

EXPERIMENTAL ANALYSIS OF THE MECHANICAL PROPERTIES OF PLA REINFORCED COIR FIBRE POLYMER COMPOSITE USING STIR CASTING PROCESS

*Report submitted to the SASTRA Deemed to be University
as the requirement for the course*

MEC 400 PROJECT WORK

Submitted by

Moulish Kumar R (Reg. No.: 122009146)

Praveen S (Reg. No.: 122009183)

Saran Nithish S B (Reg. No.: 122009218)

July 2022



SASTRA
ENGINEERING · MANAGEMENT · LAW · SCIENCES · HUMANITIES · EDUCATION
DEEMED TO BE UNIVERSITY

(U/S 3 of the UGC Act, 1956)



THINK MERIT | THINK TRANSPARENCY | THINK SASTRA

T H A N J A V U R | K U M B A K O N A M | C H E N N A I

SCHOOL OF MECHANICAL ENGINEERING

THANJAVUR, TAMIL NADU, INDIA – 613 401



SASTRA
ENGINEERING · MANAGEMENT · LAW · SCIENCES · HUMANITIES · EDUCATION
DEEMED TO BE UNIVERSITY

(U/S 3 of the UGC Act, 1956)



THINK MERIT | THINK TRANSPARENCY | THINK SASTRA

T H A N J A V U R | K U M B A K O N A M | C H E N N A I

SCHOOL OF MECHANICAL ENGINEERING

THANJAVUR – 613 401

Bonafide Certificate

This is to certify that the report titled “**Experimental analysis of the mechanical properties of PLA reinforced coir fibre polymer composite using Stir casting process**” submitted in partial fulfillment of the requirements for the award of the degree of B. Tech. Mechanical Engineering to the SASTRA Deemed to be University, is a bonafide record of the work done by **Mr. Moulish Kumar R (Reg. No.: 122009146), Mr. Praveen S (Reg. No.: 122009183) and Mr. Saran Nithish S B (Reg. No.: 122009218)** during the final semester of the academic year 2021-22, in the School of Mechanical Engineering, under my supervision. This report has not formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title to any candidate of any University.

Signature of Project Supervisor : 

Name with Affiliation : Dr. P. Dinesh Babu
Associate Professor – School of Mechanical
Engineering

Date : 09-July-2022

Project Viva-voce held on _____

Examiner 1

Examiner 2



THINK MERIT | THINK TRANSPARENCY | THINK SASTRA

T H A N J A V U R | K U M B A K O N A M | C H E N N A I

SCHOOL OF MECHANICAL ENGINEERING

THANJAVUR – 613 401

Declaration

We declare that the report titled “**Experimental analysis of the mechanical properties of PLA reinforced coir fibre polymer composite using Stir casting process**” submitted by us is an original work done by us under the guidance of **Dr. Dinesh Babu P, Associate Professor, School of Mechanical Engineering, SASTRA Deemed to be University** during the final semester of the academic year 2021-22, in the **School of Mechanical Engineering**. The work is original and wherever We have used materials from other sources, we have given due credit and cited them in the text of the report. This report has not formed the basis for the award of any degree, diploma, associate-ship, fellowship or other similar title to any candidate of any University.

Signature of the candidate(s) : Moulish kumar. R.

S. R. A.

h

Name of the candidate(s) : Moulish Kumar R
Praveen S
Saran Nithish S B

Date : 09-July-2022

Acknowledgement

At the very outset of this report, we would like to extend our sincere and heartfelt obligation towards all the personages who have helped us to complete the Project. Without their active guidance, help, cooperation and encouragement, we would not have made headway in the project work.

It is our pleasant duty to express deep sense of gratitude to our Honourable Vice chancellor **Dr. S. Vaidhyasubramaniam**, SASTRA Deemed to be University the paramount of the institution, for his patronage and **Prof. R. Chandaramouli**, The Registrar, SASTRA Deemed to be University for providing us the necessary facilities to carry out this work in our university campus.

Foremost, we would like to express our sincere gratitude to our project guide **Dr. P. Dinesh Babu** for his continuous support towards our project work, with patience, motivation, enthusiasm, and immense knowledge. We are ineffably indebted to him for the conscientious guidance and encouragement to accomplish this project work successfully.

We also would like to extent our Gratitude to NIT, Physics Department for Technical Assistance and NIT management for providing testing facility for completing our project. Last but not least, we also thank our friends who shared their knowledge to complete this project work successfully and also our Family for supporting us during this time. Any omission in this brief acknowledgement does not mean lack of gratitude.

List of figures

Figure No.	Title	Page No.
3.1	PLA pellets before melting	4
3.2	Powdered coir fibre	4
3.3	Stir casting equipment with drum view	6
3.4	Steps involved in the Stir casting	8
3.5	Tensile testing specimen	9
3.6	Impact testing specimen	10
4.1	Tensile test results	12
4.2	Graph showing Tensile strength	13
4.3	Impact test results	14
4.4	Graph showing Impact strength	15
4.5	Graph showing Hardness	16
4.6	SEM Image of composite internal at 250X magnification – 1	17
4.7	SEM Image of composite internal at 250X magnification - 2	17
4.8	Stress - Strain curve	18

List of tables

Table No.	Table	Page No.
3.1	Properties of PLA	5
3.2	Percentage distribution of concentration of PLA and coir reinforcement	7
4.1	Tensile test results	12
4.2	Impact test results	14
4.3	Hardness test results	16
4.4	Tensile strength of PLA/ Flax composite [9]	19
4.5	Tensile strength of PLA/ Flax composite [6]	19
4.6	Tensile strength of PLA/ Cordenka composite [6]	20
4.7	Tensile strength of PLA/ Natural Fibre composite [7]	20
5.1	Final results of all tests	21

Table of Contents

Title	Page No.
Bona-fide Certificate	i
Declaration	ii
Acknowledgements	iii
List of Figures	iv
List of Tables	v
Abstract	vi
Abstract	vii
Abstract	viii
1. Introduction	1
1.1. Overview	1
1.2. Manufacturing Process	1
1.3. Drawbacks and solution	1
1.4. Motivation	2
2. Objective	3
3. Methodology	4
3.1. Material	4
3.2. Fabrication of composites	
3.2.1 Stir casting	6
3.2.2 Pure PLA substrate	7
3.2.3 PLA with coir composite	7
3.3. Tensile Testing	9
3.4. Impact Testing	10
3.5. Hardness testing	11

4. Results and Discussion	
4.1. Effect of Tensile strength property on polymer composite	12
4.2. Effect of Impact strength property on polymer composite	14
4.3. Effect of Hardness property on polymer composite	16
4.4. Scanning Electron Microscope (SEM) Images	17
4.5. Stress – Strain Curve	18
4.6. Interpretation	19
5. Conclusions and Further Work	21
6. References	22
7. Appendix	33
7.1 Similarity check index	

Abstract

Name: Moulish Kumar R

Poly-Lactic Acid (PLA), an environmentally friendly biopolymer which has exclusive properties, such as good processability, high rigidity, glossy nature is commonly used in the additive manufacturing field is being used as matrix and tested against mechanical properties in the pure state and also with the composite mixture with coir fibres at different compositions at different percentage ranging from 5% to 30% for improvement in the properties. Coir fibre is chosen as the reinforcement polymer due to its good thermal stability, mechanical properties, structural properties, critical length and water absorption characteristic. The composite mixture is attained by the stir-casting method which is considered to be the one of the best composite casting methods due to the simple experimental processes, cost efficient. The composite's mechanical properties such as tensile strength, impact strength, flexural properties, hardness properties will be tested and the properties will be analysed.

