Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 2070-2083
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

Preparation and Performance of Bamboo Fiber/Polypropylene Intertwined Braided Composite

Haiyu Xu[1], Wei Zhang[2]*, Yinwei Wu[1], Wenbin Yao[2]
[1]Gongcheng College, Zhejiang A & F University, Hangzhou, Zhejiang, China
[2]Jiyang College, Zhejiang A & F University, Shaoxing, Zhejiang, China
*Corresponding Author.

Abstract:

Bamboo fibers (BF) and polypropylene (PP) fibers are processed into BF/PP intertwined ropes by twisting separate yarns. After plain weaving, low-PP (less than 30%) composite materials are prepared by the thermal drying-hot press process. The effects of the PP fiber content on the mechanical performance, thermal performance, and water absorption ability of the composite materials are studied. As the content of the PP fiber increases, the tensile strength of the composite material decreases and its flexural strength increases. Thermal analysis and water absorption experiments show that with increasing polypropylene content, the thermal stability of the composite material increases, whereas the moisture absorption ability decreases. The SEM analysis of the composite obtained show that interface combination of the two phases and mechanical properties would be improved. The trial show that the BF/PP composite with the mass ratio of 83:17 had the better comprehensive properties. Compared with the non-braided BF/PP composite, the tensile and flexural strengths are both improved. Our study could offer a making method and insights for the BF/PP weaving composite, which may be of help on the design of green materials in interior building and decoration.

Keywords*: Braided composite material, BF/PP rope, Mass ratio, Bamboo fiber, Performance.*

I. INTRODUCTION

Plant fiber has the advantages of easy degradation, renewability, low price, etc. As a new type of composite material, polypropylene (PP) composites reinforced with plant fiber have emerged as a hotspot in local and international research in recent years, and have currently been applied in automotive interiors, building materials, and other arenas. Due to the wide distribution, fast growth, and superior performance of bamboo fiber (BF), there has been increasing research on BF/PP composite materials [1-3].

Kumar et al. [4] studied a blend of BF and PP and used a needle machine to produce non-woven fabrics. Chunhong et al. [5] studied the mechanical, hygrothermal aging and moisture absorption characteristics of BF/PP composites. Tang Qiheng et al. [6] studied the effect of varying the ratio of single

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 2070-2083
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

bamboo fiber to bamboo fiber bundles on the comprehensive performance of composite materials. Zhou Song et al. [7] studied the addition of maleic anhydride grafted ethylene-octene copolymer (POE-g-MAH) for the purpose of improving the mechanical performance of BF/PP composites.

At present, most research on BF/PP composite materials use short fibers or bamboo powder as reinforcements. Zuhudi et al. [8] studied the performance of twill fabric-reinforced PP composites prepared by compression molding, and Porras et al. [9] studied the preparation and performance of braided BF and PLA composites. Although PLA can be degraded, this process is quite expensive. From the economic and environmental perspectives, as well as considering the emerging preference for pure, natural, green materials, we herein study BF braided composite materials with a low PP content (below 30%).

Bamboo fiber is a hydrophilic material with a large number of surface hydroxyl groups, while PP is hydrophobic, and the compatibility between the two is not good. At present, most studies focus on modifying the fiber or adding modifiers to improve the interface performance. Herein, considering the theory of mechanical meshing at an interface, long BF and PP fibers are first intertwined into a composite rope to improve the compatibility at the BF and PP interface while increasing the fiber strength, and then subjected to plain weaving, after which the process of thermal drying followed by hot pressing is used to prepare the BF/PP composites. The effect of different mass ratios on the performance is analyzed to provide a basis for the application of the composite materials.

II. MATERIALS AND METHODS

2.1 Test Materials and Equipment

Experimental materials: Bamboo fiber (length: 80±2 cm, fineness: 474 μm, home-made by Zhejiang A&F University) and PP fiber (length: 96±2 cm, fineness: 240 μm, Qianshan Yongchuang Brush Co., Ltd.) were used as raw materials.

Experimental equipment: The equipment used herein include a blast drying oven (DHG-9240A, Shanghai Xiqian Instrument Equipment Co., Ltd.), hot press machine (HBSCR-25T/350, Qingdao Habo Machinery S&T Co., Ltd), electronic multi-function powerful machine (YG028PC, Wenzhou Bain Instrument Co., Ltd.), electronic microcomputer-controlled universal mechanical testing machine (WDW-200C, Shanghai Hualong Testing Instrument Co., Ltd.), microcomputer-controlled wood dedicated testing machine (UTM2503, Shenzhen SUNS Technology Stock Co. Ltd.), COXEM desktop scanning electron microscope (EM-30PLUS, COXEM, Korea), and thermogravimetric analyzer (SDT-Q600 synchronous thermal analyzer, TA Instruments, USA).

