



International Journal of Innovative Research in Science Engineering and Technology (IJIRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



Impact Factor: 8.699

Volume 14, Issue 3, March 2025

Mechanical Characterization of 3D Printed Dog-Bone Specimens: A Comparative Study of ABS and PLA

S. Mahesh, K. Jagadish, B. Raghavendra, M. Sanjay Nag, P. Varun Teja, D.Hemanth, A.Vamsi,
G.Sandeep

Department of Mechanical Engineering, Nadimpalli Satyanarayana Raju Institute of Technology, Visakhapatnam,
Sontyam, Andhra Pradesh, India

ABSTRACT: This study investigates the tensile properties of dog-bone specimens fabricated using Fused Deposition Modeling (FDM) 3D printing with two commonly used thermoplastic polymers: Acrylonitrile Butadiene Styrene (ABS) and Polylactic Acid (PLA). The specimens were designed according to ASTM D638 standards and printed with varying parameters such as infill density, printing temperature, and layer height. Tensile tests were conducted to determine the ultimate tensile strength, yield strength, young's modulus, and elongation at break for both materials. The influence of printing parameters on the mechanical properties was analyzed. A comparative analysis of the tensile behavior of ABS and PLA was performed, highlighting the advantages and limitations of each material for specific applications. The results provide valuable insights into the mechanical performance of 3D-printed parts and aid in material selection for FDM-based additive manufacturing.

KEYWORDS: PLA, ABS, FSM, 3D Printing.

I. INTRODUCTION

Due to increased product obsolescence, mass customization, global competitiveness and ongoing cost-cutting pressures, businesses are being forced to find innovative ways to enhance their operational procedures. In the late 1980's the first fast prototyping technique was made accessible and utilized to create model parts and prototypes. These days, these techniques are employed in many different kinds of application and are used to produce high-quality parts in comparatively small quantities if desired without the usual crucial short-term financial resources. Rapid prototyping (RP), a new style of operation that promises to strengthen the competitive position of business adopting it, has emerged as a crucial enabler for rapid manufacturing.

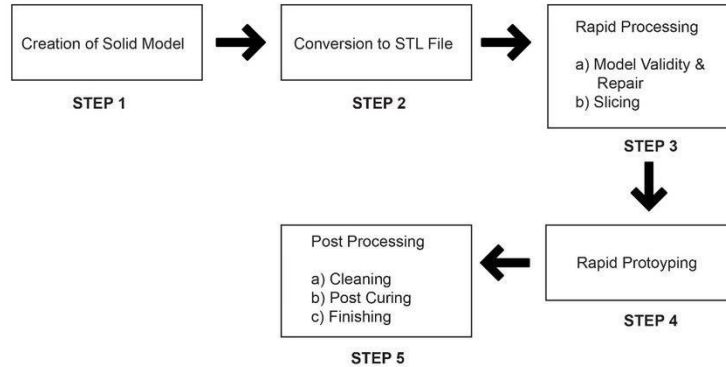
Rapid prototyping, often known as additive manufacturing, is a general phrase for a variety of technologies that allows components to be produced without the initial need for traditional tooling or even the need to hire professional model builders. A design process called rapid prototyping is used to rapidly produce models or prototypes of a product or component in order to test and validate the design. It's an essential phase in the product development cycle that enables engineers and designers to spot possible problems early on and make the required corrections before investing in costly production and tooling procedures.

Various RP system types have been developed to meet the high needs of recently released items. Stereo lithography (SLA) is the most widely used kind of RP system on the market. Modelling by fused deposition (FDM), Selective laser sintering (SLS). Manufacturing of Laminated Objects (LOM).

RP comprises of two general types-[1]

Subtractive type RP-Material removal addition process. Examples- Turning, milling, grinding, etc.

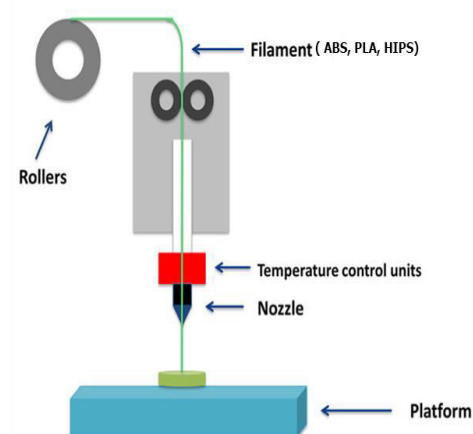
Additive type RP- Layer by layer material addition process. Examples: Stereolithography, Fused deposition Modelling(FDM),3D printing, etc.



