

**FABRICATION AND TESTING OF COMPRESSION AND
INJECTION MOULDING NATURAL FIBER THERMOPLASTIC
COMPOSITE**

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Engineering degree in Mechanical engineering.

by

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work SHYAM SUNDAR REDDY NEMALI who carried out the project entitled **“FABRICATION AND TESTING OF COMPRESSION AND INJECTION MOULDING NATURAL FIBER THERMOPLASTIC COMPOSITE”** under my supervision from December 2020 to April 2021.

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I SHYAM SUNDAR REDDY NEMALI here by declare that the project Report entitled **“FABRICATION AND TESTING OF COMPRESSION AND INJECTION MOULDING NATURAL FIBER THERMOPLASTIC COMPOSITE”** done by us under the guidance of **Mr.R.SIVA,M.E.,(Ph.D)** is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Mechanical engineering

DATE: 2/03/2021

PLACE: Chennai



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ABSTRACT

Natural polymer-based composites offer critical benefits over-engineered fiber petroleum-based composites concerning biodegradability, plan adaptability, manageability, biocompatibility. This work reports the biodegradable composite using jute and polylactic acid through raw injection moulding, extrusion-injection moulding and compression moulding. The mechanical and analytical properties of biodegradable composites prepared with polylactic acid (PLA) and jute fiber are manufactured by using raw injection moulding, extrusion- injection moulding and compression moulding with the weight concentration of 25%of fiber and 75% of PLA, the parameters are same and the only variation among the injection moulding and extrusion is fiber and PLA is extruded in twin screw extruder before preparing mold. Compression moulding is done after compounding on two roller milling and their performance is evaluated. The pursuit of this work is to know if the bonding between the fiber and the matrix will improve the properties of the composite. Experiments revealed that after tensile testing and impact testing compression and extrusion-injection moulding have shown times better results than injection moulding respectively, whereas flexural testing compression and extrusion-injection moulding samples have shown effective results than injection moldings. Further mechanical, surface morphological, water absorption, and void test results are discussed.

Keywords: - Injection moulding; extrusion-injection moulding; Raw injection moulding; Scanning electron microscopy analysis; void test.

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LIST OF SYMBOLS AND ABBREVIATIONS

PLA	Polylactic Acid
MPa	Mega pascal
rpm	Rotations per minute
min	Minutes
cm	Centimeter
mm	Millimeter
CO ₂	Carbon dioxide
J/kg K	Joule per kilogram kelvin
wt%	Weight percentage
GPa	Giga pascal
W ₁	Initial weight of specimen
W ₀	Weight after wafer absorption
gm	Gram
ASTM	American Society for Testing and Materials
W _f	Weight fraction
ρ _f	Fiber density
ρ _m	Matrix density
KV	kilo volt
N/mm ²	Newton per millimeter square
KJ/mm ²	Kilo joule per millimetre square

J/m

Joule per meter

CHAPTER 1

INTRODUCTION

The practice of using a natural fiber composite as a substitution for synthetic fiber composites has been following from ages. But due to the difficulty in the process of manufacturing, limited knowledge of its machinability and proper parametric setting have been limiting the usage of natural fiber composites. However due to the rapid increase in the pollution that is being caused by the age of the synthetic or manmade plastic non- degradable composites. Now many countries have also decided to stop the usage of plastic. This led to the increase in usage of biodegradable elements in order to be eco-friendly, which in terns helps in development of nature and reduce adverse effects of pollution caused by the non-degradable elements.

The term natural fiber is used to state filaments or fibers that are being acquired from the creatures and plants. These stands have a wide scope of utilization in the process of producing natural fiber reinforced composite materials. The word natural fiber reinforced composite materials state that natural fiber composites are a composite material comprising of a polymer matrix embedded with high-strength natural fiber, like *jute*, kenaf, oil palm, sisal and flax commonly, polymers can be arranged into two classifications, thermoplastics and thermosets. Thermosets are the composite materials that can't be remoulded or can't be reused if once they are heated and made as a mould but where it comes to thermoplastic polymers, they can be remoulded by heating them at certain temperature. in our work *jute* fiber considered to work on because of the main fiber that is used in automotive, aero and military sectors. It also has a vast range of advantages like good insulating, acoustic insulating, manufacture with no skin irritations and Low thermal conductivity. In the classification of the fibers the *jute* fiber comes under cellulose/ lignocellulose. PLA (polylactic acid) has been taken as a matrix because of its 100% biodegradable property. In PLA there are different grades are available and PLA has been performed. Extraction off *jute* fiber is done by water retting process. once the extraction has completed in order to do injection moulding fiber has to be trimmed to a size of 0-0.7 cm for doing short fiber injection moulding. In order to get in that manner, chosen ball grinding which has only gave 40% of efficiency and then

decided to cut the fiber with scissors. Then the fiber has been heated in oven for 2 hours at 100% in order to remove the moisture content inside the fiber. injection moulding and extrusion injection moulding in Kanchipuram. Injection moulding is a strategy to get moulded items by infusing plastic materials melting by heat into a shape, and then cooling and let them solidify. The technique is appropriate for the large-scale manufacturing of items with convoluted shapes, and takes an enormous part while considering plastic handling. Few parameters that are followed during the process are the temperature at 3 cylinders and nozzle are 185⁰c and 180⁰C, 170⁰C and 160⁰C respectively. While coming to extrusion-injection moulding it is Extrusion is manufacturing process used to make pipes, hoses, drinking straws, drapery tracks, poles, and fiber. The granules are liquefy into a fluid by heating which is constrained through a long pipe and get mixed well the extrusion is done in twin crew extruder at the following parameters zone temperature is set to 170 – to 190⁰c nozzle temperature is set to 190⁰c main screw rpm is set to 300 and feeder and cutter rpm is set to 20 and 32. And then it is sent to the injection moulding with the same parameters that are followed in the case of injection moulding while coming to the last part of manufacturing it is compression moulding is done after 2 Roll milling. the conditions in which 2 roll milling is done are the temperature at which the 2 rolling milling was done around 150% to 170⁰C, the rpm difference in b/w the rpm of 2 rollers is 1: 1.15, and the gap in blur the rollers is 0.5mm the time span of rolling is done for 45min and then the mixture is set in the steel mould of dimensions 200×100×3 and the compression is done at the pressure of 40 MPa. After the manufacturing of plate is done the plate is cut into required shape as per the test that are perform.

The tests that have been performed in order to understand the mechanical properties, surface morphology analysis, water absorption and void gaps in the mould. the following tests are performed tensile, flexural, impact, surface electron microscopy test, water absorption test and void tests are being performed. The test are performed in the following are performed in this machine tensile stress is done in universal tensile strength machine. impact strength is done in Izod impact stress machine. And flexural machine is done in universal flexural machine. All are done at Hyderabad at kelvin labs. And scanning electron microscopy is done at sathyabama institute of science and technology and the machine specifications are Water

absorption test is performed by using the paper as a reference of papers. void test is done by doing the density test after finding theoretical and experimental values the volumes are calculated accordingly then the void tests are performed.

The void and water absorption test are performed in order to find the degradation of the fiber composites in water with different time periods and different types of liquids like distilled, normal and sea water and the more water absorbed the more quality of the reinforced composite is low. And void gaps are one of the most important drawbacks in manufacturing of the composite this may occur due to no proper adhesion between fiber and matrix so void gaps are even calculated.

CHAPTER 2

LITERATURE SURVEY

FAO, et.al (2020) in this paper they stated the characteristics and news regarding *jute* fiber. *Jute* fiber is also known as 'golden fiber' since it one of the most important and used fiber. It is a yearly yield, planted in Spring and gathered from June to September, which requires 120 days to develop. To grow a *jute* plant, a warm and sticky environment with a temperature between 24° C to 37° C is required. One hector of *jute* plant devours 15 tons of CO₂ and deliveries around 11 tons of oxygen to the environment Developing *jute* plant requests an exceptionally modest quantity of synthetics and water which prompts less natural harm. Utilizing *jute* fiber is useful in assembling composite materials. Since, it advances clean advances, cycles, items, and administrations that diminish the environmental risk. Characteristics that are it is 100% bio degradable, inexpensive, non-toxic and has proven to be effective and also good reinforcement for thermoplastic and thermoset. Major amount of *jute* fiber is grown in India.

M. Ramachandran, S. Bansal, and P. Raichurkar, et.al (2016) in this paper they stated about the properties and major constituents of *jute* fiber. They are: *jute* fiber has good thermal insulation property having a specific heat value of 1360j/(kg. K). and it is significantly good in properties when compared to glass fiber with this major constituents of *jute* fiber are α -cellulose, hemicellulose, and lignin with a chemical composition of 58-68%, 20-24%, and 12-15% respectively. It also consists of fats, wax, water-soluble matter that does not affect its structure in a little quantity. *Jute* fiber is hydrophilic by nature due to the presence of a polar group in its structure. Hence, the polar group forms hydrogen bonds by absorbing water molecules and this induces swelling in fibers.

H.B-Nunez, P.J. H-Franco, et.al (2019) they have performed test and given physicochemical properties of *jute* fiber

They are:

Properties	<i>Jute</i> Fiber
Diameter (μm)	40-60
Cellulose content (wt%)	59-71
Lignin content (wt%)	12-13
Hemicellulose content (wt%)	14-20
Pectin (wt%)	0.2-0.5
Waxes(wt%)	0.4-0.8
Humidity(wt%)	12.5-13.7
Microfibrillar angle ($^{\circ}$)	7-9
Density (g/cm^3)	1.3-1.45
Elongation at break (%)	7.0-8.0
Tensile strength (MPa)	399-773
Tensile modulus (GPa)	10-30

Which were used for performing void test in this study.