Specific Contribution

- Literature survey
- Study of different composites and their properties
- Results, Presentation and Final report

Specific Learning

- Complete understanding of nature of PLA and its composites and their properties.
- Understanding of different casting techniques involved in casting of composites.

Abstract

Name: Praveen S

Poly-Lactic Acid (PLA), an environmentally friendly biopolymer which is commonly used in the additive manufacturing field is being used as matrix and tested against mechanical properties in the pure state and also with the composite mixture with coir fibers. Coir fiber is chosen as the reinforcement polymer due to its good thermal stability, mechanical properties, structural properties, critical length and water absorption characteristic. The composite mixture is attained by the stir-casting. The composite's mechanical properties such as tensile strength, impact strength, flexural properties, hardness properties will be tested and the properties will be analyzed.

Specific Contribution

- Literature survey
- Study of different composites and their properties
- Results, Presentation and Final report

Specific Learning

- Complete understanding of nature of PLA and its composites and their properties.
- Understanding of different casting techniques involved in casting of composites.

Abstract

Name: Saran Nithish S B

The mechanical characteristics of Poly-Lactic Acid (PLA), an environmentally benign biopolymer that is often used in additive manufacturing, are being investigated both in its pure form and as a composite with coir fibres. Due to its excellent thermal stability, mechanical characteristics, structural qualities, critical length, and water absorption characteristic, coir fibre is chosen as the reinforcing polymer. Stir-casting is the method used to create the composite mixture. The tensile strength, impact strength, flexural properties, and hardness qualities of the composite will be tested, and the properties will be assessed.

Specific Contribution

- Literature survey
- Study of different composites and their properties
- Results, Presentation and Final report

Specific Learning

- Complete understanding of nature of PLA and its composites and their properties.
- Understanding of different casting techniques involved in casting of composites.

CHAPTER 1

INTRODUCTION

1.1 Overview:

PLA – Poly Lactic Acid, a compostable, biodegradable thermoplastics made from renewable sources such as wheat, corn, starch which has a distinct property of sustainable, bio-compatible and low toxicity. PLA is also an environmentally friendly polymer that has good processability, high rigidity and glossy nature which finds its common usage in additive manufacturing field.

This PLA is made into composites with coir as reinforcement which has a particular property such as good thermal stability, stable mechanical properties, structural properties, critical length and water absorption properties, by using Stir casting methodology.

1.2 Manufacturing Process:

PLA and coir reinforced composites are made using stir casting method as it has a simple experimental process and cost efficient.

1.3 Drawbacks and solution:

Despite of having great nature and adaptability the PLA polymer has a poor mechanical property and that reduces the usability of the PLA.

To overcome the drawback coir fibre is added as reinforcement at different percentages to PLA and made into composites and tested to determine which combinations serves the best final results.

1.4 Motivation:

As there is need for replacement of petrochemical products in the market in every industry with degradable products. So, introduction a bio-degradable and sustainable products such as PLA is needed, but the drawback of the usage in industries is mechanical properties and the motivation is to address the issue and find a modification sustainable enough and overcome the drawback.

CHAPTER 2

OBJECTIVE

The basic objective of the project is to improve the mechanical properties of the PLA by addition of coir fibre as reinforcement by stir casting methodology.

Coir fibre is added as reinforcement to PLA at different percentages ranging from 5% to 25% and each combination is made into 3 samples for repetition and each sample is tested for tensile strength, impact strength, hardness and flexural strength and comparison is made to check the improvement in the above-mentioned properties with the pure PLA substrate to combinations of PLA and coir reinforcement and provide the results.

Find the combination in which all the properties are better than the pure PLA substrate and establish the results.

CHAPTER 3

METHODOLOGY

3.1 Material:

For the project the materials are chosen at standards,

- Matrix - Poly Lactic Acid (PLA), in the pellet form is used for the production of composites – melting temperature of the PLA pellets is 300° Celsius, density of 1.6 gram. The appearance of the PLA pellet is shown in **fig 3.1**. **Table 3.1** shows the physical and mechanical properties of PLA
- Reinforcement – Coir fibre is added as reinforcement for the production of composites, coir fibre is added in powdered form for the proper mixing and to make consistent composites. The appearance of the coir fibre is shown in **fig 3.2**



Fig 3.1 PLA pellets before melting.



Fig 3.2 Powdered coir fibre

Table 3.1 Properties of PLA [4]

Sl. NO.	Property	Value
1.	Molecular weight	66000 g/mol
2.	Specific gravity	1.27
3	Solid density	1.2515 g/cm ³
4	Glass transition temperature	55 °C
5	Melting temperature	165 °C
6	Tensile strength	59 MPa
7	Elastic modulus	3500 MPa
8	Shear modulus	1287 MPa
9	Yield strength	90 MPa
10	Notch Izod impact	26 J/m
11	Rockwell hardness	88 HR
12	Percent of elongation	11.3 %
13	Young's modulus	1280 MPa

3.2 Fabrication of composites:

Fabrication of PLA composites is done by using stir casting methodology.

3.2.1 Stir Casting:

Stir casting methodology is selected because of its simplicity and ease to use nature, comparing other casting methods such as open moulding, extrusion, Injection moulding and RTM, stir casting methodology is cost efficient way and more reliable way of creating polymer. **Fig 3.3** shows the Stir casting machine used,



Fig 3.3 Stir casting equipment with drum view.

Step 1 involves pre heating of the reinforcement materials – powdered coir and then continued by melting of substrate in our case PLA pellets, stainless steel is used as drum for casting process because the melting temperature of the Stainless steel is 1400° to 1500° Celsius which is way higher than the melting temperature of PLA pellets which is 300° Celsius.

The melting point of PLA is found by using trial and error method for different temperature of 200°, 250°, 300° Celsius to find the perfect solidifying temperature in which PLA reaches condition where it perfect flowable polymer, for each temperature the PLA polymer is melted and solidified into specimen and tested. It is found that at 300° Celsius the polymer formed is optimal for the usage.

Melted polymer is then transferred to stir casting drum for proper mixing and converting into flowable polymer state for further solidification. Totally two different paths are

selected for physical fabrication I) Pure PLA substrate II) PLA composite with Coir fibre as reinforcement.

3.2.2 Pure PLA substrate:

PLA pellets are taken and melted in the resistance furnace to convert them into flowable polymer. PLA is melted at 300° Celsius as discussed earlier and transferred to stirrer to stir at 600RPM to increase the viscosity and increase flow properties for 10 to 20 minutes. The melted PLA is poured into pattern from which solidifications occurs into required specimen.

3.2.3 PLA with Coir composite:

In this case the same process is followed until melting of PLA, then melted flowable polymer is transferred into stir casting drum and stirred for 10 to 20 minutes and preheated coir fibre in powdered state is added into the stirrer and continued for 15 to 20 minutes. The individual compound is allowed to mix using mechanical vertical stirrer powered by motor.