Rapid Prototyping Process Chain

Creating a 3D digital model of a product, transforming it into a format appropriate for the selected fast prototyping technology, building a physical prototype, and then making design adjustment in response to testing and feedback are all steps in rapid prototyping process chain. This iterative technique enables quick design validation and improvements prior to full-scale production.

Fused Deposition Modeling (FDM)



Fused Deposition Modeling (FDM) is a 3D printing process that builds objects layer by layer. Thermoplastic filament is melted in a heated extruder and then placed in exact patterns based on a digital design. After coming into touch with the build platform, the extruded material solidifies, taking on the required shape. FDM is a well-liked option for manufacturing, prototyping and other applications because of its affordability, adaptability and variety of materials.

Process Parameters

The production efficiency and part qualities of the FDM process are greatly influenced by a number of process parameters. Air gap, build orientation, extrusion temperature, infill density, infill pattern, layer thickness, number of shells, print speed, raster orientation, raster width, and heat treatment temperature (post-processing parameter) are a few of the most often used process parameters. Below is a description of the primary process parameters.

Layer height : As this additive manufacturing method uses layer by layer printing, the Layer Height Parameter plays an important role in variation in mechanical as well as physical properties. Layer Height varies from 0.06 to 0.4 mm for 0.4 mm diameter nozzle.[2]

Build orientation : It is the process of aligning a part with regard to the X,Y and Z axes on a build platform. Build orientation was regarded as categorical parameter in some works [11,20], whereas it was a quantitative parameter in others[13,19].

Extruder temperature

The temperature at which a material's filament is heated during the FDM process. Extrusion temperature is influenced by a number of factors, such as print speed and material type.

Infill density: It denotes the material volume printed on the given component. Infill density directly influences the printed component's properties. A solid cross section has a small effect on the failure of the material considerably with a lower infill used, though an optimum infill density gives a better mechanical strength for fair material customization and build time. [3]

Infill pattern: It is the methodology used to print the interior structure of the component being printed. A lot of filling pattern are available like linear, hexagonal, cubic, honeycomb, and diamond, among which honeycomb is better for good mechanical properties of the internal structures. [3]

Layer Thickness: The height of the deposition layers along the z-axis, which is often an FDM machine's vertical axis, is known as the layer thickness. It typically relies on the nozzle's diameter and is smaller than the extruder nozzle's diameter.

Print Speed: This speed is chosen to ensure a good balance between print quality and efficiency. Slower speeds can improve the detail and strength of the print, reducing the risk of defects.[4]

Raster Gap: The distance between the two adjacent filaments deposited in the same layer is the air gap. The number of contours is the number of filaments positioned at the outer edge.[5]

Raster Angle: The raster angle refers to the angle between the nozzle direction and the X axis of the FDM printer board. Raster angles between two consecutive layers differ by 90 degrees. The raster angle affects the shape precision and mechanical efficiency of the sample being printed. [5]

Common Materials used in FDM

PLA (Polylactic Acid) : Biodegradable, easy to print, good strength-to-weight ratio and available in a wide range of colors.

ABS (Acrylonitrile Butadiene Styrene) : It has high impact resistance, good chemical resistance and high tensile strength.

PETG (Polyethylene Terephthalate Glycol) : It was tough, flexible, good layer adhesion and high impact resistance.

TPU (Thermoplastic Polyurethane) : It was flexible, elastic and good abrasion resistance.

Nylon : It has high strength, stiffness and chemical resistance.

Tensile Test

A Comparative Analysis of Tensile Properties for FDM -Fabrication PLA and ABS Dog Bone Specimens

To evaluate the tensile properties of 3D-Printed specimen and the variability in these properties when different 3D printing parameter values are used, tensile tests were carried out in a Zwick/Roell Z050 tensile machine at a speed of 5mm/min. The geometry and dimensions of the 3D-printed tensile specimens were type V according to ASTM D638-14 [6]. Also, tensile tests of feedstock filament were carried out for both ABS and PLA in a Zwick/Roell Z0.5 tensile machine at a speed of 5mm/min.[7]

This study uses fused deposition modelling (FDM) technology to examine the tensile behavior of dog bone specimen made from polylactic acid (PLA) and acrylonitrile butadiene styrene (ABS). To clarify how material selection affects the specimen's overall structural integrity, the analysis focusses on important mechanical characteristics such as tensile strength, modulus and elongation at break.

