THE EFFECT OF PERCENTAGE OF REMAINING HAIR, BREED AND AMBIENT RELATIVE HUMIDITY ON ELECTRICAL RESISTANCE OF CASHMERE FIBER

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Abstract Among different types of controlling systems, the ON/OFF digital relative humidity control was used for measuring electrical properties of cashmere fibers to make the ambient relative humidity fixed. To achieve this goal the required hardware and software were designed and fabricated. The electrical resistance of fine and coarse hair cashmere fiber was measured by charge and discharge condenser method using Rothschild static voltmeter type R-4021 made in Germany. Experimental results show that the electrical resistance of the fine under coat fibers is considerably greater than that of the coarse under coat fibers. The difference depends on the breeds. With increasing relative humidity, difference of electrical resistance of fine under coat and coarse outer coat cashmere fiber is decreased.

Key Words Cashmere, Relative Humidity, Dehairing, Control ON/OFF, Electrical Resistance

چکیده در تحقیق حاضر برای کنترل رطوبت محیط آزمایش، از کنترل کنندهٔ رطوبت نسبی دیجیتالی OFF/ON استفاده گردیده و برای این منظور نرم افزار و سخت افزار لازم تهیه گردید. سپس در فضایی که رطوبت نسبی آن تحت کنترل قرار گرفته بود، مقاومت الکتریکی کرک و موی کشمیر ، توسط روش شارژ و دشارژ یک خازن با استفاده از دستگاه ولت متر استاتیکی(Static Voltmeter) مدل R-4021 ساخت شرکت Rothschild اندازه گیری گردید. نتایج حاصله بیانگر آن است که مقاومت الکتریکی الیاف کرک از الیاف مو بیشتر می‌باشد ، این تفاوت در نژادهای مختلف متفاوت می‌باشد . الیاف کشمیر با درصد موهای گوناگون ، دارای مقاومت الکتریکی مختلف می باشد و همزمان با افزایش رطوبت نسبی، اختلاف بین مقاومت الکتریکی الیاف کرک و الیاف موی کشمیر کاهش می‌یابد.

INTRODUCTION

Cashmere is one of the most important animal fibers used in textile industry. This fiber is obtained from a kind of goat named Capra Hircus Laniger. The body of this animal is covered by two kinds of fibers. The fine under coat, which is known as down cashmere fiber and the outer fiber or coarse outer coat, which is known as guard hair [1,2]. The separation of these fibers from each other is called dehairing. If the percentage of guard hair in cashmere fiber increases, the price of the fiber will decrease and the textile processing would become difficult [3,4].

Two factors will affect on the process of dehairing. The first one is external, which is related to the kind of machinery used. The second is related to the physical properties of the fiber used [1]. Electrical property is a physical one; perhaps the most important property in dehairing process [1] of the cashmere fibers.

Electrical properties of materials are interrelated.

The electrical resistance showing the liability of a material to a static charge, for example, is mainly determined by permittivity [5,6,7]. This means that the electrical resistance of the fiber used must be considered.

Moisture is one of the most important factors affecting the electrical resistance of the textile materials. It can change the electrical resistance of these materials up to 10^{10} times. A 10 to 90% change in relative humidity results, for example, in a million folds difference in electrical resistance. A ten fold electrical resistance, for every 13% increase in relative humidity has, for example, been reported [8]. To study the electrical properties of the fibers, the humidity of the testing area should, hence, be controlled at a certain level.

The dynamic equation of the testing laboratory, in which the relative humidity is variable, is considered together with the necessary hardware and software to design and fabricate the conditions necessary for the experiments [9] in this work. The relative humidity of the testing area was, therefore, kept constant and the electrical resistance of different breeds of cashmere fiber, down fiber and guard hair was examined, in different relative humidity (R.H.).

