Weaving and mechanical properties test of polylactic acid/ramie composite fabric

Wang Yang
School of Materials Design and Engineering
Beijing Institute of Fashion Technology
Wangyang@bift.edu.cn

Abstract. In view of the weak mechanical properties of polylactic acid fiber, the excellent mechanical properties of ramie fiber are selected to enhance the performance of polylactic acid fiber, thereby forming a composite fabric, and weaving plain weave fabric, twill weave fabric, satin weave fabric and square plain fabric by weaving method. Twill change fabric and satin change fabric six kinds of fabrics. Electronic thickness meter, electronic strength meter, and electronic bursting tester were used to test the thickness, tensile fracture and burst performance of 6 kinds of fabrics, and the reasons for the differences between the fabrics were discussed. The research results show that the mechanical properties of composite fabrics are better than those of pure polylactic acid fabrics. In addition, in terms of tensile fracture performance, the satin weave fabric is the strongest, and the satin weave is the strongest in burst performance. In terms of fabric thickness, the lowest thickness value is plain weave, but the thickness value, tensile breaking and bursting properties of square flat fabrics are ranked second, so the overall performance is always the strongest.

1. Introduction
In recent years, with the development of biodegradable materials, a series of polylactic acid materials for different purposes have been produced and used. For example, it is currently used in plastic fields such as food packaging, in medical and health fields such as bandages, absorbent cotton, and gauze [1]. In order to further expand the use of polylactic acid fiber, many scholars focus on the field of textiles and clothing [2] to enhance the research of composite fabrics. For example, H Ebadi-Dehaghani etc. have studied the compatibility and incompatible blends of polylactic acid and various compositions containing nano-clay particle. They are prepared by melt mixing in a twin-screw extruder and studied the tensile and impact properties of composite materials [3], Zhu Luping in the article "Preparation, performance optimization and hot water aging research of ramie/polylactic acid composites" The influence of tensile properties and bending properties [4], therefore, as far as the current literature is concerned, there are few studies on the production of polylactic acid composite fabrics by woven methods, which is not conducive to the large-scale promotion of polylactic acid materials in the textile and clothing field.

The woven method is a method of forming a composite fabric through the interweaving of the warp and weft of the yarn. The production process is relatively environmentally friendly, and it occupies a large market in the textile and apparel industry [5]. Therefore, in view of the current situation of poor mechanical properties of polylactic acid materials and less research on woven methods, we plan to use the woven method to composite polylactic acid materials and ramie materials, and test the mechanical properties, in order to increase the production methods and effective methods of polylactic acid
composite fabrics. To reduce the environmental pollution caused by chemical modification, in addition, woven ramie fiber and polylactic acid fiber can give full play to the advantages of China's ramie industry and provide a feasible design method for the physical modification of polylactic acid fiber.

2. Polylactic acid/ramie composite fabric experiment and performance test

2.1. Experimental materials
Polylactic acid yarn, 100% corn fiber, 21 counts, Henan Puyang Yurun New Material Co., Ltd.; Ramie yarn, 100% pure ramie, 21 public counts, 350 twists, Hongqing Hemp Industry Co., Ltd., Tongling City, Anhui Province.

2.2. Polylactic acid/ramie composite fabric weaving method
2.2.1. Pretreatment of ramie yarn
Ramie has high cellulose content and long hairiness, which leads to entanglement during weaving with polylactic acid. Ramie is used as a warp and rubs against the yarn during the movement of the reed to produce hairiness entanglement. The uneven force causes the warp to be broken as a result. Therefore, surface treatment of ramie yarn by alkali treatment is an effective way to solve the problem of warp breakage. Under normal temperature conditions, ramie yarn is completely immersed in 15% alkaline sodium hydroxide solution for 12 hours. The impurity and semi-fiber on the surface of the ramie yarn are effectively reduced by soaking, thereby improving the efficiency of forming composite fabrics [6].

