Journal of Materials, Processing and Design (2025)
Clausius Scientific Press, Canada

DOI: 10.23977/jmpd.2025.090117
ISSN 2516-0923 Vol. 9 Num. 1

A Review of Mechanical Properties of 3D Printing of Continuous Fiber /PLA Composites

Chunlei Luo[1,2,a], Xiaohui Song[2,*], Minggan Wang[3,b], Lu Chen[1,c], Xin Yang[4,d], Yinyu Xiao[2,e], Shijie Wei[2,f], Jinqiu Li[2,g]

[1]School of Mechanical and Electrical Engineering, Guilin University of Electronic Technology, Guilin, Guangxi, China
[2]Guangxi Key Laboratory of Special Equipment and Control University Engineering Research Center of Non-standard Intelligent Equipment and Process Control Technology, Guilin University of Aerospace Technology, Guilin, Guangxi, China
[3] Engineering Department, Cooler Master (Huizhou) Co, Ltd, Huizhou, Guangdong, China
[4]College of Mechanical and Control Engineering, Guilin University of Technology, Guilin, Guangxi, China
[a]523231044@qq.com, [b]1724979415@qq.com, [c]cl3439646357@qq.com, [d]2919492663@qq.com, [e]1584021879@qq.com, [f]1052452887@qq.com, [g]2151146836@qq.com
**Corresponding author: songxiaohui2010@163.com*

Keywords: 3D printing of continuous fiber; polylactic acid; mechanical properties; processing parameters; impregnation; route planning

Abstract: Continuous fiber reinforced polymer composites (CFRPCs) have been widely used in various fields due to their excellent mechanical properties. Polylactic acid (PLA) is a new biodegradable material with a wide range of applications in many aspects due to its good properties, and in addition PLA is one of the materials commonly used for 3D printing of continuous fiber. This review introduced the mechanical properties of the continuous fiber reinforced PLA for 3D printing, including tensile, impact, and flexural strength; and detailed the effects of continuous fiber type, processing parameters of 3D printing, impregnation and route planning. Finally, an outlook on the future research of 3D printing of continuous fiber technology and PLA material properties was made.

1. Introduction

In recent years, 3D printing technology has developed rapidly, and applied in various industries dramatically. 3D printing, also known as additive manufacturing (AM), is a technological method to create complex structures by a layer-by-layer addition of materials. AM offers numerous benefits such as a short design cycles, high material utilization and suitable for manufacturing complex structures[1]. Therefore, AM has been used in a wide range of applications such as aerospace[2], automobiles[3], medical device[4], construction[5], clothing[6] and so on. Current AM processes include fused deposition modeling (FDM), stereo lithography(SL), selective laser sintering (SLS), and laminated object manufacturing (LOM)[7]. FDM is the most widely used 3D printing process due to its low cost and simplicity of operation[8]. The operational principle involves melting the polymer matrix in a melting device and then being extruded from the nozzle, following by a predetermined path of layer-by-layer deposition, the printed material eventually cools on the print platform[9].

Brenken et al.[10] summarized the mechanical properties of 3D printing short fiber reinforced composites, and concluded that the tensile strength and modulus was usually 30~70 MPa and 2~15GPa, respectively. Although short fibers improved the mechanical properties of pure polymers, the improvement was much less than that of continuous fibers[11]. Compared to other 3D printing, 3D printing of continuous fiber is unique to FDM, and was not found in other AM technologies[12]. 3D printing of CFRPCs technology had become a current research hotspot, which is also challenges, for high-performance 3D printing of CFRPCs and wide range of applications in all walks of life.

Currently, the main polymers used for 3D printing were polylactic acid (PLA), polyamide (PA), acrylonitrile butadiene styrene (ABS), polyphenylene sulfide (PPS), polycarbonate (PC), and polyether ether ketone (PEEK). Among them, PLA is a polyhydroxy acid, which can be completely decomposed into carbon dioxide and water under certain conditions,and possesses good physical properties, biocompatibility and degradability[13,14]. Nowadays, PLA has become one of the popular materials for 3D printing of continuous fiber. However, shortcomings of PLA, such as high brittleness, poor thermal stability, slow degradation rate, and high price have limited its application in 3D printing of continuous fiber [15]. Therefore, it is necessary to improve the performance of PLA in order to expand its application. In recent years, many scholars have made great contributions in enhancing the performance of PLA.

In order to detailed the above introduction, this paper introduced the basic properties of PLA, reviewed literatures related to the properties of 3D printing of continuous fiber reinforced PLA in recent years, and described the mechanical properties of PLA, including tensile, impact, and flexural strength. Subsequently, the effects of continuous fiber type, processing parameters of 3D printing, impregnation and route planning were discussed. Finally, an outlook on the future research of 3D printing of continuous fiber technology and PLA material properties were made.