The stir speed is also found by trial and error method, the stir speed is gradually increased and 600 RPM is noted to be the optimal stir speed for perfect flowable polymer and maximum bonding of composite is achieved, beyond which the drum starts to rotate with the machine and composite mixing is not achieved and also below 600 RPM proper mixing is not achieved.

PLA with reinforcement is created into different compositions with increase in percentage of concentration of coir fibre into the PLA substrate. The following are the combinations of PLA and coir fibre composites that are made in our case.

Table 3.2. Percentage distribution of concentration of PLA and coir reinforcement

Specimen Concentration	PLA Percentage	Coir Fibre Percentage	Specimen
Pure PLA	100%	-	A
PLA + Coir	95%	5%	B
PLA + Coir	90%	10%	C
PLA + Coir	85%	15%	D
PLA + Coir	80%	20%	E
PLA + Coir	75%	25%	F

After the flowable and perfectly bonded composite polymer is transferred into mould of each testing specimen for solidification.

Fig 3.4 shows the procedure followed in the process of making composites.

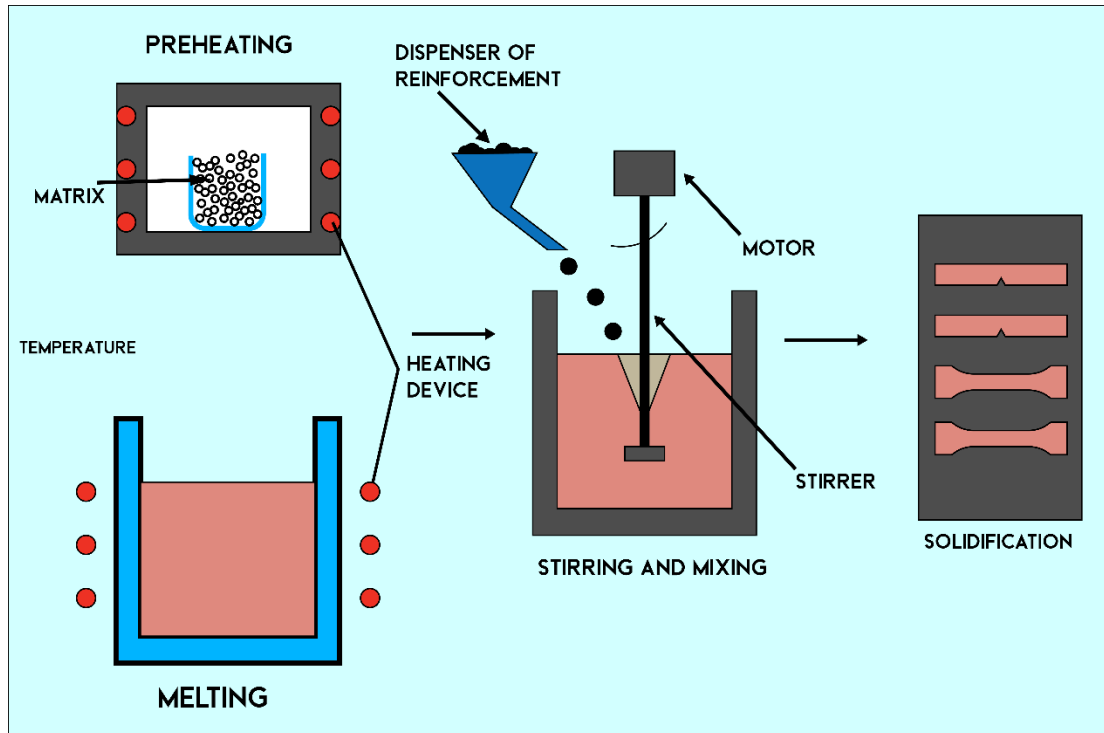


Fig 3.4 Steps involved in the Stir casting.

Preheating – Melting – Stirring with reinforcement - Solidification

3.3 Tensile testing:

Tensile testing is done to determine various mechanical properties of a material. The tensile testing in our case is done in universal tensile testing machine at NIT Trichy. The tensile specimen is made to hold in firmly between two jaws, upper jaw and lower jaw, the lower jaw is fixed in the surface on a static position and the upper jaw is made to move in positive Y direction.

When the upper jaw moves and the metal starts to deform plastically and all the required mechanical properties such as **tensile strength, yield strength, and elongation** are obtained at the point of deformation and all the values are plotted with stress against strain, thus stress-strain curve is obtained.

➤ ASTM D3039 – 115mm X 19mm X 4mm

In our case, the tensile specimen is selected based on the above-mentioned ASTM and mould is made using this standard. Totally 2 specimens for each combination of

- Pure PLA, 95%PLA + 5% coir, 90% PLA + 10% coir, 85% PLA + 15% coir, 80% PLA + 20% coir, 75% PLA + 25% coir is made

The figure shows the tensile specimens



Fig 3.5 Tensile testing specimen

3.4 Impact testing:

Impact testing is done to determine the energy that a notched specimen can absorb during collision. This energy absorbed is used to determine the impact strength, toughness and fracture resistance, which involves in the crucial step of selection of materials for industry of impact loading and collision depend industry.

In this project Charpy V-Notch impact testing in NIT Trichy is carried out for finding the impact strength of the pure PLA and composite of PLA and coir fibre. The test is conducted by striking the specimen with pendulum with sample being held at both the ends, the absorbed impact energy is determined by measuring the reduction of speed in the returning pendulum. Charpy test sample is also selected from the ASTM standard,

➤ **ASTM D256 – 66mm X 13mm X 3mm**

In our case, the Impact specimen is selected based on the above-mentioned ASTM and mould is made using this standard. Totally 2 specimens for each combination of

- Pure PLA, 95%PLA + 5% coir, 90% PLA + 10% coir, 85% PLA + 15% coir, 80% PLA + 20% coir, 75% PLA + 25% coir is made

The figure shows the Impact specimens



Fig 3.6 Impact testing specimen

3.5 Hardness testing:

Hardness testing is used to determine the resistance of the material for deformation by penetration of another harder material. Hardness testing allows user to determine the basic material properties such as ductility, strength and wear resistance properties. All these properties also depend on the loading profile, loading time, specific loading capacity of indenter.

In our case hardness testing is done in Vickers micro hardness machine in SASTRA University, which uses diamond indenter for creating indentation in rhombus shape, the area of the indentation is calculated and proportional to hardness value. Polished surface is used for hardness calculating

$$HV = 1.854(F/D^2)$$

F – Force being applied.

D – Area of the indentation.

The figure shows the flexural specimens

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Effect of Tensile strength property on polymer composite:

Tensile testing is done for each sample of Pure PLA and all the combination of PLA and coir fibre as reinforcement and the average value of all the values of tensile test for each sample is found, results are obtained and comparison is made and established.

