The Effect of Different Veils on the Impact Resistance of Fabric and Its Adoption in Sports Protective Suit

Xudong Yang [1], Yue Wang[1, *] and Fan Gu [2]

[1] Sports Department, Shenyang Jianzhu University, Shenyang 110168, China.

[2] School of Civil Engineering, Shenyang Jianzhu University, Shenyang 110168, China.

[*] Corresponding author email: 646577365@qq.com

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Abstract: In order to verify the difference of impact resistance of the sports protective suit samples made of different veils and apply them to the protective clothing, in this study, 5 different materials including 7.8tex(70D)/48F nylon, 7.5tex(70D)/72F Cooldry, 7.8tex(70D)/48F trefoil nylon, 7.8tex(70D)/48F round-hole nylon, and 40S cotton are used as veil materials. 2.2 tex(20D)/4.4 tex(40D) nylon spandex covered yarn is used as base material. The representative 1+3 rib structure of weft is taken as the organizational structure. The single factor analysis method is used to test the impact resistance, tensile elasticity, plastic deformation rate, air permeability, moisture absorption, moisture permeability, bursting strength, and other performance of the sports protective suit. The results show that the sports protective suit made of 7.8 tex(70D)/48F trefoil nylon veils has the highest impact penetration energy, reaching 26.2J, and there is a significant correlation between surface density and impact penetrability; 7.8 tex(70D)/48F trefoil nylon veils have the highest permeability, evaporation, and moisture permeability among the 5 veils; the moisture content of the fabric made of 7.5 tex(70D)/72F Cooldry veil is the highest, which is 5.84%, and that of the sports protective suit sample made of 7.8 tex(70D)/48F trefoil nylon is 5.36%. According to the analysis of the deformation rate, the transverse and longitudinal deformation rates of sports protective suit samples made of 7.8 tex(70D)/48F trefoil nylon are 5.1% and 6.6% respectively, which is the smallest among the 5 kinds of veers. After the analysis of the jacking property, it is found that 7.8 tex(70D)/48F trefoil nylon veils have the largest breaking strength. Taking all the indexes into consideration, it is found that using 7.8tex(70D)/48F trefoil nylon as the veil can increase the wear-ability and protective performance of protective clothing.

1. Introduction

Safety protection means to take certain protective measures to protect people from mechanical and biochemical factors in a specific environment. Knitting materials and its products are widely used in the design of safety protection products due to their advantages of soft and comfortable, light weight, excellent mechanical properties, low manufacturing cost, and being able to realize large area protection. With the progress of science and technology and the development of the times and the continuous progress and improvement of knitting technology, seamless knitting products came into being. Sports seamless knitting products have higher requirements on the veil, which no longer adhere to the traditional natural fiber or nylon and functional yarn, but choose materials with good permeability, moisture absorption, and quick drying as the veil as far as possible [1]. The properties of veils directly affect the impact resistance of fabrics and the performance of sports protective suit [2]. Through the analysis of the anti-impact function of commonly used veils and the study of their protective fabric properties, it is expected to select the veils suitable for sports protective suit. This kind of material should have the protective function of resisting the impact, at the same time have the good performance of taking, such as the elasticity, breathable, moisture permeable performance and so on, and provide the reference basis for the design of sports protective suit.

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2. Methodology

2.1 Sample Preparation and Parameter Measurement of Sportswear Fabric

Nylon wire has high breaking strength, good wear resistance, large elastic recovery, and elongation, and is often used in the production of sports protective suit [3]. In this study, five raw materials of 7.8 tex(70D)/48F nylon, 7.5 tex(70D)/72F Cooldry, 7.8 tex(70D)/48F trefoil nylon, 7.8 tex(70D)/48F round-hole nylon, and 40S cotton are selected to make the veil. The brocade/ammonia coated yarn has the characteristics of good moisture absorption and good elasticity. The fabric made of this material can make the sports protective suit comfortable. Therefore, 4.4 tex(40D) spandex /2.2 tex(20D) nylon covered yarn is used as the raw material for the sample preparation. In this study, the typical 1+3 false rib structure is used to prepare the sports protective suit.

The density, thickness, and surface density of sports protective suit made of different veils are also different [4]. According to fz70002-1991 knitted fabric coil density standard method, the density of sports protective suit sample is measured. The thickness of the fabric is measured according to the standard GB/T 3820-1997. According to the standard FZ/T 70010-2006, the surface density of the sports protective suit sample is measured, and the weight of the fabric is calculated by equation (1).

$$G' = G \times 100 \tag{1}$$

After the sports protective suit samples of different veils are measured according to the standards of each index, the density, thickness, and surface density of the sports protective suit samples are calculated according to the average value, which is used as the basis for the correlation analysis of the knitted fabric thickness, gram weight, and fabric performance in the subsequent studies. The specific values are shown in table 1.