2. Mechanical properties of 3D printing of continuous fiber/PLA composites

Differences in fiber types and processing methods would make different enhancement effects on PLA properties[16] At present, continuous fiber used to reinforce polymers mainly carbon fiber, glass fiber, Kevlar fiber and natural fiber[17]. The properties of continuous fiber reinforced PLA are shown in Table 1.

Table 1. Mechanical Properties of Continuous Fiber Reinforced PLA.

Continuous fibers	Fiber content (%)	Tensile strength (MPa)	Tensile modulus (GPa)	Flexural strength (MPa)	Flexural modulus (GPa)	Impact strength (KJ/m^2)	References
Carbon	18.2vol%	245.4	27.93	-	10.63	-	18
	28.2vol%	61	8.0	152	13.0	-	19
	8.9vol%	256	20.6	265	13.3	38.7	20
	6.6vol%	185.2(±24.6)	19.5(±2.08)	133	5.93	-	21
Glass	5.21/6.24vol%	171.66	-	148	-	-	22
	45wt%	240.66	-	325.64	-	168.32	23

		94.97	-	113.8	-	-	24
Kevlar	3.46vol%	47.4 (+1.2)	-	69.8(±5.6)	2.37(±0.535)	-	25
	4.74vol%	71.5 (+3.3)	-	77.5(±2.9)	2.23(±0.295)	-	
	20.53vol%	84.1 (+7.3)	-	84.9(±9.9)	2.68(±1.03)	-	
Kevlar	6.54vol%	104.64	-	-	-	-	26
Aramid	8.6vol%	203	9.340	-	-	-	27
Sisal	40wt%	-	-	187.76	9.66	20.2	28
	60wt%	173	6.7241	-	-	-	
Flax	25vol%	159	8.3	136	11.5	70.65	29

2.1. Continuous carbon fiber (CCF)

Maqsood et al.[18] printed continuous carbon fiber (CCF) reinforced PLA, and found that the tensile strength of the composite was 245.4 MPa and higher than PLA by 460%. Heidari-Rarani et al.[19] prepared CCF reinforced PLA composites using FDM. The experimental results showed that the tensile and flexural strengths of CCF/PLA composites were increased by 35% and 108%, respectively, when compared to pure PLA. Tian et al.[20] investigated the mechanical properties of recycled and remanufactured CCF/PLA composites, and the tensile and flexural strengths of the CCF reinforced 3D printed samples were approximately 256 MPa and 265 MPa, respectively, and the tensile strength of these was approximately four times that of pure PLA. Matsuzaki et al.[21]prepared CCF/PLA composites using FDM. The flexural strength and modulus of the composites were 133 MPa and 5.93 GPa, respectively, for CCF volume fraction of 6.6%.

2.2. Continuous glass fiber (CGF)

Wang et al.[22] prepared CGF reinforced PLA composites based on FDM, when the fiber volume fractions were 5.21% and 6.24%, respectively, the samples had the maximum tensile and flexural strengths, which were 400% and 204% higher than pure PLA samples, respectively. Yu et al.[23] prepared CGF reinforced PLA composites. When the fiber volume fraction was increased to 45%, the mechanical properties of CGF/PLA prints reached the maximum value, with tensile, flexural, and impact strengths of 240.66 MPa, 325.64 MPa, and 168.32 kJ/m2, respectively. Wang et al. et al.[24] prepared CGF reinforced PLA composites, and found that the tensile strength of the printed parts was 94.97 MPa, and the bending strength was 113.8 MPa.

2.3. Continuous kevlar fiber (CKF)

Cersoli et al.[25] prepared three different volume fractions of CKF reinforced PLA composites and conducted mechanical experiments, concluded that volume fraction of 20% CKF enhanced the mechanical properties of composites greatly, shown in Fig. 1. Tey et al.[26] used PLA as the matrix and CKF as the core material to fabricate a co-extruded reinforced plastic part, and obtained significant enhancement in tensile strength, Young's modulus, and tensile strain. Bettini et al.[27] investigated aramid fiber reinforced PLA composites with fiber volume fraction of 8.6%, and demonstrated that the tensile strength of the composites was much enhanced than that of pure PLA.