The tensile testing results are depicted below in the **Table 4.1.**,

Table 4.1 Tensile test results

SI. NO.	Combination	Tensile strength (MPa)
1.	Pure PLA	20.5
2.	95% PLA + 5% Coir	18.7
3.	90% PLA + 10% Coir	21.65
4.	85% PLA + 15% Coir	22.05
5.	80% PLA + 20% Coir	16.7
6.	75% PLA + 25% Coir	12.05

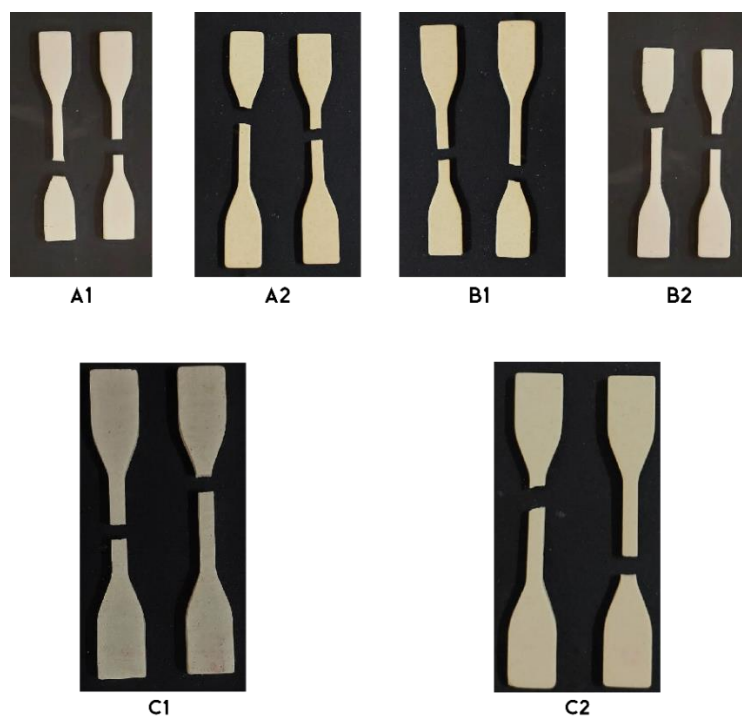


Fig 4.1 Tensile test results

Fig 4.1 shows the tensile specimen after the testing is done and shows the breaking of sample had happened in the neck region and the point of the breaking is where all the results are obtained,

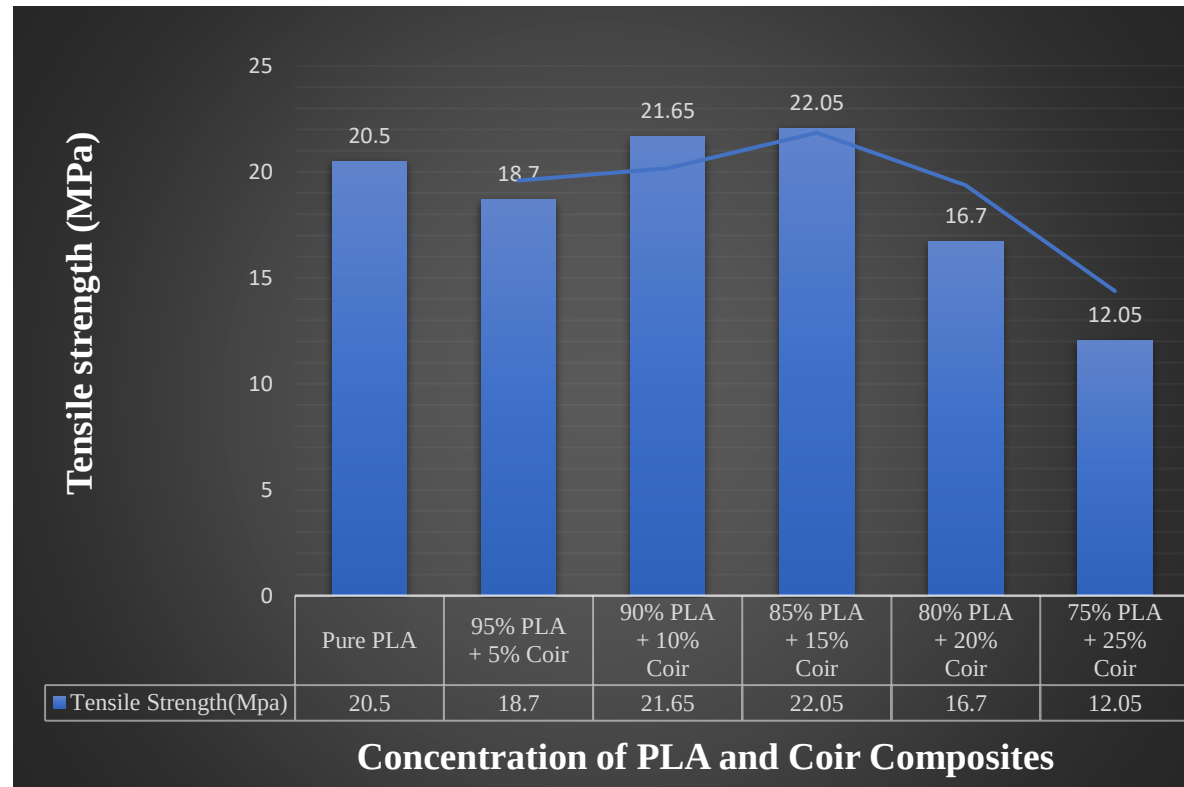


Fig 4.2 Graph showing Tensile strength

Fig 4.2 depicts the graph distribution of tensile strength of the all the concentration of PLA and Coir composites. It is noted that the tensile strength of the composite started to ascend in comparison to pure PLA in composite and descend after crossing a particular concentration. It is established that the correct concentration of inclusion of coir reinforcement to the PLA substrate for improvement in the tensile strength is 15% Coir reinforcement in addition to 85% PLA substrate. And 75% PLA and 25% Coir reinforcement shows the least of all tensile strength and the it is assumed that the tensile strength of the composite starts to descend as the increase in the coir reinforcement concentration after a particular level.

It is noted that the highest of all Tensile strength is found at 85% PLA and 15% Coir reinforcement.

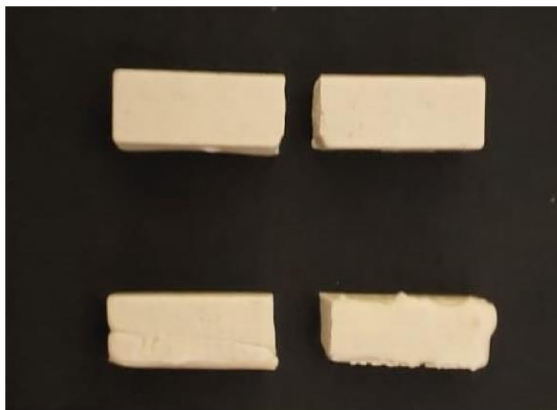
4.2 Effect of Impact strength property on polymer composite:

Impact testing is done for each sample of Pure PLA and all the combination of PLA and coir fibre as reinforcement and the average value of all the values of Impact test for each sample is found, results are obtained and comparison is made and established.