2.2 Preparation of BF/PP Braided Composite

2.2.1 Preparation of BF/PP Intertwined Rope and Braided Material

The composite rope was intertwined based on the GB/T 11787-2017 [10] process. Three BF and 1-5 PP fibers were intertwined into 15 composite ropes (as shown in Figure 1), with mass ratios of 93:7, 88:12,

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 2070-2083
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

83:17, 78:22, and 73:27, respectively. After testing, the tensile performance of the bamboo fiber, PP fiber, and BF/PP composite rope with different mass ratios was determined, as shown in Table 1. The composite ropes were then woven into braided materials with different BF/PP mass ratios, with a size of 210 mm × 200 mm, by using the plain weave method (Figure 2). These materials were respectively weighed and their surface density calculated, as shown in Table 2. The process for preparing the BF/PP braided material is shown in Figure 3.

Fig 1: BF/PP intertwined rope

Fig 2: BF/PP (3 × 4) braided material.

TABLE 1. Tensile performance of BF, PP, and BF/PP ropes with different mass

Tensile performance		Breaking strength(cN/dtex)	Elastic modulus (cN/dtex)	Elongation at break(%)	Linear density(dtex)
BF		76.2	27.40	14.45	12.35
PP		81.4	11.53	8.58	2.65
BF/PP (BF:PP)	93:7(3×1)	95.12	29.41	13.91	38.35
	88:12(3×2)	100.82	33.59	16.11	40.24
	83:17(3×3)	111.84	36.15	17.37	43.37
	78:22(3×4)	119.24	40.79	21.29	48.00
	73:27(3×5)	125.36	43.91	21.44	53.84

TABLE 2. Surface density of BF/PP composites

Mass ratio (BF×PP)	3 × 1	3 × 2	3 × 3	3 × 4	3 × 5
Surface density (g/m^2)	7.723	7.615	6.83	6.603	6.515

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 2070-2083
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

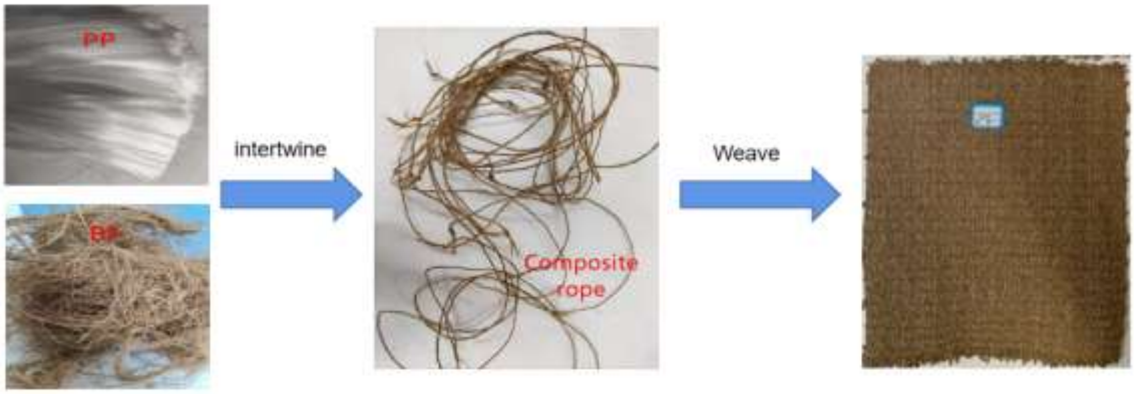


Fig 3: Preparation of BF/PP braided material

2.2.2 Compositing process for BF/PP braided material

The compositing process applied to the BF/PP braided material is shown in Figure 4. The BF/PP braided composite material was placed in a preheated blast drying oven set to a temperature of 170 ℃ and held at a constant temperature for 8 min, after which the material was taken out and placed in a hot press machine coated with a release agent; the temperature inside the press was 170 °C, the pressure was 5 MPa, and the pressure was applied for 30 s. The prepared BF/PP composite board was placed at room temperature for 48 h and allowed to stand until the moisture content became stable.

