# STUDY OF RING-, ROTOR- AND COMPACT-SPUN YARN FABRICS: EFFECT OF SPINNING METHOD ON THERMAL RESISTANCE OF FABRICS

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## Abstract

Fabrics woven from ring, rotor and compact spun yarns have been compared from the standpoint of thermal comfort. Emphasis has been placed on the thermal aspects by the use of the Kawabata Thermolabo-II. For all experimental combinations, the ring spun yarn fabrics possess better thermal resistance, poor air permeability. Also it has been seen that spinning method does not have significant effect on GSM and thickness of fabric, but within spinning method with increase in GSM and thickness of fabric thermal insulation of fabric also increases.

**Keywords**: *air permeability, compact-spun yarn, thermal comfort, thermal resistance, ring-spun yarn, rotor-spun yarn,*

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## Introduction

Assuring the thermal stability of the human body is one of the most important functions of clothing. Its thermal insulation properties play a crucial role for a human's heat maintenance. Clothing can also influence work in warm or cold environment.

The thermal characteristics of fabric depends along with other factors, on the structure and types of yarn used [1]. Yarn produced by using different spinning technologies differ from one another in respect of their structure, bulk, mechanical and surface properties. The properties of fabric produced from these yarns are affected by such yarn properties as well as by their fabric construction parameters. All the spinning technologies have their own advantages and disadvantages, which are inherent irrespective system. An extensive work has been done on a thermal properties of fabrics, very little has been reported on spinning technologies.

Comfort properties of fabric woven from Ring-, rotor-, and friction spun yarns have been compared by Behera, Ishtique and Chand [2]. Das et.al [3, 4] reported the characteristics of cotton shrinkable acrylic blended bulked yarns and fabric produced from ring spun yarns. Das et. al [5, 6] studied the comfort properties of fabrics made from bulked yarns from different spinning technologies. Tyagi G.K. et.al [7, 8] reported the thermal comfort aspects of ring and MJS yarn fabrics. The object of investigation described in present paper was to compare the properties of fabrics woven from ring-, rotor-, and compact –spun yarns, from the thermal comfort point of view and to analyze the results with the help of yarn properties.

## 2. Materials and methods

### 2.1 Materials

#### 2.1.1. Preparation of yarn samples

The yarns were produced with 100% cotton by using three spinning methods viz. ring, compact and rotor spinning method. Roving hank of 1.025 was used to produce $16^s$, $24^s$ and $30^s$ Ne ring and compact yarn, whereas sliver hank of 0.139 was used to produce rotor yarns. Twist multiplier of 4.0, 3.8 and 3.8 was used to produce ring and compact yarn of $16^s$, $24^s$ and $30^s$ Ne respectively, whereas twist multiplier of 5.3, 5.0 and 4.8 was used to produce rotor yarn of $16^s$, $24^s$ and $30^s$ Ne respectively. 12000 rpm spindle speed was used to produce ring and compact yarns, and 90000 rpm rotor speed was used to produce rotor yarns.

#### 2.1.2. Preparation of fabric samples

Twenty seven fabric samples were prepared on a Dornier rigid rapid machine. The details of the fabrics are given in table-I. No finishing was done on the fabric samples. All samples were tested in the gray form.

**Table-I Fabric Details**

| Method | Ring | | | Compact | | | Rotor | | |
|---|---|---|---|---|---|---|---|---|---|
| Count | 16 | 24 | 30 | 16 | 24 | 30 | 16 | 24 | 30 |
| Fabric Combination | 84x52 | 84x52 | 84x52 | 84x52 | 84x52 | 84x52 | 84x52 | 84x52 | 84x52 |
| | 84x44 | 84x44 | 84x44 | 84x44 | 84x44 | 84x44 | 84x44 | 84x44 | 84x44 |
| | 84x36 | 84x36 | 84x36 | 84x36 | 84x36 | 84x36 | 84x36 | 84x36 | 84x36 |

**2.2. Experimental Method**

**2.2.1. Evaluation of yarn properties.**

Yarn unevenness was measured on the Premier yarn Unevenness tester according to ASTM D1425 method. Yarn tenacity and breaking elongation were measured on a Premier Tensomax-7000 tester according to ASTM D2256 procedure. Hairiness of yarn was measured on Zweigle hairiness tester according to the ASTM D5647 method.

