

# Mechanical behaviour of the post processed 3D printed PLA parts using polar and non-polar solvents

ORIGINAL PAPER Published: 18 July 2023

Volume 81, pages 4257–4274, (2024) Cite this article



Polymer Bulletin



Aims and scope

Submit manuscript

Nagarjun Jayakumar , Hariharan Arumugam & Anto Dilip Albert Selvaraj 326 Accesses  1 Citation [Explore all metrics](#) →

## Abstract

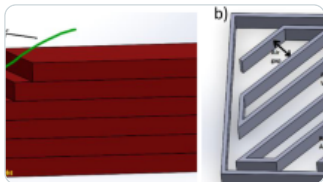
FDM, being the most popular AM technology, has a wide user base across the globe. The process makes use of a layer-by-layer approach, causing a staircase effect on the material's printed surface. Though it affects several mechanical properties, its effect on surface integrity is highly detrimental and needs to be addressed. Chemical vapour dip and immersion techniques can provide a rapid solution using solvents. The solvents employed in the current study were the polar solvents- acetone and ethyl acetate, the mid-polar solvent- tetrahydrofuran (THF), and the non-polar solvents- chloroform and dichloromethane (DCM). The superior surface finish obtained during the post processing of 3D printed parts was having mean roughness value ( $R_a$ ) of  $0.67 \mu\text{m}$ , originally  $11.42 \mu\text{m}$ . It was obtained when experimentation was carried out with the chemical vapour technique using THF. The optimum surface finish was readily achieved with mid- and non-polar solvents, whereas the polar solvents were slow to react with the surface of the PLA. A number of variables, including the solvent's polarity, boiling point, vapour pressure, and water miscibility, have an impact on the final surface's appearance and strength. During vapour treatment, the tensile strength of the 3D printed parts got reduced between 11.6% (THF) to 43.78% (DCM). On the other hand, the chemical immersion technique has a even more impact on the material's strength and hardness. It reduces hardness to the maximum of 44.41% (THF), whereas the vapour evaporation technique reduces hardness by only up to 14.64% (chloroform).

 This is a preview of subscription content, [log in via an institution](#)  to check access.

**Access this article**[Log in via an institution](#)**Buy article PDF 39,95 €**

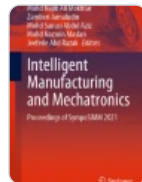
Price includes VAT (India)

Instant access to the full article PDF.

Rent this article via [DeepDyve](#) [Institutional subscriptions](#) →**Similar content being viewed by others**

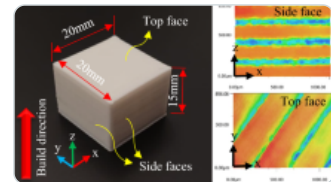
**Surface finish enhancement in fused deposition modeling of PLA using chloroform: a comprehensive characterization...**

Article | 12 May 2024



**Influence of Humidity on the Tensile Strength of 3D Printed PLA Filament**

Chapter | © 2022



**Effect of printing parameters and post-process on surface roughness and dimensional deviation of PLA parts fabricated by extrusion-...**

Article | 16 March 2022

**References**

1. Palanisamy C, Raman R, Dhanraj PK (2022) Additive manufacturing: a review on mechanical properties of polyjet and FDM printed parts. Polym Bull 79(9):7065–7116  
[Article](#) [CAS](#) [Google Scholar](#)
2. Mishra V, Negi S, Kar S (2023) FDM-based additive manufacturing of recycled thermoplastics and associated composites. J Mater Cycles Waste Manag 66:1–27  
[Google Scholar](#)
3. Samal BB, Jena A, Varshney SK, Kumar CS (2023) 4D printing: an experimental case study on processing of shape memory polymer by FDM/FFF for nature inspired structures. In: Advances in additive manufacturing artificial intelligence, nature-inspired, and biomanufacturing. Elsevier, pp 361–377

4. Taib N-AAB et al (2023) A review on poly lactic acid (PLA) as a biodegradable polymer. *Polym Bull* 80(2):1179–1213

[Article](#) [CAS](#) [Google Scholar](#)

5. Palaniappan M, Tirlangi S, Mohamed MJS, Moorthy RMS, Valeti SV, Boopathi S (2023) Fused deposition modelling of polylactic acid (PLA)-based polymer composites: a case study. In: Development, properties, and industrial applications of 3D printed polymer composites: IGI Global, pp 66–85

6. Nagarjun J, Manimaran S, Krishnaprakash M (2021) Additive manufacturing of nylon parts and implication study on change in infill densities and structures. In: Palanikumar K, Natarajan E, Sengottuvelu R, Davim JP (eds) *Futuristic trends in intelligent manufacturing: optimization and intelligence in manufacturing*. Springer, Cham, pp 245–260

[Chapter](#) [Google Scholar](#)