Hot Bake Hot pressing

Fig 4: Process flow for BF/PP braided material composite

2.3 Performance of BF/PP Composite Material

Mechanical performance

A universal mechanical testing machine is used to test the warp tensile and warp flexural performance of the sample. The tensile strength test is carried out according to GB/T 1040.3-2018 [11], the size of the

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 2070-2083
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

test piece is 150 mm × 10 mm, the selected span is 100 mm, the loading speed is 5 mm/min, and there are five test pieces in each group. The flexural performance test is based on the standard GB/T 9341-2008 [12], the sample size is 80 mm × 25 mm, the loading speed is 1 mm/min, and there are five test pieces in each group.

Electron microscope

A desktop scanning electron microscope is used to spray gold on the surface of the sample, and surface microscopic morphology of the composite material is observed at an operating voltage of 15 kV.

Thermal performance

A thermogravimetric analyzer is used to test the thermal decomposition performance of the test piece under N2 gas, where the temperature is increased from 50 °C to 500 °C at a heating rate of 10 °C/min.

Water absorption performance

The water absorption of the composite materials is tested based on GB/T 1034-2008/ISO62-2008 [13]. The test piece is immersed in distilled water and placed at a stable room temperature of 30 ℃ to test the difference in quality before and after the test piece absorbs water. The moisture absorption rate of the test piece is expressed as the percentage mass difference before and after water absorption to the initial mass, the size of the test sample is 25 mm × 25 mm, and there are five test samples in each group. The test time is varied as 2, 4, 6, 8, 24, 48, 72, and 96 h.

The water absorption rate, W (%), is expressed as follows:

$$W = \frac{M - M_0}{M_0} \times 100\%, \tag{1}$$

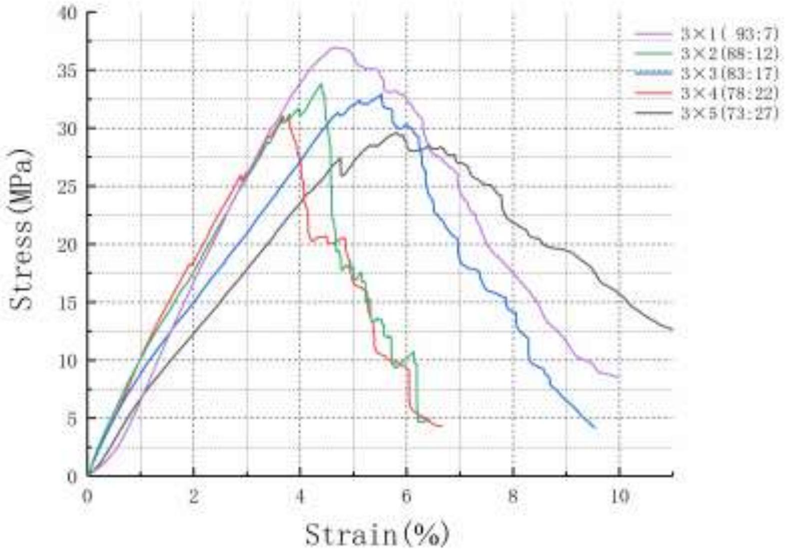
In the formula, M_0 is the absolute dry mass of the sample before water absorption (unit: g); M is the mass after water saturation (unit: g).

III.RESULTS AND DISCUSSION

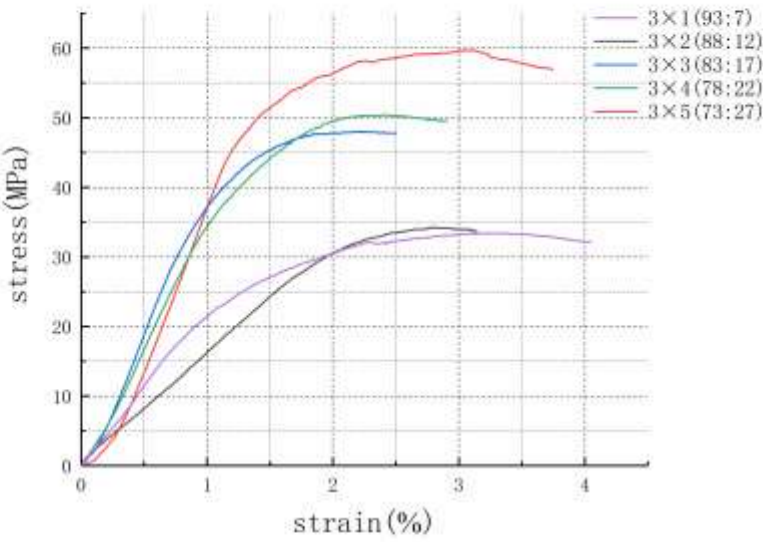
3.1. Analysis of Mechanical Performance

The tensile performance profiles of the BF/PP composites with different mass ratios are shown in Figure 5(a), and the flexural performance profiles are shown in Figure 5(b). Tables 3 and 4 show the tensile strength, modulus and flexural strength,modulus of the composite materials with different mass ratios.

