Research on thermal comfort properties of Mongolian robes

Xiao-Fang GUO¹ and Hua-Xin LIU¹

¹Department of Light Industry & Textiles, Inner Mongolia University of Technology, No. 49, Ai-min road, Hohhot 010051, China

Abstract: In order to reveal the thermal comfort performance of Mongolian robes, three types of Mongolian gowns were selected in this experiment, including four single gowns, three cotton gowns and two leather gowns. Three Mongolian robes were tested and analyzed in the form of single part and combination respectively by using the thermal manikin. The clothing area factors of two kinds of Mongolian robes were investigated by camera method. The relationship between the clothing area factor and the thermal insulation value of Mongolian robes was obtained by using SPSS. The approximate range of thermal resistance of Mongolian robes is obtained. It has important significance to improve the design of Mongolian robes and adapt to the local environment.

1. Introduction

Located in the Inner Mongolia Plateau of Northwest China, it is composed of desert and grass-land. The local climate is dry, the four seasons are windy and sandy. With the climate, Mongolians need clothes that are perfectly adapted to the environment and nomadic life. Wearing clothes not only requires easy wear and heat dissipation, but also requires better warmth retention. Strong solar radiation also requires clothing to prevent skin sunburn. So Mongolia clothing is characterized by broad structure, thick material and spacious robe. Mongolian robes are the main form of clothing of Mongolian tribes. Influenced by economic conditions, geographical environment, production methods, historical inheritance and ethnic exchanges, Mongolian robes are unique in their structure and material.

At present, the research on minority costumes mainly focuses on costume culture and aesthetics in China, but there are few studies on basic functions. It has very national characteristics and rich connotations. A border or a button contains the innovation and inheritance of the Mongolian robes have very national characteristics. An edge and a button contain the Mongolian's innovation[1]. Studying the thermal insulation of Mongolian robe is based on exploring the scientific principles contained in national costumes from the engineering point of view, which can have a deeper understanding of the functional beauty of national costumes. At present, all kinds of clothing culture like hundred flowers in bloom[2]. Researching the thermal insulation lays a foundation for the functional comfort of Mongolian robe, it also provides ideas for the research of other minority clothing.

In this research, four single robe, three cotton robe and two leather robe were selected as test objects to study the thermal insulation of Mongolian robe. Research on thermal insulation will play a positive role in inheritance and improvement of Mongolian robes.

2. Materials and methods

The Mongolian robe used in the experiment are tested in the climate cabin of plateau environment by using the thermal manikin system. There are two methods to determine the clothing area factor of a clothing ensemble: an estimated equation and the photographic method, a more complicated
photographic method with a digital camera was used in this research and analyzed by SPSS. The functional relationship between the area factor of Mongolian garment and the basic thermal resistance of garment is supported by experimental data.

| Code | Style       | Texture | Weight | Colour   |
|------|-------------|---------|--------|----------|
| D1   | Single Robe | silk    | 1337.8 | L-green  |
| D2   | Single Robe | silk    | 1351.4 | blue     |
| D3   | Single Robe | silk    | 1242.2 | white    |
| D4   | Single Robe | silk    | 1074.5 | Wathet   |
| M1   | Cotton Robe | cotton  | 1623.3 | V-blue   |
| M2   | Cotton Robe | cotton  | 1871.9 | gules    |
| M3   | Cotton Robe | cotton  | 1445.4 | Sky blue |
| P1   | Fur Robe    | velvet  | 2500.8 | N-Blue   |
| P2   | Fur Robe    | Polyest + wool | 4502.6 | black    |

2.1. Mongolian robe selected
The Mongolian robe selected in this research includes four single robe, contain one improved single robe, three cotton robe and two leather robe. The waistcoat, autumn dress, autumn trousers, trousers and socks are used as basic garment as shown in Table 1 and Table 2.

2.2 Thermal manikin
In this research, experiments were performed using a dry and copper thermal manikin of the FTD17 type (developed by Donghua University), which can simulate dry heat loss from the human body. The
height of the manikin is 168 cm and the body surface area 1.68 m². There are a total of 11 electrically independent heating segments about the manikin: in the head, chest-back, abdomen, buttocks left and right arms, thighs, legs and feet. Each segment is individually controlled. As shown in Fig 1.