2. DEFINITIONS, MACHINERY, METHODS AND MATERIALS

2.1 Definitions The electrical resistance of a specimen (R in ohms) is defined as the ratio of the voltage across the specimen, V (in volts) to the current passing through it (I in ampere) (Equation 1) [10,11].

$$R=V/I \tag{1}$$

Specific electrical resistance, ρ (in Ωm) is also defined as the resistance between opposite faces of a 1-m cube. For fibers, specific mass resistance, Rs (with units of $\Omega kg/m^2$) is defined as the resistance between the ends of a fiber sample with 1-m length and a mass of 1 Kg. The two quantities are related as follows (Equation 2) [10].

$$Rs = \rho\times d \tag{2}$$

where

Rs: specific mass resistance in Ω(ohms)kg/m^2

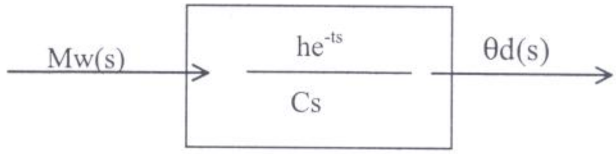

Figure 1. Transfer function of relative humidity control system [9].

ρ : specific resistance in Ω(ohms)m

d : density of material in kg/m^3

In practice, it is more convenient to express Rs in Ω(ohms)/cm^2, because of the ease of calculation. Because of the wide range of resistance values, the results are frequently expressed in terms of the logarithm of the resistance [8].

2.2 Machinery and Methods

2.2.1 Measurement of Electrical Resistance Electrical resistance must be measured carefully and quickly in a constant voltage. The difficulty of this method increases whenever the electrical resistance is so high that the results are not reliable and repeatable. Hence different methods of measurement of electrical resistance have been proposed [10].

By using a static voltmeter, the high electrical resistance of a sample can be measured through charging and discharging of the capacitor via Equation 3 [10,12,13].

$$R=t/(C\times 1n\times U/u) \tag{3}$$

where

R: electrical resistance in ohms

C: capacity of capacitor in farad

U: the input charge of the capacitor in coulomb

u: the output charge of the capacitor in coulomb

t: in second, the required time for reducing initial charge (U to u)

n: constant factor

In this research a Static Voltmeter model R-4021 made by Rothschild was used to measure the electrical resistance of the cashmere fibers [13].

2.2.2 Control of Relative Humidity According to thermal dynamic relations [14] and the available curve for heat and moisture [15], the block

TABLE 1. The Specification of Cashmere Fibers.

Code of	Diameter of	Remaining Hair	Mean Length	Color	Region
B.P.T.T.S	15.38 mic	27.5%	66.11 mm	Black	Khorasan-Iran
A.1.P.T.T.S	15.31 mic.	15.4%	46.32 mm	Black	Khorasan-Iran
A.2.P.T.T.S	15.21 mic	7.0%	36.41 mm	Black	Khorasan-Iran
A.3.P.T.T.S	15.20 mic	4.0%	30.52 mm	Black	Khorasan-Iran
A.4.P.T.T.S	15.19 mic	3.9%	28.45 mm	Black	Khorasan-Iran
P.D.F.1	15.19 mic	0.0%	28.45 mm	Black	Khorasan-Iran
P.G.H.1	0.0 mic	99.9%	45.25 mm	Black	Khorasan-Iran
P.D.F.2	14.98 mic	0.0%	31.46 mm	Bony	Kerman-Iran
P.G.H.2	0.0 mic	99.9%	47.85 mm	Bony	Kerman-Iran

Note (1): B.P.T.T.S and A.P.T.T.S refer to before and after passing through Trash Seprator.

Note (2): A.1 - A.4 refer to different passages of the material through Trash Separator.

Note (3): P.D.F and P.G.H indicating Pure Down Fiber and Pure Guard-Hair respectively.

diagram of the system, in which the variable is the relative humidity, [9] can be shown as in Figure 1.

