Study on the bending property of shirt sleeve slits

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Abstract. Shirts are the clothing products that people need in all seasons. The folding effect of shirt sleeves directly affects the quality of the sleeves. In this paper by controlling the fabric of the shirt, the folding pressure and the additional pressure time, the fold recovery performance of the sleeves are studied from three aspects: bending stiffness, wrinkle recovery angle and bending recovery force. The experimental results show that the greater the real density of the fabric is, the greater the restoring force is, the less likely the sleeves are folded. Under operation time of 5 minutes, the pressure of 30 N, 40 N, 50 N is applied to the wool fabric and the polyester fabric respectively, the restoring force was 1.0 cN, 0.75 cN, 0.5 cN and 1.2 cN, 0.8 cN, 0.6 cN respectively. At the same time the experimental results show that, the greater the additional pressure is, the smaller the resilience is, and the better the folding effect of the sleeves is. The research in this paper provides a theoretical basis for the actual production of the folding of the shirt sleeves and improves production efficiency by controlling the relationship between negative pressure and negative pressure time.

1. Introduction

With the improvement of people's life quality, people have higher and higher requirements on clothing. As a necessity of people's daily life, shirt is a kind of clothing favoured by consumers. People's demand for shirts is not only limited to wearing, but an aesthetic sense of the shirt is also increasingly important, today the market has a variety of styles, fashionable shirt products. A shirt belongs to the traditional classic clothing, attention to details and grasp in a men's shirt is particularly important. Sleeve slits are an important component of men's shirts, and their structure and technological form determine the quality and style of shirts [1]. With the development of science and technology, automation device has been used in all aspects of industry, but in the process of making sleeve slits, it faces many problems. For example, the production of armbands is low in automation and requires large labour costs. Even though some enterprises put in use the folding mechanism, it can only be applied to the folding of a single type of cloth and cannot be widely applied to the folding of cloth of different materials and thickness, which increases the production cost. In order to develop a folding mechanism suitable for different fabrics, it is urgent to study the bending properties of different fabrics. In this paper, the bending property of shirt fabric is examined on the basis of the study of shirt sleeve fabric.

The bending property of the fabric has a great influence on the appearance of the garment, its machinability and comfort. The bending property of fabric is an important mechanical property index for evaluating the style of fabric. The bending property of fabric is related to the bending property of
fiber, the structure of yarn and fabric, post-finishing, etc. The relationship between them is very complex [2]. The methods used to study the bending properties of fabrics are analytical method, numerical method and rheological method. At present, the evaluation method of fabric folding and ironing effect is mainly subjective. The subjective evaluation method mainly evaluates the appearance of durable pressing products. Since it is a subjective evaluation, human factors, such as the observation proficiency of rating personnel, make the test results easy to produce bias, affecting the final results [3]. In this paper, the bending properties of different shirt fabrics are studied from the three aspects: bending stiffness, folding angle and bending restoring force; thus, the best folding effect of shirt sleeve fabric is found in order to choose the fabric better and achieve the best folding and ironing effect.

2. Bending rigidity of fabric

Researchers at home and abroad are committed to making objective evaluation standards for the bending properties of fabrics, putting forward many testing schemes and forming many bending theories, such as an inclined plane method, a heart method, a gray method, a cantilever method, a pure bending method and a saddle method. The inclined plane method mainly uses the mechanical model of cantilever beam to measure the bending length and calculate the bending stiffness, which has become the standard test method in various countries. The selection of experimental materials follows the principle of combining commonness, diversity and representativeness. According to the different thickness of fabrics and the different structure and organization, different groups of common cotton fabric, silk fabric and wool fabric are selected to be numbered respectively. Selected fabric basic parameters are shown in table 1 (fabric density units: gm⁻²).

| Surface density | Cotton | Cotton | Polyester | Polyester | Silk | Silk | Wool fabric | Wool fabric |
|-----------------|--------|--------|-----------|-----------|------|------|-------------|-------------|
| Tissue          | Plain  | Twill  | Plain     | Satin     | Plain| Satin| Plain       | Satin       |
| Surface density | 55.7   | 156.0  | 66.1      | 122.4     | 43.1 | 79.3 | 153.0       | 205.5       |

According to GB/T 18318–2001 “Determination of the bending length of textile fabrics”, the bending length of the sample in the standard atmospheric environment was tested by YG(B) 022D automatic fabric stiffening apparatus. The calculation method of bending stiffness can be expressed as follows [4]:

$$B = W \cdot C^3 \cdot 9.807 \cdot 10^{-6}.$$  

In the formula, $B$ is bending stiffness (cN cm² cm⁻¹); $W$ is the fabric surface density (gm⁻²); $C$ is bending length (mm).