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 2070-2083
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022



(a) tensile strength curve



(b) flexural strength curve

Fig 5: Tensile and flexural performance of BF/PP composites with different mass ratios

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 2070-2083
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

TABLE 3. Tensile performance of composite materials with different mass ratios

BF/PP (BF×PP)	Tensile strength (MPa)	Tensile modulus (MPa)
3 × 1	36.9	982.3
3 × 2	33.8	1049.6
3 × 3	32.9	915.1
3 × 4	31.0	891.2
3 × 5	29.9	951.1

TABLE 4. Flexural performance of composite materials with different mass ratios

BF/PP (BF×PP)	Flexural strength (MPa)	Flexural modulus (MPa)
3 × 1	33.4	1575.1
3 × 2	34.2	1679.3
3 × 3	48.1	2375.0
3 × 4	50.4	2545.3
3 × 5	59.6	2477.4

The changes in the tensile strength and flexural strength as a function of the ratio of the composite fiber intertwined yarns were obtained from Figures 5(a) and 5(b), and are plotted in Figures 6 and 7.

Figure 6 shows that as the PP content increases, the tensile strength of the braided BF/PP composite material decreases. This is because the surface density of the composite material decreases as the PP content increases (Table 2). The higher the surface density, the denser the arrangement of the composite rope per unit area, and the better the tensile performance. Figure 7 shows that as the PP content increases, the degree of flexure of the material increases. The flexural performance of the BF/PP braided composite material depends on the PP content per unit area. When the PP content is higher, the flexural performance of the composite material is better. From Table 2, it can be seen that the tensile strength and tensile modulus of the 3 × 1 BF/PP composite material with the best tensile performance are 36.9 MPa and 982.3 MPa, respectively; when there are 2-3 strands of PP, the tensile strength decreases slowly. Figure 5 shows that the best flexural performance is achieved with the 3 × 5 mass ratio BF/PP composite material, with a flexural strength and flexural modulus of 59.6 MPa and 2477.4 MPa, respectively. When there are 3-4 strands of PP, the flexural strength increases more gradually. Therefore, the BF/PP composite with a mass ratio of 3 × 3 has better overall performance, with a tensile strength of 32.9 MPa and flexural strength of 48.1 MPa. These values are higher than those of the BP/PP composite materials prepared in previous studies. Xiong Xiaoyi [14] reported that for the BF/PP composite, the best performance is achieved when the PP content is 40%, with a tensile strength of 27.94 MPa and flexural strength of 45.77 MPa. The tensile strength and flexural strength of the BF/PP (83:17, 3 × 3) intertwined braided composite material prepared in this study are 17.8% and 5% higher than the reported values, respectively.

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 2070-2083
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

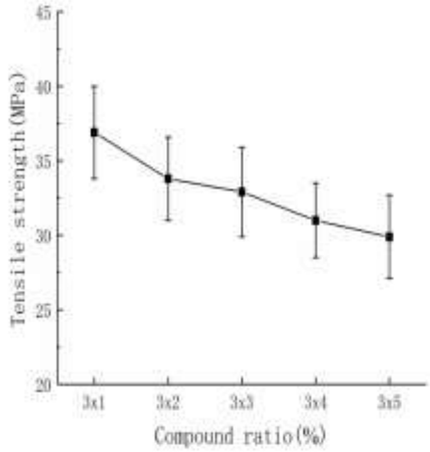


Fig 6: Effect of mass ratio on tensile performance of composite materials

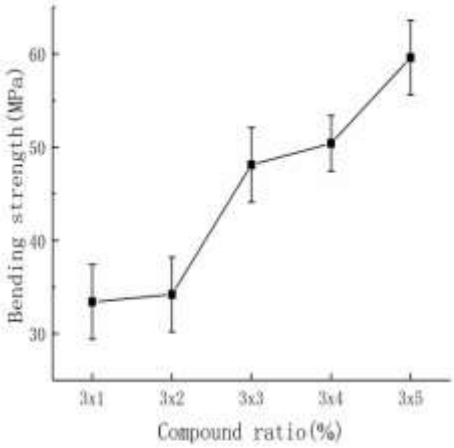
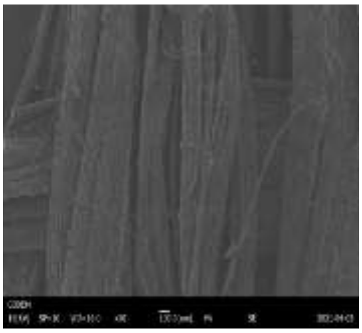