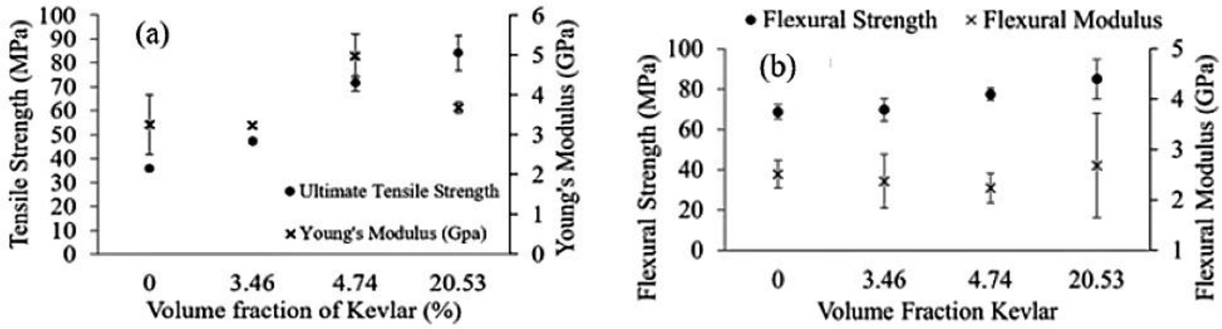

Fig.1. Mechanical properties of CCF/PLA composites: (a) tensile strength; (b) flexural strength.[25]

2.4. Continuous natural fiber (CNF)

Continuous natural fibers possessed excellent flexibility and mechanical properties, which have been used as reinforcing materials for PLA. Zhu[28] prepared continuous sisal fiber reinforced PLA composites by using continuous fiber wrap molding machine, and found that when the content of continuous sisal fibers increased to 40wt% and 60wt%, the flexural and tensile strengths reached to peak values, respectively. Long et al.[29] used continuous flax fibers to reinforce PLA, and found that the impact strength of 3D printed composites were significantly improved by 17.5% at a fiber volume fraction of 25%,when compared to the PLA samples. Hinchcliffe et al.[30] prepared flax fiber reinforced BM/PLA-CM composites, and found that the tensile strength and flexural of the composites was increased by 116% and 12%,respectively, than pure PLA.

3. Effects of processing parameters on properties in PLA

The processing parameters of 3D printing also affect the performance of PLA. Inappropriate processing parameters could affect the mechanical properties, interfacial bonding ability, and internal porosity of the composite samples[31]. This section focuses on the effects of printing layer height, printing temperature and speed[32], the mechanical properties of the composites were improved.

3.1. Printing layer height

The print layer height has a large impact on the quality of 3D printed product. Generally, the smaller the layer height, the higher the printing quality. However, too small layer height would slow down the printing speed, extend printing time, and increase material consumption. Wang et al.[22] investigated the mechanical properties of CGF reinforced PLA composites, and found that no matter the samples are with 3 or 5 fiber layers, the highest tensile strength at the same fiber volume fraction with a print layer height of 0.2 mm. As shown in Fig. 2. Hu[33] prepared CCF/PLA composites to investigate the effects of printing layer height on the flexural properties. The test results showed that the CCF/PLA composites had the best flexural properties when the printing layer height was 0.8 mm. The flexural strength and modulus reached to 127.09 MPa and 5.55 GPa, which were 82.1% and 144.4% higher than that of the pure PLA, respectively. Vinoth et al.[34]prepared CCF/PLA composites, and the printed rectangular and hexagonal patterns showed better tensile and bending properties at a printed layer height of 0.64 mm than other layer height. Akhoundi et al.[35] prepared CGF/PLA composites using glass fiber yarns, and found that the tensile modulus and strength reached to 478 MPa and 29.4 GPa, respectively, at a print layer height of 0.22 mm.

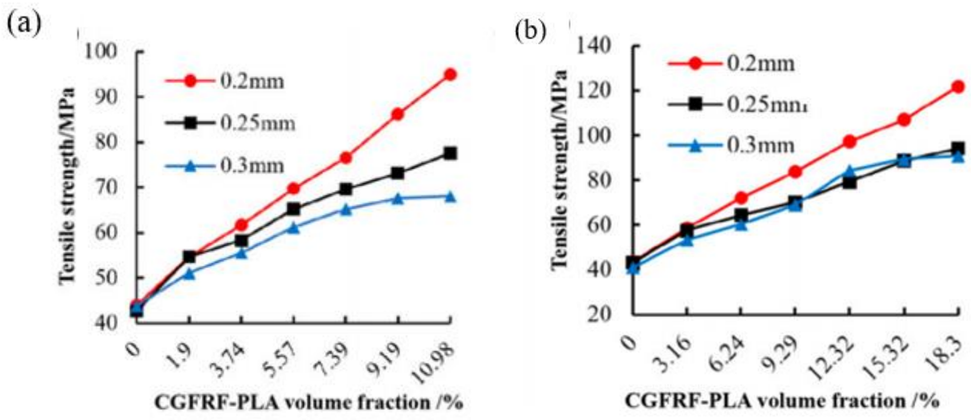

Fig.2. Tensile comparison of different printing layer heights: (a) sample of the 3 layers, (b) sample of the 5 layers.[22]