7. Durgun I, Ertan R (2014) Experimental investigation of FDM process for improvement of mechanical properties and production cost. *Rapid Prototyp J* 6:66

[Google Scholar](#)

8. Dey A, Yodo N (2019) A systematic survey of FDM process parameter optimization and their influence on part characteristics. *J Manuf Mater Process* 3(3):64

[CAS](#) [Google Scholar](#)

9. Valerga AP, Batista M, Fernandez-Vidal SR, Gamez AJ (2019) Impact of chemical post-processing in fused deposition modelling (FDM) on polylactic acid (PLA) surface quality and structure. *Polymers* 11(3):566

[Article](#) [CAS](#) [PubMed](#) [PubMed Central](#) [Google Scholar](#)

10. Lavecchia F, Guerra MG, Galantucci LM (2022) Chemical vapor treatment to improve surface finish of 3D printed polylactic acid (PLA) parts realized by fused filament fabrication. *Prog Addit Manuf* 7(1):65–75

[Article](#) [Google Scholar](#)

11. Verma VK, Kamble SS, Ganapathy L, Tarei PK (2023) Overcoming the post-processing barriers for 3D-printed medical models. *Rapid Prototyp J* 29(1):33–49

[Article](#) [Google Scholar](#)

12. Garg A, Bhattacharya A, Batish A (2017) Chemical vapor treatment of ABS parts built by FDM: analysis of surface finish and mechanical strength. *Int J Adv Manuf Technol* 89(5):2175–2191

[Article](#) [Google Scholar](#)

13. Solomon IJ, Sevvell P, Gunasekaran J (2021) A review on the various processing parameters in FDM. *Mater Today Proc* 37:509–514

[Article](#) [CAS](#) [Google Scholar](#)

14. Verma VK, Kamble SS, Ganapathy L, Tarei PK (2022) Overcoming the post-processing barriers for 3D-printed medical models. *Rapid Prototyp J* 6:66

[Google Scholar](#)

15. Panda SS, Chabra R, Kapil S, Patel V (2020) Chemical vapour treatment for enhancing the surface finish of PLA object produced by fused deposition method using the Taguchi optimization method. *SN Appl Sci* 2(5):916

[Article](#) [CAS](#) [Google Scholar](#)

16. Grasso M, Azzouz L, Ruiz-Hincapie P, Zarrelli M, Ren G (2018) Effect of temperature on the mechanical properties of 3D-printed PLA tensile specimens. *Rapid Prototyp J* 24(8):1337–1346

[Article](#) [Google Scholar](#)

17. Singh R, Singh S, Singh IP, Fabbrocino F, Fraternali F (2017) Investigation for surface finish improvement of FDM parts by vapor smoothing process. *Compos Part B Eng* 111:228–234

[Article](#) [CAS](#) [Google Scholar](#)

18. Baran EH, Erbil HY (2022) Surface modification of 3D printed PLA objects by fused deposition modeling: a review. *Colloids Interfaces* 3(2):66. <https://doi.org/10.3390/colloids3020043>

[Article](#) [CAS](#) [Google Scholar](#)

19. Nguyen TK, Lee B-K (2018) Post-processing of FDM parts to improve surface and thermal properties. *Rapid Prototyp J* 6:66

[Google Scholar](#)

20. Mishra P, Sood S, Pandit M, Khanna P (2021) Additive manufacturing: post processing methods and challenges. *Adv Eng Forum* 39:21–42

21. Lluch-Cerezo J, Meseguer MD, García-Manrique JA, Benavente R (2022) Influence of thermal annealing temperatures on powder mould effectiveness to avoid deformations in ABS and PLA 3D-printed parts. *Polymers* 14(13):2607

[Article](#) [CAS](#) [PubMed](#) [PubMed Central](#) [Google Scholar](#)

22. Kuczko W, Górski F, Wichniarek R, Buń P (2017) Influence of post-processing on the accuracy of fdm products. *Adv Sci Technol Res J* 11(2):172–179

[Article](#) [Google Scholar](#)

23. Chen Y-F, Wang Y-H, Tsai J-C (2019) Enhancement of surface reflectivity of fused deposition modeling parts by post-processing. *Opt Commun* 430:479–485

[Article](#) [CAS](#) [Google Scholar](#)

24. Totaro G, Sisti L, Fiorini M, Lancellotti I, Andreola FN, Saccani A (2019) Formulation of green particulate composites from PLA and PBS matrix and wastes deriving from the coffee production. *J Polym Environ* 27(7):1488–1496

[Article](#) [CAS](#) [Google Scholar](#)

25. Mansingh BB et al (2023) Characterization and performance of additive manufactured novel bio-waste polylactic acid eco-friendly composites. *J Polym Environ* 6:66

[Google Scholar](#)

26. More N, Avhad M, Utekar S, More A (2023) Polylactic acid (PLA) membrane—significance, synthesis, and applications: a review. *Polym Bull* 80(2):1117–1153