If the dry temperature in the test laboratory is 22°C and relative humidity is 70%, in a dead time of 2 seconds, the final Transfer Function will be as follows (Equation 4) [16] and block diagram with Z transfer will be as shown in Figure 2 [17].

$$T.F=\theta d(s)/Mw=(e^{-2s})/(0.22S) \qquad (4)$$

Equations related to the above-mentioned block diagram, are based on the following relationships [17]:

$$G(z)=Z\left[\frac{1-e^{-Ts}}{s}\times\frac{e^{-2s}}{0.22s}\right]$$
$$=\left(1-Z^{-1}\right)Z^{-2}Z\left[\frac{1}{0.22s^2}\right]=\frac{2Z^{-1}(1-Z^{-1})Z^{-1}}{0.22\left(1-Z^{-1}\right)^2} \qquad (5)$$

$$G(z)=\frac{9.09Z^{-2}}{\left(1-Z^{-1}\right)}=\frac{9.09}{Z^2-Z}=\frac{9.09}{Z(Z-1)} \qquad (6)$$

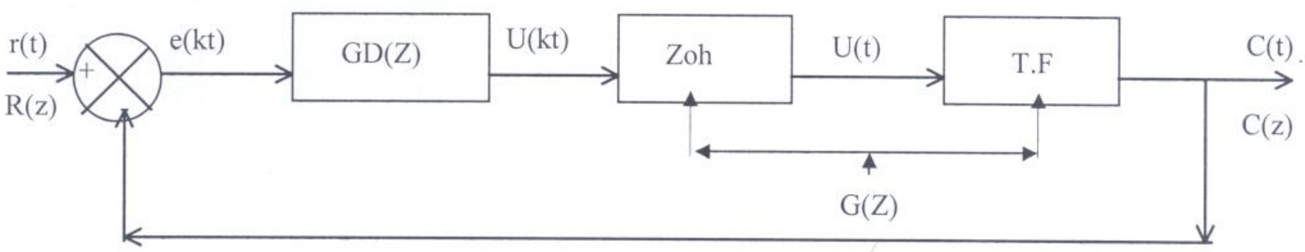

Figure 2. Block diagram of digital control of relative humidity [9].

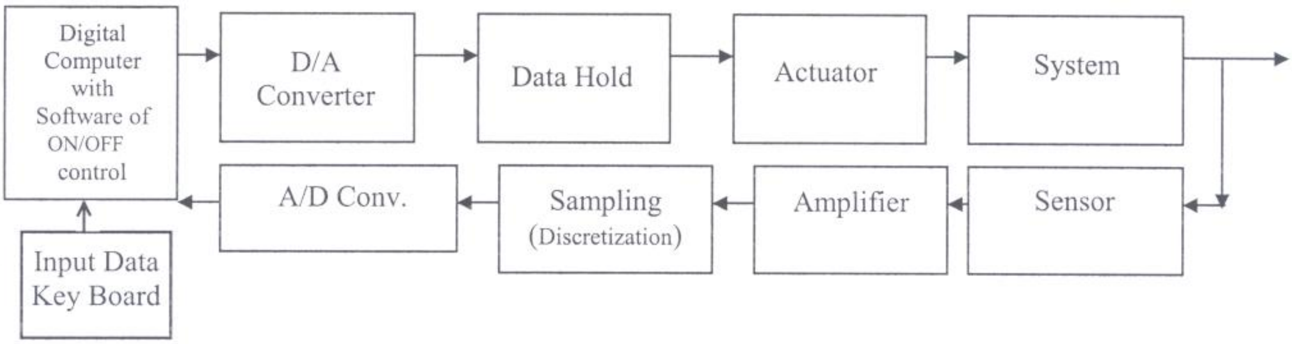

Figure 3. Diagram of the apparatus used for On/Off digital control of relative humidity (Hardware & Software) [9].

In any textile process, it is important to keep the relative humidity constant for a given time. By considering the abilities of the controllers and their expenses, the ON/OFF controller system was found to be the more suitable one than the other types of controllers [16]. The flow chart of the controller used is shown in Figure 3 [9].

The necessary equipment was provided and the required digital relative humidity was fabricated [9] according to the flow chart shown in Figure 3. After preliminary tests, the final curve of relative humidity vs. time of this controller was as shown in Figure 4.

2.3 Materials The characteristics of the cashmere fibers, which have been used in this study, are shown in Table 1. The procedures of the measurement were based on Iranian and ASTM standards [18,19,20].