3.2. Printing temperature

Temperature is also important for the performance of the 3D printed product. When the printing temperature then affects the strength of the sample bonding interface. Cui et al.[36] used CGF to reinforced PLA and investigated the effects of printing temperature and speed on the mechanical properties of the composites. The experiment showed that when the printing temperature were 230 ℃, the CGF/PLA composites possessed the optimum mechanical properties, with the bending, tensile, impact, and interlaminar shear strength of 301.21 MPa, 213.58 MPa, 148.26 KJ/m^2, and 11.925 MPa. Zhang et al.[37] studied the effects of the printing parameters on the mechanical properties of CCF composites, and found that the printing temperature of 200 ℃ were the best choice for the mechanical properties of printed samples. Tian et al.[38] investigated the effect of printing temperatures on the mechanical properties of 3D printing CCF/PLA composites, and during the fracture strength measurements, the fibers were stripped from the matrix at 180 ℃, resulted in the failure of load transfer to the fiber bundles (Fig.3a), and so the flexural strength were only 110 MPa. With the increasing of the printing temperature, the interfacial properties improved significantly (Fig.3b), and the flexural strength at 240 ℃ reached to 155 MPa. Suteja et al.[39] discovered that continuous pineapple leaf fiber reinforced PLA composites could be effectively 3D printed only when the printing temperature was between 200 and 210 ℃, while maintaining excellent tensile properties.

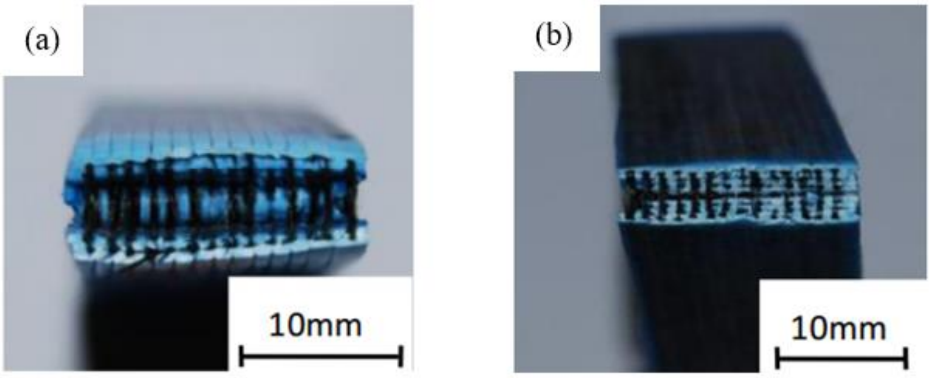

Fig.3. Fracture patterns of fractured cross section of CFR PLA composites:(a) 180℃, (b) 240℃.[38]

3.3. Printing speed

Print speed affects the structural stability of the printed part. When the printing speed is too fast, the continuous fiber material is prone to fracture, and when the printing speed is too slow, the printing efficiency will be reduced. Dou et al.[40] performed mechanical property tests of CCF/PLA composites and found that the printing speed affect the fiber-matrix bonding interface. At the printing speed of 50 mm/min, the highest tensile strength and stiffness of the specimens were found to be 200.43 MPa and 23.31 GPa, respectively. Lian et al.[41] investigated the effect of printing parameters on the mechanical properties of CCF-reinforced PLA composites , and found that the composites had the highest tensile strength and Young's modulus at a printing speed of 40 mm/s under the condition of 10 wt% fiber content. Instead, the mechanical properties became lower and lower when the printing speed increased. Hu et al.[42] investigated the effect of three different printing speeds on the mechanical properties of CCF/PLA composites, and found that at printing speed of 60 mm/min, the best bending performance was achieved, and the bending strength could reach 610.092 MPa.

4. Impregnation of continuous fiber

In the processing of continuous fiber reinforced thermoplastic materials, the impregnation process is a very critical step. Mainly impregnation process divide into in-situ impregnation and pre-impregnation. Fig. 4(a) shows the 3D printing process of in-situ impregnation method, which adopted single nozzle. After impregnation of the molten resin with continuous fibers in the melt chamber, the printing was carried out layer-by-layer by means of extrusion until finishing the composite products[43]. Figure 4(b) shows the 3D printing process of pre-impregnation method with dual nozzle. The prepreg filament and resin containing continuous fibers were melted and extruded in two printing nozzles, respectively[44].