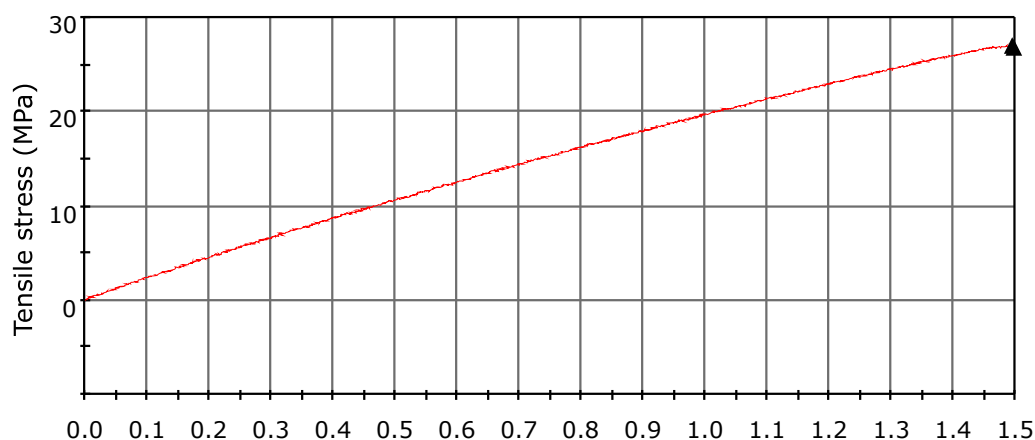


ABS (Acrylonitrile Butadiene Styrene)

ABS (Acrylonitrile butadiene styrene) is a thermoplastic polymer renowned for its exceptional balance of properties. It exhibits a unique combination of toughness, rigidity, and processability, making it a versatile material in various industries. ABS is characterized by its superior impact resistance, dimensional stability, and chemical resistance, further enhancing its suitability for demanding applications. Its amorphous structure contributes to its ease of processing and ability to be molded into intricate shapes.

Organization	GITAM (Deemed to be University)
Laboratory	Material Testing Laboratory
Requester Details	
Requestor Organisation	
Type of Test	Tensile test
Material Grade	
Rate 1	1.00000 mm/min

Specimen 1



Specimen #
1

Tensile strain (%)

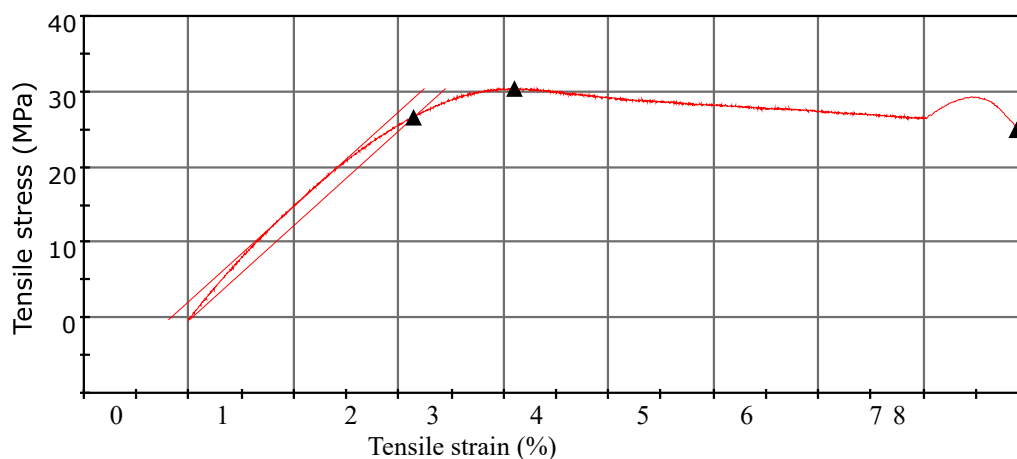
	Specimen Label	Width (mm)	Thickness (mm)	Length (mm)
1		12.00000	3.00000	60.00000
	Maximum Load (N)	Load at Break (Standard) (N)	Extension at Tensile Strength (mm)	Ultimate Tensile Strength (UTS) (MPa)
1	971.63	964.31794	0.89974	26.99