Two types of the cashmere fiber were used. The first one was shown with the code number of B.P.T.T.S. This type was passed four times through trash separator and was coded as A.1.P.T.T.S to A.4.P.T.T.S as shown in Table 1. After dehairing, down fiber separated from guard hair and then were coded as P.D.F.1 and P.G.H.1 (Table 1).

The second type of cashmere fiber was also dehaired and its down fiber and guard hair were coded as P.D.F.2 and P.G.H.2 (Table 2).

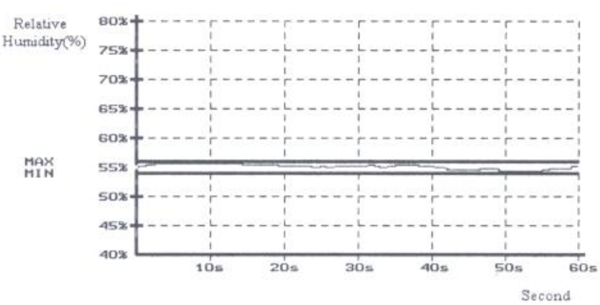

Figure 4. The relation between the relative humidity value and time when used the digital control of relative humidity.

3. RESULTS AND DISCUSION

3.1 Effect of Percentage of Remaining Hair and Breed Type on Electrical Resistance of Cashmere Fibers The result of measuring electrical resistance shows that the electrical resistance of down cashmere fibers are greater than that of guard-hair. The electrical resistance of two-breed type of cashmere is also significantly different (Figure 5 and Table 2).

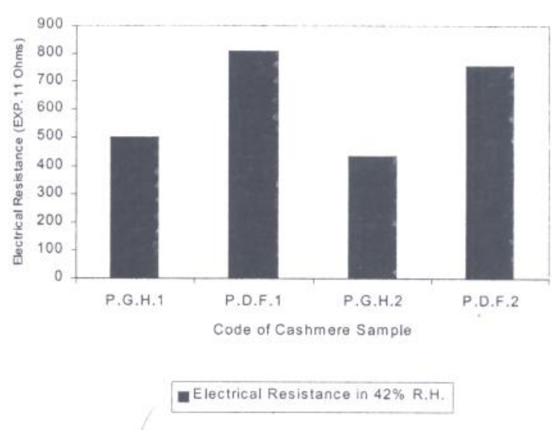

Figure 5. The relationship between the electrical resistance value and breed type of cashmere sample.

TABLE 2. Electrical Resistance of Cashmere Fibers in 42% R.H.

Code of Cashmere Sample	Electrical Resistance (Ohm)
B.P.T.T.S	525×10^{11}
A.1.P.T.T.S	576×10^{11}
A.2.P.T.T.S	635×10^{11}
A.3.P.T.T.S	706×10^{11}
A.4.P.T.T.S	799×10^{11}
P.D.F.1	811×10^{11}
P.G.H.1	501×10^{11}
P D.F.2	754×10^{11}
P G.H.2	433×10^{11}

Reduction of guard - hair in cashmere fiber increases the electrical resistance (Figure 6).

According to Hersh and Montgomery [21] Boxter [10] and others [12], there are two possible causes for variation in resistance. The first possibility is the change in the number of ions available for conduction: the second is the change in the rate at which the ions move through the material under a given applied voltage. Hence it might be possible to conclude that the difference between chemical structure of down cashmere fiber and guard - hair and the blending percentage of these fibers are both responsible for difference in the electrical resistance of the cashmere fibers.

3.2 The Effect of Ambient Relative Humidity on Electrical Resistance of Cashmere Fiber

The results indicate that the increase in relative humidity causes a reduction in electrical resistance of down cashmere fiber and guard - hair. At 56 percent relative humidity and over, the electrical resistance of all cashmere fibers is nearly the same and cannot be distinguished by the static voltmeter (Figures 7 and 8 and Table 3).

Hearle has shown that Equation 7 governs the relationship between the relative humidity and the electrical resistance [8].

$$\log(Rs) = -aH + b \tag{7}$$

where

H: relative humidity in %

Rs: electrical resistance

a and b: constant factors.

