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目录

Lecturing and Reflections on the Fiber Heats of Sorption

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Abstract: For the topics in the course of teaching "textile materials" about heat of sorption phenomenon, with reference to several available domestic versions of "Textile Materials" textbooks, "Textile Physics" textbook as well as the "Physical Properties of Textile Fibers" textbook edited by W. E. Morton、J. W. S. Hearle in regard to knowledge on the phenomenon of fiber heats of sorption, the definitions of differential heat of sorption and integral heat of sorption, and the relationship between the two indexes, the effect of fiber moisture regain on heat sorption, were elucidated. With examples of wool fiber and the newly developed Eks fiber of heat generating on sorption heat, the fiber heat of sorption and heat release calculation and the effect on human body were discussed. Both of which would provide students with a fundamental understanding of the mechanism of fiber sorption heats and the effect of heat release, an accurate understanding on the effectiveness of some new fibers on the current market. A number of recommendations of future class lecturing on this part are put forward.

Key words: differential heat of sorption; integral heat of sorption; wool fiber; Eks fiber; heat release calculation

1 Introduction

The heats of sorption phenomenon of fibers in the "Textile Materials" accounts for a very small proportion in the chapter of textile materials moisture absorption, the teaching is usually just to enable students to grasp the two concepts-the differential and integral heat of sorption, but its mechanism and its heat insulation effect on the human body are less elaborated. Therefore students just mechanically memorize these two definitions without understanding their implications, and always are confused when using the concepts to analyze related moisture absorption problems.

For the topics in the course of teaching "textile materials" about heat of sorption phenomenon, with reference to several available domestic versions of "Textile Materials"[1,2,3] textbooks, "Textile Physics"[4] textbook as well as the "Physical Properties of Textile Fibers"[5] textbook edited by W. E. Morton、J. W. S. Hearle in regard to knowledge on the phenomenon of fiber heats of sorption, the definitions of differential heat of sorption and integral heat of sorption, and the relationship between the two indexes, the effect of fiber moisture regain on heat sorption, were elucidated. With examples of wool fiber and the newly developed Eks fiber of heat generating on sorption heat, the fiber moisture of sorption and heat release calculation and the effect on human body were discussed. Both of which would provide students with a fundamental understanding of the mechanism of fiber sorption heats and the effect of heat release, an accurate understanding on the effectiveness of some new fibers on the current market. A number of recommendations of future class lecturing on this part are put forward.

2 Comparison of the textbooks in regard to the knowledge of sorption heat

2.1 Several widely used teaching textbooks

The second edition of "*Textile Materials*"[1] with editor-in-chief of Academician Mu Yao, published by the China Textile Publishing in June, 1990 had been widely used for a long term as a textbook by most domestic textile institutes. In May, 2006, the first edition of another textbook "*Textile Materials*"[2] with editor-in-chief of Professor Weidong Yu, was published by China Textile Publishing, and in Jan,2009, the third edition of "*Textile Materials*"[3] with editor-in-chief of Academician Mu Yao, was also published. These three textbooks have been widely used as textbooks for undergraduates, and have great changes and differences in style and content. Besides, other two textbooks of great influence mainly used for graduates are "*Textile Physics, 1st edition*"[4], published in January 2002 by Dong Hua University with editors-in-chief of Professor Weidong Yu and Professor Caiyuan Yu, and "*Physical Properties of Textile Fibers*"[5], published in May 1962 by the Textile Institute and Butterworth Co. Ltd Publishing House with editors of W. E. Morton, J. W. S. Hearle.