K. Immonen, et.al (2018) they have stated about the process of extrusion. extrusion process can be carried out by using single screw or twin-screw extruder which has a ability to use co- rotating or the counter rotating feature. These are the best to use for most of the short wood finer consisting thermoplastic composites. Generally, a single screw extruder is utilized, if the blending of the result doesn't influence the eventual outcome, while a twin-screw extruder is utilized assuming acceptable scattering is required in the eventual outcome. Notwithstanding, for lignocellulosic fiber, cleaving or pounding the strands to build the mass thickness and flowability helps the compounding of natural fiber with the matrix. Further, for dampness touchy PLA, it is desirable to overuse cold air cooling rather than the basic water bath strategy.

V. K. Thakur, et.al (2020). With the reference of this fiber In the planning of bio composites with plant strands, a significant factor is the homogeneous circulation of the fibers into the polymer matrix. It grants more prominent contact between the fiber and matrix which in turn improves the mechanical properties. Bio composites can be prepared as customary engineered composites. In any case, the handling temperature of bio composites relies upon the preparing temperature of the fiber and the polymer. In this manner, the choice of the preparing method is centred around getting the best properties of bio composite for the ideal application. No matter what method one uses for preparation of the composite for the best result the bonding in between the matrix and fiber has to be good.

Y. Arao, T. Fujiura, S. Itani, T. Tanaka, et.al (2014) they have stated the process followed in manufacturing method, its high processability and many other advantages of the injection moulding and due to the injection moulding the fibers are degraded. And it has mainly two units: injection unit and clamping unit. In injection unit the thermoplastic material gets melted and mixed up with the fiber. Then the molten material will be sent to clamping unit. Whereas, in the clamping unit, melted materials enter into a mould through a gate and runners using pressure. Then after opening the mould the mould is taken out by using the ejector pins. Injection moulding is better than extrusion because of having a direct contact between fibers and polymer closer. And also, the mixture of the fiber and the matrix in a twin-screw extruder or single screw extruder that has a capacity to co-rotate or counter rotate the screws will degrade a lot more than of injection moulding. the temperatures at which this process of injection moulding is done has been discussed. And as said removing of mould using ejector pin in order to cool down the specimen has been also discussed.

S. Chaitanya, and I. Singh, et al (2017) Thesis states about the manufacturing of composite material in compression moulding. It is an interaction of applying tension on a polymeric material put on the lower side of a form and pushed the upper part descending until it fits totally with its counterpart. compression moulding is a generally utilized handling technique for manufacturing plant fiber-reinforced polymer bio composites. however, this technique is utilized to create medium to enormous size items which have a level or straightforward shape. w the procedure tat is carried out while the compression moulding is done, in compression moulding the pre heated moulding material is placed in an open heated cavity and the mould is closed by a hydraulic press. And pressure is applied in order to allow materials to keep contact with all the mould. And thermoplastics, the temperature should be greater than Tg during the process.

Abu Sadat Muhammad Sayem, Julfikar Haider, Bilal Naveed, M. M. Alamgir Sayeed & Sravanthi Sashikumar, et.al (2020). This article states about the performing of the water absorption test. In this paper they have made water absorption test using three different kind of water and three different kind of time period. They are: sea water, distilled water, sea water, at the time interval of 1,3 and 5 days. The water absorption is calculated by the weight difference between the dry and wet samples The percentage water gain by the specimens was measured at different time intervals using an equation

$$W(\%) = ((w_1 - w_0)/w_0) * 100.$$

where, W% is the percentage of water absorbed, W_2 is the weight of composite specimen (gm), after immersing in water, W_1 is the weight of dry composite (gm) before immersing in water

G. Arun Kumar, A.M. Ramesh Abu et.al (2020). With the reference of this journal the basic information about mechanical properties of a fibre and basic procedure of a mechanical properties. Here they were discussed about Tensile strength, Flexural strength and Impact strength. From these the tensile test sample is taken from a fabricated composite as per the American society for testing and material (ASTM) standard dimension and tensile strength of laminate was measured by ASTM with the help of Universal Testing Machine (UTM) with load capacity of 400KN for load rate of 5mm/min. The flexural test is carried out by three-point bend testing as specified in ASTM using Universal Testing Machine at a room temperature. In this Study the impact strength is carried out by using Geotech Testing Machine and notch is kept at an angle of 90^0 and tested at a ambient condition according to ASTM and average load is noted and also the strength and resistance is noted.

M. Jawaid, H.P.S. Abdul Khalil, A. Abu Bakar, P. Noorunnisa Khanam, et.al(2010) In this thesis how the void test is being conducted, it is determined by using the theoretical and experimental density of the composites using a equation

$$\text{Void content} = (\rho_{\text{theoretical}} - \rho_{\text{experimental}}) / \rho_{\text{theoretical}}$$

And for finding the theoretical density of the sample the formula used is

$$\rho_{\text{theoretical}} = 1 / [(W_f / \rho_f) + (W_m / \rho_m)]$$

Where W_f is the fibre weight fraction, W_m the matrix weight fraction, ρ_f the fibre density, and ρ_m is the matrix density.

Due to the presence of the void content there will be a significant reduction in the composites mechanical properties is also discussed.

CHAPTER 3

AIM AND SCOPE OF THE PROJECT

3.1 Aim

Aim and scope of the project is explained below. The intention of the project is to compare between raw injection moulded, extrusion-injection moulding and compression moulding.

- To prepare natural reinforced composite material by raw injection moulding, extrusion-injection moulding and compression moulding with *jute* and polylactic acid (PLA) with weight concentration of 25% of fiber and 75% of PLA
- To perform tensile, flexural, impact strength tests are to be performed
- The mechanical properties of the composites are compared
- To perform scanning electron microscopy test (SEM)
- To compare all three SEM analysis
- To perform and study about the water absorption of the composites in each mode
- To perform and study about the void test of the composites in each mode

3.2 SCOPE OF THE PROJECT

The primary scope of this work is to find in which method of production will there be a good bonding in b/w the 3 different manufacturing process by performing the tests and compare all the other properties and mentioning the advantages of each and every method of composite manufacturing method used in the work. The secondary scope of the work done is to promote the natural fiber reinforced composites and help to retain the environmental condition of the earth back instead of using the synthetic fiber and push it to too bad situations

CHAPTER 4

MATERIALS AND METHODS

4.1 MATERIALS REQUIRED

Jute fiber, polylactic acid pellets (2003-d)

4.2 METHODOLOGY

The methodology of the process is divided into five parts

- The extraction of the fiber
- Preparing of fiber and matrix for composite preparation
- Composite preparation
- Testing

4.2.1 THE FIBER

Jute fiber is one of the most used natural fiber in industrial sector because of its advantages like good insulating, acoustic insulating, manufacture with no skin irritations and Low thermal conductivity. Since there is need of huge amount of fiber.it has been purchased from nature tech limited Chennai. Which has been extracted through water retting process which is one of the most used fiber extraction method that is being followed from eras and while coming to the extraction process the plant stems that are neat and good are being collected cleaned and then placed in water for 15 to 20 days. After such a long time the fiber layers on the stem will become weak and then the fiber is being extracted and dried under sunlight until the fiber losses its moisture and is packed in a air sealing cover which will help not to degrade the quality of fiber.



Fig:4.1 : Jute fiber that has been purchased

4.2.2 PREPARING OF FIBER AND MATRIX FOR COMPOSITE PREPARATION

Selected short fiber injection moulding the fiber has to be in the size of 0 to 0.70 cm in order to get better results in the composite preparation process firstly tried ball milling in order to make the fiber into powder al pieces that are under the size mentioned above but it has given only Go to 60% of efficiency. it time-consuming and also costly



Fig:4.2 : Ball milling

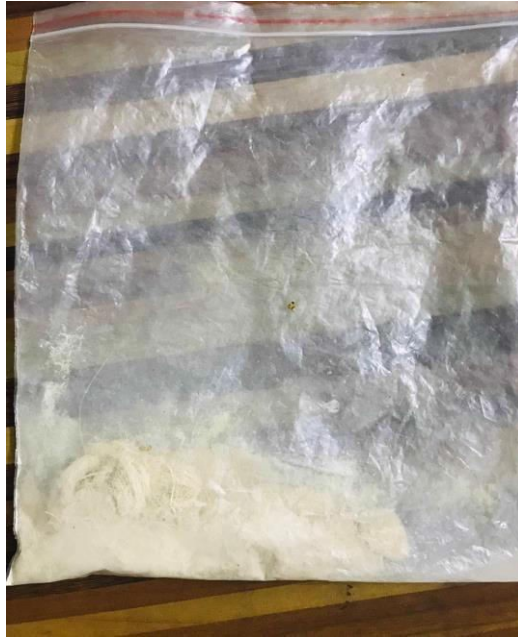


Fig:4.3 : Ball milling result

so Alternatively, chosen to cut the fiber using scissors in the length of 0 to 0.70cm and then the whole fiber is kept in the Oven at 100°C for 2 hours in order to lose the moisture from the fiber.



