Mansoura Engineering Journal

Volume 13 | Issue 2 Article 24

8-1-2021

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Recommended Citation

El-Hadidy, Adel (2021) "The Morphology of Layered Non-Woven Fabrics.," *Mansoura Engineering Journal*: Vol. 13 : Iss. 2 , Article 24.
Available at: https://doi.org/10.21608/bfemu.2021.189590

THE MORPHOLOGY OF LAYERED NON-WOVEN FABRICS

مورفولوجة الاقمشة الغير منسوحة عديدة الطبقـــــــات

Dr. Adel El-Hadidy

الخلاصـة: المورفولوجية (الطبوغرافية) الاقمشة الغيرمنسوجه عديدة الطبقات التى يكثر استخدامها فى صناعة الملابس أمكن دراستها باستخدام سمك القماش، معامل التغطية ، صلابة القماش، معامل الانضغاط. كل هذه العوامل يمكن تقديرها عند تعرض القماش للانضغاط.

وجـد أنه للاقمشة المكونة من طبقات فى هذا البحث تقل صلابتها ، بينما يزيد معامل انضغاطها وعليه يكون حاصل ضربهما ثابتا ، يزيد السمك، لايتغير كثيرا معامل التعبئه.

ABSTRACT: The morphology of layered NW fabrics has been studied in terms of fabric thickness (t_L), packing density coefficient ($Ø_L$), fabric hardness (H_L), and energy-absorbed index (b_L). All these terms are obtained when the fabric is subjected to compression. For multi-layer NW fabric, energy-absorbed index was found to increase as fabric hardness decreases. The product of fabric hardness and compression energy index for all tested NW fabrics is constant, i.e. Hb = 435. Also it was found that as the no. of layers increase the multi-layered thickness and/or mass per unit area is increase while the packing density coefficient of multi-layer NW fabric has minor differences between $Ø_s$ and $Ø_L$.

1. INTRODUCTION:

Since the non-woven 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 fabrices.

The purpose of the present investigation is to find a suitable parameter that could be used to describe the structure of multi - layers, non-woven fabrics.

1.1. Definitions:

1.1.1. Non-woven fabrics NW (1):

Textile fabrics made of fibrous layer, which may be a carded web, a fibre web, a system of random laid or oriented fibres or threads, possibly combined with textile or non-textile materials such as conventional textile fabrics, plastic films, foam layers, metal foils, ... etc, and forming with them a mechanically bounded or chemically bonded textile product.

1.1.2. Morphology of NW:

The need to information about the morphology of NW have been known from early times of NW research. This phenomenon has helped from going out of the complication of the internal structure of NW products and the following parameters have been known for this study:

- thickness,
- mass per unit area,
- mass per unit volume, and
- packing density coefficient.

1.1.3. NW fabric hardness for single and layered NW fabrics:

Fabric hardness as defined by Peirce (3), is the pressure required to reduce the thickness of a fabric by the amount of (t_1-t_2), where:

t_1 = is the thickness measured at pressure P_1,

t_2 = is the thickness measured at pressure P_2.

The equation of hardness (H_s) for single layer NW fabric, is in the form of:

$$H_s = \frac{P_2 - P_1}{t_1 - t_2} \; (gf.\ cm^{-2}\ .\ mm^{-1}) \qquad ....(1)$$

The hardness was measured at two pressures namly 0.6 and 104.2 (g/cm^2) according to Ref.(6).

NW fabric hardness in case of multi-layers could be predicted from the following equation:

$$H_L = \frac{\bar{H}}{N} \qquad ....(2)$$

where; $\bar{H}$ = Average fabric hardness,
N = No. of layers.

1.1.4. Energy-absorbed index:

The energy-absorbed index (b) could be assessed by the following equation:

$$d = a + b/(p + c) \qquad ....(3)$$

where; d = thickness of NW at 0.6 g/cm^2 (mm),
a = thickness of NW at 104.2 g/cm^2 (mm),
c = correction of pressure (3.6 g/cm^2 according to Ref. 2,6 and 7,
p = pressure (g/cm^2) and
b = parameter describes the energy absorbed per unit area of NW fabric.

The procedure of using this equation is given in Ref.(5).