2.2 Elucidations on the heat of sorption phenomenon in the textbooks

The related content in Subsection 5 "The effect to heat properties", of Section 3 "The effect of hygroscopicity on the properties of textile materials", of Chapter 6 "Hygroscopicity of textile materials" of the textbook ***"Textile Materials", 2nd Edtion***, edited by Academician Mu Yao, describes the heat sorption phenomenon as follows[1]: water molecules in the air are attracted by and then bonded with polar groups of fibrous macromolecules; the kinetic energy of water molecules is lowered, then heat is generated and released with the conversion of kinetic energy to heat. The differential heat of sorption is the heat evolved when one gram of water is absorbed by the material at given moisture regain. It is expressed in joules per gram (J/g). The differential heat of sorption of dry fiber are close to about 837.4~1256J, as shown in Figure 1. The integral heat of sorption is the total heat evolved when a specimen of the material at a given regain, whose dry mass is one gram, is completely wetted. It is expressed in joules per gram (J/g) (of dry material) and is almost always given in terms of absorption from the liquid state,as shown in Figure 2. Comparing with the two concepts, the differential heat of sorption is more important to study the fiber absorption mechanism. The differential heat measurement is not easy, however the integral heat measurement is comparatively easy, so differential heat is often obtained by measuring the integral heat. The fiber absorption heat is also related to temperature, usually the lower the temperature, the greater the heat sorption under a certain constant humidity. On temperature difference of 1℃, heat sorption difference is about 0.3%. The water diffusion and heat transfer within the fiber is a dynamic process, hence fiber absorption heat helps slow down the rapid change in temperature, and this is very useful to dress material. For non-hygroscopic fiber, the delayed temperature change is only resulted from the insulation effect of the material. Thus fiber hygroscopicity is an important property related to the thermal-wet comfort performance of fabric. The thermal effect of the fiber moisture absorption needs to be considered for the design of thermal balance calculations of the drying equipment during spinning, weaving, dying and finishing. The fiber absorption heat should be noted for storage of the fiber and its products. If under high humidity, and poor ventilation storage conditions, absorption heat may cause fiber moldy degeneration, and even gives rise to spontaneous combustion.

In the textbook of ***Textile Material, 3rd Edition*** edited by Academician Mu Yao[3], the knowledge points of the absorption heat are written in Subsection 2.2.2 "the major factors impacting on the thermal properties of fiber aggregates" of Subsection 2.2 "fiber aggregates thermal conductivity" of Section 2 "thermal conductivity" of Chapter 10 "textile material thermal properties", which says: Textile materials have obvious heat effects, that is heat generation on moisture absorption or heat absorption on moisture desorption. Then the same as the second edition, the differential and integral heat are defined, and illustrated the Fig.1 and Fig.2, but this part of the related content is shorter than that of the second edition.