Fig:4.4 : The fiber that has been cut by scissors



Fig:4.5 : Owen treatment at 100⁰C

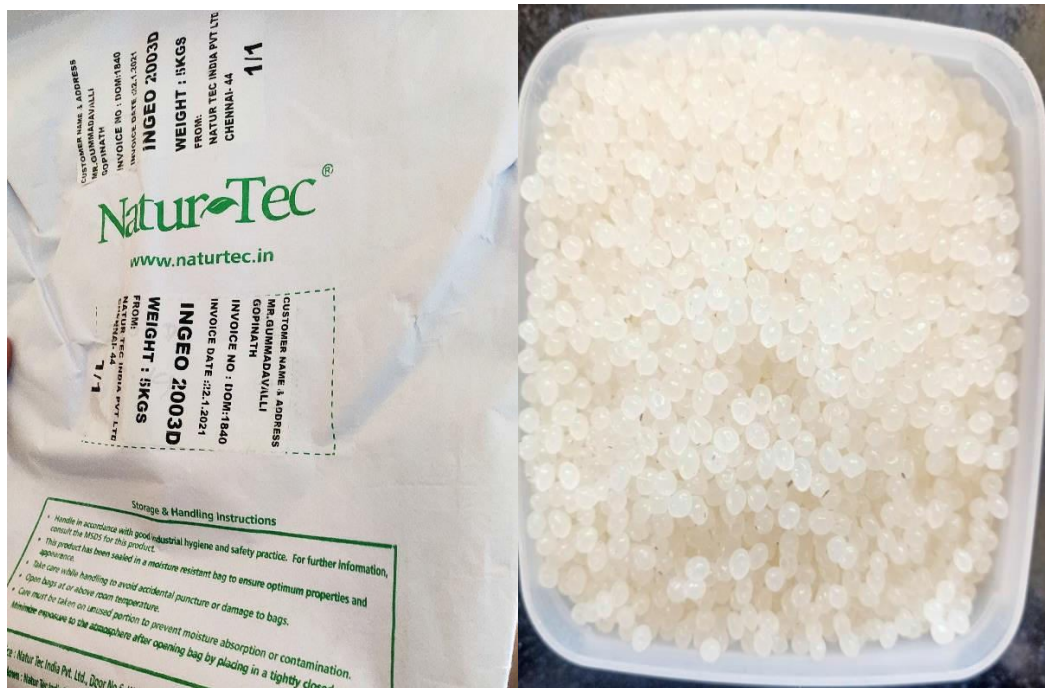


Fig:4.6 : PLA that has been purchased at nature tech

PLA (polylactic acid) of grade 2003 D grade is purchased from nature tec limited Chennai

4.2.3 COMPOSITE PREPARATION

This process will be further divided since this study has 3 different manufacturing procedure

- Injection moulding
- Extrusion injection moulding
- Compression moulding

4.2.3.1 INJECTION MOULDING

injection moulding it is process in which plastic materials or any kind of materials will be melted down with high temperature and the mixture is made into a mould. in over case the fiber and PLA are being in the place of plastic the whole work inside the injection moulding is done in temperature above 150°C and the machine in injection moulding is performed in a injection moulding machine that belongs to The Japan steel works limited the properties of machine are being mentioned below in image (4.6 & 4.7). and the parameters that are followed all through the process are given in Table 4.1 & 4.2.



Fig:4.7 : injection moulding machine

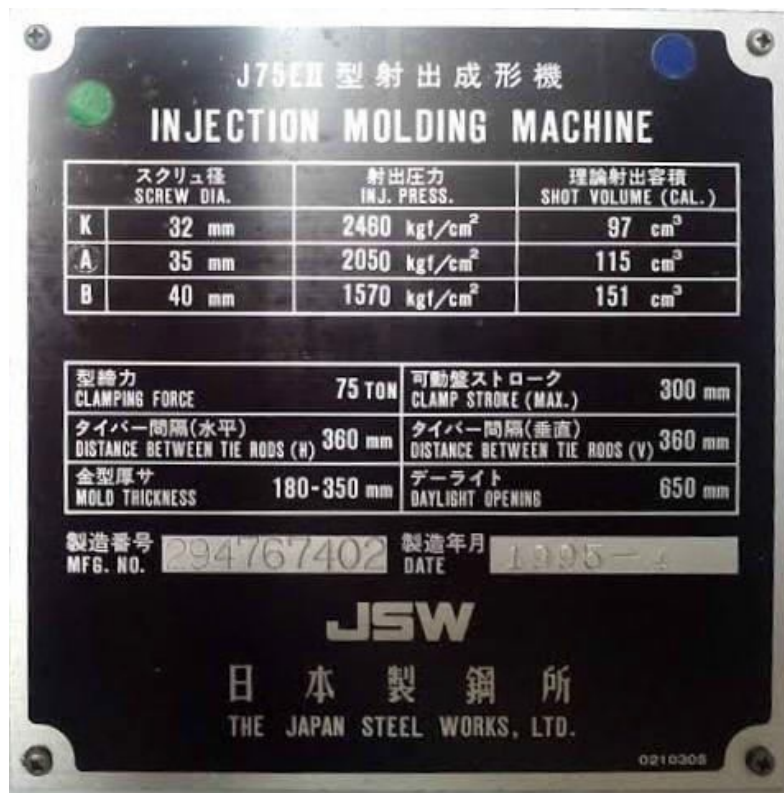


Fig.4.8 : specifications of the machine

Table 4.1 : Given parameters for the production

Settings	NOZZLE	CYL 1	CYL2	CYL3
Set temp.	185.0	180	170	160
Pos tol.	50.0	50.0	50.0	50.0
Neg tol.	50.0	50.0	50.0	50.0
Lowering	50.0	50.0	50.0	50.0
Enable	yes	yes	yes	yes

Table 4.2 : Actual values

Act. Temp.	185.2	180.1	169.4	159.7
Heat out	18.7	9.4	14.9	20.9
Cool out	0.0	0.0	0.0	0.0



Fig:4.9 : Injecting the extruded mixture to molds

The composites that are required are being manufactured as per the requirement the moulds that have been prepared are shown in Figure 4.10, 4.11 & 4.12



Fig:4.10 : Tensile samples by injection moulding



Fig:4.11 : Flexural samples by injection moulding



Fig:4.12 : Impact samples by injection moulding

4.2.3.2 EXTRUSION-INJECTION MOULDING

in this method firstly fiber and PLA are being extruded, in the process of extrusion the fiber and PLA are grinded along with heating so that the fiber and PLA are gently mixed so that the bonding of the fiber and the PLA can be increased. In over case the extrusion of the fiber and PLA is done by Twin screw extruder Figure 4.12, then the mixture or compound that has been produced.



Fig:4.13 : Twin-screw extruder

Once the extrusion of fiber and PLA is done, it will be once again the send to the injection moulding Figure 4.14. in order to prepare moulding



Fig:4.14 : injection moulding machine

The parameters that are performed during the process extrusion are in Table 4.3

Table 4.3 : parameters of twin screw extruder

Zone temperature	170-190 °C
Nozzle temperature	190 °C
Main screw speed	300 rpm
Feeder speed	20 rpm
Cutter speed	32 rpm

The parameters that are performed during the process injection moulding are in Table 4.4

Table 4.4 : Given parameters for the production

Settings	NOZZLE	CYL 1	CYL2	CYL3
Set temp.	185.0	180	170	160
Pos tol.	50.0	50.0	50.0	50.0
Neg tol.	50.0	50.0	50.0	50.0
Lowering	50.0	50.0	50.0	50.0
Enable	Yes	Yes	Yes	Yes

Table 4.5 : Actual values

Act. Temp.	185.7	179.1	169.7	159.4
Heat out	18.7	9.4	14.9	20.9
Cool out	0.0	0.0	0.0	0.0

The moulds that have been prepared by using extrusion injection moulding done according to the requirement for the testing and are shown in Figure 4.14& 4.15



Fig:4.15 : Tensile samples by extrusion-injection moulding



Fig:4.16 : Flexural and impact samples made of extrusion-injection moulding

Extra samples are also created using the above methods in order to perform other tests like void and water absorption test

4.2.3.3 COMPRESSION MOULDING

Compression moulding is done by compression machine and a mould, in order to prepare a natural fiber reinforced. composite using compression moulding, firstly the fiber and matrix that is being used has to be extruded or grided using any kind of grinding process so here two roll milling (Figure 4.16 & 4.17) has been performed using two roll milling in order to grind the fiber and PLA mixture. the parameters that are followed in order to grinding the fiber is in Table 4.6 .



Fig:4.17 : Grinding PLA with 2 roll milling



Fig:4.18 : Fiber grinding along with PLA

Table 4.6 : parameters used for extrusion

Temperature	155 -160 ⁰ C
Gap in between the rollers	0.5cm
Speed ratio b/w rollers	1:1.5
Time period	45 min



Fig:4.19 : Plate that has been made through compression moulding

After the completion of making mould the plate has been cut into the shapes as per the requirement for the testing process



Fig:4.20 : Tensile samples by compression moulding



Fig:4.21 : Flexural samples by compression moulding



Fig:4.22 : impact test samples by compression moulding

After the completion of the manufacturing composites 3 different methods mentioned above and the moulds are sent to testing.