Fig 7: Effect of mass ratio on flexural performance of composite materials

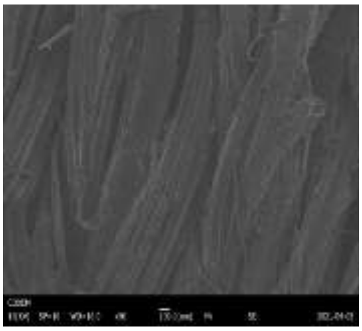
3.2 SEM Observation

The surface morphology of the BF/PP braided composites with different mass ratios is observed by electron microscopy. Figures 8 and 9 present the SEM images magnified 50 times and 400 times, respectively. Figure 8 shows that the main body of the braided composite material comprises bamboo fiber. With increasing PP content, the PP on the surface of the fiber and the PP between the fibers gradually increases. Figure 9 clearly shows the combined morphology of PP and bamboo fiber. When the mass ratio is 3 × 1, only a small amount of unevenly distributed polypropylene can be seen in the figure. This is mainly due to the low polypropylene content. After melting at high temperature, polypropylene condenses as it cools, and only a small amount will remain on the surface, and there is less area of bamboo fiber covered by polypropylene. With increasing PP content, the distribution gradually becomes continuous and uniform. When the mass ratio is 3 × 3, PP is continuously distributed on the surface of the bamboo fiber. When the mass ratio is 3 × 4, PP connects the adjacent fibers, and when the mass ratio is 3 ×5, the surface of the bamboo fiber is evenly covered by PP. Thus, the method of re-weaving with intertwined rope helps to enhance the occlusal connection between the bamboo fiber and the PP interface due to the mechanical force between the fibers in the composite rope, thereby improving the interface performance and the strength of the composite material.

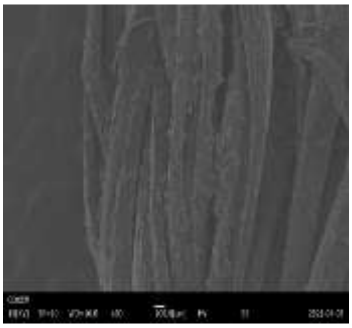
Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 2070-2083
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022



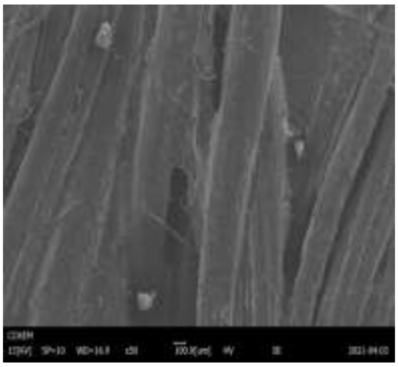
3 × 1



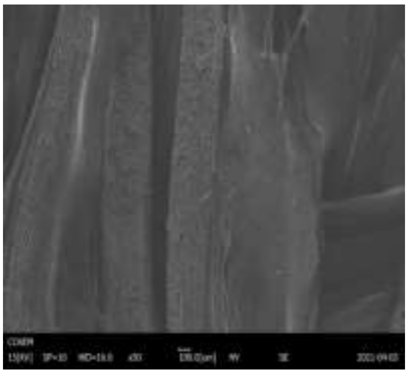
3 × 2



3 × 3

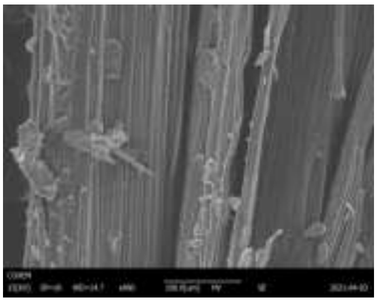


3 × 4

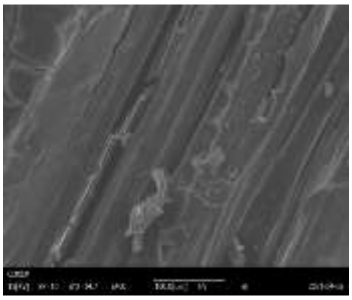


3 × 5

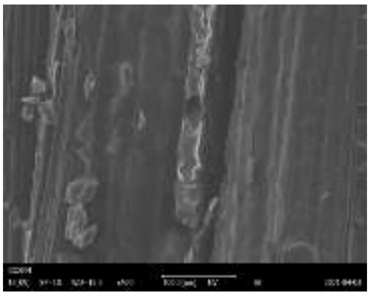
Fig 8: SEM images of BF/PP composites with different mass ratios (50× magnification)