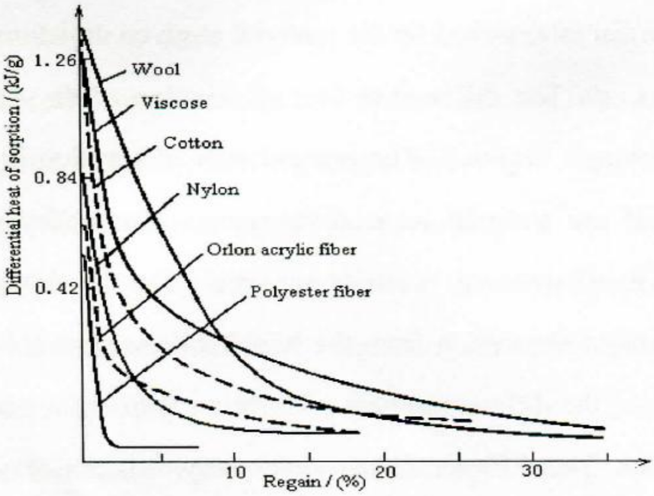

Figure 1 The differential heat of sorption of some common fibers

(Excerpt from reference 1：P345，figure 6-9；reference 2：P290，figure 11-1）

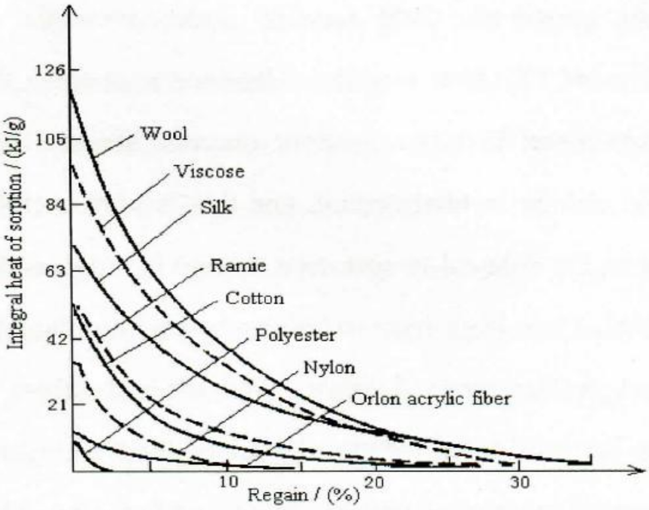

Figure 2 The integral heat of sorption of some common fibers

(Excerpt from reference 1: P345, figure 6-10；reference 2: P290, figure 11-2）

Subsection 3.5, "the effect of the hygroscopicity on fiber thermal properties" of Section 3, "the effect of hygroscopicity on the fiber properties" of Chapter 4, "fiber hygroscopicity" of the textbook of ***Textile Material, 1st Edition*** edited by Professor Weidong Yu, includes the following information[2]: The integral heat definition is given first and the relationship curve between the integral heat and regain is then illustrated in Figure 3, which is similar to Figure 2. The integral heat in figure 3 is for wool, rayon, cotton and acetate fiber. Comparing with Figure 2, there are some differences in figure 3, which may result from measurement errors. Also the measurement method of integral heat is given. The differential heat definition and Figure 4, similar to Figure 1, are then given, and the complete integral heat and the differential heat comparison of common fibers are shown in Table 1. In addition, the relationship between the integral and the differential heat is added to this section, the differential heat can be obtained by the actual measured integral heat and regain curve by differentiation:

$$q = dQ / dW \qquad (1)$$

Where q is the fiber differential heat (kJ/g) in a definite regain; Q is the integral heat; W is the regain at beginning. Or the differential heat can be obtained by the fiber moisture absorption isotherm at different regains:

$$q = -R\left[\frac{\partial \ln \varphi}{\partial (1/T)}\right]_W \qquad (2)$$

Where R is ideal gas constant; φ is relative humidity decided by the ratio of actual vapor pressure to saturation vapor pressure; T is absolute temperature; subscript W is moisture regain. Here only the correlation and conversion are given, not the detailed process of derivation.

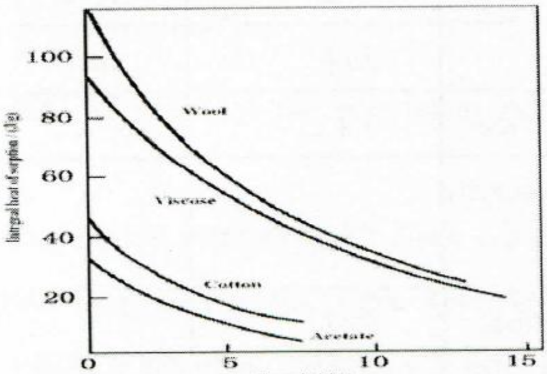

Figure 3 Integral heats of sorption of fibers versus regain relationship

(Excerpt from reference 3: P96, figure 4-12; reference 4: P53, figure 2-8; reference 5:

P182, figure 8.3)**

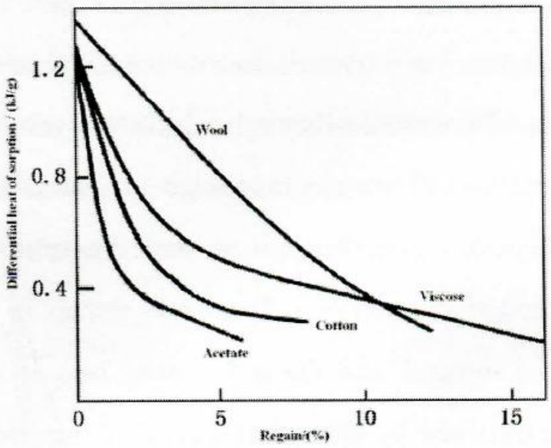

Figure 4 Differential heats of sorption of fibers versus regain relationship

(Excerpt from reference 3: P97, figure 4-13; reference 4: P54, figure 2-9; reference 5: P183, figure 8.5)

Table 1 Comparison of complete integral and differential heat of sorption

Material	Integral heat of sorption (J/g)	Differential heat of sorption(J/g)
Cotton	46.1	1240
Wool	112.6	1340
Ramie	46.5	-
Silk	69.1	-
Acetate	34.3	1240
Nylon	30.6	1050
polyester fiber	3.4	-
Orlon acrylic fiber	7.1	-
Vinylon fiber	35.2	-

(Excerpt from reference 3: P97, table 4-4)

Three points are described in Section 2, "fiber absorption heat" of Chapter 2, "fiber hygroscopicity" of the textbook ***Textile Physics, 1st Edtion*** edited by Professor Weidong Yu and Caiyuan Chu[4]: absorption heat indexes, the factors affecting the fiber heat absorption, the measurement methods of fiber absorption heat.