**2.2.2. Evaluation of fabric construction parameters**

The end and pick densities were measured with a pick glass at ten randomly selected positions for each sample.

**2.2.3 Evaluation of fabric tensile properties.**

The tensile behavior off all fabric samples were measured by using Instron tensile tester and the test was carried out according to ASTM D5035-95 method.

**2.2.4. Evaluation of fabric thickness and GSM**

Fabric thickness was measured with a thickness tester as per the ASTM D1777 standard. GSM of fabric samples were measured by GSM cutter according to ASTM D3776 standard.

**2.2.5 Evaluation of transmission properties of fabrics**

Air permeability of all the fabric samples was measured on air permeability tester and the test was carried out according to ASTM D737. The thermal insulation was evaluated on KES-FB5 (Thermo lab II). The test was carried out according to ASTM D1518 standard.

**3. Results and Discussion**

### 3.1 Yarn Properties

The results for the yarn properties are shown in Table- II. It may be seen from the results that the compact yarns are the best from the standpoint of breaking strength, which may be due to the minimization of the spinning triangle, enables almost all fibres to be incorporated into the yarn

**Table- II Yarn Properties**

| **Parameters** | Ring | | | | Compact | | | Rotor | |
|---|---|---|---|---|---|---|---|---|---|
| | 16 | 24 | 30 | 16 | 24 | 30 | 16 | 24 | 30 |
| **Count** | 15.3 | 23 | 30 | 15 | 22.9 | 29.6 | 16.08 | 23.82 | 31.1 |
| **Count CV** | 0.93 | 0.97 | 0.62 | 0.81 | 0.37 | 1.01 | 2.04 | 1.07 | 4.82 |
| **RKM** | 21.63 | 21.31 | 19.4 | 22.77 | 21.48 | 22.89 | 15.67 | 15.2 | 14.05 |
| **RKM CV** | 4.59 | 5.81 | 6.97 | 10.53 | 6.35 | 6.87 | 6.16 | 8.28 | 8.26 |
| **Elongation %** | 6.48 | 5.83 | 5.63 | 6.12 | 5.62 | 5.98 | 5.99 | 5.97 | 4.03 |
| **Elon. CV** | 4.15 | 5.32 | 7.28 | 10.59 | 5.23 | 7.31 | 8.28 | 10.11 | 10.72 |
| **Hairiness S3 Value** | 2132.6 | 1448.2 | 1288 | 723.5 | 367 | 468.6 | 515.7 | 312 | 396.6 |
| **Hairiness CV** | 4.5 | 3.21 | 7.86 | 4.83 | 12.46 | 8.43 | 5.04 | 12.33 | 5.66 |
| **U%** | 7.94 | 9.48 | 9.64 | 7.65 | 8.84 | 9.12 | 8.84 | 9.78 | 11.66 |
| **U% CV** | 1.33 | 2.86 | 2.01 | 2.69 | 1.41 | 1.98 | 5.35 | 2.75 | 0.66 |

structure with maximum possible length and pre-tension of the fibres, irrespective of their position in the spinning triangle. The uniform pre-tension of the majority of fibres enables more synchronic breakage of the majority of the fibres, which contributes to higher yarn strength. The rotor spun yarn has been found to be the bulkiest yarn, the diameter of compact yarns are lesser than ring and rotor yarn which may be due to the more compact structure of compact spun yarn. Hairiness of ring yarn is found more than compact and rotor yarn, this is may be to the more spinning triangle, rotor yarn shows lower hairiness might be due to the wrapper fibres on the yarn surface. U% of compact spun yarn is found better than ring and rotor spun yarn.

### 3.2 Fabric Properties

Fabric properties were shown in Table-III. Results were studied statistically by using general linear model of $3^3$ full factorial experiments.

#### 3.2.1 Air permeability

The air permeability results for the fabric samples are shown in Table-III. The main effect of spinning method is shown in graph-I. From the statistical analysis we can say that there is significant effect of spinning method on fabric air permeability. Air permeability of fabrics woven with rotor spun yarn shows higher air permeability than fabrics woven with compact and ring spun yarn. The higher air permeability through rotor yarn fabrics in spite of greater yarn bulk may be due to air flow through wrapper fibers. Compact yarn fabrics shows more air permeability than ring yarn fabrics may be due to more compact structure of compact yarn.