2. RESULTS:

2.1. Thickness-Pressure Relationship of Layered Non-Woven Fabrics:

Since the calculation of packing density coefficient and fabric hardness necessitates the determination of layered fabric thickness, hence it was necessary to determine first the pressure at which thicness should be measured. To find this for tested layered non-woven fabrics of the present work, thickness was measured at pressure ranges between 0.20 and 104.2 g/cm^2. A relationship in the

$$t_L = a_L + b/p+c$$

was found suitable (6 and 7) to relate the thickness (t_L) to the pressure "p" where "a_L" is the thickness measured at 104.2 g/cm^2, "c" is a correction for the pressure and "b" is a constant. Over the range of pressure used b was approximately constant at pressures ranging between 0.20 and 1.2 g/cm^2 for majority of fabrics. Also over this range the difference (%) between thickness at any pressure and that measured at 0.2 g/cm^2 was not more than 10% (i.e. within the permissible experimental error). Hence b could be obtained directly at $P = 0.6\ g/cm^2$, since the average b- value obtained is very close to that calculated at this pressure. The value of b at 0.6 g/cm^2 ($t_{0.6}$) was used for calculating packing density coefficient (Ø) and hardness (H). This is more logic since the thickness used in the packing density coefficient equation should be measured actually at Zero[4] pressure, but because of the practical difficulty of this, the choice of the pressure at which thickness is measured was arbitrary, but as low as possible and withen the lowest pressure provided by the thickness matter used. Details of layered NW fabrics are given in Appendix.

2.1.1. Thickness of maulti-layered NW fabrics:

Plotted in Fig. 1 the relationship between thickness (t_L) and no. of layers (N). For the examined structures, statistical analysis has shown that linear relationships in the form of; $t = mN + a$ fits well the results. Given in Table 1 the values of a and m(slope of the line) for tested NW fabrics.

Table (1)

Variety	Best fit equation	
NW1 made from PES_s undyed,	$t_L = 8.173\ N + 0.458$	......(4)
NW2 made from W_s,	$t_L = 6.443\ N + 0.793$	......(5)
NW3 made from PES_s waste'	$t_L = 10.23\ N + 1.2$	......(6)
NW4 made from PES_s dayed'	$t_L = 8.954\ N + 0.96$	......(7)
NW5 made from PAN_s	$t_L = 9.235\ N + 0.208$	......(8)

2.1.2. Determination of mass per unit area:

This was obtained by taking the average of weighting 10 samples of the same area. The results were expressed as Kilo-grams per square meter (Kg/m^2).

For the exaimed NW fabrics, statistical analysis has shown that linear relationships in the form of; $Q_{sL} = mN + a$ fits well the results. Given in Table 2 the values of a and m_{sL}(slope of the line) for all tested NW fabrics. It is intereasting to observe that for these tested NW fabrics, that the slope is generally constant and indeoendent of no. of layers.

Table 2.

Variety	Best fit equation	
NW1	$Q_{sL} = 0.595\ N - 0.479$	......(9)
NW2	$Q_{sL} = 0.595\ N - 0.046$	......(10)
NW3	$Q_{sL} = 0.698\ N - 0.006$	......(11)
NW4	$Q_{sL} = 0.599\ N - 0.055$	......(12)
NW5	$Q_{sL} = 0.579\ N - 0.005$	......(13)

2.1.3. Determination of mass per unit volume of layered NW fabrics:

The density of layered tested NW fabrics was defined from knowing the weight per unit area and the thickness of the material. It was expressed in kilogrammes per unit volume ($Kg.m^{-3}$)

$$\text{Density } Kg/m^3 = \frac{\text{Weight of surface area}}{\text{fabric thickness}}$$

$$\text{i.e. } Q = \frac{Q_{sL}}{t_L} \qquad ......(14)$$

It was found that (Q) ranges between 50.593 Kg/m^3 and 80.946 Kg/m^3.

2.1.4. Fabric packing density Ø:

The fabric packing density may be calculated from the relation:

$$Ø_L = \frac{Q_{sL}}{\bar{\rho}\ t_L} \qquad ......(15)$$

where Q_{sL} is the fabric weight per unit area in Kg/m^2 obtained from 2.1.2., t_L is the fabric thickness in m according to 2.1.1m and $\bar{\rho}$ is the average fibre density, Table 3 shows values of packing density coefficient Ø for single and multi-layered NW fabrics.

Table 3: Shows values of packing density coefficient Ø for single and mutli-layered NW fabrics.

Variety	Packing density coefficient			
	$Ø_s$	$Ø_{1+2}$	$Ø_{1+2+3}$	$Ø_{1+2+3+4}$
NW1	0.037	0.037	0.064	0.039
NW2	0.001	0.001	0.001	0.001
NW3	0.046	0.046	0.046	0.049
NW4	0.043	0.042	0.044	0.047

The values of the packing density coefficient ($Ø_s$) were calculated according to Ref. 2. For the fabrics examined in this work, the value of $Ø_s$ (single layer) ranges between 0.001 and 0.046. Naturally as the value of of $Ø_s$ approaches unity ($Ø_s = 1$) the packing of fibres within the fabric is maximum.