The impact testing results are depicted below in the **Table 4.2.**,

Table 4.2 Impact test results

SI. NO.	Combination	Impact Strength (J/m ²)
1.	Pure PLA	8
2.	95% PLA + 5% Coir	9.5
3.	90% PLA + 10% Coir	15
4.	85% PLA + 15% Coir	19
5.	80% PLA + 20% Coir	16.5
6.	75% PLA + 25% Coir	10



A



B

Table 4.3 Impact test results

Fig 4.3 shows the Impact specimen after the testing is done and shows the breaking of sample had happened in the notch region and the point of the breaking is where all the results are obtained,

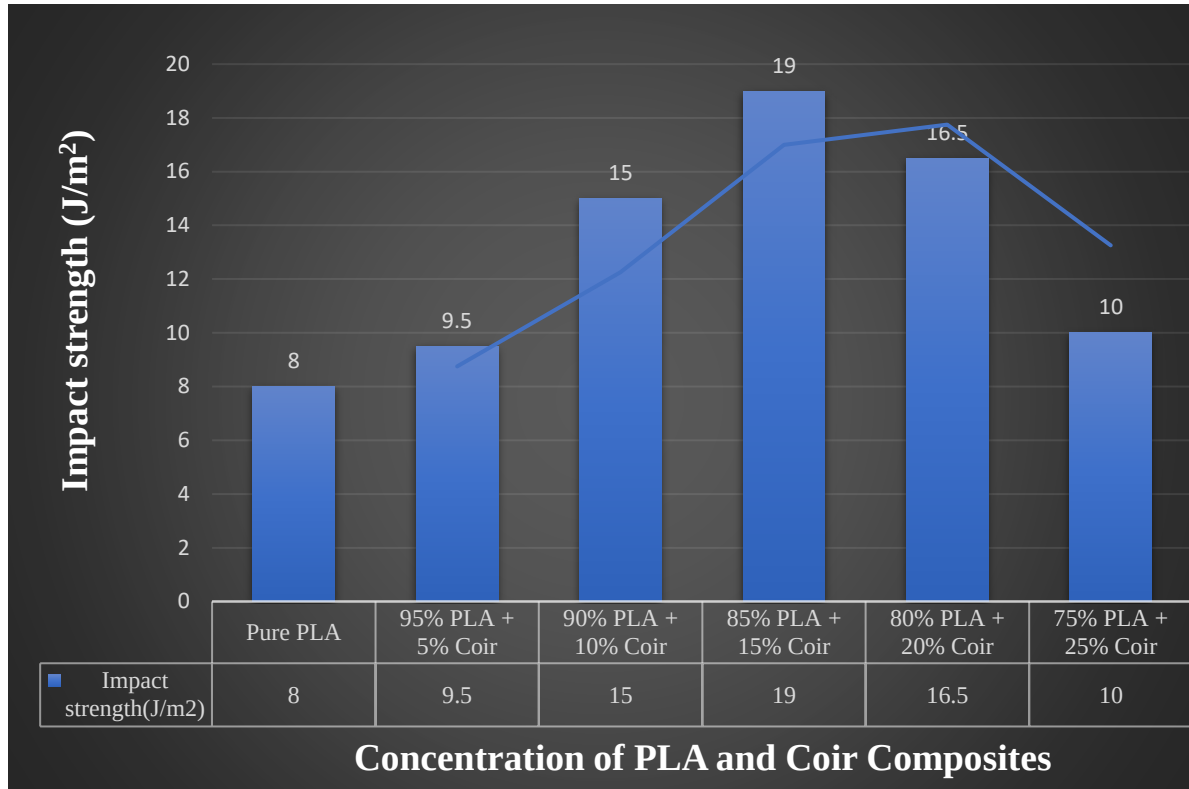


Fig 4.4 Graph showing Impact strength

Fig 4.4 depicts the graph distribution of impact strength of the all the concentration of PLA and Coir composites. It is noted that the impact strength of the composite started to ascend in comparison to pure PLA in composite and descend after crossing a particular concentration. It is established that the correct concentration of inclusion of coir reinforcement to the PLA substrate for improvement in the impact strength is 15% Coir reinforcement in addition to 85% PLA substrate. And pure PLA substrate shows the least of all impact strength and the it is assumed that the impact strength of the composite starts to descend as the increase in the coir reinforcement concentration.

It is noted that the highest of all impact strength is found at 85% PLA and 15% Coir reinforcement.

4.3 Effect of Hardness property on polymer composite:

Hardness testing is done for each sample of Pure PLA and all the combination of PLA and coir fibre as reinforcement and the average value of all the values of hardness test for each sample is found, results are obtained and comparison is made and established.

The Hardness testing results are depicted below in the **Table 4.4.**,

Table 4.3 Hardness test results

SI. NO.	Combination	Hardness (HBR)
1.	Pure PLA	101
2.	95% PLA + 5% Coir	40
3.	90% PLA + 10% Coir	72
4.	85% PLA + 15% Coir	92
5.	80% PLA + 20% Coir	50
6.	75% PLA + 25% Coir	30