After multiple measurement and comparison the conclusion has been drawn: the fabric with the same material, the greater the surface density is, the greater the bending stiffness of the fabric is, the less easy it is to fold and iron; the same material fabrics, twill than plain when the bending stiffness; as a whole, the bending stiffness of mulberry silk is less than that of wool and less than that of the surface. According to the above results, the folding and ironing scheme can be appropriately adjusted when the sleeve vents of different materials are folded and ironed to achieve the best folding and ironing effect.

3. Fabric folding recovery angle

The crease recovery angle of the fabric is mainly used to judge the good or bad resilience of the fabric, and to test the anti-crease seam of the fabric [5]. However, in the opposite direction, it can also be used to judge the quality of fabric folding and ironing effect. Once the drape rebound angle of fabric is bigger, the flexibility of cloth is better, going against fold iron. There are two existing testing
standards for fabric crease recovery in China, one is GB/T 3819–1997 “Determination of crease recovery angle method for textile fabric”, which is an objective testing method, the other is GB/T 29257–2012 “Appearance evaluation method for textile fabric crease recovery”, which is a subjective evaluation method. GB/T 3819–1997 is to keep the specimen folded along the warp (longitudinal) and weft (transverse) direction for a certain time, remove the load and recover for a certain time, measure the crease recovery angle, and use the measured angle to express the fabric fold recovery performance. The larger the rebound angle of the crease is, the better the crease resistance is. GB/T 29257–2012 is to apply a certain load to the torsion sample at a certain angle of three-dimensional torsion, so that it will produce wrinkles. The load will be removed and restored for a certain time, and then the degree of appearance wrinkling will be evaluated. Series is higher, fold is less, fight fold performance is better. Method 1 is more commonly used. In this paper, GB/T 3819–1997 “Determination of crease recovery angle of textile fabric” was used to identify the recovery angle of fabric folds [6]. In order to obtain a comprehensive result, several pieces of different fabrics with different thicknesses were selected, each material is shown in table 1 above, respectively to test the warp and weft bending performance and the warp and weft dry crease recovery angle (DCRA) of these fabrics. First sample cut into “product” glyph, in order to provide stability of the sample testing and representativeness, will be folded fabric according to the regulation, reply to wing sample size to 40 mm × 30 mm, and fixed on the wood, will reply wings folded, pressure on the regulation of the weight of a heavy hammer, after a certain time load is removed, unload load is measured with a protractor measuring sample reply wing back angle, 5 min after the crease recovery angle, the heavy hammer weight and loading time are recorded. The elastic recovery angle of longitude and latitude was measured 10 times respectively, and the average value of each direction was taken.

SAS is a famous data analysis software system in the world, and it is the first choice for data management and statistical analysis at home and abroad. We used the SAS system to conduct statistical regression by taking the warp and weft bending direction, bending property $B$ and $2HB$ of the fabric as independent variables and its slow elastic wrinkle recovery angle as dependent variables. Through analysis and calculation, the regression equation of three independent variables is obtained [7]:

$$Y = 104.16293 - 10.35455 \cdot X_1 + 158.27376 \cdot X_2 - 235.39270 \cdot X_3,$$

where $Y$ is the dry wrinkle recovery angle of slow elasticity (°); $X_i$ is the longitude and latitude density (g km$^{-1}$);
$X_2$ is the bending stiffness (cN cm$^2$ cm$^{-1}$); $X_3$ is the bending hysteresis moment (cN cm$^2$ cm$^{-1}$).

According to the experimental observation results, by establishing a regression model with bending stiffness $B$ and bending lag moment $2HB$ as independent variables and slow elastic wrinkle recovery angle as dependent variables, it is concluded that there is a great correlation between them. The larger the bending stiffness is, the larger the crease recovery angle of the fabric will be.

