UTILIZATION OF ALAMBETA APPARATUS IN PREDICTING THERMAL PROPERTIES OF SINGLE AND MULTIPLE LAYERS OF WOVEN AND NONWOVEN FABRICS

الاستفادة من جهاز ALAMBETA فى تقدير الخواص الحرارية للاقمشة المنسوجة و الغير منسوجة عديدة الطبقات

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الخلاصة :

استخدام جهاز ALAMBETA لقياس الخواص الحرارية للاقمشة المسطحة المنسوجة و الغير منسوجة المفردة و العديدة الطبقات و المبتكر بقسم الخامات النسيجية بكلية علوم المنسوجات بالجامعة التكنولوجية بليبرتس بدولة التشيك.

هذا الجهاز قادر على تقدير الخواص الحرارية التالية :

١- المقاومة الحرارية Thermal Resistance

٢- الموصلية الحرارية Thermal conductivity

٣- الانتشارية الحرارية Thermal Diffusivity

٤- الامتصاصية الحرارية Thermal Absorbtivity

وذلك بسرعة كبيرة)بعد دقيقتين(، و بدقة عالية باستخدام عينة واحدة من القماش المختبر ، بالاضافة الى قياس سمك ذلك القماش فى نفس التجربة. كرر ذلك على عشر اصناف من الاقمشة المنسوجة و الغير منسوجة و المصنوعة من معظم الشعيرات النسيجية وكانت النتائج كما يلى :

(أ) وجد ان المقاومة الحرارية للاقمشة الختبرة تزداد طرديا بزيادة سمك القماش واحتل القماش الغير منسوج من العوادم المرتبة الاولى بينما جاء القماش المنسوج من البولى أميد فى المرتبة الاخيرة.

(ب) وجد ان الموصلية الحرارية تتاثر ايضا بسمك القماش حيث جاء قماش البولى أميد فى المرتبة الاولى بينما جاء قماش العوادم فى المرتبة الاخيرة.

(جـ) وجد ان الامتصاصية الحرارية لا تتوقف على سمك القماش.

خواص الاقمشة الغير منسوجة ن العوادم)٤٠٪ صوف ، ٤٠٪ فسكوز ، ٢٠٪ قطن(ثبتت انها مناسبة للاستخدام كحشوات لصناعة الملابس الجاهزة)البدل الرجالى - قماش خارجى صوفى - حشو من قماش غير منسوج - قماش بطانة من القطن(، وثبت انه لاتوجد علاقات مباشرة بين الخواص الحرارية للاقمشة المفردة و وخواصها وهى مجتمعة معا.

ABSTRACT :

A new computer controlled device ALAMBETA to measure the thermal properties of flat woven and nonwoven textiles was developed at the technical University in Liberec. Within one measuring operation taking no more than two minutes it yields the values of thermal resistance, conductivity, and diffusivity thickness of the sample and its thermal - contact characteristic, the thermal absorbtivity expressing the warm - cool feeling of the fabric [4].

By means of this instrument the thermal parameters of up to five layers of identical woven and nonwoven fabrics were investigated.

The following results were found :

1- Thermal resistance increases with the total thickness linear (for "NW" fabrics) or slower. The highest value exhibits "NW" out of textile wasters the lowest PAD and Vs fabrics.

2- Thermal absorbtivity theoretically does not depend on the thickness [4]. The experiments confirm that thermal absorbtivity varies with the thickness unsubstantially. The highest increase (for eight layers of NW) presents 104.7%.

3- Thermal conductivity increases with the thickness substantially slower than linear [2]. The highest values of thermal conductivity exhibit PAD, then Vs and PES while the lower level belongs to "NW" out of textile wastes.