With respect to multi-layered the values of the packing density coefficient $\emptyset_L$ were calculated from equ. 15, and then compered with packing density coefficient of single layer $\emptyset_S$.

Plotted in Fig. 2 the values of packing density coefficient $\emptyset_L$ and no. of layers (N) of all NW fabrics used in the present investigation. From the figure one may observe that the relationship is linear and positive.

2.2. Hardness of Multi-layered NW Fabrics:

With respect to fabric hardness, it was calculated using equ. 1 and equ. 2 at two pressure namely 0.6 and 104.2 g/cm^2. Table (4) shows the correlation between H_L (meas.) and H_L (predicted) (r = 0.89 - 0.941 and highly significant at 5% level).

Table 4: Shows the relationship between H_S, H_L (measured), and H_L (Predicted) for tested NW fabrics.

Variety	NW fabric hardness H						
	Single layer	Multi-layers					
	$\bar{H}_S$	H_L (measured)			H_L (predicted)		
		1+2	1+2+3	1+2+3+4	1+2	1+2+3	1+2+3+4
NW1	23.546	12.0	8.6	6.6	11.7	7.9	5.9
NW2	39.846	19.4	18.7	15.9	19.9	13.3	9.9
NW3	23.546	11.7	9.1	7.9	11.8	7.9	5.9
NW4	31.399	12.7	9.4	8.9	15.7	10.5	7.9
NW5	27.263	14.7	10.2	8.3	13.6	9.1	6.8

Plotted in Fig. 3 the relationship between NW fabric hardness (H_L) and no. of layers (N).

2.3. Energy Absorbed of Multi-layered NW Fabric:

The relation between energy absorbed (b_L) and no. of layers of multi-layered NW fabric is shown in Fig. 4. For all tested NW fabrics, the energy absorbed were tends to increase by increasing the no. of layers.

According to the definition of b_L, it represents the energy absorbed in compression, hence one would expect this value to be low for hard to press layered structures and vice-versa. This is more clear from Fig. 5 in which the values of b_L are plotted versus hardness for all layered structures. Also it is interesting to find that the product of (H_L) and (b_L) is always constant irrespective of the structure, i.e. $H.b \doteq 435$ ...... (16).

This result could be proved from the original definitions of H_L and b_L as follows (6):

Since $$H_L = \frac{P_{104.2} - P_{0.6}}{t_{0.6} - t_{104.2}} \ g/cm^2/mm \qquad ......(17)$$

and $b_L = (t_{0.6} - t_{104.2})(p+c)$ ......(18)
(the thickness "t" is measured at pressure p = 0.6, and 104.2 g/cm^2).
then equ. (17) could be written as

$$H_L = \frac{104.2 - 0.6}{b_L/(p+c)} \qquad ......(19)$$

The value of (p+c) as determined from the thickness-pressure relationship is equall to 4.2 g/cm^2, then equ. 19 becomes:

$$H_L b_L \simeq 435$$

3. CONCLUSION:

From the previous results obtained in this work, the following conclusions could be made:-

1- The multi-layered NW fabric thickness and/or mass per unit area is greatly affected by the no. of layers. As the no. of layers increases the thickness and/or mass per unit area increase also.

2- There is no significant differences between the experimental packing density coefficient results and the layered packing density coefficient values using equation 15, the correlation coefficient (r) is very high (0.999) and highly significant at the 5% level.

3- For multi-layered NW, fabric hardness my be predicted using the formula:

$$H_L = \frac{\bar{H}}{N}$$

where; $\bar{H}$ = average fabric hardness ($g/cm^2/mm$),
N = no. of NW layeres.

4- The correlation coefficient between H_L (predicted) and H_L (measured) for layered NW fabrics, is high (r = 0.89 to 0.94) and highly significant at 5% level.

5- As the no. of layers increased the fabric hardness (H_L) tended to decrease and vice versa.

6- The product of (H_L) and (b_L was found constant and equall to 435.

APPENDIX:

Details of layered NW fabrics.
Specifications of Fabrics.
Commerical Needle-Punched Fabrics.

