process. Though pultrusion process has lower fiber percentage, it shows comparatively higher flexural strength and flexural modulus. Approximately similar fiber percentages are used in compression molding, resin transfer molding and autoclave molding. Among all of them, compression molding gives higher flexural strength which is 13-36% higher than pultrusion and autoclave molding process.

Polypropylene as a thermoplastic has lower mechanical properties but the process associated with thermoplastics is little easier than thermosets. The properties are shown in Fig. 10 of polypropylene-flax composites with various fiber percentages which are prepared from Injection molding, Compression molding, Pultrusion, and Filament winding.

The results show similar properties except Filament winding because of the higher percentage of flax on it. The orientation of fiber in filament winding is closely packed and orientated rather than compression molding and injection molding. Pultrusion process deal with long fiber which creates directional dependency but gives more strength compared to similar percentages of fiber in compression and injection molding. Pure polypropylene has only tensile strength of 35MPa [124] and flax fiber can show maximum 1500MPa tensile strength while the minimum is 88MPa [123]. The fiber percentage can play a tremendous effect on mechanical properties because of the higher properties of flax fiber compared to polypropylene. With increasing 1.5 times of fiber percentages from pultrusion to filament winding tensile strength increased 2.6 times as well as the tensile modulus.

#### 4 Future work

Currently, natural fiber reinforced composites are suffering from lower mechanical strength, lower heat resistance, lower water, and moisture resistance. These properties are strongly dependent on adhesion between matrix and fiber. More the adhesion ensures more mechanical strength, more thermal resistance, more water, and moisture resistance. Suitable manufacturing processes, chemical, and physical treatments of fiber can enhance these properties of NFCs. The above mentioned conventional manufacturing process can give better properties when optimum process parameters and effective physical and chemical treatments of fibers are applied.

#### 5 Conclusion

The advancement of natural fiber reinforced composite has become attractive for eco-friendly production. Uses of NFCs have been growing firstly in outdoor and as well as load-bearing applications because of its lightweight and higher specific strength. The manufacturing process associated with it, is developing for suitable and cost-effectiveness. Though it is uncertain to say which process and chemical treatment of fiber are most suitable for a specific product. This article addresses recent developments and issues associated with different natural fiber reinforced composite conventional manufacturing processes. However, researchers are trying to develop economic

and effective manufacturing process like additive manufacturing for case dependent simultaneously trying to reduce the production time and to find the most suitable process parameters of individual case. This article addresses recent developments and issues associated with different natural fiber reinforced composite conventional manufacturing processes. Advance composite production is being enriched by injection and compression molding processes where complex geometrical shape can be manufactured with higher mechanical strength compared to others. Rely on this report, it can be remarked that, natural fibers are compatible for reinforcing various polymer for enhancing mechanical properties of it which can be used in wide range of sectors like automotive, housing, packaging, infrastructure etc.

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