Table 1. Basic parameters of sports protective suit of different veils

Different veil fabrics	Horizontal density	Vertical density	Thickness(mm)	Areal density(g/m2)
Nylon	178	115	1.64	626
Cooldry	182	129	1.71	617
40S cotton	159	107	1.93	598
Trefoil nylon	133	93	1.69	587
Round hole nylon	146	91	1.75	605

2.2 Impact Resistance Test of Sports Protective Suit Sample

The impact resistance of sports protective suit samples is tested referring to the internationally used European BS EN 1621-1-2012 and BS EN 1621-2-2014 impact resistance standards. RCL-300 drop hammer impact tester is used to test the energy absorption capacity of the moving protective clothing sample after receiving impact. The calculation method of impact kinetic energy is shown in equation (2). Among them, Q isthe kinetic energy of impact, m is the weight of falling hammer of 10kg, v is the speed of drop hammer, and h is the lifting height of drop hammer.

$$Q = \frac{mv^2}{2} = mgh \tag{2}$$

2.2 Performance Test of Sports Protective Suit Sample

With reference to the standard GB/T 5453-1997, the YG (B) 461 d - II digital type main permeability tester is adopted for the permeability test of protective clothing fabrics, with permeability as the experimental index. According to the standard GB/T 21655.1-2008, the quick-drying performance of the sports protective suit sample is tested, and the rapid drying performance is measured by evaporation rate. According to GB/T 19976-2005, YG013D-500 electronic strength tester is used to test the bursting performance of the sports protective suit samples. According to the national standard GB/T 9995-1997, the hygroscopicity of sports protective suit samples is tested. Moisture content is used to calculate the moisture absorption of the fabric. The calculation method of moisture content is shown in equation (3). Among them, G is the quality of the fabric before drying, G0 is the dry weight when the ratio between the two quality differences and the mass ratio of the two times is less than 0.05%.

$$MC = \frac{G - G_0}{G} \times 100\% \tag{3}$$

According to FZ/T 70006-2004, the tensile elasticity of sports protective suit fabric is tested. The calculation method of its plastic deformation rate is shown in equation (4). Among them, L0 is the original length of the sample, L1 is the length obtained by testing repeated stretching.

$$N = \frac{L_1 - L_0}{L_0} \tag{4}$$

The moisture permeability of sportswear fabric samples is analyzed referring to the standard GB/T 12704-91 fabric moisture permeable cup method. YG (B)601-I/II type automatic fabric moisture permeability instrument is adopted to measure. Moisture permeability refers to the mass of water vapor passing through the fabric per unit area in unit time under constant vapor pressure [5]. Moisture permeability represents the quick-drying ability of sportswear fabric samples in the state of liquid sweat. The higher the moisture permeability is, the better the moisture permeability is [6]. The calculation equation of moisture permeability is shown in equation (5).

$$WVT = \frac{\Delta m}{A \times t} \tag{5}$$

Among them, WVT is the moisture permeability per square meter per hour; Δm is the difference between two weights of the same test combination, and the unit is g; A is the effective experimental area, and the experimental device area is 0.00283m2; T is the test time.

3. Results and discussion

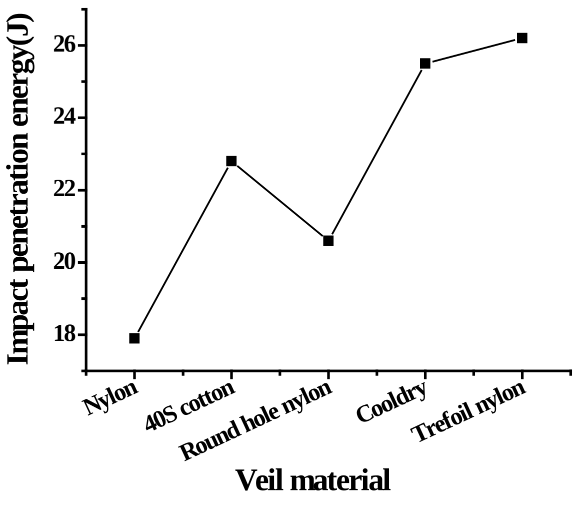

Figure 1. Diagram of impact resistance of different veil materials

After the sportswear fabric samples of different veils are measured according to the shock resistance standard of protective gear, the specific indexes are adjusted according to the actual situation, as shown in Figure 1. Among the 5 samples of sportswear fabric made of veils, the sample of 7.8 tex(70D)/48F trefoil nylon is the most impact-resistant, the sample of 7.5 tex(70D)/72F Cooldry is the second, and the sample of 7.8 tex(70D)/48F nylon is the least impact-resistant.