[Article](#) [CAS](#) [Google Scholar](#)

27. Rajeshkumar G et al (2021) Environment friendly, renewable and sustainable poly lactic acid (PLA) based natural fiber reinforced composites—a comprehensive review. *J Clean Prod* 310:127483

[Article](#) [CAS](#) [Google Scholar](#)

28. Song X, He W, Han X, Qin H (2020) Fused deposition modeling of poly (lactic acid)/nutshells composite filaments: effect of alkali treatment. *J Polym Environ* 28(12):3139–3152

[Article](#) [CAS](#) [Google Scholar](#)

29. Donate R, Monzón M, Alemán-Domínguez M. Elena (2020) Additive manufacturing of PLA-based scaffolds intended for bone regeneration and strategies to improve their biological properties. *e-Polymers* 20(1):571–599  
[Article](#) [CAS](#) [Google Scholar](#)
30. Ghilan A, Chiriac AP, Nita LE, Rusu AG, Neamtu I, Chiriac VM (2020) Trends in 3D printing processes for biomedical field: opportunities and challenges. *J Polym Environ* 28(5):1345–1367  
[Article](#) [CAS](#) [PubMed](#) [PubMed Central](#) [Google Scholar](#)
31. Byun Y, Whiteside S, Thomas R, Dharman M, Hughes J, Kim YT (2012) The effect of solvent mixture on the properties of solvent cast polylactic acid (PLA) film. *J Appl Polym Sci* 124(5):3577–3582  
[Article](#) [CAS](#) [Google Scholar](#)
32. Casasola R, Thomas NL, Trybala A, Georgiadou S (2014) Electrospun poly lactic acid (PLA) fibres: Effect of different solvent systems on fibre morphology and diameter. *Polymer* 55(18):4728–4737  
[Article](#) [CAS](#) [Google Scholar](#)
33. Verónica LA, Amparo M, Gallardo M, Maria LGM (2021) Influence of Solvent and Substrate on Hydrophobicity of PLA Films. *Polymers* 13(24):4289  
[Article](#) [Google Scholar](#)
34. Sato S, Gondo D, Wada T, Kanehashi S, Nagai K (2013) Effects of various liquid organic solvents on solvent-induced crystallization of amorphous poly (lactic acid) film. *J Appl Polym Sci* 129(3):1607–1617  
[Article](#) [CAS](#) [Google Scholar](#)
35. Özdemir B, Nofar M (2021) Effect of solvent type on the dispersion quality of spray- and freeze-dried CNCs in PLA through rheological analysis. *Carbohydr Polym* 268:118243  
[Article](#) [Google Scholar](#)
36. Pelit H, Budakçı M, Sönmez A, Burdurlu E (2015) Surface roughness and brightness of scots pine (*Pinus sylvestris*) applied with water-based varnish after densification and heat treatment. *J Wood Sci* 61(6):586–594  
[Article](#) [Google Scholar](#)
37. Dickson AN, Barry JN, McDonnell KA, Dowling DP (2017) Fabrication of continuous carbon, glass and Kevlar fibre reinforced polymer composites using additive manufacturing. *Addit Manuf* 16:146–152

## Funding

---

The authors received no financial support for the research, authorship, and/or publication of this article.

## Author information

---

### Authors and Affiliations

Department of Mechanical Engineering, PSG Institute of Technology and Applied Research, Coimbatore, Tamil Nadu, India

Nagarjun Jayakumar & Anto Dilip Albert Selvaraj

Polymer Engineering Laboratory, PSG Institute of Technology and Applied Research, Coimbatore, Tamil Nadu, India

Hariharan Arumugam

### Contributions

JN contributed to conceptualization, experimentation, methodology, visualization, investigation, data curation, original drafting, writing–reviewing and editing. AH contributed to methodology, validation, proof reading, project administration, supervision. AAD contributed to experimentation, validation, project administration.

### Corresponding author

Correspondence to [Nagarjun Jayakumar](#).

## Ethics declarations

---

### Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

## Additional information

---

### Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

## Rights and permissions

---

Springer Nature or its licensor (e.g. a society or other partner) holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.

[Reprints and permissions](#)

## About this article

---

### Cite this article

Jayakumar, N., Arumugam, H. & Albert Selvaraj, A.D. Mechanical behaviour of the post processed 3D printed PLA parts using polar and non-polar solvents. *Polym. Bull.* **81**, 4257–4274 (2024). <https://doi.org/10.1007/s00289-023-04900-8>

Received

03 March 2023

Revised

22 June 2023

Accepted

28 June 2023

Published

18 July 2023

Issue Date

April 2024

DOI

<https://doi.org/10.1007/s00289-023-04900-8>

### Keywords

[Post processing](#)

[Chemical vapour technique](#)

[FDM](#)

[Solvents](#)

[Polarity](#)