**Graph-I Main effects plot for air permeability**

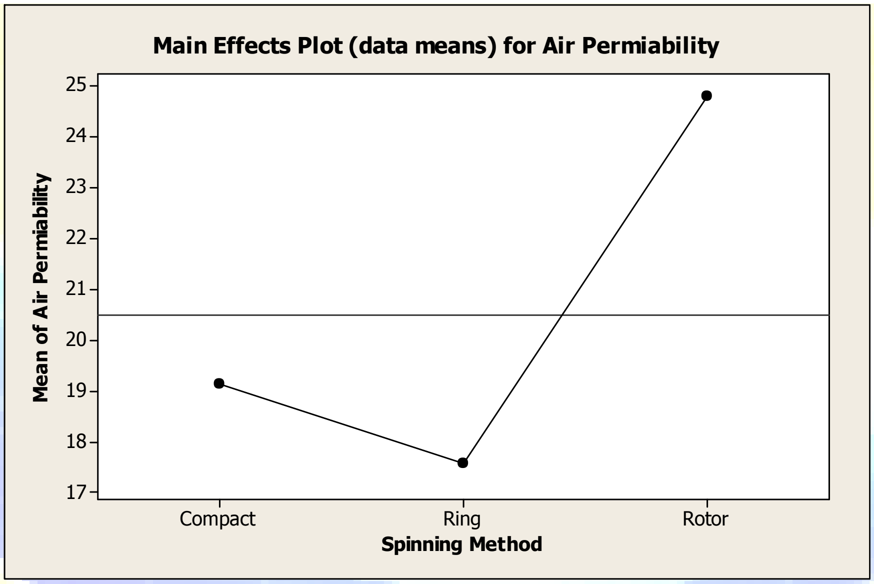



**Table-III Fabric Properties**

| Count | PPI | Spinning Method | Air Permeability | Thickness | GSM | clo | Brk.Str Weft way | Brk.Elgn Weft way |
|---|---|---|---|---|---|---|---|---|
| 16 | 36 | Ring | 25.033 | 0.4475 | 166.67 | 0.531 | 48.29 | 7.35 |
| 16 | 44 | Ring | 9.894 | 0.464 | 182.82 | 0.535 | 66.37 | 8.13 |
| 16 | 52 | Ring | 3.415 | 0.4735 | 198.54 | 0.543 | 81.71 | 8.24 |
| 24 | 36 | Ring | 32.988 | 0.414 | 139.15 | 0.517 | 32.94 | 7.71 |
| 24 | 44 | Ring | 17.77 | 0.425 | 149.75 | 0.516 | 39.2 | 7.85 |
| 24 | 52 | Ring | 5.925 | 0.446 | 165.17 | 0.492 | 50.67 | 7.57 |
| 30 | 36 | Ring | 34.522 | 0.396 | 131.59 | 0.506 | 22.61 | 7.12 |
| 30 | 44 | Ring | 18.47 | 0.4055 | 140.65 | 0.51 | 28.96 | 7.26 |
| 30 | 52 | Ring | 10.02 | 0.417 | 149.47 | 0.524 | 35.21 | 7.17 |
| 16 | 36 | Compact | 27.391 | 0.4365 | 162.55 | 0.501 | 47.91 | 17.49 |
| 16 | 44 | Compact | 13.824 | 0.456 | 176.65 | 0.5 | 55.63 | 7.39 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 16 | 52 | Compact | 3.906 | 0.4705 | 197.99 | 0.518 | 77.09 | 9.94 |
| 24 | 36 | Compact | 37.372 | 0.4095 | 144.5 | 0.486 | 33.85 | 8.37 |
| 24 | 44 | Compact | 18.182 | 0.4265 | 154.79 | 0.513 | 42.95 | 8.34 |
| 24 | 52 | Compact | 8.627 | 0.4395 | 165.83 | 0.504 | 52.14 | 8.59 |
| 30 | 36 | Compact | 33.502 | 0.391 | 134.07 | 0.486 | 26.84 | 6.66 |
| 30 | 44 | Compact | 19.5 | 0.4045 | 142.71 | 0.495 | 33.75 | 6.49 |
| 30 | 52 | Compact | 9.811 | 0.431 | 149.66 | 0.485 | 38.46 | 7.69 |
| 16 | 36 | Rotor | 35.539 | 0.443 | 159.84 | 0.467 | 33.21 | 7.51 |
| 16 | 44 | Rotor | 12.511 | 0.454 | 176.96 | 0.48 | 47.72 | 7.6 |
| 16 | 52 | Rotor | 7.797 | 0.4735 | 193.99 | 0.519 | 64.19 | 8.19 |
| 24 | 36 | Rotor | 42.605 | 0.4115 | 142.01 | 0.467 | 23.22 | 7.55 |
| 24 | 44 | Rotor | 20.409 | 0.4245 | 150.89 | 0.471 | 30.41 | 7.39 |
| 24 | 52 | Rotor | 10.292 | 0.4435 | 162.09 | 0.503 | 39.21 | 7.71 |
| 30 | 36 | Rotor | 51.246 | 0.394 | 132.28 | 0.465 | 18.61 | 6 |
| 30 | 44 | Rotor | 27.159 | 0.404 | 139.62 | 0.487 | 22.49 | 6.53 |
| 30 | 52 | Rotor | 15.628 | 0.4195 | 150.35 | 0.475 | 28.72 | 6.72 |