Page 1 of 2

	Tensile stress at Tensile Strength (MPa)	Tensile strain at Tensile Strength (mm/mm)	Tensile stress at Yield (Offset 0.2 %) (MPa)	Load at Yield (Offset 0.2 %) (N)
1	26.98981	0.01494	----	----

	Tensile stress at Break (Standard) (MPa)	Tensile stress at Preset Point (Tensile strain 2 %) (MPa)	Tensile strain at Maximum Load (mm/mm)	Tensile strain at Break (Standard) (mm/mm)
1	26.78661	----	0.01494	0.01496
	Energy at Tensile Strength (J)	Modulus (Automatic) (MPa)		
1	0.47685	2214.60809		

Specimen 2



	Specimen Label	Width (mm)	Thickness (mm)	Length (mm)
1	1	12.00000	3.00000	60.00000

	Maximum Load (N)	Load at Break (Standard) (N)	Extension at Tensile Strength (mm)	Ultimate Tensile Strength (UTS) (MPa)
1	1094.37	897.96474	1.86176	30.40

	Tensile stress at Tensile Strength (MPa)	Tensile strain at Tensile Strength (mm/mm)	Tensile stress at Yield (Offset 0.2 %) (MPa)	Load at Yield (Offset 0.2 %) (N)
1	30.39911	0.03097	26.58150	956.93394

	Tensile stress at Break (Standard) (MPa)	Tensile stress at Preset Point (Tensile strain 2 %) (MPa)	Tensile strain at Maximum Load (mm/mm)	Tensile strain at Break (Standard) (mm/mm)
1	24.94346	25.55211	0.03097	0.07879
	Energy at Tensile Strength (J)	Modulus (Automatic) (MPa)		
1	1.29643	1601.53924		

Key Observations:

Essentially, while both specimen are labelled “1” , they show notable difference in their mechanical properties. Specimen 2 is stronger and more ductile, but less stiff than specimen 1 .This suggests potential variations in the material or testing conditions.

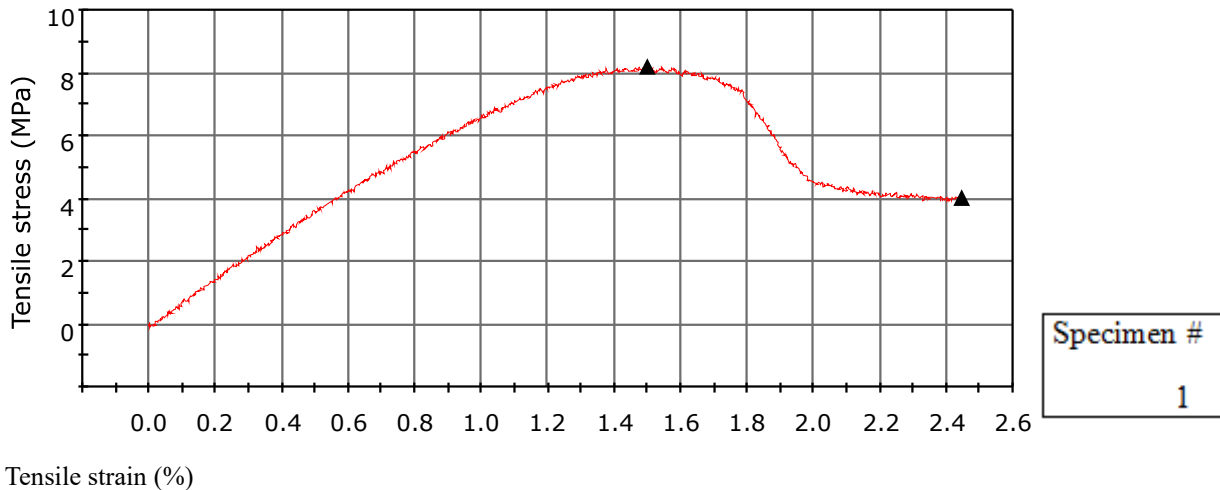
PLA(Polylactic Acid)

Polylactic acid exists in the form of polymers that are biodegradable polyesters obtained from lactic acid (LA) or 2-hydroxy propionic acid, typically obtained from agricultural crops such as maize, potatoes, and cassava through bacterial fermentation of carbohydrates. PLA is categorised as a biopolymer originated from chemically treated bio-based monomers, LA [8]. It exhibits a semi -crystalline morphology, with its degree of crystallinity influencing its mechanical properties, ranging from ductile to brittle behaviour depending on processing parameters and molecular weight distribution.