4. The fabric bends to restore force

In the process of wearing and storage, the fabric is deformed due to external forces such as folding, compression and washing. Even after the external forces are removed, it is difficult to restore to the original flat state, which is called crease [8]. Although drape is an insurmountable problem in the appearance of clothes, it can be used in the production of sleeve slits. How to maintain drape, how much force to use and how long to achieve the best folding and ironing effect under negative pressure are also problems to be solved urgently. Many scholars have done a lot of research on the wrinkle problem, but most of the literatures focus on the theoretical analysis and discussion of anti-crease finishing and fold characterization of fabrics. When the fabric creases, the external force is much greater than the bending force, and the process of creasing and deformation also changes with time. Research make fabric drape and fabric bending force of bending force, both to test and to improve the fabric drape performance, better use of principle of fold, better wrinkle fabric production, and can give the fabric folded iron to provide theoretical basis for support, how to control the size of the force and effect time, achieve the best folding hot effect, make the fabric external appearance more beautiful. The parameters of the structure and bending performance of polyester fabric and wool fabric are shown in table 2. The experimental tools include weights of different weights, timers, protractor, force measuring devices etc. In order to control the independent variables and reduce the influence of other dependent variables, the experimental environment is the condition of constant temperature and humidity.

| Sample       | Organization | The linear density (tex) | The density (article·(10 cm)$^{-1}$) | The surface density (gm$^{-2}$) | The thickness (mm) | The bending stiffness (cN cm$^2$ cm$^{-1}$) |
|--------------|--------------|-------------------------|--------------------------------------|-------------------------------|-------------------|------------------------------------------|
| Polyester    | plain        | 26                      | 224 193                              | 161                           | 0.0329            | 10.81 8.05                               |
| Wool fabric  | plain        | 34                      | 320 248                              | 238                           | 0.0618            | 16.58 13.53                              |

Reference fabric crease performance test method standard of vertical method to test, in order to sample testing of stability and a representative sample, the sample reply wing is 40 mm × 30 mm size, and fixed on the block, the shape of the sample for the “product” word, will reply wings folded, pressure on the regulation of the weight of a heavy hammer, after a certain time after the removal of load, the chock with sample according to the rules set direction quickly in good homemade load device, sensor fabric from 3 mm, measuring the initial wrinkle recovery force from the fold. Under the condition of keeping the load action time constant, change the size of the load, measure for many times, and observe the size of the experimental restoring force.

In addition, the size of the load is maintained, and the duration of the variable action time is measured again to measure the drape recovery force of the sleeve slits of different materials, so as to better understand the influence factors and effect of the recovery force.

The result is shown in figure 3:
Figure 3. Relationship between recovery force and negative pressure and negative pressure time of different fabrics (curve 1–3 kg weight, curve 2–4 kg weight, curve 3–5 kg weight).

Observation and statistics of the final experimental results show that the pressure time will directly affect the wrinkle recovery force. For the same kind of fabric, the longer the pressing time is, the smaller the crease recovery force will be, and with the increase of time, the crease recovery force will start to decline rapidly and become gentle after a certain time. The different time of hammering will directly affect the size of the recovery angle of slow elastic wrinkle, for the same kind of fabric, the longer the pressing time is, the smaller the crease recovery angle will be. And with the increase of time, the crease recovery angle of the fabric with slow elasticity starts to decrease rapidly and becomes gentle after a certain time. Different fabrics under the same negative pressure and negative pressure time, the size of the recovery force is not the same.

5. Conclusions
Folding and ironing play an important role in the production of clothing. The folding and ironing of shirt sleeve slits is the process of making the cloth from one steady state to another steady state [9].

In this paper, cotton, wool, polyester, silk and other shirt fabrics of different density were selected for research. The research results show that:

- For cotton fabrics with different areal densities, the larger the areal density is, the larger the fold recovery angle is, which is not conducive to folding hot; choose different shirt fabrics, the greater the surface density is, the larger the fold recovery angle is, the folding effect is not obvious, which is not conducive to folding.

- The comparison of study results of two kinds of shirt fabrics: with polyester fiber and wool fiber, shows that under the same fabric and the same pressure action time, as the applied pressure increases, the resilience is getting smaller and smaller, and the folding effect is more obvious. Conversely, as the applied pressure is reduced, the resilience will increase and the folding effect will be poor. For the same material fabric, in case of a certain additional pressure, the longer the additional force action time is, the smaller the resilience is, the more obvious the folding effect is. In longer time period the resilience remains essentially unchanged and reaches a steady state.

- Under the same negative pressure and negative pressure time, the recovery force of the wool fabric is greater than that of the polyester fabric, because the surface density of the wool fabric is greater than that of the polyester fabric. Again, the greater the surface density is, the better the folding effect is, and the more favorable the folding of the fabric hot is.

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This paper mainly studies the difference of three forms of expression under different negative pressures of different fabrics. It is concluded that the negative pressure is increased in production as much as possible, and the negative pressure time is shortened in order to improve production efficiency. There are also many influencing factors related to the folding and ironing effect, such as temperature, humidity, etc. In the follow-up study, the influence effect of various factors will be improved to show the best folding and ironing effect more accurately.

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