Equation 7 was also tested in this research for the samples and the values of a and b (Table 4). By testing Equation 7 with the data shown in Table 4, it

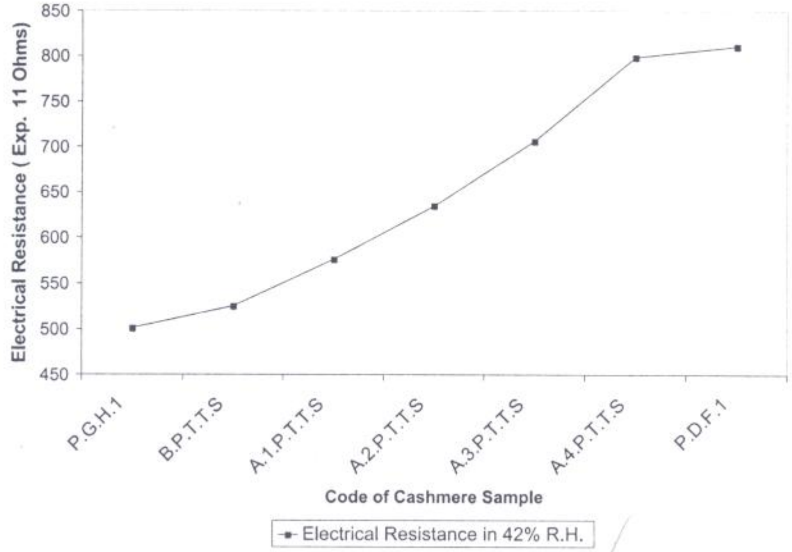

Figure 6. The relation between the electrical resistance value and percentage of remaining hair in cashmere samples.

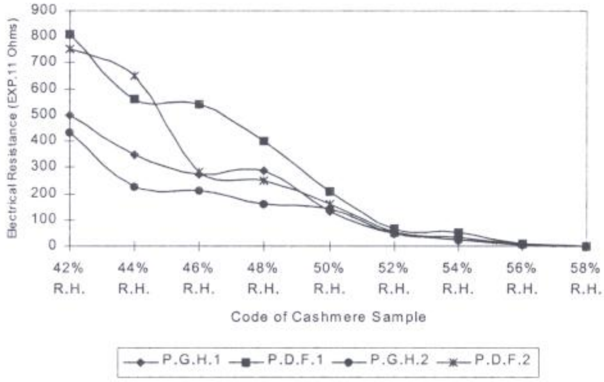

Figure 7. The relation between the electrical resistance value and relative humidity in different breed type of cashmere sample.

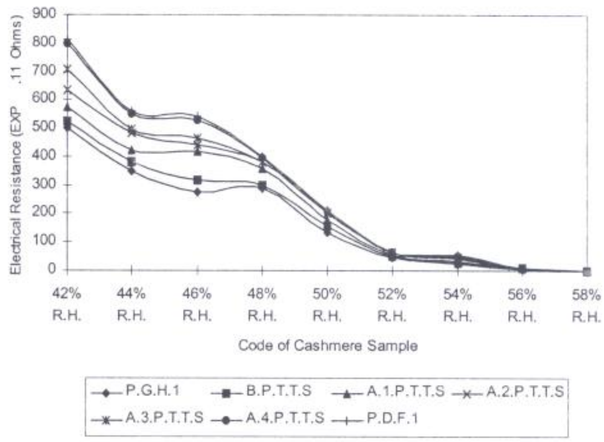

Figure 8. The relation between the electrical resistance value and relative humidity in different percentage of remaining hair cashmere sample.

was found that there was a good match between the equation and the data.

The accuracy of the equation for measuring the electrical resistance of the cashmere fiber can be proved between 42 and 56% of the relative humidity.

4. CONCLUSION

From the recorded results, the following points can be concluded:

Measurements made by the designed controller were reasonably accurate (within the range of ±0.5).