The "absorption heat indexes" in this book are slightly different with the three textbooks mentioned above. In addition to the definition of absorption heat, this textbook further gives the total heat generation Q_v in consideration that moisture is generally absorbed from steam, and Q_v is given as:

$$Q_v = Q_l + L \qquad (3)$$

Where L is the latent heat of condensation of water in J/g at a given temperature, Q_l is the fiber differential heat of sorption, and sometimes called the heat of swelling. The definition is also given for the integral heat. And usually the differential and integral heat is all the release heat by absorbing liquid water. The relation between the integral heat and regain is illustrated as Fig.5. The increase of the regain by dr causes an amount of heat equal to $Q_l \cdot dr/100$ to be evolved. If this is integrated from a regain r to the saturation regain, r_s, it will give the total amount of heat evolved W when the specimen is wetted, that is, the heat of wetting for regain r. Thus:

$$W = \int^{r_s} \frac{Q_l \cdot dr}{100} \qquad (4)$$

Conversely, if regain drops *dr*, the heat generation will decrease $Q_l \cdot dr/100$, that is, the differential heat is given as:

$$Q_l = -100\frac{dW}{dr} \qquad (5)$$

Each of equations (4) and (5) expresses the correlation between the integral and differential heat.

In the subsection of "factors affecting the sorption heat", Table 2 is given for comparison of integral heat for different fibers from zero regain. Table 2 shows the heat of wetting is greater for fibers with higher moisture absorbing capacities. When close to saturation, water molecules attaches to fiber surface and thus less heat generated. And this is nearly the same as the wetting heat in Table 1. Figure 6 shows that the heat evolved from 0% to 65% r.h. is proportional to the regain of the fiber at 65% r.h.. From figure 6 we can see that the heat of wetting is the highest for wool fiber with higher moisture absorbing ability, the heat of wetting of silk fiber is between that of cotton and wool fiber, and the synthetic fiber regain is low, which results in low heat. In addition, two curves, the same as Figure 3 and Figure 4 for the correlation between integral or differential heat and regain, are also listed. Table 3 illustrates the differential heat absorption of fiber is related to the polarity of hydrophilic groups. The fibers with same hydrophilic groups have the same differential heats. Table 3 shows a class of cellulose fiber having very close differential heats, and the differential heats of wool and nylon fiber are also close. But I don't think this conclusion is appropriate based on the data in Table 3 and 4. This book has given an example, which will then be discussed in section 3.1 of this paper.

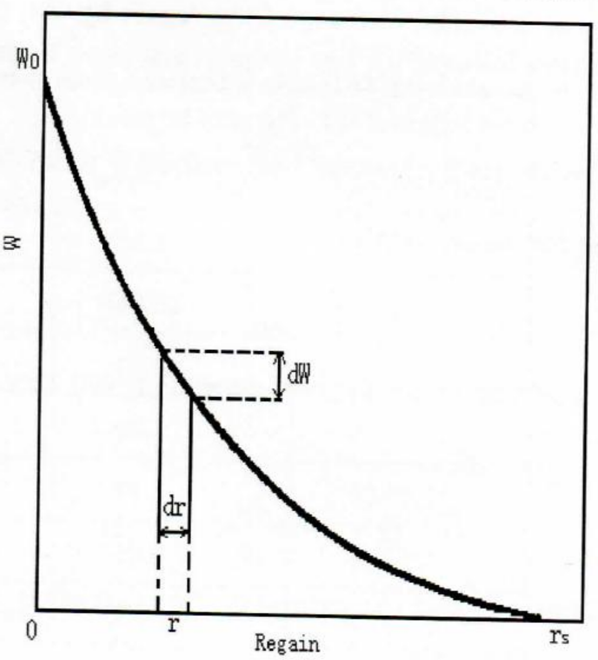

Figure 5 Integral heat of sorption versus regain relationship

(Excerpt from reference 4: P53, figure 2-6; reference 5: P179, figure 8.2)

Table 2 Heats of wetting from zero regain (J/g)

(Excerpt from reference 4: P53, table 2-2; reference 5: P181, table 8.1)