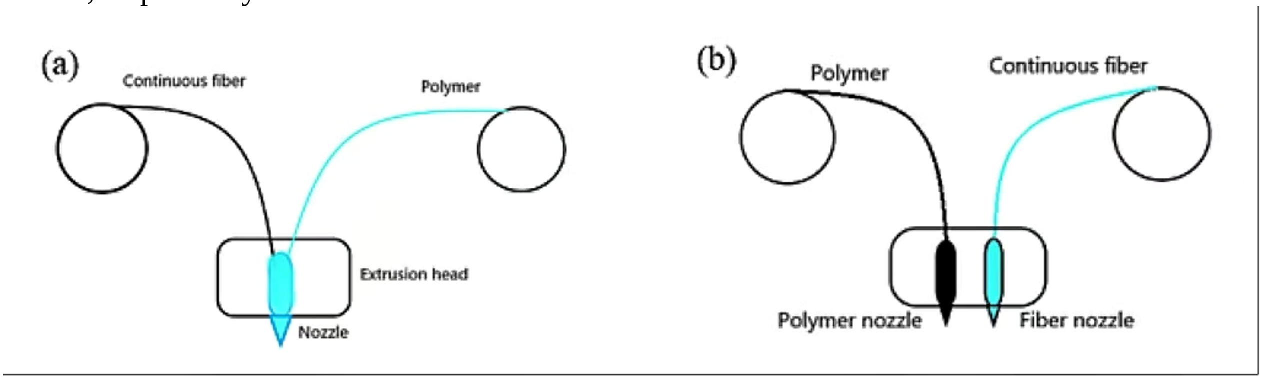

Fig.4. Schematic diagram of 3D printing process of continuous fiber thermoplastic composites, (a) single nozzle, (b) dual nozzles.

The impregnation processing can affect the combining quality between the matrix material and reinforcing fibers, the interlayer and interline quality, the pore size inside the printed part, and further affect the surface quality and mechanical properties of 3D printed samples[16]. Yang et al.[45] from Xi'an Jiaotong University used in-situ impregnation equipment to 3D printed of the CCF/PLA composites, and discovered that the fiber content, temperature, pressure, and other processing parameters had a significant effect on the properties of composites. Matsuzaki et al.[21] proposed a CCF thermoplastic composite molding process based on the FDM. They improved the printer nozzle, and allowed the CCF and PLA to enter into nozzle through two inlets. The impregnation processing was achieved inside the nozzle, following by extrusion. The 3D printed CCF/PLA composites exhibited 5 times increase in tensile modulus and 3.4 times increase in tensile strength, when compared to pure PLA samples. Wang et al.[46] developed a theoretical model to identify the impregnation procedure with different parameters. The experiment results showed that the effect of impregnation rate on tensile strength was in agreement with the theoretical predictions. The tensile strength was the maximum with 221.78 MPa at 33% impregnation rate. Increasing the impregnation percentage by 25% improved the tensile strength by 45%.

The continuous fiber impregnation processing of the aforementioned method mainly takes place inside the nozzle, where the impregnation time is relatively short, making it difficult to achieve sufficient impregnation of the continuous fibers. Hu et al.[42] proposed a new manufacturing method for continuous fiber pre-impregnation, using a single-screw extruder to prepare carbon fiber prepreg filaments prior to printing. However, this method did not allow the thermoplastic polymer to uniformly coat the reinforcing fibers, and results in non-uniform fiber filaments. Therefore, Chen et al.[47] prepared CGF/PLA composites using homemade pre-impregnation equipment and optimized the processing parameters of 3D printing. That studied the influence of nozzle diameter on the mechanical properties of the composites, and found that with a nozzle diameter of 1.2 mm, the maximum bending and tensile strength could reach to 313 MPa and 241 MPa, respectively. Le Duigou et al.[48] used a pre-impregnation process to impregnate PLA onto flax yarns, and found that the tensile strength of the composites was 5 times higher than that of pure PLA. Qiao et al.[49] improved the pre-impregnation of CCF reinforced PLA composites using ultrasound, and the tensile and flexural strengths of the composites were increased by 34% and 29%, respectively, compared with that of the untreated PLA.

5. Route planning of 3D printing of continuous fiber

Route planning of continuous fiber 3D printing process can also affect the mechanical properties and improving the printing efficiency. Tan et al.[50] developed an adjustable "Z" fill algorithm, and found that adjusting the fill angles for different fill regions reduced the number of jumps. Rajan et al.[51] adopted a scan fill method to reduce the number of scan line segments in the current printing layer's fill region, and reduced the number of path jumps and improved the printing efficiency. Zhou et al.[52] divided the contour of the 3D printing layer into different regions and then used spiral fill to reduce the computational complexity of printing path generation and improve the efficiency of printing software slicing. The verification found that the printing results of models 1 and 2 were consistent with the simulation results, proving the feasibility of this algorithm, as shown in Fig. 5. Yuan[53] divided the trajectory into fill paths, contour paths, and jump paths, and designed corresponding algorithms for each path to ensure the continuity of CCF in 3D printing, resulting in the reduction of idle travel distance and improving print accuracy. Wang et al.[54] proposed a novel load-dependent path planning (LPP) method has been proposed to generate printing path for CFRPs, which accurately follows the load transfer path of the parts and could provide higher mechanical properties. Huang et al.[55] used MATLAB software to improve FDM based adaptive layering algorithm, realized global adaptive layering, and found that the average maximum warpage of printed samples was reduced by 60.7%, and the printing efficiency was improved by about 3.93%.