4.2.4 TESTING

In order to perform the analysis on mechanical, surface morphology analysis, water absorption and void test are performed for composites that are prepared with three different methods. Tests that are performed are

- Tensile strength
- Flexural test
- Impact strength
- SEM test (scanning electron microscopy)
- Water absorption test
- Void test

The machines and mechanism that are done while testing the fiber are explained below

4.2.4.1 TENSILE TESTING

Tensile test is also called as tension test, it is a fundamental materials science and engineering test in which a sample is subjected to controlled tension until failure. Properties that can be estimated by means of a tractable test are extreme elasticity, decrease in zone. Uniaxial tensile testing is most commonly used for obtaining the mechanical properties of isotropic materials the test is carried out as per the American society for testing and material standard D-3039 the testing process. The test is performed on universal testing machine with load capacity of 400KN & federate of 5mm/min. time elapsed for performing tensile test on each sample.



Fig:4.23 : Universal tensile testing machine

4.2.4.2 FLEXURAL TESTING

Flexural testing examines the force required to break a beam of plastic material and it determines the resistance of the specimen to flexing or stiffness of the material. Flex modulus is inductive of how much the material can expand or flex before the deforming permanently.

The flexural strength is calculated from below equation $f = 3pl/2bd^2$

Flexural modulus is calculated from slope of the stress vs strain in deflection curve. the equation is $f = L^3m/4bd^3$

The flexural strength is carried out at a room temperature through three-point bend testing as specified in ASTM D-790

Machine that has been used to perform flexural test Instron model 5582 in Universal Testing Machine. The speed of the cross head is 2mm/min

The properties of the specimen that can be obtained through this test are yield force, yield deflection, max force, max deflection, Flexural strength@ yield and, Flexural strength@ max, Flexural strain.

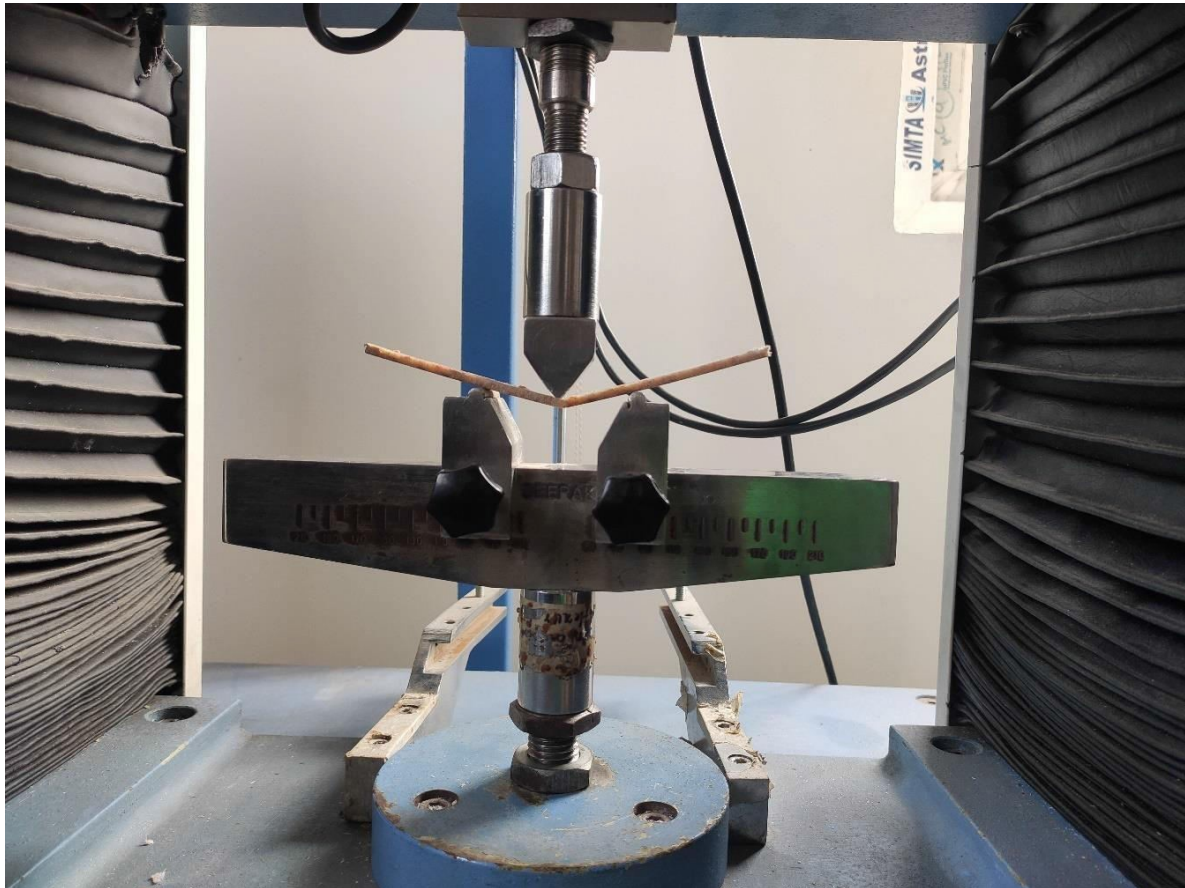


Fig:4.24 : Flexural testing machine

4.2.4.3 IMPACT TESTING

Impact strength is the capability of a material to resist a instantly applied load and its expressed in terms of energy. It also measured in Izod impact strength and Charpy impact strength. It determines the amount of energy was absorbed by a material during fracture. The absorbed energy is a measure of materials toughness and brittleness and ductile transition. The temperature is lowered over a series of tests to indicate the brittle temperature of a material. Before starting the Izod impact test the sample is notched at a Geotech testing machine Model-7045 MD after making a notch at an angle of 90 degrees and carried out the test on Izod impact tester. The impact strength is calculated from Impact strength and impact resistance of a sample



Fig:4.25 : Impact testing machine

The properties of specimen that were obtained by this test are impact strength and impact resistance by a sudden load acting on it.

4.2.4.4 SEM TEST

This test is used to perform analysis of the bonding in between the fiber and the matrix to a range of 500 to 1 micrometres so that one can get a clear view and idea about the sample braking during tensile stress and it is performed in HITACHI Model S3000H with 3 KV potential was to inspect the samples with a working distance of 5 mm machine at Sathyabama institute of science and in this method images will be captured by emitting the electrons over the surface of the braking point so that they can make a study about the braking in a micro level and investigate what are the reasons caused for the baking. They study of bonding in between the material is also studied easily.



Fig:4.26 : SEM testing machine

4.2.4.5 WATER ABSORPTION TEST

Water absorption test is performed in order to know the rate of water absorption in composite. After treating the composite of size 1 *1 cm for 10 min at 100⁰C. with different time period and different kind of water. Water absorption test is performed by using distilled water, sea water and mineral water at three different time period of 1 day, 3 day and 6 day and then the weight is being compared for every sample and water absorption of the fiber is calculated by using the formula,

$$(\%) = \frac{1 - 0}{0} \times 100. \text{ ----(1)}$$



Fig:4.27 : 1*1 cm samples for water absorption test



Fig:4.28 : Samples that are being tested for water absorption

4.2.4.6 VOID TEST

Void test is used to perform in order to find if there are any void gaps or the porosity of the composite is obtained by the volumetric comparison of the composite by using theoretical and actual volume of the composite by performing the density test of the fiber used then the both volume values are calculated and compared by using this formula.

$$= \frac{h}{h} \text{ ----(2)}$$

$$\frac{h}{h} = \frac{1}{[(\rightarrow) + (\text{---})]} \text{-----}(3)$$

The most widely recognized reason for voids is the inadequacy of the matrix to displace all the air which is entrained inside the woven or chopped filaments as it passes through the network impregnation.

CHAPTER 5

RESULTS AND DISCUSSION

In this part the discussion of analysis and the results of the tests that have been done through tables, bar graph, images and more.

The test results and analysis that are being discussed below are

- Tensile strength
- Flexural test
- Impact test
- SEM test
- Water absorption
- Void test

5.1 TENSILE STRENGTH

Tensile test has been performed on 3 samples for each manufacturing process and the results are discussed below.

This tensile strength test is performed at kelvin labs, hyderabad, telangana. By using universal testing machine. The dimensions of the samples are 125×14×3mm as shown in the Figure 5.1.



Fig:5.1 : injection moulded sample after tensile test

These are the samples after testing tensile strength Figure 5.1. The composite weight composition is 25% of *jute* fiber and 75% of PLA 125*14*3 mm Made by using injection moulding.

Table 5.1 : Results obtained from tensile strength of injection moulding

Sample no.	Tensile strength in N/mm ²	Modulus of elasticity in N/mm ²	Elongation	Max Elongation In mm
1	27.83	3407.80	1.04%	0.52
2	53.73	3909.45	1.91%	0.95
3	58.34	4389.09	1.90%	0.95



Fig:5.2 : Extrusion-injection moulded sample after tensile test.

These are the samples after testing tensile strength Figure 5.2. The composite weight composition is 25% of *jute* fiber and 75% of PLA 125*14*3 mm made by using extrusion-injection moulding.

Table 5.2 : Results obtained by performing tensile test on extrusion- injection moulding

Sample no.	Tensile strength in N/mm ²	Modulus of elasticity in N/mm ²	Elongation	Max Elongation In mm
1	66.91	3254.16	2.54%	1.27
2	52.69	3398.32	1.78%	0.89
3	43.33	3070.05	1.90%	0.95



Fig:5.3 : Compression moulded sample after tensile test.