Material	Integral heat	Material	Integral heat
Cotton	46	Viscose rayon	106
Flax	55	Acetate	34
Mercerized cotton	73	Nylon	31
Wool	113	Terylene polyester fiber	5
Silk	69	Orlon acrylic fiber	7

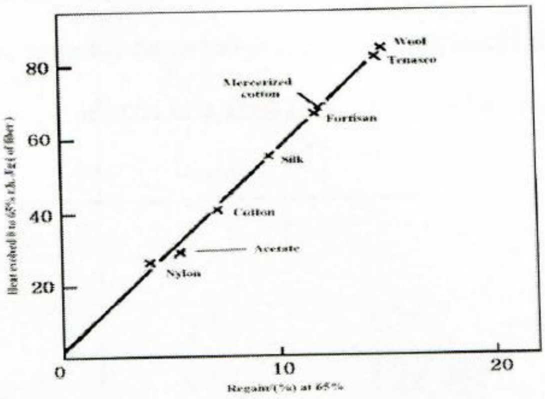

Figure 6 Relationship between evolution of heat and regain

(Excerpt from reference 4: P53, figure 2-7; reference 5: P182, figure 8.4)

Table 3 Differential heats of sorption

(Excerpt from reference 4: P54, table 2-3; reference 5: P183, table 8.2)

	Relative humidity (%)					
	0	15	30	45	60	75
Cotton	1.24	0.5	0.39	0.32	0.29	—
Viscose rayon	1.17	0.55	0.46	0.39	0.32	0.24
Acetate	1.24	0.56	0.38	0.31	0.24	—
Mercerized cotton	1.17	0.61	0.44	0.33	0.23	—
Wool	1.34	0.75	0.55	0.42	—	—
Nylon	1.05	0.75	0.55	0.42	—	—

The subsection of "the measurement methods of fiber absorption heat" gives the test method of fiber absorption heat, and a detailed list of the testing methods for integral and differential heat is described in section 4 of this paper.

The textbook of "***Physical Properties of Textile Fibers***"[5] edited by W. E. Morton、J. W. S. Hearle is similar to the textbook of "Textile Physics" mentioned above in regards to the knowledge of absorption heat. Four key points are give in Chapter 8 of "heat absorption". First the definition of the absorption heat is given. Figure 7 demonstrates a graphic show of the relationship between the absorbed liquid water and water vapor. This book also gives formula (4) and (5) to illustrate the relation between integral and differential heat, and gives Figure 5 for the relation between integral heat and regain.

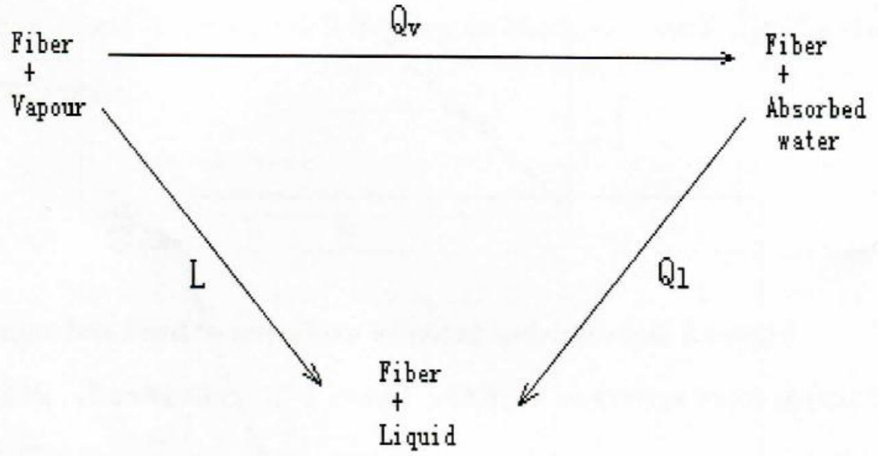

Figure 7 Relation between heats of sorption from vapour and liquid

(Excerpt from reference 5: P178, figure 8.1)

The second point introduces the same testing methods as the textbook "Textile Physics", as described in section 4 of this paper.

The third point introduces Table 2 for heat of wetting from zero regain, the relation between the integral, differential heat, heat generation and regain respectively, the same as Figure 3、4 and 6. Also Table 3 is given for differential heat at different humidity of several common fibers. Besides, differential heat of cotton and rayon fiber at zero regain and 65% humidity is added, as given in Table 4.