3 × 1

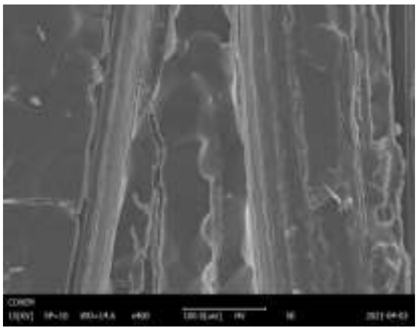


3 × 2

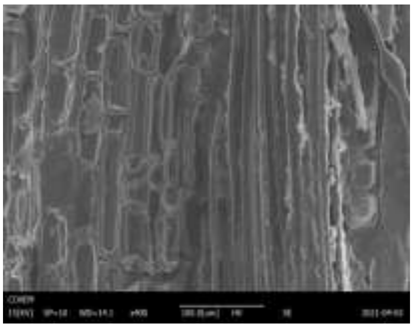


3 × 3

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 2070-2083
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022



3 × 4



3 × 5

Fig 9: SEM images of BF/PP composites with different mass ratios (400× magnification)

3.3. Analysis of Thermal Performance

The thermal stability is an important indicator for evaluating the performance of natural fiber composite materials. Thermal analysis can be used to determine the thermal stability of a material. Figures 10(a) and (b) show the TGA and DTG curves of the respective BF/PP braided composite materials. The thermal weight loss curve of the BF/PP braided composite material in Figure 10(b) can be roughly divided into three stages (50–100 ℃, 200–320 ℃, 350 ℃ and above). The first stage of the weight loss curve is flat due to vaporization of moisture in the composite material and the second stage corresponds to degradation of the bamboo fiber, where the cellulose in the bamboo fiber in the sample begins to undergo thermal degradation at 220 ℃ [15]. Upon reaching the second peak at ~320 ℃, all five groups of samples reach their respective maximum weight loss rates. The 3 × 1 (93:7) group undergoes the largest weight loss because it has the highest fiber content. The third stage mainly corresponds to the thermal degradation of PP in the composite material, where the thermal degradation temperature of PP is 350-380 ℃; thus, it is found that the 3 × 5 composite material has the most intense second peak, which is attributed to the highest PP content in the 3 × 5 group. When the temperature reaches 500 °C, the mass gradually stabilizes.

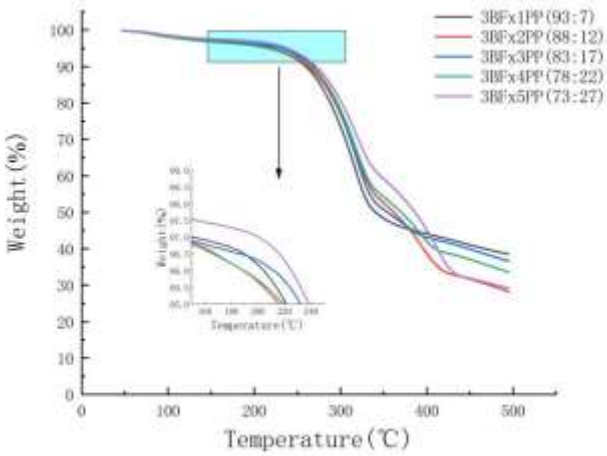
The TGA data for the BF/PP braided composites with different mass ratios are summarized in Table 3. The thermal degradation temperature increases with increasing PP content. Because the PP content does not vary greatly, the thermal degradation temperature and weight loss rate also do not vary greatly. When the BF:PP mass ratio is 73:27, the initial thermal degradation temperature of the composite material is the highest, the weight loss rate at 200 °C is the lowest, and the heat resistance is optimal. This is because the area of the bamboo fiber covered by polypropylene increases and the thermal stability of the material improves as the polypropylene content increases.