1. INTRODUCTION :

Fabric thermal properties are one of the most important textile properties which are related to the user comfort feeling. The measurement of these properties has been a much discussed topic in the literature. In some of this papers, L.Hes gives some references of the most important authors working in this field [1-2]. Hes developed the ALAMBETA apparatus to evaluate the thermophysical properties of textile fabrics following partially the ideas of Yoneda and Kawabata [3]. Some studies on fabric thermal properties have been done up to date [4-6], although neither have dealt about suitable of nonwoven out of textile wastes as interlining for garment industry nor about the influence of multiple layers (composite fabric) on fabric thermal properties.

Sang et al., (9) were developed a theoretical model for thermal transmission through nonwoven structures. that model provides a good explanation of the roles played by fibre and fabric variables in determining thermal insulation of nonwoven barrier materials.

Using the ALAMBETA T 675 apparatus [7] a study on single and multiple layers of woven and nonwovens out at wastes on fabric thermal properties have been done. The Alambeta apparatus gives the following results :

1. **Thermal diffusivity (a)** : Velocity of heat propagation in the sample.
2. **Thermal absorptivity (b)** : Rate of warm-cool feeling change of fabrics.
3. **Thermal conductivity (λ)** : Quantitiy of heat passing through the sample in steady state under specific conditions.
4. **Fabric thickness**.
5. **Thermal resistance (r)** : Ratio of thickness and thermal conductivity.

Table (I) : Accepted formula and symbols of ALAMBETA apparatus.

Symbol	Description	Formula for calculation	Units
a	Thermal diffusivity	$a = \lambda/\rho c$	$[m^2/s.10^{-6}]$
b	Thermal absorbtivity	$b = \sqrt{\lambda \rho c}$	$[Watt.\sqrt{s}/m^2.k]$
h	Fabric thickness	-----	[mm]
r	Thermal resistance	$r=[q/\Delta t)]^{-1}$	$[Watt.k.m.^2 10^{-3}]$
λ	Thermal conductivity	$\lambda=q/t$	$[Watt/m.k.10^{-3}]$

Where :
"ρ" and "c" sample density and specific heat, while "q" is the quantity of heat flow between two bodies and t" is temperature drop between the skin and fabric.
The above table (Table I) was adopted in Ref. [7].

2. SELECTED FABRICS

Qualitative composition, mass per unit area, and thickness are shown in table 1.

To evaluate the influence of the chemical composition, all kinds of common natural and synthetic polymers were used to prepare ten sets of woven and nonwoven fabrics with similar structure and thickness.

Table II.

Material Used (woven and nonwoven)	Cot., PAD, PAN, PES, POP, PVA, PVC, V_S, W.
Range of Mass/Unit area (g/m^2)	100 - 340
Range of thickness (mm)	0.22 - 1.60

3. EXPERIMENTS :

The knowledge of thermophsical properties of materials is very important in many technical fields. But the method of measurement known in the world up to present time require for their determination either long time (up to 2 hours) or complicated preparation and using the samples of considerably large sizes.

The principal function of the ALAMBETA consists in mathematics processing the time behavior of heat flows that come through the tested material due to the different temperatures of the lower measuring body (the temperature of surrounding) and the measuring head (heated 10 degrees higher, respectively 40 degrees higher). After the sample insertion and head placing the heat flows become stable and the thermophysical properties of the measured subject can be evaluated.

Fig. 1 shows the main features of ALAMBETA.

4. RESULTS :

The following results were found :

4.1. Thickness:

This results are mainly influenced by the type of fabric, although pressure and temperature influences too. Fig. 2 shows the interaction between fabric and pressure. Depending on the type of fabric pressure logically decreases fabric thickness, while temperature, due to some dilation phenomena, cause thickness increasing, pressure, logically, causes a decreasing in it.