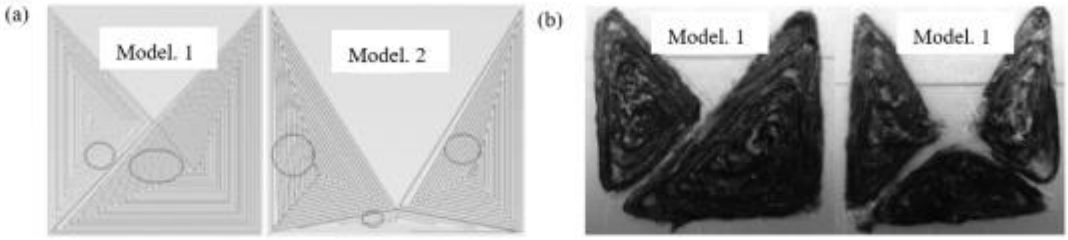

Fig.5. Improved simulation and printing results: (a) simulation, (b) Model Printing.[52]

6. Conclusions and outlook

This paper reviewed the research progress on the 3D printing of continuous fiber from the aspects of mechanical properties of continuous fiber reinforced PLA composites, processing parameters of 3D printing, impregnation of continuous fiber, and route planning of 3D printing, and summarized and prospected the future of the 3D printing of continuous fiber.

This review described the enhancement effect of different types of continuous fibers on the mechanical properties of PLA. These include CCF, CGF, CKF and CNF. The mechanical properties of these CFRPCs are closely related to the fiber, matrix, and interfacial properties. At present, there are still issues in 3D printed CFRPCs, such as low fiber volume content, low interfacial bond strength and high porosity. Therefore, improving the compatibility between the polymer matrix and the continuous fiber is the key to solve these issues.

Printing layer height, temperature and speed are the most direct printing parameters that affect the mechanical properties of CFRPCs. This paper did not discuss the effects of printing parameters such as extrusion flow rate and fiber layup direction on the mechanical properties of CFRPCs, and the existing papers did not contain a comprehensive study of the processing parameters. It is necessary to enhance mechanical properties of composites by designing comprehensive processing parameters of 3D printing in the future.

Impregnation of continuous fiber was usually adopted in-situ impregnation or pre-impregnation.The disadvantage of the former would lead to voids, uneven-distributed polymer, cracks due to the impregnation was not enough, while the disadvantage of the latter was that the prepreg filament material was fused to the matrix material, resulting in a reduced content of continuous fibers, which limited the mechanical properties of the composites. Therefore, improving the impregnation processing to enhance the continuous fiber content and impregnation time has become a focus of current research.

The path planning of 3D printing could improve the mechanical performance and printing efficiency of parts by optimizing algorithms. Therefore, in order to meet the requirements of different application fields, it is necessary to improve the efficiency and accuracy of path planning.

Acknowledgements

This paper was financially supported by the Institution of National Natural Science Foundations of China (52365043), Natural Science Foundations of Guangxi province (2023JJA160223, 2023JJA160056), Middle-aged and Young Teachers' Basic Ability Promotion Project of Guangxi (2020KY21012) and Guangxi Science and technology planning project (2023AB01248.

References

[1] Zhang H, Huang T, Jiang Q, et al. Recent progress of 3D printed continuous fiber reinforced polymer composites based on fused deposition modeling: a review. J Mater Sci.2021; 56: 12999-13022.

[2] Joshi SC and Sheikh AA. 3D printing in aerospace and its long-term sustainability. Virtual Phys Prototyping. 2015; 10: 175-185.

[3] Pei E, Eujin Pei D, Shen J, et al. Direct 3D printing of polymers onto textiles: experimental studies and applications. Rapid Prototyping J.2015; 21: 556-571.

[4] Revilla-Leon M and Ozcan M. Additive Manufacturing Technologies Used for Processing Polymers: Current Status and Potential Application in Prosthetic Dentistry. J Prosthodont.2019; 28: 146-158.

[5] Paolini A, Kollmannsberger S and Rank E. Additive manufacturing in construction: A review on processes, applications, and digital planning methods. Addit Manuf .2019; 30: 100894.

[6] Jasminka K and Josipa Š. 3D print additive technology as a form of textile material substitute in clothing design–interdisciplinary approach in designing corsets and fashion accessories. Ind Textila .2018; 69: 190-196.