These are the samples after testing tensile strength Figure 5.3. The composite weight composition is 25% of *jute* fiber and 75% of PLA 125*14*3 mm Made by using compressionmoulding.

Table 5.3 : Results obtained by performing tensile test on compression moulding

Sample no.	Tensile strength in N/mm ²	Modulus of elasticity in N/mm ²	Elongation	Max Elongation In mm
1	67.01	1690.39	4.47%	1.90
2	62.54	3041.81	7.82%	3.91
3	61.83	2811.94	2.54%	1.27

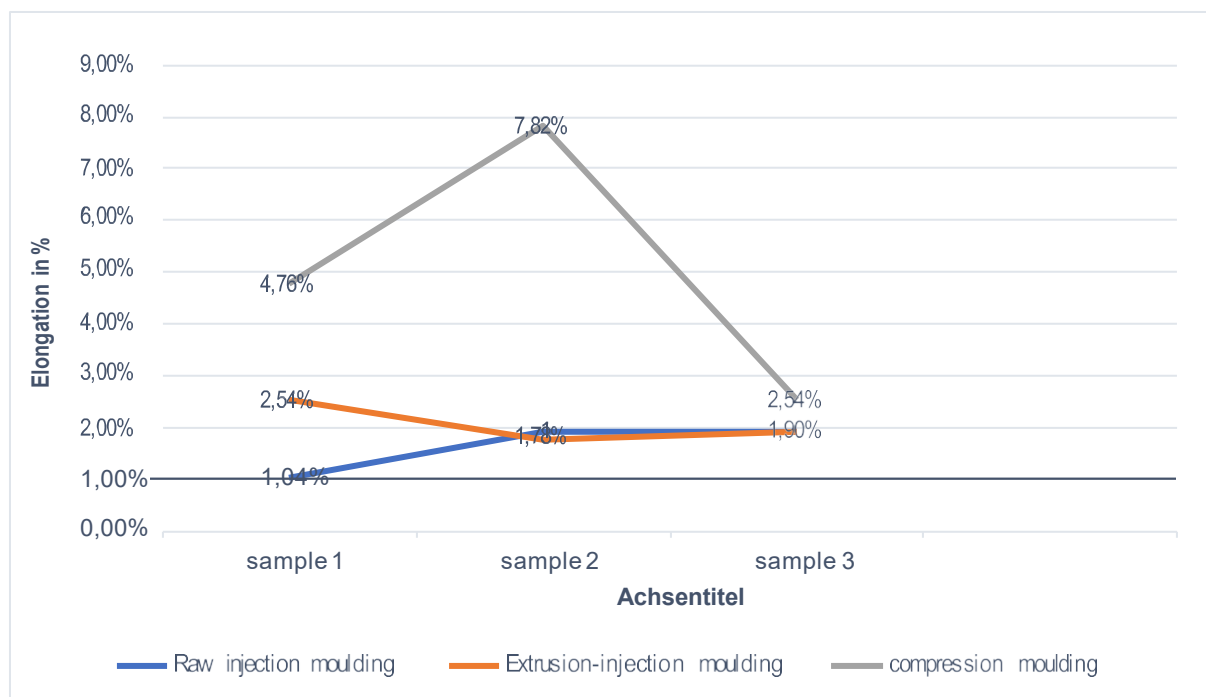


Fig:5.4 : comparison of all specimen elongation due to tensile strength test

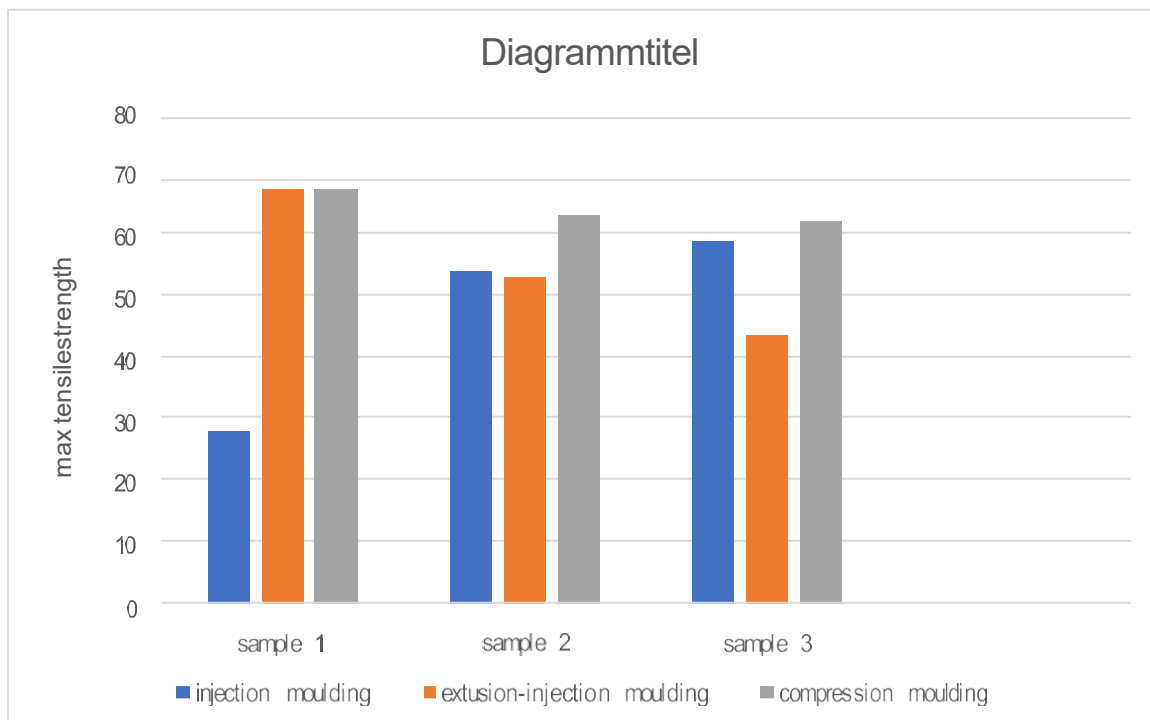


Fig:5.5 : comparison of max tensile strength of all samples

From Figure 5.5, the comparison states that compression moulding specimens got higher values when compared to other two methods i.e., compression moulding and Extrusion-Injection moulding samples have shown 136% & 116% more efficient than injection moulding samples. The main reason behind compression moulding getting higher value of tensile strength is because of its manufacturing advantage there is very low chance of getting a void gap or any air trapping inside a composite while doing in this method. [6] while coming to injection moulding and extrusion-injection moulding the rate of void gaps is more because of its manufacturing method, not only this but also since weight concentration of 25% fibre and 75% PLA has been used. Because of it the interaction between fibre and Fiber has been increased than PLA and fibre and during the manufacturing of injection moulding and extrusion injection moulding the temperatures at which the composite created is higher than compression moulding which in turn degrades the fibre quality this may even be a reason for less tensile value when compare to compression moulding.

5.2 FLEXURAL STRENGTH

Flexural strength is also been tested 3 samples for each manufacturing methods and the results have been discussed below.

This flexural strength test is performed at KELVN Labs, Hyderabad, Telangana. By using universal testing machine. The dimensions of the samples are 150×135×3mm.



Fig:5.6 : Injection moulded sample after flexural test.

These are the samples after testing Flexural strength (Figure 5.6). The composite weight composition is 25% of *jute* fiber and 75% of PLA 150×135×3mm made by using injection moulding.

Table 5.4 : Results obtained by flexural strength made of injection moulding

Sample no	Flexural strength @Max	Flexural modulus of elasticity	Max Deflection
1	66.91	1571.30	4.5
2	59.38	1394.20	4.3

3	53.69	1260.84	3.8
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Fig:5.7 : Extrusion-Injection moulded sample after flexural test

These are the samples after testing Flexural strength Figure 5.7. The composite weight composition is 25% of *jute* fiber and 75% of PLA 150×135×3mm made by using extrusion-injection moulding.

Table 5.5 : Results obtained by flexural strength made of Extrusion-injection moulding

Sample no	Flexural strength @Max in N/mm ²	Flexural modulus of elasticity in N/mm ²	Max Deflection in mm
1	56.20	1171.02	3.7
2	59.35	1163.87	4.6
3	64.08	1453.11	4.3



Fig:5.8 : Compression moulded sample after flexural test

These are the samples after testing Flexural strength Figure 5.8. The composite weight composition is 25% of *jute* fiber and 75% of PLA 150×135×3mm Made by using compression moulding.

Table 5.6 : Results obtained by flexural strength made of compression moulding

Sample no	Flexural strength @Max in N/mm ²	Flexural modulus of elasticity in N/mm ²	Max Deflection in mm
1	54.62	596.45	3.8
2	59.19	832.96	4.3
3	39.85	808.35	4.3

From all the above results are being obtained.in Table 5.6 as result states that only one sample has shown a lesser value than 40. This may be because of the deformation of the composite during the cutting process of the specimen from the plate that has been manufactured by using compression moulding.