The forth point introduces the effects of absorption heat, as described in section 3.1 of this paper.

Table 4 Integral and differential heat of sorption at zero regain and 65% r.h.

(Excerpt from reference 5: P184, table 8.3)

	At zero regain		At 65% r.h.
	$W\ (kJ/g)$	$Q_l\ (kJ/g)$	$Q_l\ (kJ/g)$
Cotton			
Bengals	47.3	1.33	0.25
Texas	46.1	1.19	0.20
Sea Island	46.9	1.24	0.28
various sorts and methods	41-54		
Viscos Rayon			
continuous-filament			
staple-fiber	106	1.17	0.30
various sorts and methods	97	1.22	0.27
	84-105		

3 Calculation of absorption heat and examples

3.1 Example 1: The calculation of the heat evolved by wool

There is one example in the textbook of "*Textile Physics*" and "*Physical Properties of Textile Fibers*": From an indoor atmosphere of 18℃, 45% r.h., to an outdoor atmosphere of 5℃, 95% r.h., the regain of wool would change from 10 to 27%. A man's suit, weighing 1.5kg, would give out 6000 kilojoules owing to this environmental change, which is as much as the heat of the human metabolism in 1.5 hours. This evolution of heat is of physiological advantage, since it gives human body time to adjust itself to the new condition. But there is no detailed calculation process in the two textbooks and here gives the detailed derivation as follow. We suppose the amount of wool fiber is infinite.

Water absorbed by wool fibers weighing 1.5kg from 10% to 27% regain is calculated as:

$$1.5kg \cdot (27\% - 10\%) = 0.255kg$$

The differential heat is calculated as: $Q_l = 0.255(kg)\cdot 10^3(g/kg)\cdot 0.42(kJ/g) = 107.1kJ$

If we consider the effect of temperature, in the 2nd version of "*Textile Materials*" edited by Mu Yao, mentioned in page 346, "usually the lower the temperature, the greater the heat sorption under a certain constant humidity. On temperature difference of 1℃, heat sorption difference is about 0.3%. ". On the temperature difference of 13℃ here, the estimated heat of absorption increases to about 3.9% of the original, approximates to 0.436kJ/g, the differential heat is calculated as:

$$Q_l = 0.255(kg)\cdot 10^3(g/kg)\cdot 0.436(kJ/g) = 111.3kJ$$

The discrepancy of differential heat is 4.2kJ compared with the differential heat when temperature influence on absorption heat isn't considered.

Because the water is absorbed from water vapor, the heat generation is Q_v, and at one atmosphere pressure, the latent heat for water is 2480kJ/kg at 5℃, then latent heat of water absorbed by wool is calculated by formula (3) as:

$$L = 0.255(kg)\cdot 2480(kJ/kg) = 632.4kJ$$

Therefore heat release through water absorbing by 1.5kg wool is calculated as:

$$Q_v = 111.3kJ + 632.4kJ = 743.7kJ$$

In the above calculation, infinite wool and differential heat at relative humidity of 45% were assumed; actually the absorption heat of 1.5kg wool should be smaller than this value.

In the above two textbooks, the released heat are all $6000\,kJ$, I don't know whether these large discrepancies between the textbooks and calculation in this paper is resulted from that there are typing errors in the textbooks, or the calculations here have lapses or errors. In the textbook edited by W. E. Morton、J. W. S. Hearle, heat evolution is listed for several fibers with 1kg weight when relative humidity changes from 40% to 70%, as shown in Table 5. The heat evolution of 1kg wool is 159kJ in Table 5, although the temperature change wasn't specified and the relative humidity change was also smaller, the discrepancy between $6000\,kJ$ is also very large. Thus it is estimated that the absorption heat listed in the two textbooks is a typing or reference error.

Table 5 Heat evolved by 1kg of fibers from 40 to 70% r.h.