2.2.2. Composite fabric weaving method
The polylactic acid yarn is the weft yarn, and the ramie yarn is the warp yarn. The fabric is woven on the SGA598 semi-automatic shuttle loom using the woven technique to obtain fabrics with different organizational structures with a width of 300mm [7]. The specific operation method is: In the first step, use SJA192 model warping machine to arrange the ramie yarn onto the warp beam. The parameters are: The total number of warp threads is 500, the width is 300mm, and each circle is 1.8m, a total of 5 loops are arranged. In order to avoid warp yarn breakage, keep the ramie yarn moist; The second step: Put the warp beam on the shuttle loom; The third step: Use the straight-through method to draw in, a total of 8 Heald frames; The fourth step: Use one reed and two reeds. Step 5: Wind the threaded warp onto the cloth spool. At this time, adjust the tension of the warp to keep the tension consistent. Step 6: Input the pattern patterns of the six fabrics: plain weave, twill weave, satin weave, square weave, twill change weave, and satin weave change on the shuttle loom. After the preparation work is completed, start weaving. When the distance between the end of the fabric and the reed is less than 25cm, when the fabric is rolled onto the cloth shaft, the weaving process of the interwoven fabric is shown in Figure 1.

![Interwoven fabric weaving process](image-url)

Figure 1 Interwoven fabric weaving process
2.2.3. Organizational structure design and fabric weaving

Plain weave is the most basic, simplest and most compact of all fabrics. It is often used in summer cloth, canvas, plain cloth, etc. The interweaving law of warp and weft yarns is floating and sinking [8].

Twill fabric is also a common fabric. It is often used in denim, denim, etc. It is characterized by the continuous arrangement of warp or weft points in the fabric structure to form a diagonal line, and a certain angle of floating line appears on the surface of the fabric. When there are more warp weave points than weft weave points, it is warp twill, and when weft weave points are more than warp weave points, it is weft twill [8].

Satin weave is the most complicated one among the three original fabric weaves. It can be divided into warp satin and weft satin. Since there will be longer floating lines in one weave cycle, the fabric surface has a smooth and even surface. Rich in luster, soft texture and other characteristics [8].

Figure 2 Organization chart and fabric formed by woven

2.3. Structural characterization and performance test experimental design of composite fabrics

2.3.1. Characterization of composite fabric structure

(1) Appearance characterization

Phenom-type scanning electron microscope (CFP-1100AI, PMI, USA) and field emission scanning electron microscope (ZEISS EVO18, Carl Zeiss, Germany) were used to observe the surface morphology and microstructure of the fiber. The microscopic morphology of different fiber membranes was compared in order to obtain nanofiber waterproof and moisture-permeable fabrics with fine fiber diameters and good welding conditions.

(2) Structural characterization

In the experiment, a capillary pore size analyzer (CFP-1100AI, PMI, USA) was used to test the pore structure of the fiber membrane, and to explore the change law of each parameter corresponding to the micropore structure of the fiber membrane. Use a micrometer (CHY-C2, China Languang Instrument Co., Ltd.) to measure the thickness of the corresponding membrane fabric on the fabric prepared under different parameter conditions, and find the average value. In addition, when characterizing the microscopic pore structure of the fiber membrane, the calculation method of its porosity can be calculated by the density method, and the calculation method is shown in formula 1.

\[
\text{Porosity} = \left(1 - \frac{m}{t \times s \times p}\right) \times 100\% \quad (1)
\]
Where \( m, t, S \) are the mass, thickness and area of the measured nanofiber membrane, \( \rho \) is the density of the polymer raw material (for multiple components, it can be weighted according to the mass fraction).

2.3.2. Experimental design of composite fabric performance test

(1) Fabric thickness test

According to the national standard GB/T 3820-1997 "Determination of Thickness of Textiles and Textile Products", the YG141N electronic thickness instrument of Ningbo Textile Instrument Factory was used to sample six composite fabrics. The size of each fabric was 15cm*15cm. Performed 5 tests.