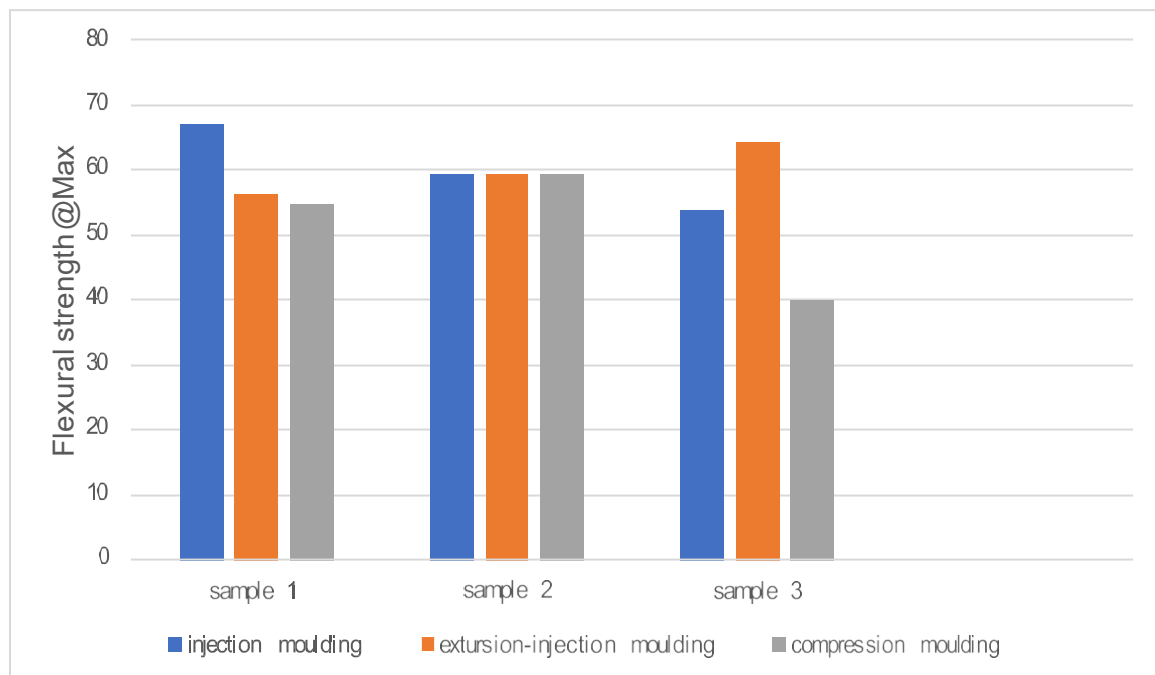


Fig:5.9 : Comparison of max flexural strength all the samples after testing

Injection moulding as got higher results when compared to the compression and extrusion moulding, there is only a slight change in between samples.

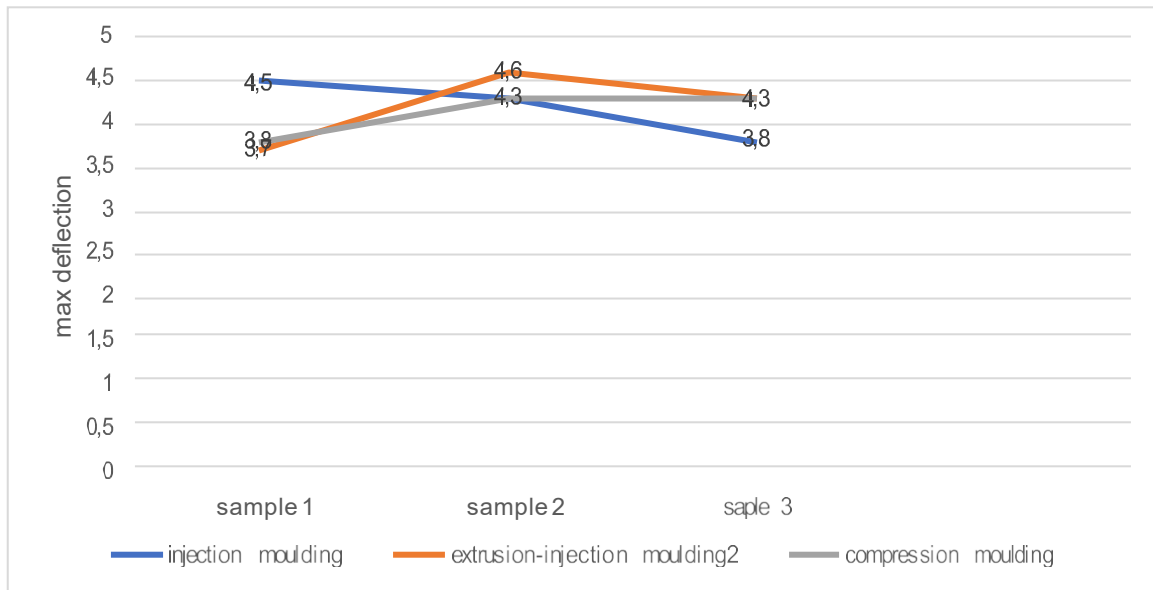


Fig:5.10 : Comparison of max elongation all the samples during testing

The elongation of the specimens is also quite same. There is same kind of performance in flexural test by every sample made of each different method.

The strength and solidness of the flexural test example rely upon the indeed, even circulation of the jute fiber and the PLA matrix. Besides, due to the addition of jute fiber, the increment in flexural properties was ascribed to the expanded bond between the constituents inside the composites

5.3 IMPACT STRENGTH

Impact test is also made for three samples for each manufacturing process and the results are discussed below. This impact strength test is performed at KELVN Labs, Hyderabad, Telangana. By using Izod impact machine.



Fig:5.11 : injection moulded samples after Impact testing

This samples have been tested impact strength made of *jute* reinforced poly lactic acid composite, made of weight concentration of 25% of fiber and 75% of PLA by injection moulding.

Table 5.7 : Impact results obtained by injection moulded samples

Samples	WIDTH (mm)	THICKNESS (mm)	W/d×1000 (J/m)	IMPACT STRENGTH (KJ/mm ²)
Sample 1	12.76	3.23	0.704	17.081
Sample 2	12.67	3.15	0.704	17.639
Sample 3	12.88	3.36	0.876	23.962

From Table 5.7 sample 3 has shown a higher impact strength when compared to remaining samples.

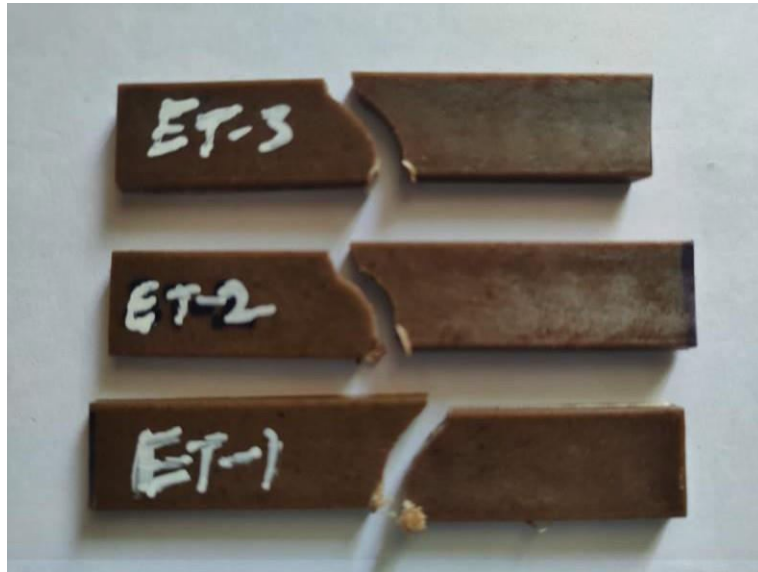


Fig:5.12 : Extrusion-injection moulded samples after Impact testing

This samples have been tested impact strength made of *jute* reinforced poly lactic acid composite, made of weight concentration of 25% of fiber and 75% of PLA by extrusion-injection moulding & the results obtained by performing impact test on the above-mentioned samples in Figure 5.12 are in below Table 5.8.

Table 5.8 : Impact results obtained by Extrusion-injection moulded samples

Samples	WIDTH (mm)	THICKNESS (mm)	W/d×1000 (J/m)	IMPACT STRENGTH (KJ/mm ²)
Sample 1	10.45	3.47	0.704	19.470
Sample 2	10.4	3.50	0.704	19.340
Sample 3	10.2	3.62	0.760	20.582

From the Table 5.8 sample 3 has shown better results when compared to other 2 samples.



Fig:5.13 : Compression moulded samples after Impact testing

This samples have been tested impact strength made of *jute* reinforced poly lactic acid composite, made of weight concentration of 25% of fiber and 75% of PLA by compression moulding & the results obtained by performing impact test on the above-mentioned samples in Figure 5.13 are in below Table 5.9.