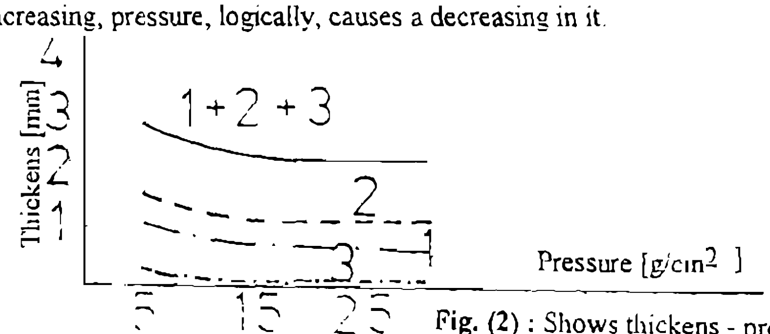

Fig. (2) : Shows thickens - pressure relationship.

4.2 Thermal Absortivity :

Higher values are obtained by higher density fabrics independently of its composition.

Theoretically does not depend on the thickness. The experiments confirm that thermal absorbtivity varies with the thickness unubstantially. The highest increase (for "NW") presents 104.7%.

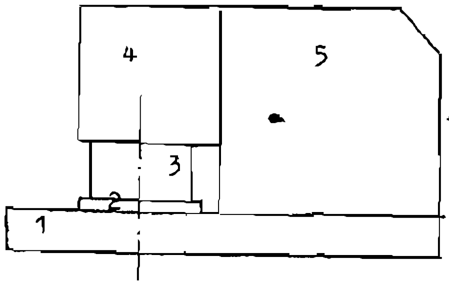

Fig. 1 : Shows main features of "ALAMBETA"
1) Measuring body (treated area).
2) Specimen
3) Measuring head.
4) Heat flow, and measured values.
5) Computer device "ALAMBETA".

The measurement procedure :

The sample size 100 x 100 mm (for a textile fabric it is sufficient 50 x 50 mm). Thickness is 0.5 + 10 mm.

The principal function of the instrument consists in mathematic processing the time behaviour of the heat flows (4) that come through the tested material (2) due to the different temperature of the lower measuring body (1) and the measuring head (3) heated flows become stable and the thermophysical properties of the measured subject can be evaluated.

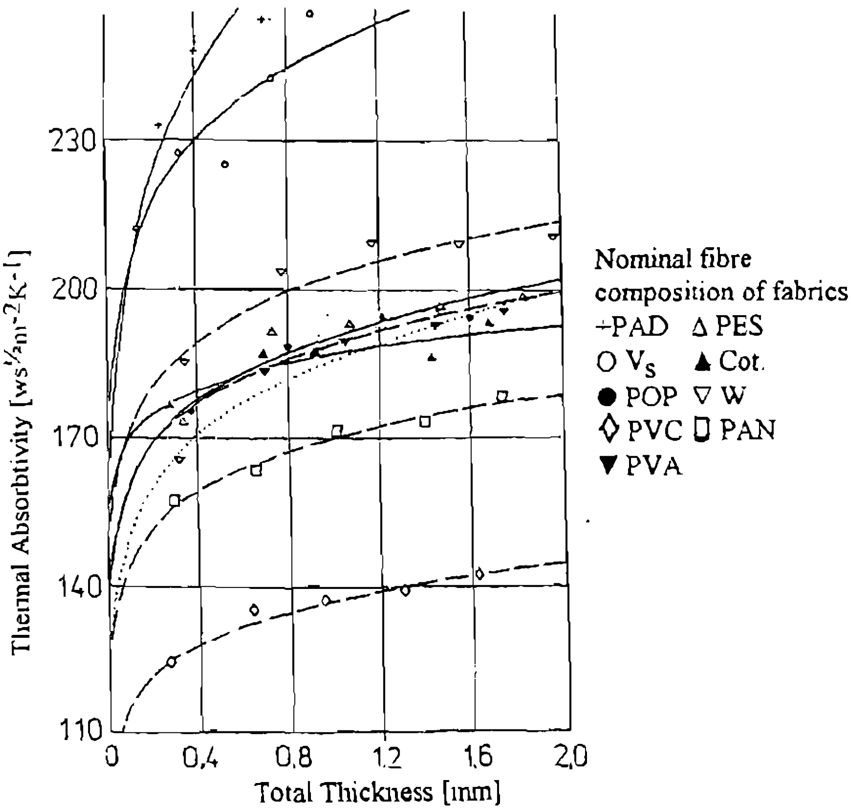

Fig. (3) : Shows thermal absorbtivity of multiple layers of fabrics. [4]

4.3 Thermal diffusivity :

In this case the type of fabric have a significative influence on the thermal diffusivity. (see Fig. 3-6).