[7] Ligon SC, Liska R, Stampfl J, et al. Polymers for 3D Printing and Customized Additive Manufacturing. Chem

Rev.2017; 117: 10212-10290.
[8] Wickramasinghe S, Do T and Tran P. FDM-Based 3D Printing of Polymer and Associated Composite: A Review on Mechanical Properties, Defects and Treatments. Polymers (Basel).2020; 12: 1529.
[9] Vyavahare S, Teraiya S, Panghal D, et al. Fused deposition modelling: a review. Rapid Prototyping J.2020; 26: 176-201.
[10] Brenken B, Barocio E, Favaloro A, et al. Fused filament fabrication of fiber-reinforced polymers: A review. Addit Manuf .2018; 21: 1-16.
[11] Zhuo P, Li S, Ashcroft IA, et al. Material extrusion additive manufacturing of continuous fibre reinforced polymer matrix composites: A review and outlook. Compos Part B Eng.2021; 224: 109143.
[12] Ruibing Q, Aiyiti W and Yong T. Recent progress on FDM 3D printing. Manuf Technol Mach Tool.2020: 40-44(in Chinese).
[13] Haoqin Z, Wenchao Y, Yueling C, et al. Research Progress on Modification of Transparent and Heat-resistant Polylactic Acid Materials. Eng Plast Appl. 2021; 49: 164-170(in Chinese).
[14] Ingrao C, Tricase C, Cholewa-Wojcik A, et al. Polylactic acid trays for fresh-food packaging: A Carbon Footprint assessment. Sci Total Environ.2015; 537: 385-398.
[15] Chengcheng W, Mengqian L, Wen L, et al. Research Progress on 3D Printing Polylactic Acid and Its Composites. Plast Sci Technol.2016; 44: 89-91(in Chinese).
[16] Lintao Y, Xiangfan N and Chuyang. L. Progress in 3D Printing of Continuous Fiber Reinforced Composites Based on Fused Deposition Modeling. Aero Weapon.2022: 1-14(in Chinese).
[17] Zhi W, Ning Y and Jing L. Research Progress in Fused Deposition Modeling of Fiber-reinforced Composites. Mater Rep.2021; 35: 15197-15204(in Chinese).
[18] Maqsood N and Rimašauskas M. Characterization of carbon fiber reinforced PLA composites manufactured by fused deposition modeling. Composites Part C: Open Access.2021; 4: 100112.
[19] Heidari-Rarani M, Rafiee-Afarani M and Zahedi AM. Mechanical characterization of FDM 3D printing of continuous carbon fiber reinforced PLA composites. Compos Part B Eng.2019; 175: 107147.
[20] Tian X, Liu T, Wang Q, et al. Recycling and remanufacturing of 3D printed continuous carbon fiber reinforced PLA composites. J Clean Prod.2017; 142: 1609-1618.
[21] Matsuzaki R, Ueda M, Namiki M, et al. Three-dimensional printing of continuous-fiber composites by in-nozzle impregnation. Sci Rep.2016; 6: 23058.
[22] Wang Y, Kong D, Zhang Q, et al. Process parameters and mechanical properties of continuous glass fiber reinforced composites-polylactic acid by fused deposition modeling. J Reinf Plast Compos.2021; 40: 686-698.
[23] Yu L, Chen K, Xue P, et al. Impregnation modeling and preparation optimization of continuous glass fiber reinforced polylactic acid filament for 3D printing. Polym Compos.2021; 42: 5731-5742.
[24] Wang Y, Lyu C, Zhang Q, et al. Preparation and Performance Index Test of Continuous Glass Fiber Reinforced Filament- Polylactic Acid for 3D Printer. Journal of Physics: Conference Series.2021; 1906: 012053.
[25] Cersoli T, Yelamanchi B, MacDonald E, et al. 3D printing of a continuous fiber-reinforced composite based on a coaxial Kevlar/PLA filament. Compos Adv Mater.2021; 30: 26349833211000058.
[26] Tey JY, Ding WO, Yeo WH, et al. 3D printing of continuous kevlar reinforced polymer composite through coextrusion method. IOP Conference Series: Earth and Environmental Science.2020; 463: 012091.
[27] Bettini P, Alitta G, Sala G, et al. Fused Deposition Technique for Continuous Fiber Reinforced Thermoplastic. J Mater Eng Perform.2016; 26: 843-848.
[28] Zhihua Z. Pretreatment of Sisal Fiber Based on the Analysis of Chemical Composition and Research on the Preparation and Properties of Sisal Fiber Reinforced Polylactide Biocomposites. PhD Thesis, South China University of Technology, China, 2017.
[29] Long Y, Zhang Z, Fu K, et al. Efficient plant fibre yarn pre-treatment for 3D printed continuous flax fibre/poly(lactic) acid composites. Compos Part B Eng.2021; 227: 109389.
[30] Hinchcliffe SA, Hess KM and Srubar WV. Experimental and theoretical investigation of prestressed natural fiber-reinforced polylactic acid (PLA) composite materials. Compos Part B Eng.2016; 95: 346-354.
[31] Weibing L, Sujuan Q and Zhidong L. Research progress and optimization of process parameters of polymer materials for 3D printing. China Synth Resin Plast.2020; 37: 85-89(in Chinese).
[32] Yu L, Yan L and Kunkun F. Recent advances in 3D printed fiber reinforced composites:Processing technique and mechanical performance. Acta Mater Compositae Sin.2022; 39: 4196-4212(in Chinese).
[33] Jiarong H. Study on Bending Properties of 3D Printing Continuous Carbon Fiber Reinforced Thermoplastic Composites. Plast Sci Technol.2019; 47: 40-43(in Chinese).
[34] Vinoth Babu N, Venkateshwaran N, Rajini N, et al. Influence of slicing parameters on surface quality and mechanical properties of 3D-printed CF/PLA composites fabricated by FDM technique. Mater Technol. 2021; 37: 1008-1025.
[35] Akhoundi B, Behravesh AH and Bagheri Saed A. Improving mechanical properties of continuous fiber-reinforced thermoplastic composites produced by FDM 3D printer. J Reinf Plast Compos.2018; 38: 99-116.