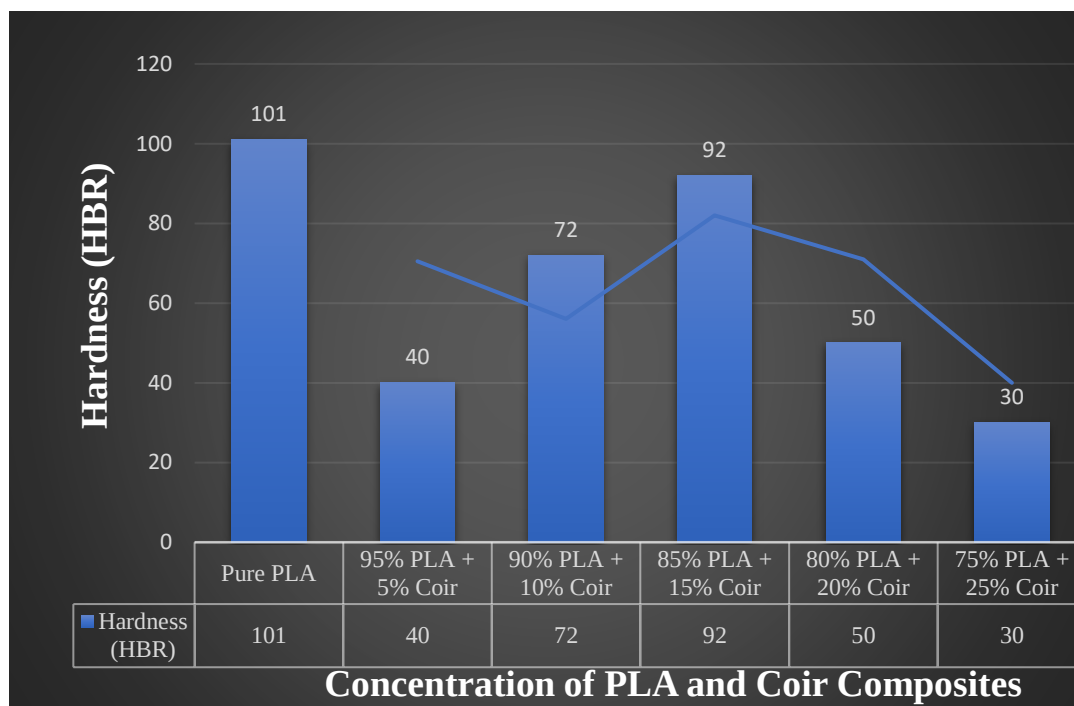


Fig 4.5 Graph showing Hardness

4.4 Scanning Electron Microscope (SEM) Images:

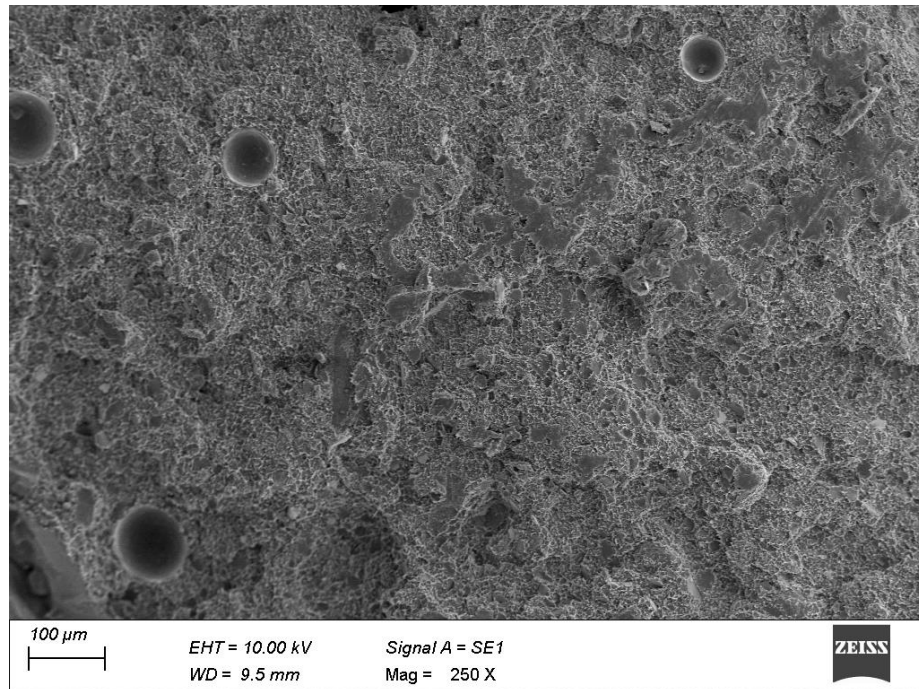


Fig 4.6 SEM Image of composite internal at 250X magnification - 1

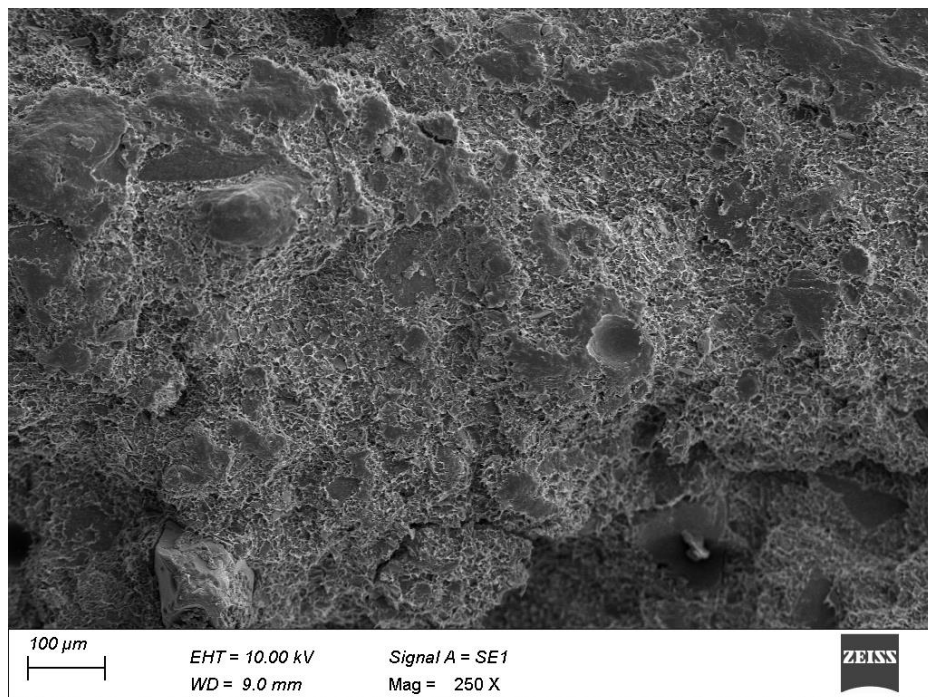


Fig 4.7 SEM Image of composite internal at 250X magnification - 2

In **fig 4.6** and **fig 4.7**, we can observe that a clean surface shows that in the stir casting method, the selected temperature and stir speed is accurate and helps in the proper mixing of the PLA and coir reinforcement and thus shows that the fibre and PLA are separated during the casting process. And also, there is no clean fibre visible is fractured this shows the proper adhesion between the PLA and the fibre.

In **fig 4.6**, we can observe four pores in the surface of the composites shows that the air bubbles are formed during the process, and helps in improving mechanical properties.

In **fig 4.7**, we can observe small flat surface across the surface of the composites, that shows the availability of the fibre is the composites and it is uniformly distributed, and the effect of the uniform distribution is observed in the mechanical behaviour of the composites.

4.5 Stress Vs Strain curve:

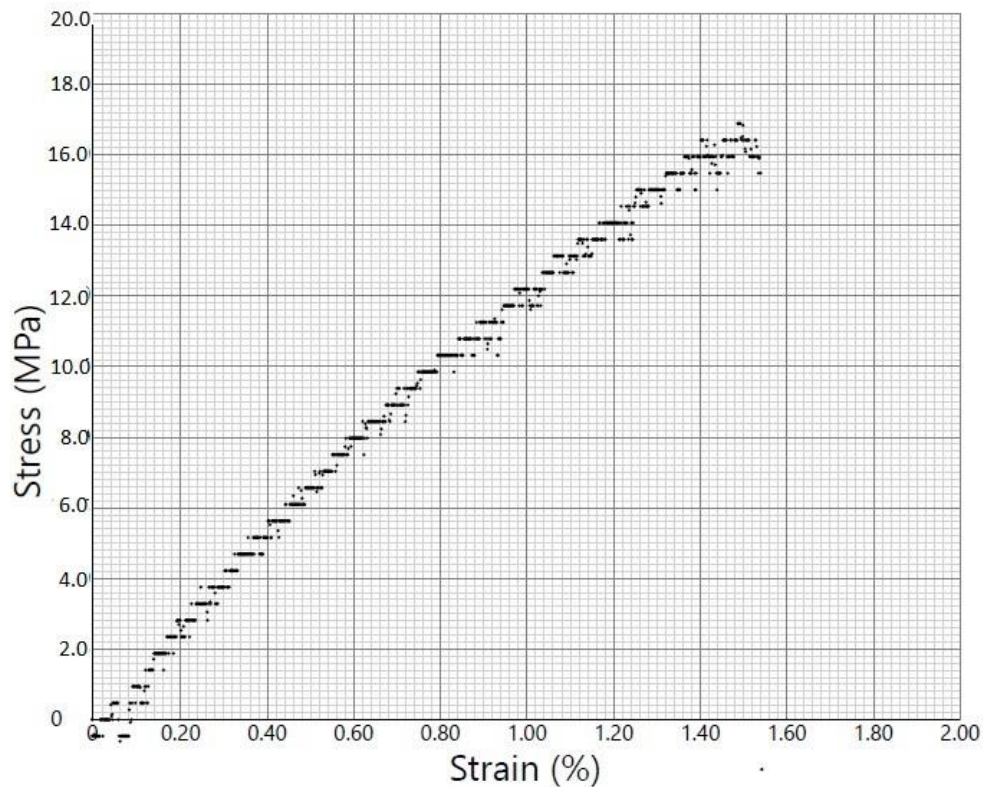


Fig 4.8 Stress - Strain curve

4.6 Interpretation:

Based on the testing done the results are obtained and all the results are interpreted with the article that are collected for literature survey and discussion is made based on the establishment.