SPSS19.0 software is used to conduct correlation analysis on the thickness, square meter gram weight, and impact resistance of sportswear fabric samples. The results show that the correlation coefficient between the sample thickness and impact resistance of sportswear fabric is 0.056, so there is no correlation between the sample thickness and impact resistance of sportswear fabric. The surface density and impact resistance of the fabric are P=0.008, that is, P<0.05, so the sample density of sportswear fabric is correlated with the impact penetrability.

The longitudinal tensile force value, transverse tensile force value, impact penetration energy longitudinal deformation rate, transverse deformation rate, air permeability, moisture permeability, moisture content, and bursting strength of different types of protective sports clothing for veils are evaluated and analyzed. It can be found from table 2 that the sample of sportswear fabric with 7.8tex(70D)/48F trefoil nylon as the veil has the highest permeability, while the sample of sportswear fabric with 7.8tex(70D)/48F round-hole nylon as the veil has the lowest permeability. The evaporation rates of 5 different kinds of veils sportswear samples are analyzed. The veil material with the fastest evaporation rate is 7.8 tex(70D)/48F trefoil nylon, and 7.8 tex(70D)/48F nylon has the worst evaporation rate. After analysis of moisture content, it is found that the moisture content of sportswear fabric samples with 7.5 tex(70D)/72F Cooldry as the veil is 5.84% at the highest and 7.8 tex(70D)/48F nylon fiber at the lowest, whose moisture content is only 1/3 of the sample of sportswear fabric with 7.5 tex(70D) /72F Cooldry as the veil. After the comparative analysis of the longitudinal tensile force and the transverse tensile force, it is found that the sportswear fabric samples with 7.5 tex(70D)/72F Cooldry as the veils has the maximum longitudinal tensile force, and the sportswear fabric samples with 7.8 tex(70D)/48F trilinear polyvinyl polyvinyl resin has the maximum longitudinal tensile force. Further analysis shows that the longitudinal test pieces of sportswear fabric are generally more difficult to be stretched than the transverse test pieces, and the required tensile force is greater when they are stretched to a predetermined elongation. Through the analysis of longitudinal deformation rate and transverse deformation rate, it is found that the fabric of 7.8tex(70D)/48F trefoil nylon fiber has the smallest longitudinal plastic deformation rate of the fabric, and the fabric of 7.8tex(70D)/48F round -hole nylon fiber has the highest longitudinal plastic deformation rate. 7.8 tex(70D)/48F round hole nylon has the smallest transverse plastic deformation rate of the fabric, followed by 7.8 tex(70D)/48F trefoil nylon; the transverse plastic deformation rate of 40S cotton is the highest. Through the analysis of the moisture permeability of the sports protective suit sample, it is found that the sports protective suit sample with the veil of 7.8 tex(70D)/48F trefoil nylon fiber has the largest moisture permeability, while the sports protective suit sample with the veil of 7.8 tex(70D)/48F nylon fiber has the smallest moisture permeability. Finally, the jacking strength of the sample is analyzed. The jacking strength of 7.8tex(70D)/48F trefoil nylon veil is the largest and the jacking strength of 7.8tex(70D)/48F nylon is the smallest.

Table 2. Performance test and analysis of sports protective suit fabric samples

Different veil fabrics	Nylon	Cooldry	40S cotton	Trefoil nylon	Round hole nylon
Air permeability (mm/s)	135.56	117.49	104.73	148.81	92.64
Evaporation rate (g/h)	0.34	0.42	0.37	0.45	0.29
Moisture content (%)	1.57	5.84	4.03	5.36	3.29
Longitudinal tensile force(N)	263	341	192	328	285
Transverse tensile force(N)	196	307	121	315	274
Longitudinal deformation rate (%)	7.5	6.7	7.2	6.6	8.4
Lateral deformation rate (%)	6.4	5.7	8.1	5.1	4.9
Moisture Permeability(g/m2·h)	243.72	298.61	263.44	310.93	278.3
Burst strength(N)	335.4	681.7	531.5	763.9	607.6

4. Conclusion

Through the comparison and analysis of different veil materials, it is found that the sports protective suit samples with 7.8tex(70D)/48F trefoil nylon as the veils have good impact resistance, at the same time, its air permeability, quick drying, moisture absorption, and elasticity are good as well. Using 7.8tex(70D)/48F trefoil nylon as the veil can increase the wear-ability and protective performance of sports protective suit. However, orthogonal experiment is not carried out for orthogonal analysis in the study, and only single factor study is conducted on the anti-impact performance and the performance related to sports clothing of sports protective suit samples. In the later stage, the correlation experiment should be carried out for orthogonal analysis. In conclusion, the results of this study can provide a theoretical basis for the fabric selection of sports protective suit.

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