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 2070-2083
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

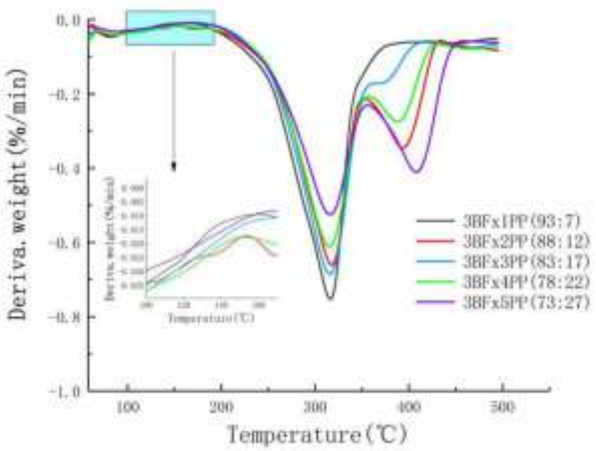
TABLE 5. TGA data for BF/PP braided composites with different mass ratios

Combination	Weight loss rate at 200 ℃ (%)	Tmax1 (℃)	Tmax2 (℃)	Weight loss rate (%)
3 × 1 (93:7)	3.899	316.1	356.2	60.92
3 × 2 (88:12)	4.419	316.5	376.6	70.71
3 × 3 (83:17)	3.747	317.6	389.2	62.64
3 × 4 (78:22)	4.042	315.3	393.8	65.59
3 × 5 (73:27)	3.041	316.6	408.1	70.15

In the Table 5, T_{max1} and T_{max2} are the decomposition temperatures for the maximum weight loss of bamboo fiber and polypropylene, respectively.



(a) TGA curve



(b) DTG curve

Fig10: TGA and DTG curves of BF/PP composites with different mass ratios

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 2070-2083
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

3.4 Water Absorption Analysis

The characteristics governing moisture absorption by composite materials should be such that they can be used in hot and humid environments; these parameters are used as an index to predict their service life. The moisture absorption curves of the BF/PP braided composite materials with different mass ratios after exposure to a water density of 1.0 g/cm^3 at a temperature of 23℃ are shown in Figure 11. The moisture absorption of the composite materials with different mass ratios followed similar trends. The moisture absorption rate was fast in the first 10 h. This period is called the initial stage of moisture absorption. With the progress of time, the moisture absorption rate gradually slows down. After 96 h, the moisture absorption no longer increases, and the water absorption of the sample reaches saturation.

Figure 11 also shows that as the mass of PP increases, the water absorption capacity of the test piece declines and the time at which the water absorption reaches a plateau is delayed. This is because when the PP content increases, the area where PP is attached to the bamboo fiber increases, which reduces the water absorption range of the bamboo fiber, and enhances the water resistance of the composite material. However, the water absorption rate is high due to the low PP content and the fact that PP in the intertwined rope cannot completely cover the bamboo fiber. Therefore, the composite materials in this study are suitable for use as decorative materials for interior building and decoration.

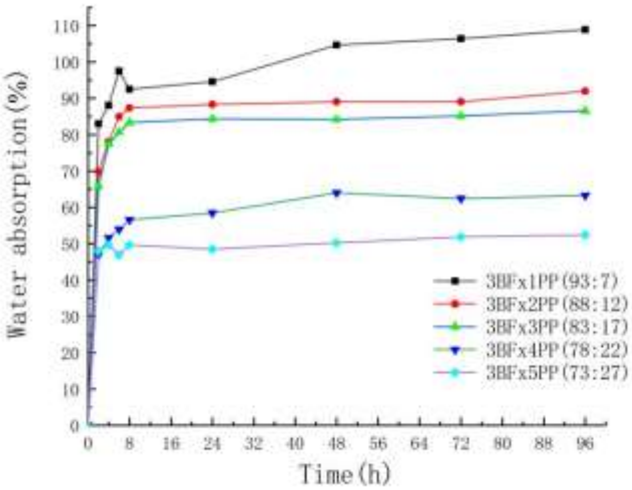


Fig 11: Water absorption curves of BF/PP composites with different component ratios

IV. CONCLUSION

BF/PP plain weave material made of bamboo fiber and polypropylene fiber intertwined rope is subjected to the thermal drying-hot press process to prepare a BF/PP composite. The tensile strength of the composite veneer is reduced and its flexural performance is improved with increasing polypropylene content.The BF/PP composites (83:17, 3×3 strands) exhibit better comprehensive performance, with a tensile strength of 32.9 MPa, and flexural strength of 48.1 MPa. Compared with the non-braided BF/PP composite, the tensile and flexural strengths are both improved. The thermal stability of the composite increases as the propylene content increases. When the BF:PP mass ratio is 73:27(3×5 strands), the initial thermal degradation temperature of the composite material is the highest, the weight loss rate at 200 °C is the lowest, and the heat resistance is optimal. The PP content has a significant impact on the moisture absorption ability of the composite material. With increasing PP content, the moisture absorption ability of the composite material decreases. After 96 h, the moisture absorption no longer increases, and the water absorption of the sample reaches saturation,and is between 50% and 110%.