[36] Yonghui C, Liguo Y and Mingyin J. Study on 3D Printing Technology of Continuous Fiber Reinforced PLA Composite. Fiber Compos.2020; 37: 95-100(in Chinese).
[37] Fan Z, Yuegang T, Guofeng M, et al. Research on the Forming Process of Continuous Carbon Fiber Composite 3D Printing. Mach Des Manuf.2019; No.341: 96-98+102(in Chinese).
[38] Tian X, Liu T, Yang C, et al. Interface and performance of 3D printed continuous carbon fiber reinforced PLA composites. Compos Part A Appl Sci Manuf .2016; 88: 198-205.
[39] Suteja J, Firmanto H, Soesanti A, et al. Properties investigation of 3D printed continuous pineapple leaf fiber-reinforced PLA composite. J Thermoplast Compos mater.2020; 35: 2052-2061
[40] Dou H, Cheng Y, Ye W, et al. Effect of Process Parameters on Tensile Mechanical Properties of 3D Printing Continuous Carbon Fiber-Reinforced PLA Composites. Materials (Basel).2020; 13: 3850.
[41] Lian K, Yang L, Zhu D, et al. Effect of printing parameters on 3D-printed carbon fiber-reinforced polymer composites under magnetic field control. J Manuf Processes.2023; 101: 1443-1452.
[42] Hu Q, Duan Y, Zhang H, et al. Manufacturing and 3D printing of continuous carbon fiber prepreg filament. J Mater Sci.2017; 53: 1887-1898.
[43] Wang Y, Shi J and Liu Z. Bending performance enhancement by nanoparticles for FFF 3D printed nylon and nylon/Kevlar composites. J Compos Mater.2020; 55: 1017-1026.
[44] Araya-Calvo M, López-Gómez I, Chamberlain-Simon N, et al. Evaluation of compressive and flexural properties of continuous fiber fabrication additive manufacturing technology. Addit Manuf .2018; 22: 157-164.
[45] Yang C, Tian X, Liu T, et al. 3D printing for continuous fiber reinforced thermoplastic composites: mechanism and performance. Rapid Prototyping J.2017; 23: 209-215.
[46] Wang F, Wang G, Ning F, et al. Fiber–matrix impregnation behavior during additive manufacturing of continuous carbon fiber reinforced polylactic acid composites. Addit Manuf .2021; 37: 101661.
[47] Chen K, Yu L, Cui Y, et al. Optimization of printing parameters of 3D-printed continuous glass fiber reinforced polylactic acid composites. Thin Wall Struct..2021; 164: 107717.
[48] Le Duigou A, Barbé A, Guillou E, et al. 3D printing of continuous flax fibre reinforced biocomposites for structural applications. Mater Des.2019; 180: 107884.
[49] Qiao J, Li Y and Li L. Ultrasound-assisted 3D printing of continuous fiber-reinforced thermoplastic (FRTP) composites. Addit Manuf .2019; 30: 100926.
[50] Ruishi T, Mingyao L, Fan Z, et al. Continuous Path Planning Algorithm for Carbon Fiber Composite Material 3D Printing. Mach Des Manuf .2019: 1-4(in Chinese).、
[51] Rajan VT, Srinivasan V and Tarabanis KA. The optimal zigzag direction for filling a two-dimensional region. Rapid Prototyping J.2001; 7: 231-241.
[52] Zude z, Fei C, Fan Z, et al. Efficient Spiral Bias Filling Algorithm for Continuous Carbon Fiber 3D Printing. J Wuhan University Technol .2017; 39: 81-87(in Chinese).
[53] Ye Y. Research on trajectory planning of 3D printing of continuous carbon fiber reinforced composites. MSc Thesis, JiangNan University, China, 2022.
[54] Wang T, Li N, Link G, et al. Load-dependent path planning method for 3D printing of continuous fiber reinforced plastics. Compos Part A Appl Sci Manuf .2021; 140: 106181.
[55] Zhipeng H. Research on 3D Printing Layering and Path Planning Based on FDM Technology. MSc Thesis, Hangzhou Dianzi University, China, 2021.