### 4.3.2 Thermal resistance (Clo value)

Graph-II shows the main effects plot for clo value of fabrics, the statistical analysis showed that the clo value of ring, compact and rotor fabrics differs significantly at 0.05 significance level. It is shown that fabrics woven from ring yarns has more thermal resistance than those woven from compact and rotor spun yarns. The ring spun yarn fabrics show higher thermal resistance than compact spun yarn fabrics is may be due to more hairiness, larger diameter of yarn and lesser packing coefficient. Whereas the rotor spun yarn fabrics shows lower thermal resistance is may be due to higher twist multiplier used while manufacturing of rotor yarns, so the twist level in the yarn is more hence reduces the air pockets within yarn structure. Also the hairiness of rotor yarn is much less than ring yarn.

### 4.3.3 GSM of fabric

Graph- III shows the effect of spinning method on GSM of fabrics, the statistical analysis (Table-IV) shows that there is no significant effect of spinning method on GSM of fabrics. But within spinning method if we increase GSM of fabric then thermal resistance of fabric also increases.

**Graph II Main effects plot for clo**

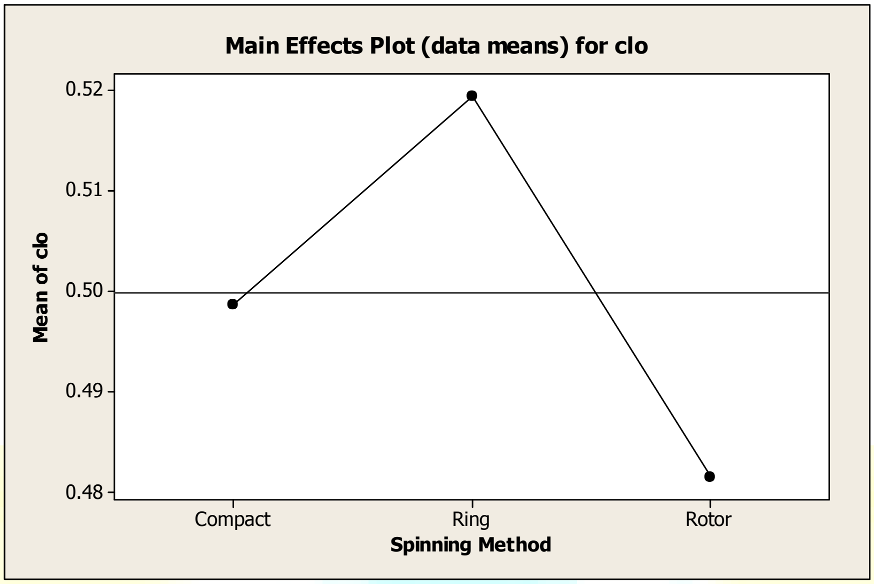
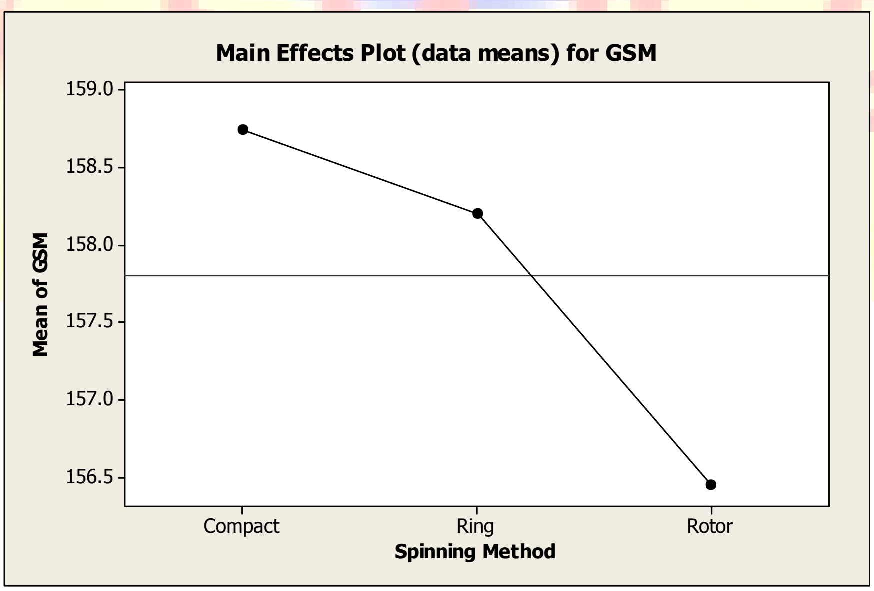