![Thermal manikin](image)

Fig 1 Thermal manikin

2.3. Measurement of Area Factor

The ratio between body surface area after wearing clothes and body surface area of naked body is called clothing area factor. The thermal insulation of a single garment can not fully reflect the human body's dress situation. In most cases, more than one garment is worn by the human body, so it is also very important to test the thermal performance of a combination garment. However the thermal insulation of combination garment is often influenced by the area factor. The measurement methods of area factor usually include an estimated equation and the photographic method. The literature [3] show that the empirical estimation Equation of garment area factor is not suitable for national garments. Therefore the area factor of Mongolian robe combination garments is evaluated by camera measurement method to obtain more accurate data and calculate by Equation (1).

$$ f_{cl} = \frac{A_{cl}}{A_n} = \sum \frac{A_{cl}}{A_{ni}} $$

(1)

In Equation 1:  $A_{cl}$ is the projection area from three directions to take pictures of the dressed body; $A_{ni}$ is the projection area from three directions to take pictures of naked body.

Taking the straight line of the human body as the reference level, the camera and the horizontal plane of the human body are distributed at zero, 45 and 90 degrees. Photoshop drawing software was used to cut out the best pictures in three directions to establish a dummy dress selection area including head, arm and foot. Then find the histogram of the window toolbar, and use the pixels as the reference of the projection area of clothing and human body. The garment surface factor is calculated by Equation (1).

3. Results and discussion

Measurements were performed in a climatic chamber of about 6 m³ volume according to the requirements of ISO15831 [4], in which the ambient condition was maintained at a constant level: the air temperature at 14 ± 0.1 °C, the air velocity at 0.4 ± 0.1 m/s, the relative humidity of air at 50 ± 5% and no radiation. The thermal manikin was clothed with the inner ensemble fist, then one Tibetan robe was chosen and clothed in the regular style. The average manikin surface temperature of each segment of the manikin was maintained at 34 °C(uniform surface temperature operation model). According to the requirements of ISO 15831[3], the total thermal insulations of clothing ensembles in three styles were measured. The parallel method, recommended by ISO9920[6], was used to calculate the total thermal insulation (IT) of the clothing ensembles according to local thermal insulations of 11 segments of the manikin. Each measurement was taken twice, and the thermal insulation of the naked manikin (Ia) was also tested in the same air conditions. According to Equation 2, the effective thermal resistance of a single garment can be obtained, as shown in Table 3.

$$ I_{elu} = I_t - I_a $$

(2)
In the Equation: $I_{cl}$ is the effective thermal resistance of clothing, $I_t$ is the total thermal resistance of clothing, $I_a$ is the thermal resistance of air layer. The thermal resistance of a single Mongolian robe is shown in Table 4. Under the same conditions, the thermal resistance of nude dummy is 0.78 clo.

3.1. Combination of test and analysis of thermal resistance of Mongolia Robe

The vest, autumn clothes, trousers and socks were used as basic clothes[7]. The total thermal resistance of the combined clothes was tested by combining them with nine Mongolian gowns. According to the international standard ISO15831[8], the test environment of clothing system is to put the thermal manikin in the climate cabin which the external conditions such as temperature and wind speed can be controlled. According to the experimental requirements, the basic clothing and test clothing are worn. The experimental environment of the clothing system is the same as the experimental settings of measuring a single Mongolian robe. But the test temperature of the experimental clothes, we need to choose the temperature similar to the experimental clothes. When testing a single Mongolian robe, the outside air temperature of the warm dummy is 20 degrees. Therefore, the test air temperature of the combined Mongolian robe clothing system is 14 degrees, and the basic thermal resistance of the combined clothes is obtained from Equation(3). The test data are shown in Table 5 and Table 6 below.

$$I_{cl}=I_t-I_a$$  \hspace{1cm} (3)
### Tab 5. Thermal resistance of base clothing

| Name          | Content         | Total | Value |
|---------------|-----------------|-------|-------|
| Basic clothing|                 |       |       |
| vest          | Cotton          | 1.40  | 1.41  |
| shorts        | Cotton          |       |       |
| Autumn Clothes| Cotton          | 1.42  |       |
| Autumn trousers| Wool           | 1.40  |       |
| Socks         | Cotton/ammonia  |       |       |

### Tab 6. Total Thermal Resistance and Basic Thermal Resistance

| Code | Name          | It  | Fcl | Icl |
|------|---------------|-----|-----|-----|
| DZ1  | D1+Basic Clothing | 1.79 | 1.49 | 1.28 |
| DZ2  | D2+Basic Clothing | 1.84 | 1.54 | 1.33 |
| DZ3  | D3+Basic Clothing | 1.88 | 1.58 | 1.39 |
| DZ4  | D4+Basic Clothing | 2.10 | 1.83 | 1.67 |
| MZ1  | M1+Basic Clothing | 2.01 | 1.65 | 1.54 |
| MZ2  | M2+Basic Clothing | 1.95 | 1.57 | 1.45 |
| MZ3  | M3+Basic Clothing | 2.16 | 1.54 | 1.65 |
| PZ1  | P1+Basic Clothing | 2.44 | 1.61 | 1.96 |
| PZ2  | P2+Basic Clothing | 2.53 | 1.77 | 2.09 |

### 3.2. The relationship between Mongolia area factor and basic resistance Robe

In order to find out the relationship between clothing area factor and clothing basic thermal resistance, the test data of the above-mentioned combination clothing are processed and the following Table 7 are obtained.