The BF/PP composite materials prepared by the intertwined rope process in this study have a low PP content, better mechanical performance, thermal performance, but the moisture absorption also better. Therefor the composite materials are suitable for use as decorative materials for walls and others areas in interior building and decoration.

ACKNOWLEDGEMENTS

This research was supported by Zhejiang Province key research plan project of China (Grant No. 2021C02017), Zhejiang Provincial Public welfare project of China (Grant No. LGN21C160006) and by Jiyang College of Zhejiang A&F University of China (Grant No.RQ1911A02).

REFERENCES

[1] L. Osorio. Morphological aspects and mechanical performances of single bamboo fibers and flexural characterization of bamboo/ epoxy composites. J. Reinfor Plast Comp, 2011, 30(5): 396-408
[2] Wang Jiangkai, Su Mengyu, Sun Zhanying, Zhang Xin, An Hangyi, Wang Shaoting, Li Xiang. Research progress of polypropylene/plant fiber composites. Eng Plast App, 2019, 47(07):151-155
[3] Gabriel Oliveira Glória et al. Differential Scanning Calorimetry Tests of Epoxy and Polyester Composites Reinforced with Giant Bamboo Fibers. Mat Sci Forum, 2016, 4101: 270-276
[4] N Senthil Kumar, K Shabaridharan, R Perumalraj, et al. Study on cross-directional tensile performances of bamboo-/polypropylene-blended needle-punched non-braided fabrics. J Indust Text, 2018, 47(6): 1342-1356
[5] Wang Chunhong and Liu Shengkai and Ye Zhanglong. Mechanical, hygrothermal ageing and moisture absorption performances of bamboo fibers reinforced with polypropylene composites. Journal of Reinforced Plastics and Composites, 2016, 35(13): 1062-1074
[6] Tang Qiheng et al. An Investigation on the Comprehensive Property Assessment and Future Directions of Single Bamboo Fiber Reinforced Polypropylene Composites Fabricated by a Non-Braided Paving and Advanced Molding Process. Materials (Basel, Switzerland), 2019, 12(16)
[7] Zhou Song, Zhu Xiaolong, Wang Gangyi, Liang Bin, Xia Shifu, Jiang Chenjie. Effect of POE-g-MAH on the performances of polypropylene/bamboo fiber composites. Eng Plast App, 2013, 41(08):30-34
[8] N.Z. Mahmud Zuhudi and K. Jayaraman and R.J.T. Lin. Mechanical, Thermal and Instrumented Impact Performances of Bamboo Fabric-Reinforced Polypropylene Composites. Polym Polym Compos, 2016, 24(9): 755-766

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
May-June 2022 Page No. 2070-2083
Article History: Received: 24 February 2022, Revised: 05 April 2022, Accepted: 08 May 2022, Publication: 30 June 2022

[9] A. Porras and A. Maranon. Development and characterization of a laminate composite material from polylactic acid (PLA) and braided bamboo fabric. Compos Part B, 2012, 43(7): 2782-2788
[10] General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China. Fibre ropes - Polyester -3-, 4-, 8- and 12-strand ropes: GB/T 11787-2017. Beijing: Standards Press of China, 2017
[11] GB/T 1040.3-2018, Determination of the tensile performances of plastics. Beijing: Standards Press of China, 2018
[12] GB/T9341-2008, Determination of the flexual performances of plastics. Beijing: Standards Press of China, 2008
[13] GB/T1034-2008/ISO62-2008, Determination of water absorption of plastics. Beijing: Standards Press of China, 2008
[14] Xiong Xiaoyi. Research on Bamboo Fiber Reinforced Polypropylene Composite. Zhejiang University of Technology, 2017
[15] Tang Qiheng, Cheng Haitao, Wang Ge, Guo Wenjing. The effect of bamboo fiber combination on the performances of bamboo fiber/polypropylene composite. Acta Materiae Compositae Sinica, 2019, 36(11):2561-2567.