Code	NW1	NW2	NW3	NW4	NW5
vpe			Random-laid		
ıbre	PES_s (undyed)	Wool 100%	Waste PES_s	PES_s (dayed)	PAN_s
Weight (g/m^2)	480	600	690	600	600
Punching Density ($stitches/cm^2$)	60	60	60	100	60

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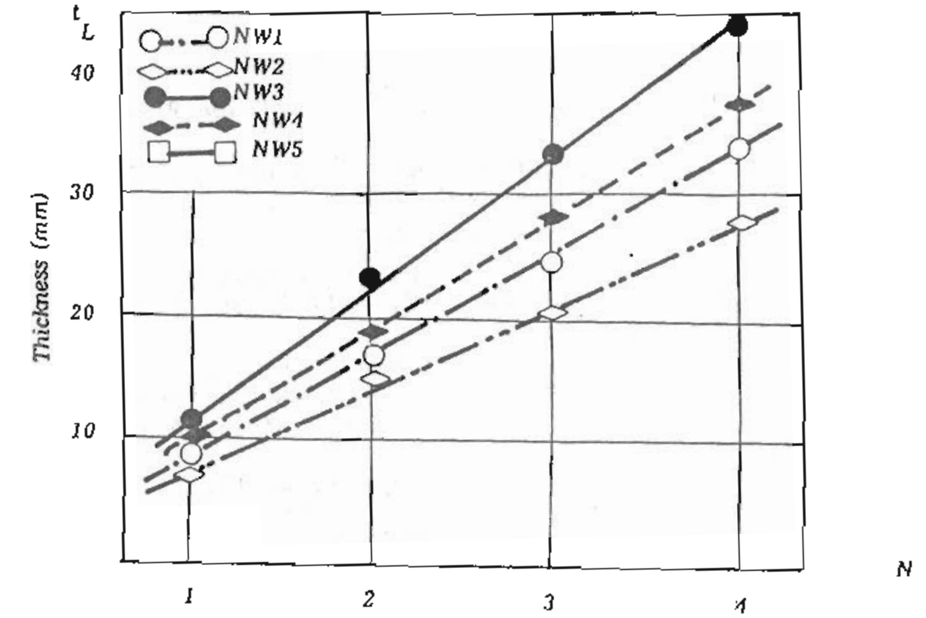