4.4. Thermal Resistance :

The thermal - isolating properties of nonwonen textiles have been tested and compared with those woven fabrics. It was found that the thermal resistance (r) [k. m^2. w^{-1}] of individual textiles is a function of material thickness. Nevertheless there is a question whether a special fibre arrangement in "NW" sheets does influence the value of thermal conductivity (W. m^{-1}. w^{-1}). The dependence of thermal resistance on the sample thickness has been measured in order to answer this question. The thickness of the sample have been controlled by either compression or area weight. It was found that the fibre orientation does not influence the value of considerably.

Obviously thermal resistance depends mainly on the fabric thickness. Fig 3 to 6 show the influence of the type of fabric on this parameter. Thermal resistance increase linear with the total thickness or slower. The highest value exhibits "NW" the lowest "PAD" and "Vs" fabrics.

4.5 Thermal Conductivity

Surprising no influence of the type of fabric, pressure and temperature were observed on this parameter. Thermal conductivity increases with the thickness substantially slower than linear. The highest values of thermal conductivity exhibit naturally the "PAD" and "Vs" fabrics, the lower level belongs to "NW" fabrics. The reason to this increase depends in the influence of the radiation conductivity which theoretically increases with the thickness of the sample according to the analysis in [2].

4.6. Changes in Contact Properties of Different Fabrics during their Wear Simulation :

During the wear, flat textile fabrics are subjected to abrasion, which deteriorates some mechanical properties of fabrics. Because of great importance of abrasion resistance of fabrics on their end - use properties, some abrasion testing instruments are widely used in textile laboratories, to simulate wear of fabric. Unfortunately majority of these instruments are still time consuming or complicated in operation.

It was found that short abrasion times (30 min.) cause greatest changes in surface structure demonstrated by highest level of compressivity lowest values of thermal absorptivity [8] it means warmest feeling and abrupt increase of the static friction coefficient. For longer abrasion times, all the mentioned parameters tend

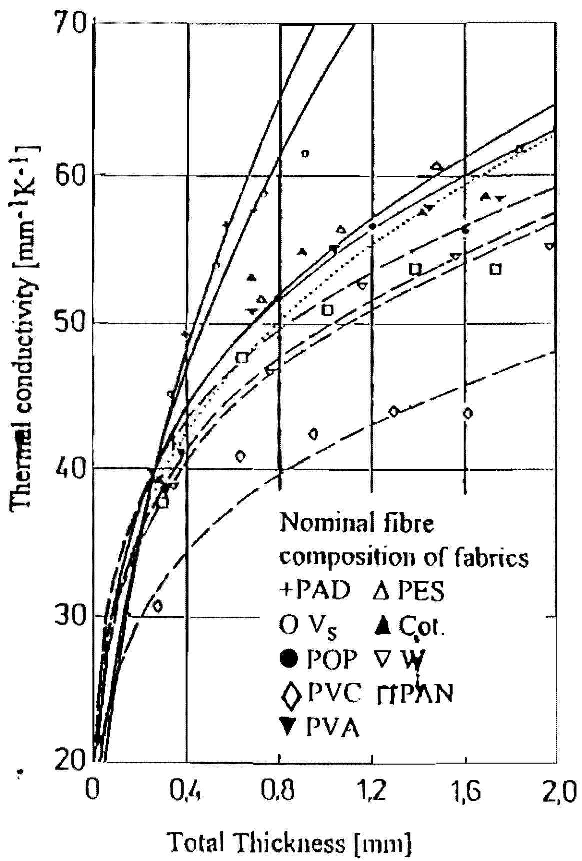

Fig. (4) : Shows thermal conductivity of multiple layers of fabrics. (4)