Table 5.9 : Impact results obtained by compression moulding samples

Samples	WIDTH (mm)	THICKNESS (mm)	W/d×1000 (J/m)	IMPACT STRENGTH (KJ/mm ²)
Sample 1	10.44	3.9	0.818	22.450
Sample 2	11.68	3.52	0.876	21.306
Sample 3	9.39	3.50	0.818	24.889

From the Figure 5.9 sample 3 has shown better results when compared to other 2 samples. from all the above results,

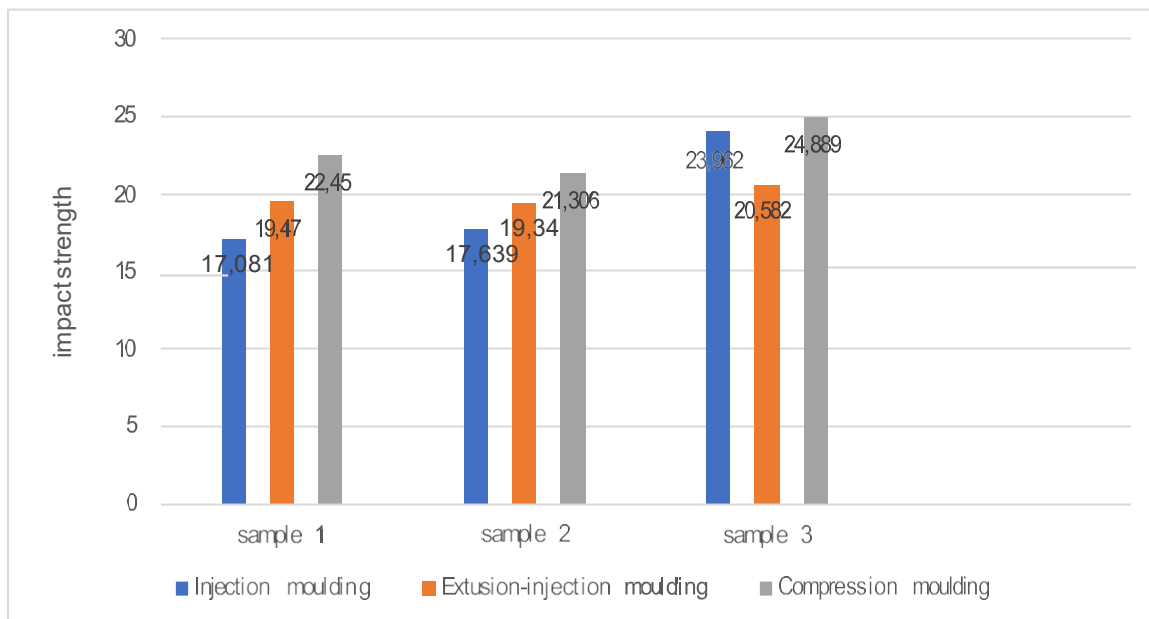


Fig:5.14 : Comparison of the impact strength after testing

From the Figure 5.14 can state that compression moulding & Extrusion-injection moulding has shown 1.16% and 1.1% improvement over the injection moulding samples the main reason behind this is void gaps in between the composites that made injection moulded samples to brake off easily.

Debonding, pull out and fiber fractures are the mechanisms of energy absorption during impact. Among these, fiber pull out requires higher energy than that of the fracture of fibers and debonding. High impact strength of injection and extrusion injection moulding composites may be attributed to more fiber pull outs due to weak interface between the fiber and the matrix. In the case of compression moulding composites, fiber fracture occurs instead of pull outs. Fiber fracture requires less energy compared to the energy re-quired for pull outs. This may be the reason for lower impact strength of injection and extrusion injection moulding composites compared to compression moulding composites

5.4 SEM TEST

This SEM test has been done in sathyabama institute of science and technology. It is a physical property test it is the scanning electron microscope which produces images of samples by scanning the surface with a focused beam of electrons on it. These electrons will interact with several atoms on the surface and produce signals which contains the information about the surface and composition.

SEM investigation is used for the characterization of wear debris created during mechanical wear testing. The high amplification, high-resolution imaging of our SEM investigation upholds the assurance of the number, size, and morphology of little particles, permitting customers to comprehend the wear properties of their material. In our case SEM test is performed on the samples that have gave the good result in the tensile test in all three manufacturing methods.

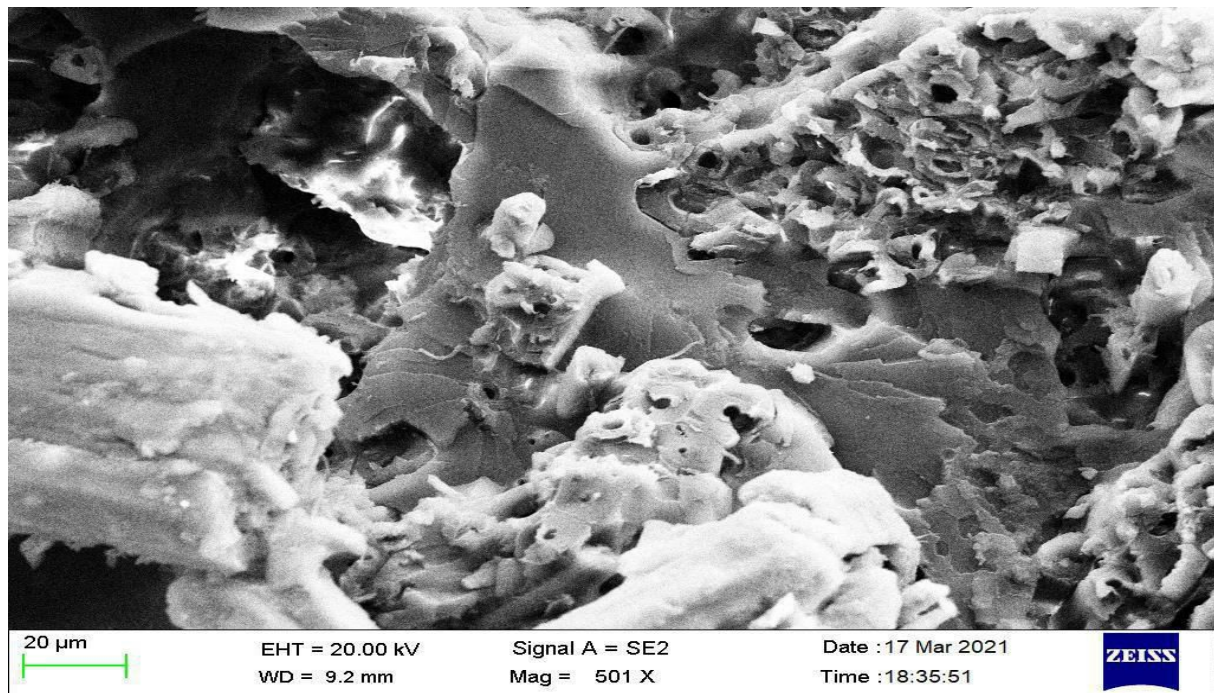


Fig:5.15 : SEM image of injection moulding sample

[4] This micrograph shows that fiber pull-out is less than extrusion-injection moulding. It very well may be unmistakably seen that separated from some fiber pulled out from the framework, a few spots lattice skin arrangement on the strands can be noticed. Further, at certain spots, it is observed that a portion of the fibers broken rather than a pull-out. Consequently, overall bonding between the *jute* fibers and the network was discovered to be good and the network was discovered to be good.

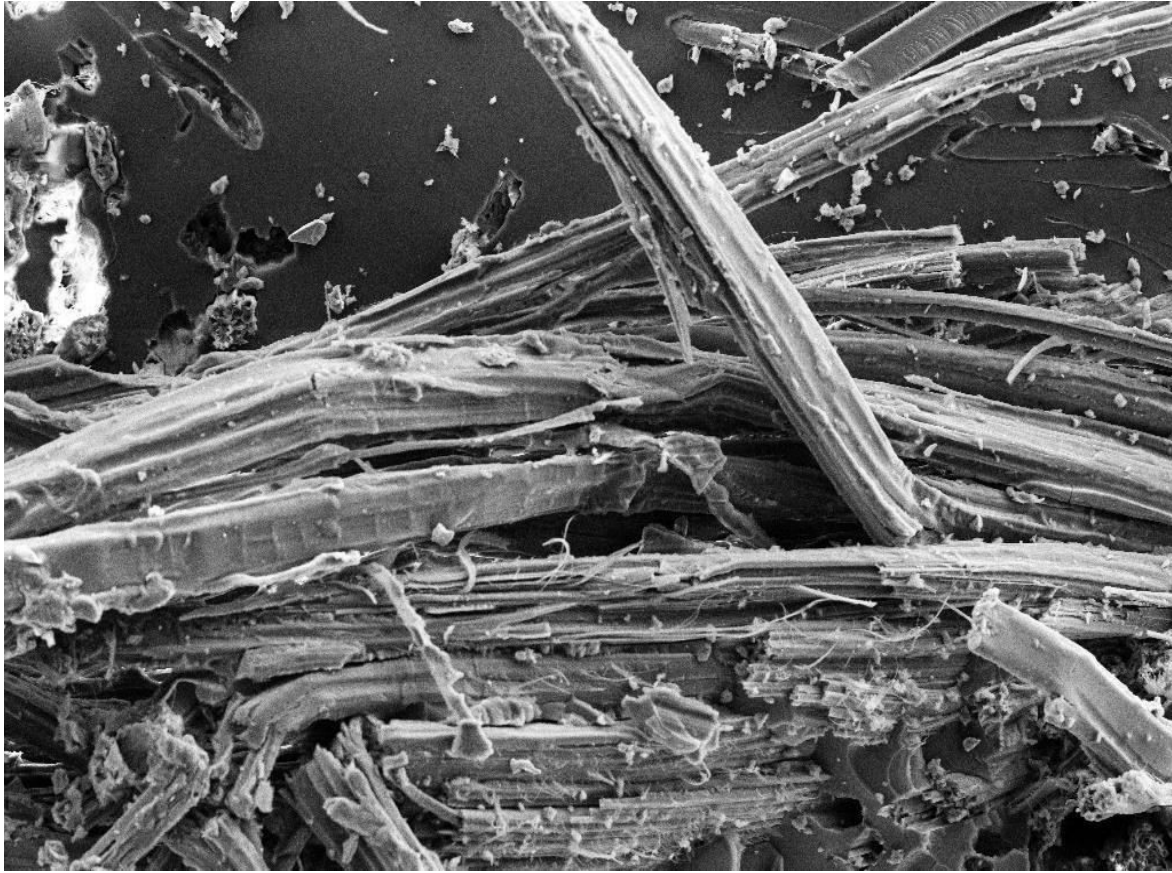


Fig:5.16 : SEM image of injection moulding sample

The Figure 5.17 has been captured at electron high tension of 20 kV and at a working distance of 9.8 mm with a magnification of 100x. There is a clear vision of bundle of fibers being pulled out at once, which means that the interaction of fiber and the matrix hasn't been that good when compared to the compression moulding and we can also see some fiber pull outs on the top right corner of the image and the de bonding between the matrix and fiber the main reason behind the may be the temperature that the process has been carried out and this might be a reason for the increase in void content of this composite and get less tensile values in the tensile test.