(2) Tensile fatigue test

According to the standard specification of GB/T13773.1-2008 "Textile Fabric and its Products Seam Tensile Performance Part 1 Strip Method", the textile Instron fabric tensile tester is used, and the tensile speed is set to 100mm/min. The holding distance is 10cm. Due to the limitation of the factory setting of the equipment program, the maximum number of fatigue design experiments is set to 20 times, and the maximum stretch rate is designed to be 50%. When the maximum stretch value is reached, it is set to stop and hold for 1 min. After that, let it stand and recover for 2 minutes, and sample the six composite fabrics.

(3) Bursting performance test

According to the national standard GB/T 19976-2005 "Determination of Bursting Strength of Textiles (Steel Ball Method)", six composite fabrics were sampled, 5 pieces of each fabric were sampled, the diameter of the fabric was 55mm ± 0.5mm, using Laizhou Electronics Instrument Co., Ltd. YG065 electronic burst tester for testing.

3. Experimental process and discussion

3.1. The influence of fabric structure on fabric thickness

Through the thickness test of six composite fabrics, the comparison is shown in Figure 3. It can be seen from the comparison chart that the highest thickness is the satin weave, and the thinnest is the plain weave. This is due to the different organizational structure of the interwoven fabrics, resulting in different lengths of floating threads on the surface of each fabric [9]. When the warp and weft yarns of the fabric have fewer interlacing points, the floating lengths are longer and the yarn cross section tends to be round, thick; When there are many interweaving points of warp and weft yarns, the floating length is shorter and the cross section of the yarn tends to be flat. At this time, the fabric is thinner. In this experiment, the floating length of the satin weave fabric is the longest, the twill weave is shorter than the satin weave, and the plain weave is the shortest, so the thickness of the interwoven fabric is: The satin weave is the thickest, the twill weave is the second, and the plain weave is the thinnest. The same pattern is in the change of the three original weaves. The satin weave is the thickest, the twill weave is the second, and the plain weave is the thinnest.
3.2. The effect of fabric structure on the tensile fatigue performance of fabric

The tensile fracture performance of six interwoven fabrics is tested. The largest change in tensile fatigue is the satin weave structure, and the smallest is the plain weave structure. The reason is that the tensile breaking strength of the ramie and polylactic acid composite fabric depends on the degree of buckling of the fabric. The less buckled yarn has a better load sharing capacity [10], and the two fibers are interwoven by warp and weft to form a fabric. However, due to different organizational structures, the degree of buckling of the yarns will be different. Among the six interwoven fabrics, the warp and weft yarns of the plain weave fabric are interwoven every other yarn, and the warp and weft yarns of the twill fabric are interwoven at least every two. The warp and weft yarns are interwoven at least once every three, so the degree of buckling changes as follows: plain weave fabric is larger than twill weave fabric and satin weave fabric. When the fabric strength meter works, the weft yarns are stretched, making the arrangement gradually close, the warp yarns are affected by the weft yarns, and the distance between adjacent warp yarns is also reduced. Therefore, the tensile fatigue performance of satin fabrics is greater than that of twill fabrics than plain weave fabrics. However, in the change structure of the three original fabrics, the tensile fracture performance of the square plain fabric is higher than that of the twill change fabric. This is because the square plain fabric has a smaller weave cycle range than the twill change fabric, and the degree of buckling is smaller, and the composite fabric has tensile fatigue. The performance is shown in Table 1.