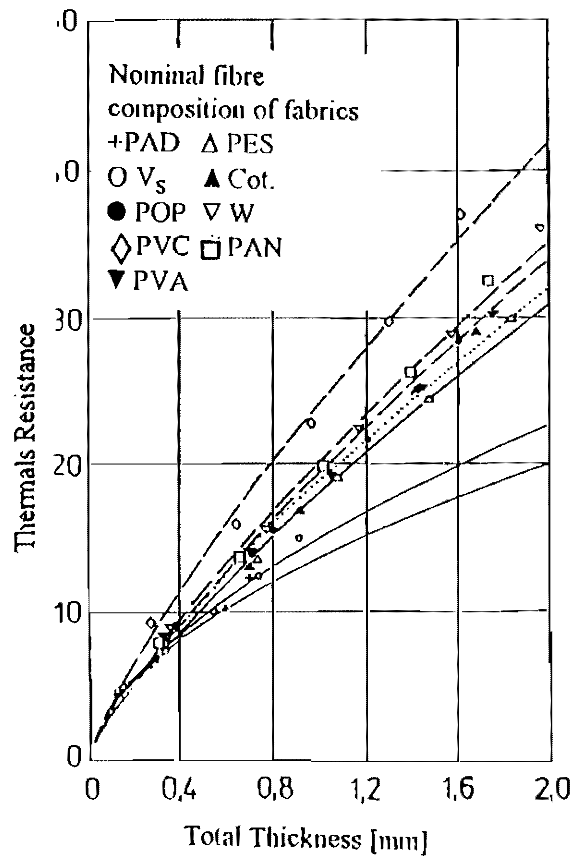

Fig. (5) : Shows thermal resistance of multiple layers of fabrics. (4)