1. In the article Natural fibers as reinforcement in polylactic acid (PLA) [9] composites, published by K. Oksman, M. Skrifvars, J.-F. Selin in 2003 discussed about the mechanical properties of PLA composite with Flax in pure and plasticized PLA and tensile properties are established.

Table 4.4 Tensile strength of PLA/ Flax composite [9]

SI. NO.	Composite	Tensile Strength (MPa)
1.	Pure PLA	50
2.	PLA with 30% Flax	53
3.	PLA with 40% Flax	44

Table 4.5 shows the tensile testing values. This indicates the tensile strength of composites increases with increase in the percentage of fibre and started to decrease after a particular value same as our case.

The composites are made by compression moulding methodology with involves mechanical compression force which makes the tighter packing of PLA and fibre and thus the mechanical property value is high in compared with our case.

2. In the article Impact and tensile properties of PLA/Cordenka and PLA/flax composites published by Benjamin Bax, Jo"rg Mu" ssig in 2008 [6] discussed the impact and tensile properties of the PLA with Cordenka and Flax fibre.

Table 4.5 Tensile strength of PLA/ Flax composite [6]

SI. NO.	Composite	Tensile Strength (MPa)	Impact Strength (kJ/m ²)
1.	PLA with 10% Flax	42.73	9.47
2.	PLA with 20% Flax	49.23	10.45
3.	PLA with 30% Flax	54.15	11.13

Table 4.6 Tensile strength of PLA/ Cordenka composite [6]

SI. NO.	Composite	Tensile Strength (MPa)	Impact Strength (kJ/m ²)
1.	PLA with 10% Cordenka	50.40	43.44
2.	PLA with 20% Cordenka	50.75	62.97
3.	PLA with 30% Cordenka	57.97	72.24

Table 4.6 and Table 4.7 shows the tensile and impact strength of PLA/Flax and PLA/Cordenka composites. The results show that the all the mechanical properties are improves with inclusion of reinforcement fibre at the particular percentage composite of 30% reinforcement. In our case the same results of improvement in the mechanical property occurs at 15% reinforcement and starts to drop.

3. In the article Mechanical performance of bio composites based on PLA and PHBV reinforced with natural fibers published by A.K. Bledzki, A. Jaszkievicz in 2010 [7] discussed result of tensile properties of PLA, PHBV, PP with composites (Natural fibers) – Man-made cellulose, Abaca, Jute and established, we take results of PLA and composites for our reference.

Table 4.7 Tensile strength of PLA/ Natural Fibre composite [7]

SI. NO.	Composite	Tensile Strength (MPa)	Impact Strength (kJ/m ²) at +23°
1.	Pure PLA	63.5	2.5
2.	PLA with Man – Made Cellulose	92	8
3.	PLA with Abaca	74	5
4.	PLA with Jute	82	4

CHAPTER 5

CONCLUSION AND FURTHER WORK

From the studies done above and the results obtained and comparisons made, it is made clear that addition of coir reinforcement with the PLA substrate matrix improves the mechanical properties thus improves the usability of the composites.

As it is shown the tensile, impact strength of the composite at 85% PLA and 15% Coir reinforcement has the highest value in compared to the pure PLA and substrate and other concentration of composite.

It is concluded that the inclusion of coir fibre to PLA at certain concentration tends to improve the mechanical property and usability of PLA in industry.

Further this project can be continued by analysing of chemical properties such as resistance to corrosion and bio-degradable properties of PLA and composites.

The final result and conclusion are tabulated.,

Fig 5.1 Final results of all tests

SI. NO.	Combination	Tensile Strength (MPa)	Impact Strength (J/m ²)	Hardness (HBR)
1.	Pure PLA	20.5	8	101
2.	95% PLA + 5% Coir	18.7	9.5	40
3.	90% PLA + 10% Coir	21.65	15	92
4.	85% PLA + 15% Coir	22.05	19	72
5.	80% PLA + 20% Coir	16.7	16.5	50
6.	75% PLA + 25% Coir	12.05	10	30

REFERENCES

1. Adewale George Adeniye, Damilola Victoria Onifade, Joshua O. Ighalo, Akorde Samson Adeoye - A review of coir fiber reinforced polymer composites - *Chemical Engineering Department, Faculty of Engineering and Technology, University of Ilorin, Ilorin, P. M. B. 1515, Nigeria* [1]
2. K. Yoganandam, Vigneshwaran Shanmugam, A. Vasudevan, D. Vinodh, N. Nagaprasad, Balasubramaniam Stalin, Alagar Karthick, Chandrabhanu Malla and Murugesan Bhararni (2021) Investigation of Dynamic, Mechanical, and Thermal Properties of Calotropis procera Particle-Reinforced PLA Bio composites [2]
3. Amrendra Pratap Singh, M. Senthil Kumar, Ajinkya Deshpande, Gaurav Jain, Jayesh Khamesra, Samarth Mhetre, Adarsh Awasthi, L. Natrayan (2020) Processing and characterization mechanical properties of AA2024/Al₂O₃/ZrO₂/Gr reinforced hybrid composite using stir casting technique *School of Mechanical Engineering, VIT, Chennai, India* [3]
4. Majid Jamshidian, Elmira Arab Tehrany, Muhammad Imran, Muriel Jacquot, and St´ephane Desobry (2010) Poly-Lactic Acid: Production, Applications, Nanocomposites, and Release Studies [4]
5. Sachin S. Raj, T.K. Kannan, M. Kathiresan, K. Balachandar, S. Krishnakumar (2020) Why not stir casting for polymer composites? Investigations on poly lactic acid-based wood plastic composite, *Department of Mechanical Engineering, Gnanamani College of Technology, Namakkal 637018, India* *Department of Mechanical Engineering, Thiagarajar College of Engineering, Madurai 625009, India* *Department of Mechanical Engineering, SASTRA University, Tanjavur 613401, India* [5]
6. Benjamin Bax, Joërg Muë ssig (2008) Impact and tensile properties of PLA/Cordenka and PLA/flax composites. *Hochschule Bremen – University of Applied Sciences, Biomimetics/Biological Materials, Neustadtswall 30, 28199 Bremen, Germany* [6]
7. A.K. Bledzki, A. Jaszkievicz (2010) Mechanical performance of bio composites based on PLA and PHBV reinforced with natural fibers – A comparative study to PP *Institut fuer Werkstofftechnik, Kunststoff- und Recyclingtechnik, University of Kassel, Kassel, Germany, Szczecin University of Technology, Institute of Materials Science and Engineering, Szczecin, Poland* [7]

8. K. Kannapiran, K. Rajchander, K. Nirmalkumar (2020) Analysing Mechanical Properties of Natural Fibers Reinforced with Egg Shell Assistant Professor, Manufacturing engineering, Mother Teresa College of Engineering & Technology, Pudukkottai Tamilnadu, India, Assistant Professor, Sri Krishna College of Technology, Coimbatore [8]
9. K. Oksman, M. Skrifvars, J.-F. Selin (2003) Natural fibres as reinforcement in polylactic acid (PLA) composites Department of Machine Design and Materials Technology, NTNU, Norwegian University of Science and Technology, Rich. Birkelands vei, SICOMP AB, POB 271, SE-94126 Pitea, Sweden, Fortum Oyj, POB 310, FIN-06101 Porvoo, Finland [9]

Peer Evaluation Form for Group Work

Your name: Moulish Kumar R

Write the name of each of your group members in a separate column. For each person, indicate the extent to which you agree with the statement on the left, using a scale of 1-4 (1=strongly disagree; 2=disagree; 3=agree; 4=strongly agree). Total the numbers in each column.