(Excerpt from reference 5: P185, table 8.5)

Material	Heat (kJ)
Wool	159
Cotton	84
Viscose rayon	168
Acetate	50
Nylon	42
Terylene	4

3.2 Example 2: The calculation of heat evolved by Eks fiber

Now there is a new fiber on the market with heat generating capacity, which could be used to make "heat generating underwear". China polyester website says like this: Eks fiber is a new material to warm body by heat generation in itself, which is a new synthetic "polyacrylate derived fiber" developed by Toyobo (Japan), and far more hygroscopic than other fibers, these properties of Eks fiber make you feel both dry and warm without stuffy wet feeling. Figure 8 shows the regain at standard atmosphere of polyester, nylon, cotton, silk, rayon, wool and Eks fibers. We will discuss the following questions: Will the heat generating underwear generate heat? Will the other fibers generate heat? What advantages have this eks fiber compared with wool fiber? If it does generate some heat, how long will the generated heat last?

Supposing the fiber is absorbing water from a completely dry state to 65% r.h., compare the absorption heat of wool and eks fiber. In one atmosphere pressure, the latent heat for water is 2446kJ/kg at 20℃. The two underwear made by wool and eks are 200g, so the water absorbed are 32g and 54g for wool (regain: 16%) and eks (regain: 27%), respectively.

The differential heat of dry wool is 1.34kJ/g, and 42.88kJ heat generation, the water latent heat is 78.272kJ, so the total heat generation is 121.152 kJ.

The specific heat of dry wool is 1.36 J/g·℃, and water is 4.18 J/g·℃, the specific heat of moisture absorption wool is 1.75 J/g·℃ after moisture absorption.

According to the heat generation value (121.152 kJ), temperature will theoretically rise up to

383.98℃ with a total weight of 232g (moisture absorption counted in) wool underwear

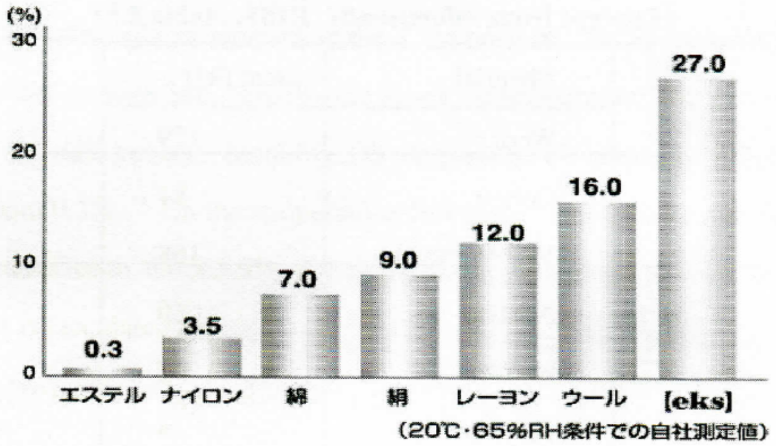

Figure 8 The regain of eks and other common fibers at 20℃, 65% r.h.

Of course, this is impossible, the actual situation is more complicated, and when the temperature rises, the specific heat also increases. There is also cooling effect of the environment. In fact, the heat generated from 16% moisture absorption is not entirely the contribution of direct absorption, so there is not so much heat. However temperature must increase. Compared with wool, Eks' regain is higher, the latent heat of absorption water is 132.084 kJ, and the total heat generation added by the differential heat is larger than that of wool, therefore the heating effect of Eks is significantly greater than that of wool.

Can the heat generation last forever? It's decided by whether there is lasting moisture absorption drive especially the direct moisture absorption. In general, there is the direct moisture absorption first, then the indirect moisture and capillary moisture. When the fiber is subject to moisture desorption, the direct absorbed moisture is not easy to release, so the heat can not keep on generation all the time.

4 The test methods of fiber absorption heat

4.1 The test of integral heat

The measurement method of integral heat is given in textbooks of "*Textile materials*" and "*Textile Physics*" edited by Weidong Yu. Put fibers with a given mass and regain into a calorimeter with a given heat capacity. Add water to immerse the fibers, and measure the temperature increment. According to the temperature increment and heat capacity of the test system, the integral heat can be calculated, and the relation curve between the integral heat and regain can be obtained, as described and mentioned in Figure 5.