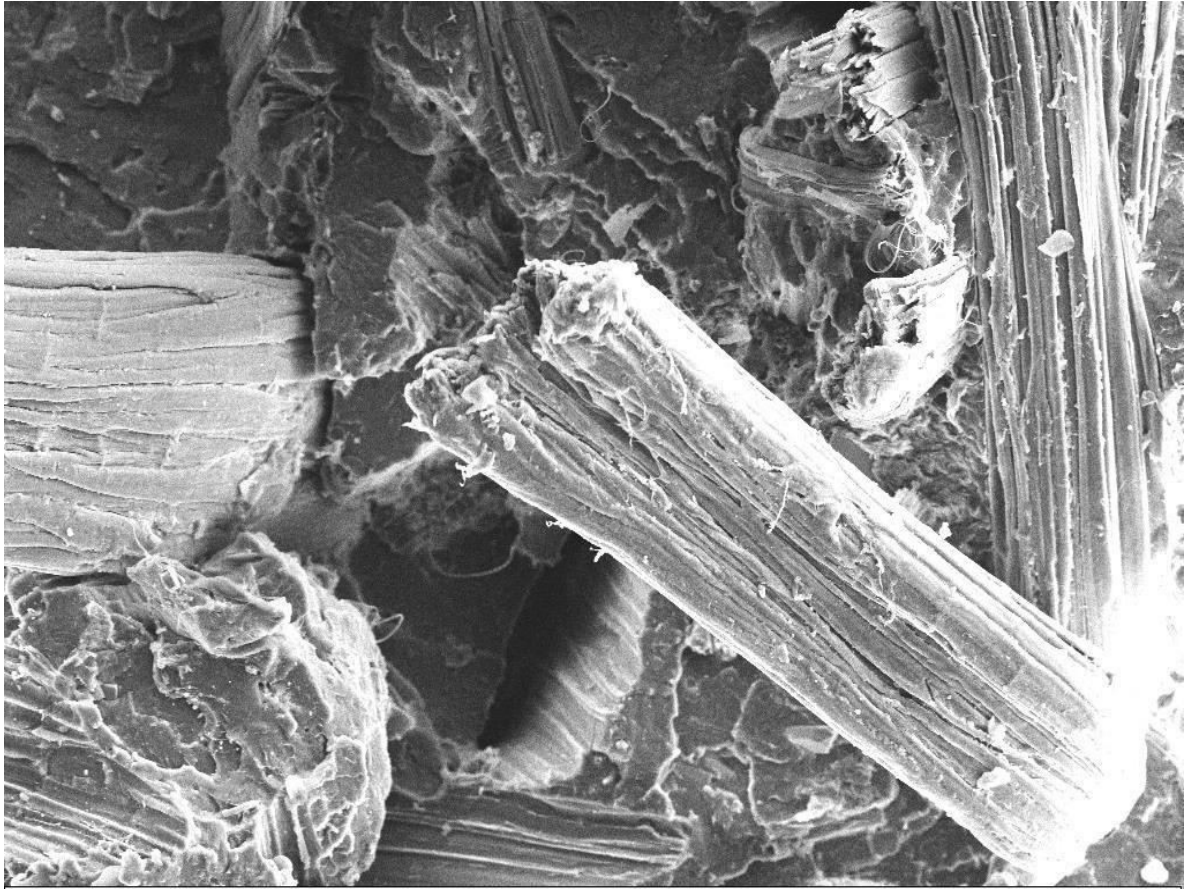


Fig:5.17 : SEM image of Compression moulding

The Figure 5.16, has been captured at electron high tension of 20 kV and at a working distance of 7.8 mm with a magnification of 128x, one can clearly see the breaking of the fiber, smooth surface of the fiber, cracks caused, fiber matrix debonding and matrix pore and also there is a clear vision of pits and all the stuff from the image. [8] There is honey combe structure that increases the bonding in between the matrix. On the contrary one can clearly say that the bonding in between the fiber and the matrix is really good when compared to the other 2 methods. Which is why the tensile flexural and impact strength values are also high when compared to other to methods.

5.5 WATER ABSORPTION TEST

Water absorption performance of a specimen is defined by the amount of water ingested within a definite amount of time. The higher the measure of water

retained, the less fortunate the specimen performance is. Water absorption performance is identified with the dimensional stability of the composites. In our scenario the water absorption test has been made on 1*1 cm blocks made of 3 different manufacturing methods. There has been a significant increase in the amount of water absorption along with time. After 24 Hours the water absorption level of specimen made of injection moulding, extrusion injection moulding, compression moulding with distilled water are 1.53%,1.43%and 1.49% respectively, in sea water 1.38%, 1.29% and 1.42% and in normal water 1.43 %, 1.38 %and 1.56%. Results obtained from the 48 Hours the rate of absorption was 2.2%, 2.09% and 2.32% with distilled water,1.96%,1.82 and 2.02% of sea water & 1.99%,1.81% and 2.12% of normal water has been absorbed by the samples, after 72 hours water absorption of distilled water samples are 2.8%, 2.45% and 2.9% ,from sea water samples 2.34%, 2.23% and 2.46% of sea water & 2.43%, 2.32% and 2.73% of normal water is being absorbed. After 100 hours of water absorption test the results of distilled, sea & normal water and sea water are (3.2%, 2.7% & 3.12%), (2.48%,2.39%&2.65%) & (2.76%,2.48% &2.93%) respectively. It is observed that the *jute* fiber composites that have been made with injection moulding and extrusion-injection moulding have low amount of water absorption due to the degradation of the fibers for keeping them at 185⁰C for long time.

The main reason for the good increase in the water absorption [3] in *jute* fiber reinforced composites is because of the presence of hydroxyl (–OH) group in the *jute* fiber structure makes it hydrophilic in nature, there may be even occurrence of swelling of fibers due to the more water absorption. The water intake quantity increased in all types of composites with increase in *jute* fiber quantity. [3] Other main reason for the increase in the water absorption is PLA since it is also hydrophobic, the rate of water absorption is increased a lot.

Void Test

The presence of void gaps in between the composites will reduce prominently the mechanical and physical properties of the composite material. [7] The most widely recognized reason for voids is the inadequacy of the matrix to displace all the air which is entrained inside the woven or chopped filaments as it passes through the network impregnation. The percentage of void content calculated by formula given below is shown in Table 5.10.

$$\text{Void content (\%)} = \frac{\text{Weight of voids} - \text{Weight of matrix}}{\text{Weight of voids}} \times 100$$

$$\text{Void content (\%)} = \frac{1}{\left(\frac{\text{Weight of voids}}{\text{Density of voids}} \right) + \left(\frac{\text{Weight of matrix}}{\text{Density of matrix}} \right)}$$

Table 5.10 : void content

Sample type	Dimension	Void content
Injection moulding	1*1 CM	3.6%
Extrusion-injection moulding	1*1 CM	2.7%
Compression moulding	1*1 CM	1.4%

[7] The main reasons for the formation of this void gaps are, While the manufacturing during impregnation of fiber into the matrix the trapped air and other volatiles exist in composites and also A strict quality control process is not followed to keep the price as low as possible, this may be even caused void gaps.

CHAPTER 6

SUMMARY AND CONCLUSION

From the above study on the natural reinforced composites from the results obtained the study states that in tensile strength, compression moulding and Extrusion-Injection moulding samples have shown 136% & 116% more efficient than injection moulding samples. In flexural test, the flexural properties of the injection moulding and the extrusion samples are almost similar results and compression moulding is the results were only 85.5% of the results when compared to others. In impact testing that compression moulding & Extrusion-injection moulding has shown 116% and 110% improvement over the injection moulding samples. Using SEM analysis an investigation about the bonding structure in between the matrix and the fiber of all samples which got higher values in tensile strength testing. using SEM analysis that the bonding in between the matrix and fiber is more efficient in extrusion-injection moulding and compression moulding than injection moulding. Using water absorption test found that in injection moulding samples after 100 hours of water absorption test absorption of distilled, sea & normal water are 3.2%, 2.48 & 2.76%. while coming to Extrusion injection moulding the results for above situation are 2.7%, 2.39% & 2.48%. For compression moulding the results were 3.12%, 2.65%, & 2.93. After the investigation of the void content the void content of injection moulding, injection-extrusion moulding and compression moulding samples are 3.6%, 2.7% and 1.4% respectively.

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