Evaluation Criteria	Group member: Praveen S	Group member: Saran Nithish S B
Attends group meetings regularly and arrives on time.	4	4
Contributes meaningfully to group discussions.	4	4
Completes group assignments on time.	4	4
Prepares work in a quality manner.	4	4
Demonstrates a cooperative and supportive attitude.	4	4
Contributes significantly to the success of the project.	4	4
Total	24	24

Feedback on team dynamics

1) How effectively did your group work?

Everyone in the group is actively participated in the group meet and pretty helpful in all the activities carried out in the project and everyone supported everyone and all fulfilled their own part.

2) Were the behaviors of any of your team members particularly valuable or detrimental to the team? Explain.

My team mates are very valuable they took part in creating ppt for review when I had class and exams and they supported me in the process.

3) What did you learn about working in a group from this mini-project that you will carry into your next group experience?

Idea sharing and supportive when ideas ran out.

Peer Evaluation Form for Group Work

Your name: Praveen S

Write the name of each of your group members in a separate column. For each person, indicate the extent to which you agree with the statement on the left, using a scale of 1-4 (1=strongly disagree; 2=disagree; 3=agree; 4=strongly agree). Total the numbers in each column.

Evaluation Criteria	Group member: Moulish Kumar R	Group member: Saran Nithish S B
Attends group meetings regularly and arrives on time.	4	4
Contributes meaningfully to group discussions.	4	4
Completes group assignments on time.	4	4
Prepares work in a quality manner.	4	4
Demonstrates a cooperative and supportive attitude.	4	4
Contributes significantly to the success of the project.	4	4
Total	24	24

Feedback on team dynamics

1) How effectively did your group work?

Everyone in the group is actively participated in the group meet and pretty helpful in all the activities carried out in the project and everyone supported everyone and all fulfilled their own part.

2) Were the behaviors of any of your team members particularly valuable or detrimental to the team? Explain.

My team mates are very valuable they took part in creating ppt for review when I had class and exams and they supported me in the process.

3) What did you learn about working in a group from this mini-project that you will carry into your next group experience?

Idea sharing and supportive when ideas ran out.

Peer Evaluation Form for Group Work

Your name: Saran Nithish S B

Write the name of each of your group members in a separate column. For each person, indicate the extent to which you agree with the statement on the left, using a scale of 1-4 (1=strongly disagree; 2=disagree; 3=agree; 4=strongly agree). Total the numbers in each column.

Evaluation Criteria	Group member: Moulish Kumar R	Group member: Praveen S
Attends group meetings regularly and arrives on time.	4	4
Contributes meaningfully to group discussions.	4	4
Completes group assignments on time.	4	4
Prepares work in a quality manner.	4	4
Demonstrates a cooperative and supportive attitude.	4	4
Contributes significantly to the success of the project.	4	4
Total	24	24

Feedback on team dynamics

1) How effectively did your group work?

Everyone in the group is actively participated in the group meet and pretty helpful in all the activities carried out in the project and everyone supported everyone and all fulfilled their own part.

2) Were the behaviors of any of your team members particularly valuable or detrimental to the team? Explain.

My team mates are very valuable they took part in creating ppt for review when I had class and exams and they supported me in the process.

3) What did you learn about working in a group from this mini-project that you will carry into your next group experience?

Idea sharing and supportive when ideas ran out.

Sample Self-Evaluation Form for Group Work

Your name: Moulish Kumar R

	Seldom	Sometimes	Often
Contributed good ideas			Yes
Listened to and respected the ideas of others			Yes
Compromised and Cooperated			Yes
Took initiative where needed			Yes
Came to meetings prepared			Yes
Communicated effectively with teammates			Yes
Did my share of the work			Yes

My greatest strengths as a team member are:

1. Planning of the work which is to be carried out.
2. Ensuring stable work flow at any situation.

The group work skills I plan to work to improve are:

1. Communicating with team mates much more often.
2. Analyse the availability of facilities before starting the process.

Sample Self-Evaluation Form for Group Work

Your name: Praveen S

	Seldom	Sometimes	Often
Contributed good ideas			Yes
Listened to and respected the ideas of others			Yes
Compromised and Cooperated			Yes
Took initiative where needed			Yes
Came to meetings prepared			Yes
Communicated effectively with teammates			Yes
Did my share of the work			Yes

My greatest strengths as a team member are:

1. Planning of the work which is to be carried out.
2. Ensuring stable work flow at any situation.

The group work skills I plan to work to improve are:

1. Communicating with team mates much more often.
2. Analyze the availability of facilities before starting the process

Sample Self-Evaluation Form for Group Work

Your name: Saran Nithish S B

	Seldom	Sometimes	Often
Contributed good ideas			Yes
Listened to and respected the ideas of others			Yes
Compromised and Cooperated			Yes
Took initiative where needed			Yes
Came to meetings prepared			Yes
Communicated effectively with teammates			Yes
Did my share of the work			Yes

My greatest strengths as a team member are:

1. Planning of the work which is to be carried out.
2. Ensuring stable work flow at any situation.

The group work skills I plan to work to improve are:

1. Communicating with team mates much more often.
2. Analyse the availability of facilities before starting the process

1

by Moulish K

Submission date: 09-Jul-2022 01:40PM (UTC+0530)

Submission ID: 1868265736

File name: Plag.pdf (1.17M)

Word count: 3465

Character count: 16400

ORIGINALITY REPORT

6%

SIMILARITY INDEX

4%

INTERNET SOURCES

4%

PUBLICATIONS

%

STUDENT PAPERS

PRIMARY SOURCES

1

Bax, B.. "Impact and tensile properties of PLA/Cordenka and PLA/flax composites", Composites Science and Technology, 200806

Publication

1%

2

dokumen.pub

Internet Source

1%

3

www.mdpi.com

Internet Source

<1%

4

"Advances in Materials and Manufacturing Engineering", Springer Science and Business Media LLC, 2020

Publication

<1%

5

Thongpin, Chanchai, Kullanith Chaemprasith, Jakapan Teeralertpanich, Parisara Saensuk, and Nontawat Kritape. "In Situ Reinforcement of PLA Using Nylon 6 in PLA/Nylon 6 Extrudate Blend via Twin-Screw Extrusion", Key Engineering Materials, 2015.

Publication

<1%

6

citeseerx.ist.psu.edu

Internet Source

<1%