PLA is a flexible polymer that is fermented into a carboxylic acid and made from sustainable agricultural waste [9,10].

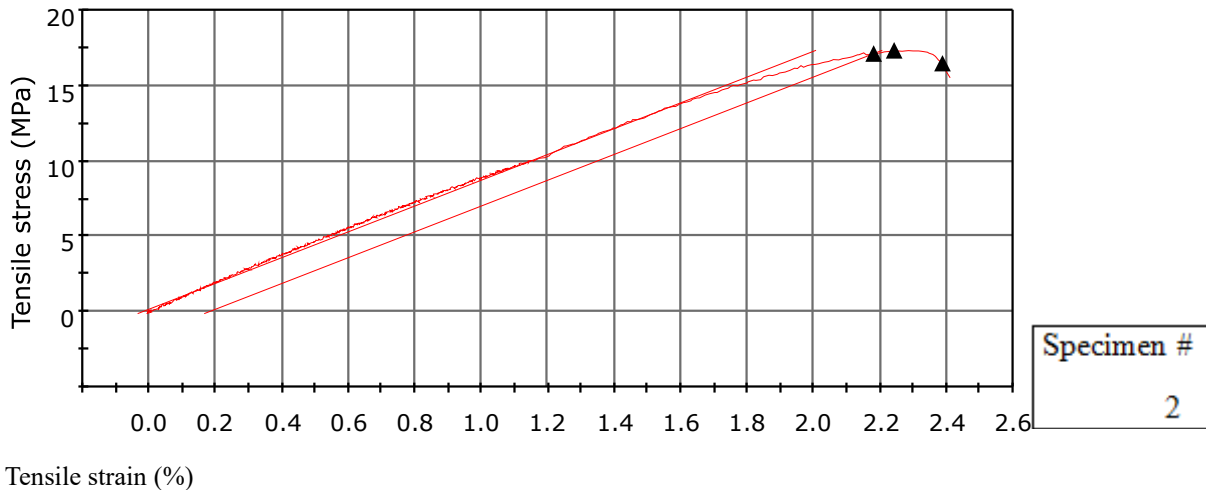
Organization	GITAM (Deemed to be University)
Laboratory	Material Testing Laboratory
Requester Details	
Requestor Organisation	
Type of Test	Tensile test
Material Grade	
Rate 1	1.00000 mm/min

Specimen 1



	Specimen Label		Width (mm)	Thickness (mm)		Length (mm)
1			9.00000	5.00000		40.00000
	Maximum Load (N)	Load at Break (Standard) (N)	Extension at Tensile Strength (mm)		Ultimate Tensile Strength (UTS) (MPa)	
1	368.76	181.76595	0.60199		8.19	
	Tensile stress at Tensile Strength (MPa)		Tensile strain at Tensile Strength (mm/mm)	Tensile stress at Yield (Offset 0.2 %) (MPa)	Load at Yield (Offset 0.2 %) (N)	
1	8.19469		0.01497	-----	-----	
	Tensile stress at Break (Standard) (MPa)		Tensile stress at Preset Point (Tensile strain 2 %) (MPa)	Tensile strain at Maximum Load (mm/mm)	Tensile strain at Break (Standard) (mm/mm)	
1	4.03924		4.50450	0.01497	0.02443	
	Energy at Tensile Strength (J)		Modulus (Automatic) (MPa)			
1	0.13020		762.18960			

Specimen 2



Tensile strain (%)

	Specimen Label	Width (mm)	Thickness (mm)	Length (mm)
1		9.00000	5.00000	40.00000
	Maximum Load (N)	Load at Break (Standard) (N)	Extension at Tensile Strength (mm)	Ultimate Tensile Strength (UTS) (MPa)
1	779.93	740.83628	0.90888	17.33

	Tensile stress at Tensile Strength (MPa)	Tensile strain at Tensile Strength (mm/mm)	Tensile stress at Yield (Offset 0.2 %) (MPa)	Load at Yield (Offset 0.2 %) (N)
1	17.33169	0.02239	17.10272	769.62243

	Tensile stress at Break (Standard) (MPa)	Tensile stress at Preset Point (Tensile strain 2 %) (MPa)	Tensile strain at Maximum Load (mm/mm)	Tensile strain at Break (Standard) (mm/mm)
1	16.46303	16.36435	0.02239	0.02384
	Energy at Tensile Strength (J)	Modulus (Automatic) (MPa)		
1	0.38780	945.85482		

Key Observations:

Specimen 2 demonstrates substantially better mechanical properties overall, being significantly stronger and slightly stiffer and more ductile than specimen 1. This points to variations in the material properties or testing conditions between the two tests.