**Table-IV Minitab test results**

| Variable | Fabric characteristics | | | | | |
|---|---|---|---|---|---|---|
| | Air permeability | Clo value | GSM | Thickness | Brk.Str Weft way | Brk.Elgn Weft way |
| Spinning Method | s | s | Ns | ns | s | s |

Note: s- Significant at 95% confidence level, and ns- Non significant at 95% confidence level

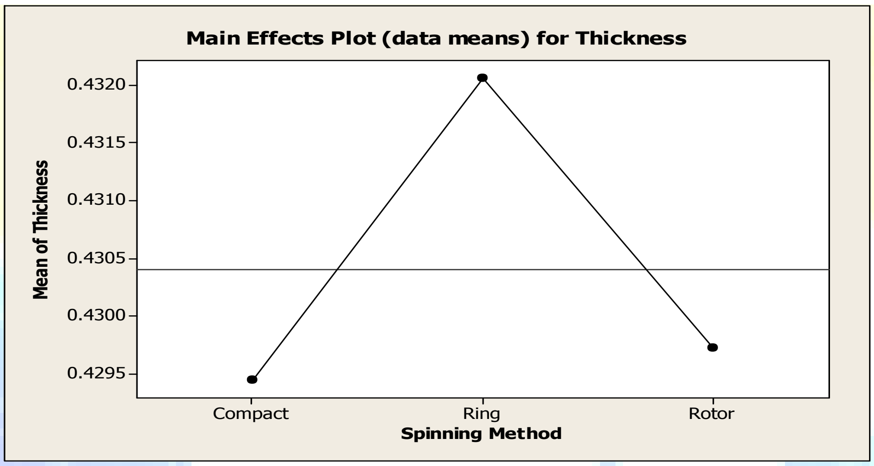
**Graph III Main effects plot for GSM**



### 4.4.4 Thickness of fabric

Graph- IV shows the effect of spinning method on thickness of fabrics, from the statistical analysis we can say that there is no significant effect of spinning method on thickness of fabric. But it has been noted that within spinning method if we increase thickness of fabric by increasing picks per inch of fabric then thermal resistance is also found to be increased, which may be due to the increase in thickness air pockets in the fabric structure also increases which lead to increase in thermal resistance.