### Tab 7. Area factor of garments

| Code | Front | 45-degree incline | Side | Fcl |
|------|-------|-------------------|------|-----|
| DZ1  | 125264| 107259            | 82996| 1.49|
| DZ2  | 130133| 111817            | 83487| 1.54|
| DZ3  | 133692| 108746            | 91010| 1.58|
| DZ4  | 157747| 128135            | 100770| 1.83|
| MZ1  | 137055| 117609            | 93025| 1.65|
| MZ2  | 131093| 117189            | 83792| 1.57|
| MZ3  | 135049| 101932            | 87431| 1.54|
| PZ1  | 138317| 112111            | 88849| 1.61|
| PZ2  | 157823| 121070            | 94536| 1.77|
| Thermal manikin | 86068| 76923             | 48068|     |

Based on the scatter plot of basic thermal resistance and clothing area factor, the existing clothing factor prediction model and the Equation of clothing area factor prediction in international standards(Table 8), it is inferred that the Mongolian robe clothing area factor and clothing basic thermal resistance value should be a linear model.

### Tab 8. Prediction model of fcl
The relationship between the area factor of Mongolian robe and the basic thermal resistance was obtained by analyzing the relevant data. Through SPSS data analysis software, we get the functional relationship between $F_{CL}$ and $I_{CL}$ (Fig 2).

\[
f_{CL} = 1.18 + 0.27 I_{CL} \quad (R=0.842, \quad R^2 =0.71)
\]

The forecasting model of Mongolian robe FCL is compared with the forecasting model of FCL in current international standards and relevant scholars literature. The results are shown in Fig3. From the image, it can be seen that the intercept of the FCL prediction model of Mongolian clothing is close to that of Tibetan clothing, about 0.08, larger than that of the western-style common clothing of ISO 7730, about 0.13.

### Table: Prediction model and Standards

| Prediction model | Type                      | Standards       |
|------------------|---------------------------|-----------------|
| $f_{CL}=1.18+0.27I_{CL}$ | Mongolian Clothing        |                 |
| $f_{CL}=1.26+0.31I_{CL}$ | Tibetan costume           | GUO XIAO FANG   |
| $f_{CL}=1+0.3I_{CL}$      | Western-style cold-proof clothes | ISO 11079 |
| $f_{CL}=1+0.3I_{CL}$      | Western-style cold-proof clothes | Mccullough |
| $f_{CL}=1+0.28I_{CL}$     | Western-style cold-proof clothes | ISO 9920 |
| $f_{CL}=1.05+0.1I_{CL}$   | Western-style cold-proof clothes | ISO 7730 |

4. Conclusion

From the experimental data, it can be seen that the thermal resistance values of different types of Mongolian robes are different. The thermal resistance of single robe, single Cotton gown, and single furred robe values are in the range of 0.55-0.82clo, 0.85-1.12clo, 1.08-1.17clo. The basic thermal resistance values of single gown, cotton gown and furred robe are 1.28-1.68 clo, 1.45-1.65 clo and 1.93-2.09 clo. The area factor of Mongolian robes was tested by photography. The thermal resistance and area factor of the combination garment show a certain functional relationship. The functional relationship between them is $f_{CL} = 1.18 + 0.27I_{CL}$. It has reference value for the improvement of Mongolian robes in the future.

### References

[1] CE Limuge L 2009 *J. Popular Literature*. pp185-186
[2] WU Yun W 2008 *J. Journal of Dec*. pp35-42
[3] LI Qing L 2002 *D. Shanghai: Donghua University*, pp4-8.
[4] GUO Xiaofang G 2016 *J. Journal of Textile Research*, pp7-37.
[5] WANG Qiang W, GAN Yingjin G, 2005 *J Shandong Textile Science Technolog*, pp34-36
[6] KIU Jaja J, WU Zhiming Z and CHU Yuming Y 2013 *J. Journal of Textile Research*. pp58-61
[7] WANG Yuan Y, 2013 *J. Journal of Silk*. pp46-50
[8] QIAN Xin X and ZHAO Meng M. 2010 *J. Journal of Textile Research*. pp100-101.