Table 1 Tensile fatigue performance test of six kinds of fabrics

| Sample                                | Total creep (mm) | Total creep energy(J) | Maximum stress displacement(mm) | Maximum displacement intensity(gf/tex) |
|---------------------------------------|------------------|-----------------------|---------------------------------|---------------------------------------|
| Pure polylactic acid fabric           | 0.0004           | 0.1073                | 0.5002                          | 5.1589                                |
| Plain weave fabric of composite fabric, | 0.5142           | 0.0065                | 0.0693                          | 7.0617                                |
| Twill fabric                         | 0.0204           | 0.2575                | 0.0677                          | 6.9059                                |
| Satin fabric and square weave        | 0.0273           | 0.3073                | 0.0539                          | 5.4962                                |
| Twill change organization,           | 0.3062           | 0.1977                | 0.0413                          | 8.0212                                |
| Satin change organization            | 0.3855           | 0.2087                | 0.0391                          | 7.8644                                |
3.3. *The impact test of fabric structure on burst performance*

Through the burst performance test of the six fabrics, the burst performance of composite fabric can be known. It is better than pure polylactic acid fabric. In addition, among the composite fabrics, the satin weave structure has the greatest bursting strength, followed by the flat weave, the satin weave again, the fourth is the twill weave, and the fifth is the twill weave. The sixth is plain weave. This result is because the greater the degree of warp and weft buckling, the greater the distance between adjacent warps or wefts, the greater the gap, and the smaller the density of the interwoven fabric. After the fabric is subjected to the breaking force of the steel ball, the stress surface is concentrated at one point, and the fabric is burst at the weakest place and the most deformed place [11]. The larger the gap between adjacent yarns, the smaller the density of the fabric. Since the buckling degree of the yarns in the plain weave is greater than that of the twill and satin, the bursting strength of the plain weave is less than that of the twill and satin. The bursting strength of the plain fabric is greater than that of the twill weave fabric but less than that of the satin weave fabric. The bursting performance of the composite fabric is shown in Table 2.

| Table 2 Bursting performance test of six kinds of composite fabrics | Bursting strength (N) | End elongation (mm) |
|-------------------------|-----------------------|--------------------|
| Plain weave fabric      | Pure polylactic acid fabric | 162.1  | 9.42 |
|                         | Composite fabric       | 185.6  | 22.28 |
| Twill weave fabric      | Pure polylactic acid fabric | 170.3  | 7.50 |
|                         | Composite fabric       | 198.6  | 21.21 |
| Satin fabric            | Pure polylactic acid fabric | 185.5  | 7.43 |
|                         | Composite fabric       | 214.2  | 20.1 |
| Square plain fabric     | Pure polylactic acid fabric | 190.3  | 7.40 |
|                         | Composite fabric       | 215.8  | 20.26 |
| Twill Variation Fabric  | Pure polylactic acid fabric | 195.1  | 9.68 |
|                         | Composite fabric       | 212.8  | 20.27 |
| Satin Variation fabric  | Pure polylactic acid fabric | 240.6  | 9.90 |
|                         | Composite fabric       | 283.2  | 22.18 |

4. Conclusion

Weaving plain weave, twill weave, satin weave, square flat fabric, twill change fabric and satin weave change fabric using woven technology, and tested the thickness, tensile fracture and burst performance, and studied the combination of different structure structures. The influence of the mechanical properties of the fabric, due to the difference in the interweaving points of the warp and weft, causes the degree of buckling of the yarn and the floating length of the warp and weft to be different, resulting in different mechanical properties of the fabric. The conclusion as below:

(1) In the fabric thickness, the satin weave has the highest thickness value, followed by the satin weave, and the twill weave again, the fourth is the twill weave, the fifth is the square weave, and the sixth is the plain weave.
(2) In the tensile fracture performance, the strongest performance is the satin weave fabric, followed by the satin weave fabric, the square flat fabric again, the fourth is the twill fabric, the fifth is the twill weave fabric, and the sixth is the plain weave fabric.

(3) In the burst performance, the performance of polylactic acid/ramie composite fabric is better than that of pure polylactic acid fabric. Among the composite fabrics, the strongest bursting force is the satin weave, followed by the flat weave, and the satin weave again, the fourth is the twill weave, the fifth is the twill weave, and the sixth is the plain weave.

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