**Graph IV Main effects plot for thickness**



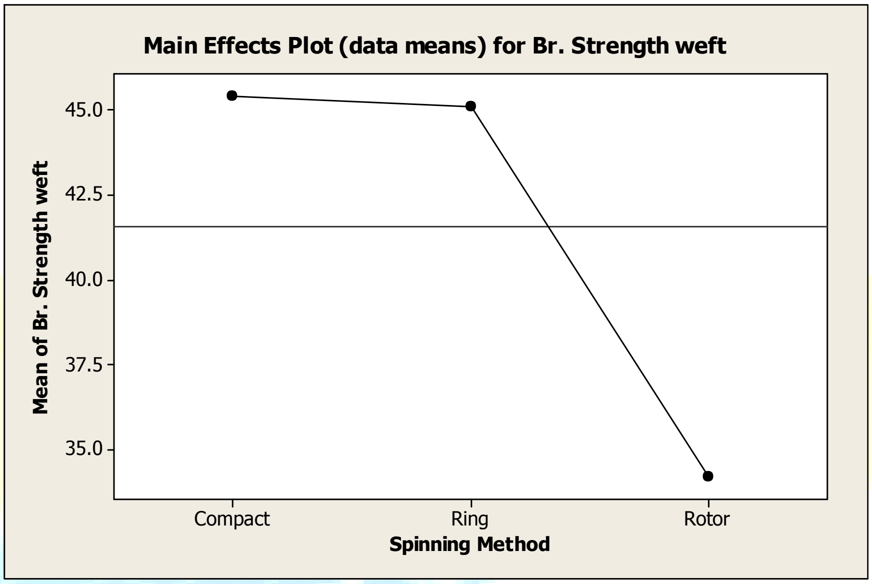

**Graph V Main effects plot for Br. Strength weft**

### 4.4.5 Breaking load

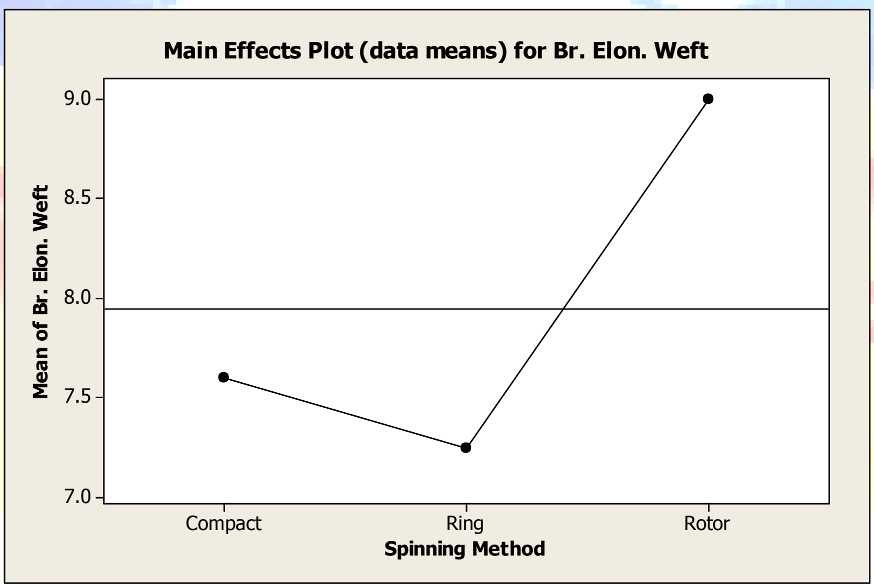
The results of fabric breaking load were depicted in graph-V. The statistical analysis also revealed that breaking load of rotor, compact and ring fabrics differs significantly. Fabrics woven with compact yarns had higher breaking loads than those woven with ring yarns. Higher breaking load of compact fabrics may be related to increasing fiber extent inside the yarn due to elimination of spinning triangle in this spinning technique. Rotor yarn fabrics shows lower breaking load may be due to the lower breaking strength of rotor yarn.

### 4.4.6 Breaking extension

The results of fabric breaking extension were depicted in graph-VI. The statistical analysis also revealed that breaking extension of rotor, compact and ring fabrics differs significantly. Fabrics woven with rotor yarns had higher breaking extension than those woven with ring and compact yarns. Higher breaking extension of rotor yarn fabrics may be due to the higher breaking strength of fabrics woven with rotor yarns.




**Graph VI Main effects plot for Br. Elongation weft**



## Conclusion

On the basis of the investigation carried out, the following conclusions can be drawn. Air permeability of fabrics woven with rotor spun yarn shows higher air permeability than fabrics woven with compact and ring spun yarn. Fabrics woven with ring yarn shows higher thermal insulation than fabrics woven with compact and rotor spun yarn. Spinning method has no effect on GSM and Thickness of fabric. But within system with increase in GSM and Thickness thermal insulation of fabric also increases. Fabrics woven with compact yarns had higher breaking loads than those woven with ring and rotor yarns.

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