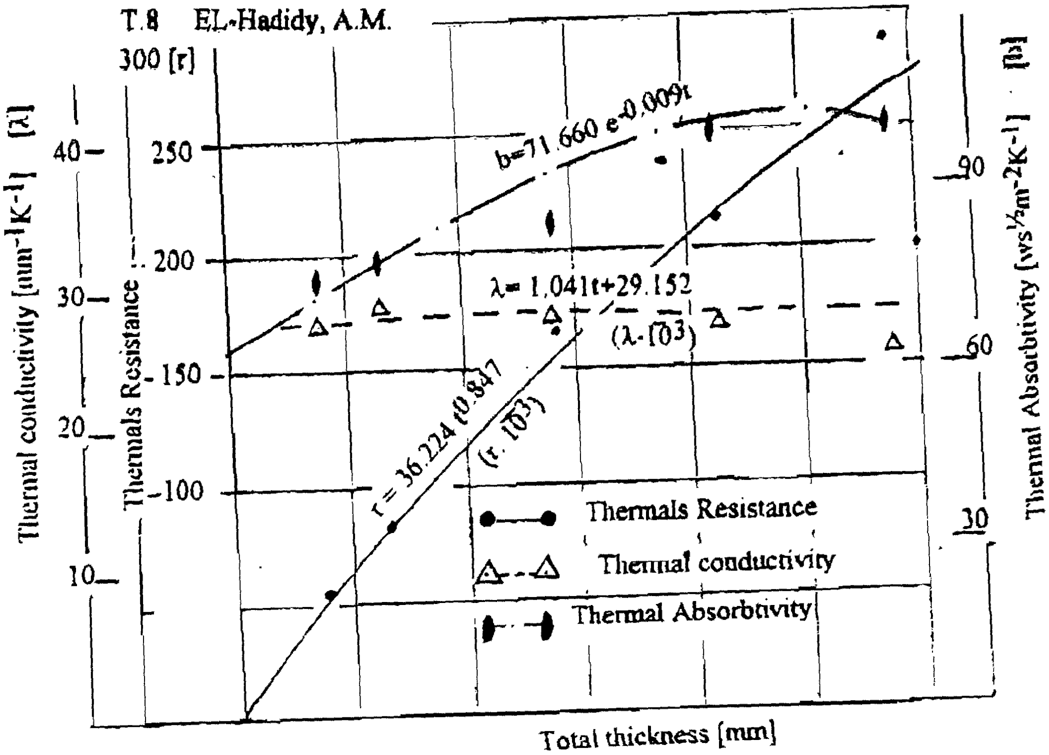

Fig. (6) : Shows thermal resistance ; thermal conductivity ; thermal absorbtivity of multiple layers of Nonwoven fabrics from textile wastes (40% Wo ; 40% Vs, 20% Cot..

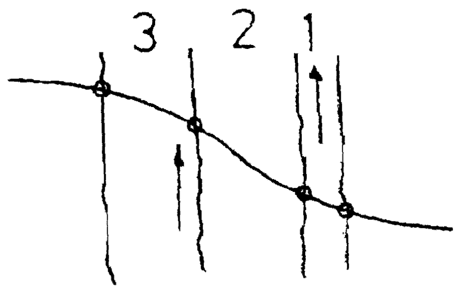

Fig. (7) : Results of thermal properties of composite fabrics.

Fabrics/Properties	(1)	(2)	(3)	(1+2+3)
Mass/area [g/m^2]	100	120	340	560
Thickness [mm]	0.22	1.61	1.08	3.03
Thermal conductivity [W/m.k.10^3]	34.2	30.7	42.3	37.80
Thermal diffusivity [m^2/s.10^6]	0.04	0.21	0.09	0.16
Thermal absortivity [W$\sqrt{S}$/m^{2}k]	171.7	68.0	139.3	91.90
Thermal resistance [k.m^2.w^{-1}.10^3]	6.37	52.24	25.60	80.40

to return to their initial values, because the fabric surface becomes again relatively smooth [8].

4.7. The Relationship Between Thermal Properties And Fabric Thickness :

In some garments such as JACKET, where three layers are used (outer fabric - interlining - lining), Since the nonwoven fabric in the apparel industry is used in the form of layers sandwitched or quilted, it is important to understand the nature of the structure of the "NW" of the new composite, either alone or when quilted with woven fabrics.

Table III shows the relationship between thermal properties and no. of layers (thickness). For the examined nonwoven fabrics, statistical analysis has shown that linear and / or non - linear relationship in the form of straight line - simple exponential - simple parabolic...... fits well the results.

Table III. Thermal Properties Versus Fabric Thickness.

Variety	Best fit equation
1- Thermal resistance ($r.\ 10^{-3}$)	$r = 36.224\ t^{0.847}$ (simple Parabolic)
2- Thermal conductivity (λ-10^{-3})	$\lambda = 1.041t + 29.152$ (Straight Line)
3- Thermal absorbitivity (b)	$b = 71.660\ e^{-0.009t}$ (Simple exponential)
4- Thermal Diffusivity ($a.10^{-6}$)	$a = 0.026t + 0.125$ (Straight Line)

Ranking correlation	coefficient (R)
$R_{(r,t)}$	R = 1
$R_{(\lambda,t)}$	R = 1
$R_{(b,t)}$	R = 0.7
$R_{(a,t)}$	R = 1

5. CONCLUSION :

It has been found that, the thermal isolating properties are heavily dependent on fabric construction and the ability of the fabric to retain excluded air. The thermal properties of nonwovens can be further improved when recycled fibres are used. The best results are abtained with 40% wool ; 40% viscose ; and 20% cotton fibres. An advantages use of these fabrics has found in the fields of thermo-isolating as well as in garment industry.

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