Tensile test results can vary significantly depending on factors like:

Specific grade of material:

Both ABS and PLA have various grades with different formulations, affecting their properties.

Processing conditions:

How the material was manufactured can influence the results.

Specimen preparation:

The shape and dimensions of the test specimen, as well as surface finish, can impact the results.

Testing environment:

Temperature and humidity during the test can play a role.

Specimens (PLA-Lower Values):

This specimen exhibits lower strength, ductility, and stiffness. This could be indicative of a material with lower overall mechanical properties, such as some grade of PLA.

Specimen (ABS-higher Values):

This specimen demonstrates higher strength, ductility, and stiffness. This could suggest a material with better mechanical properties, potentially some grades of ABS.

II. CONCLUSIONS

The investigation encompassed a comprehensive analysis of the fused deposition modelling (FDM) process, encompassing an in-depth examination of the induction phase, process chain dynamics, and critical process parameters. This meticulous approach facilitated the fabrication of tensile test specimens composed of both acrylonitrile butadiene styrene (ABS) and polylactic acid (PLA) materials. Subsequent tensile testing revealed a notable disparity in mechanical properties between the two materials.

Specifically, the ABS specimens exhibited superior durability, ductility and strength compared to their PLA counterparts. This observation suggests that ABS possesses a higher resistance to deformation and fracture under tensile stress, indicating its potential suitability for applications demanding robust mechanical performance. Conversely, PLA demonstrated a lower resistance to tensile forces, suggesting a propensity for yielding or fracturing at lower stress levels.

REFERENCES

1. Rapid Prototyping-Application in Various Field of Engineering and Technology. Yogesh Mahendra Borole [1]
2. Process Parameter Optimization for FDM 3D Printer. Yash Magdum, Divyansh Pandey, Akash Bankar, Shantanu Harshe, Vasudev Parab, Mr. Mahesh Shivaji Kadam.[2]
3. A Comprehensive Review on the Optimization of the Fused Deposition Modelling Process Parameter for Better Tensile Strength of PLA-Printed parts.[3]
4. Investigating the influence of 3d printing parameters on the mechanical characteristics of FDM fabricated (PLA/Cu) composite material. Mohamed Hamoud, Abou Bakr Elshalakany, Mohammed Gamil, Hussien Mohamed.[4]
5. A shot review on 3D printing methods, process parameter and materials. M. Manoj Prabhakara, A.K. Saravananb, A. Haider Leninc, I. Jerin lenod, K. Mayandia, P.Sethu Ramalingam.[5]
6. ASTM D638-14; Standard Test Method for Tensile Properties of Plastics. American Society for Testing and Materials: West Conshohocken, PA, USA, 2014.
7. Effect of the Process Parameters on the Mechanical Properties of 3D-Printed Specimens Fabricated by Material Extrusion 3D Printing. Anodoni Molina, Julio Acosta-Sullcahuaman.
8. Kandemir, N.; Yemencioğlu, A.; Mecitoglu, C., Elmaci, Z.S.; Arslanoglu, A.; Goksungur, Y.; Baysal, T. Production of antimicrobial films by incorporation of partially purified lysozyme into biodegradable films of crude exopolysaccharides obtained from *Aureobasidium pullulans* fermentation. Food Technol. Biotechnol. 2005, 45, 343-350
9. Drumright, R.E.; Gruber, P.R.; Henton, D.E.; Polylactic acid technology. Adv. Mater. 2000, 12, 1841-1846.
10. Nurazzi, N.M.; Harussani, M.M.; Zulaikha, N.D.S.; Norhana, A.H.; Syakir, M.I.; Norli, A. Composites based on conductive polymer with carbon nanotubes in DMMP gas sensors-AN overview, Polimeri 2021, 66, 85-97



INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 9940 572 462  6381 907 438  ijirset@gmail.com



www.ijirset.com

Scan to save the contact details