4.2 The test of differential heat

The textbook of "*Textile Physics*" edited by Weidong Yu has described the method in detail. Direct measurement of differential heat is difficult, but the differential heat may be obtained by conversion from other differential heat related property. There are two methods: one is the calorimetric method, the differential heat can be calculated at any given regain by using Equation (5) from the integral heat versus regain curve.

$$Q_l = -100\frac{dW}{dr} \qquad (5)$$

The other is the absorption isotherm method, its calculation is derived as follows: The specific volume of liquid water is neglected in comparison with that of water vapour, the Clausius-Clapeyron equation for water vapor is:

$$\frac{dp_s}{dT} = \frac{L}{TV_s} \qquad (6)$$

Where p_s is saturation vapour pressure of water, T is absolute temperature, V_s is specific volume of vapour at saturation vapour pressure, and L is the cohesion latent heat. Application of equation (6) to a textile system at constant regain r gives:

$$(\frac{dp}{dT})_r = \frac{Q_v}{TV} \qquad (7)$$

Where p is equilibrium vapour pressure in the textile system, and V is specific volume of vapour at this vapour pressure.

And relative humidity（H）is: $H = ((p/p_s)\times 100)\%$ (8)

Thus: $\ln H = \ln p - \ln p_s + \ln 100$ (9)

Differentiating with respect to temperature at constant regain, we have:

$$(\frac{\partial \ln H}{\partial T})_r = \frac{1}{p}(\frac{\partial p}{\partial T})_r - \frac{1}{p_s}\frac{dp_s}{dT} = \frac{Q_v}{pTV} - \frac{L}{p_sTV_s} \qquad (10)$$

If we assume the ideal gas law, $pV = p_sV_s = RT$, R is ideal gas constant, equation (10) transformed to:

$$(\frac{\partial \ln H}{\partial T})_r = \frac{1}{RT^2}(Q_v - L) = \frac{Q_l}{RT^2} \qquad (11)$$

$$Q_l = RT^2(\frac{\partial \ln H}{\partial T})_r = -R\left[\frac{\partial \ln H}{\partial(1/T)}\right] \quad (12)$$

Thus the differential heat of sorption can be obtained from the slope of the curve of $\ln H \sim 1/T$ at constant regain. The differential heat calculated by moisture sorption isotherm is often lower than that of calorimetric method, as shown in Table 6. However, the two textbooks do not indicate which result is closer to actual value.

Table 6 Differential heat of sorption obtained by different testing methods (direct measurement and sorption isotherms)

(Excerpt from reference 4: P55, table 2-4; reference 5: P184, table 8.4)

		Differential heat of sorption (kJ/g)	
		Calorimetric method	From sorption isotherms
Viscose rayon	0	1.17	1.09
	5	0.53	0.44
	10	0.39	0.25
Acetate	5	0.27	0.21
Cotton	5	0.32	0.27
Wool	6	0.59	0.54
	12	0.40	0.40
	18	0.17	0.26

5 Colcusions

Based on the above comparative analysis of the several widely used teaching textbooks, combined with the questions during practical teaching, the following conclusions are drawn:

(1) The description in two versions edited by Academician Yao Mu is relatively concise, suitable for students of vocational school and general textile specialty in university. The advantages are that the integral and differential heat curves in Figure 1 and 2 covers more fibers, and the relation between absorption heat effect and temperature is also included.

(2) The textbook of "*Textile materials*" edited by Professor Weidong Yu has added the relation between the integral and differential heat; The textbooks of "*Textile Physics*" edited by Professor Yu Weidong、Caiyuan Chu and "*Physical Properties of Textile Fibers*" edited by W. E. Morton, J. W. S. Hearle are similar in this regard, the detailed derivation of the relationship between the integral and differential heat is set up, and introduce the absorption heat measurement, suitable for the post-graduate teaching.

(3) The three textbooks (reference 1, 2, 3) for undergraduate have not emphasized the differential heat is the heat generation for infinite fibers absorbing 1g water, while the other two textbooks (reference 4, 5) have emphasized infinite fibers. I think that it should be added the prescription of infinite fiber quantity, and it makes it easy for students to understand the meaning of the two concepts.

(4) In future practice of teaching, not only post-graduate but also undergraduate, Figure 7 should be added, and point out the differential and integral heat are all the heat generation on absorbed liquid water without otherwise specified. The actual heat generation should be contained the water vapor latent heat, and should be explained the effect of temperature on heat absorption.

(5) For post-graduate, the ideas and derivation of fiber absorption heat calculation should be added, and based on its application, the thermal effect of heat absorption should be illustrated for high hygroscopic fiber such as wool.

Acknowledgement: Advice and assistance from Professor Caiyuan Chu of Donghua University are gratefully acknowledged.

Reference:

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