Electrical resistance of the down cashmere fiber is greater than that of guard – hair.

The electrical resistance of the cashmere fiber decreases as the relative humidity increases.

Different bread types have different electrical resistance values.

Cashmere fibers with different remaining hair presented different electrical resistance values.

In 56% R.H., electrical resistance of the down cashmere fiber and guard - hair was the same and could not be separated with static voltmeter.

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TABLE 3. Electrical Resistance of Cashmere Fiber in Difference R.H. .

Code of Cashmere Sample	Electrical Resistance (Ohm.) In 42% R.H.	Electrical Resistance (Ohm.) In 44% R.H.	Electrical Resistance (Ohm.) In 46% R.H.	Electrical Resistance (Ohm.) In 48% R.H.
B.P.T.T.S	525×10^{11}	379×10^{11}	318×10^{11}	300×10^{11}
A.1.P.T.T.S	576×10^{11}	422×10^{11}	419×10^{11}	356×10^{11}
A.2.P.T.T.S	635×10^{11}	480×10^{11}	440×10^{11}	379×10^{11}
A.3.P.T.T.S	706×10^{11}	495×10^{11}	463×10^{11}	382×10^{11}
A.4.P.T.T.S	799×10^{11}	549×10^{11}	530×10^{11}	393×10^{11}
P.D.F.1	811×10^{11}	560×10^{11}	540×10^{11}	401×10^{11}
P.G.H.1	501×10^{11}	350×10^{11}	275×0^{11}	289×10^{11}
P D.F 2	754×10^{11}	648×10^{11}	285×10^{11}	248×10^{11}
P G.H 2	433×10^{11}	225×10^{11}	212×10^{11}	160×10^{11}

Code of Cashmere Sample	Electrical Resistance (Ohm.) In 50% R.H.	Electrical Resistance (Ohm.) In 52% R.H.	Electrical Resistance (Ohm.) In 54% R.H.	Electrical Resistance (ohm.) In 56% R.H.
B.P.T.T.S	156×10^{11}	52×10^{11}	$29\ 10^{11}$	7×10^{11}
A.1.P.T.T.S	178×10^{11}	57×10^{11}	32×10^{11}	9×10^{11}
A.2.P.T.T.S	203×10^{11}	62×10^{11}	42×10^{11}	9×10^{11}
A.3.P.T.T.S	204×10^{11}	64×10^{11}	48×10^{11}	10×10^{11}
A.4.P.T.T.S	205×10^{11}	65×10^{11}	52×10^{11}	10×10^{11}
P.D.F.1	209×10^{11}	66×10^{11}	54×10^{11}	11×10^{11}
P.G.H.1	134×10^{11}	48×10^{11}	25×10^{11}	5×10^{11}
P D.F 2	161×10^{11}	53×10^{11}	32×10^{11}	9×10^{11}
P G.H 2	141×10^{11}	47×10^{11}	22×10^{11}	6×10^{11}

TABLE 3. Electrical Resistance of Cashmere Fiber in Difference R.H. (Continued).

Code Of Cashmere Sample	Electrical Resistance (Ohm.) In 58% R.H.
B.P.T.T.S	1×10^{11}
A.1.P.T.T.S	1×10^{11}
A.2.P.T.T.S	1×10^{11}
A.3.P.T.T.S	1.5×10^{11}
A.4.P.T.T.S	1.5×10^{11}
P.D.F.1	1.5×10^{11}
P.G.H.1	1×10^{11}
P D.F 2	1×10^{11}
P G.H 2	1×10^{11}

TABLE 4. Values of a and b for Cashmere Fibers.

Code of Cashmere Sample	a	b
B.P.T.T.S	0.1252	19.2041
A.1.P.T.T.S	0.1223	19.2383
A.2.P.T.T.S	0.1241	19.2575
A.3.P.T.T.S	0.1238	19.2667
A.4.P.T.T.S	0.1275	19.4725
P.D.F.1	0.1258	19.3991
P.G.H.1	0.1328	19.5133
P.D.F.2	0.1323	19.6008
P.G.H.2	0.1173	18.6858

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