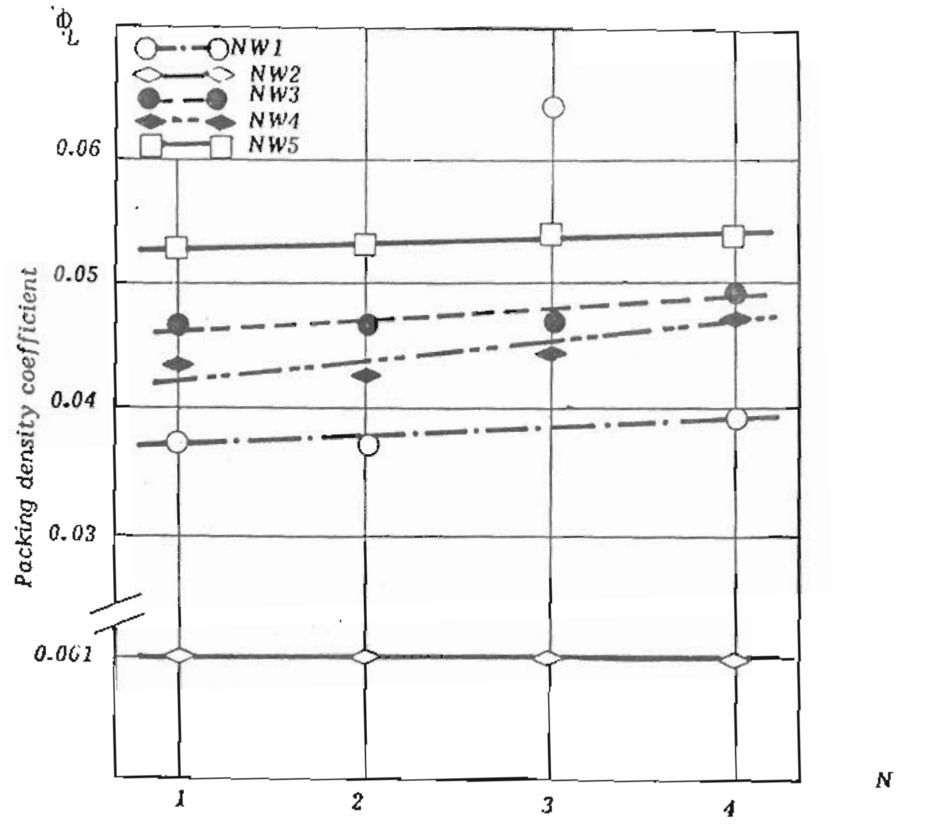


Fig.1 Shows t_L versus N

Fig.2 Shows ϕ versus N

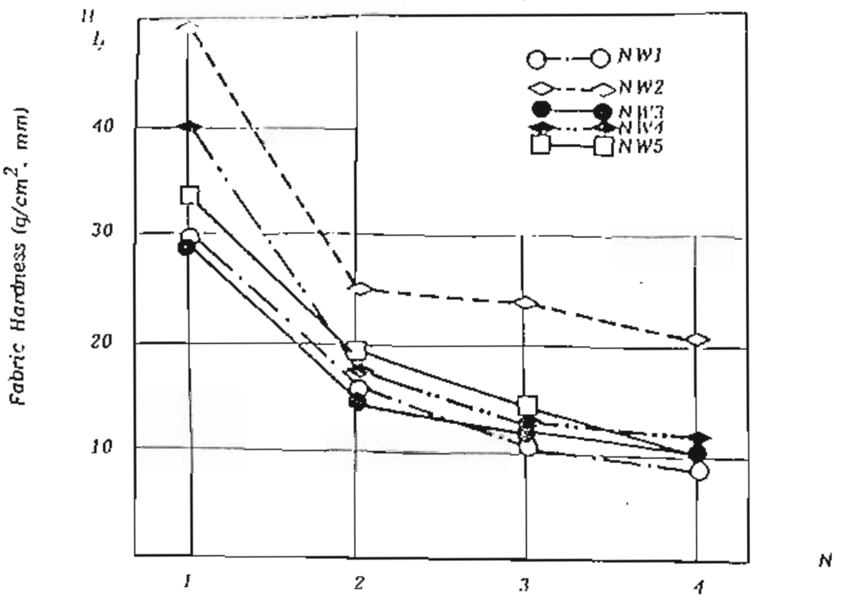
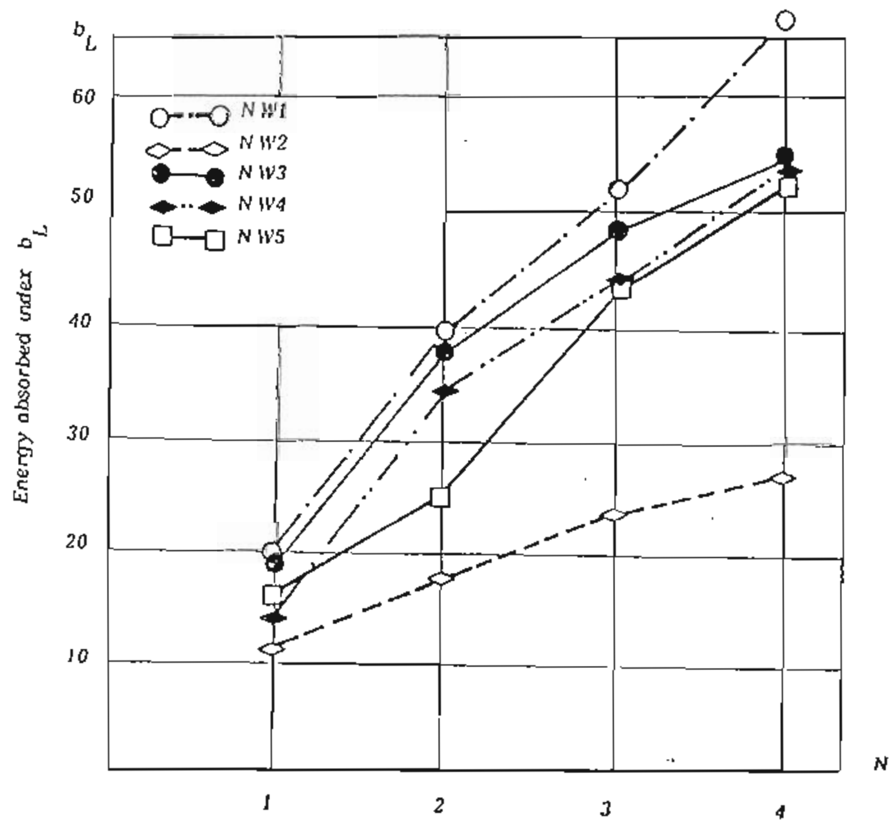


Fig.3: Shows H_L versus N



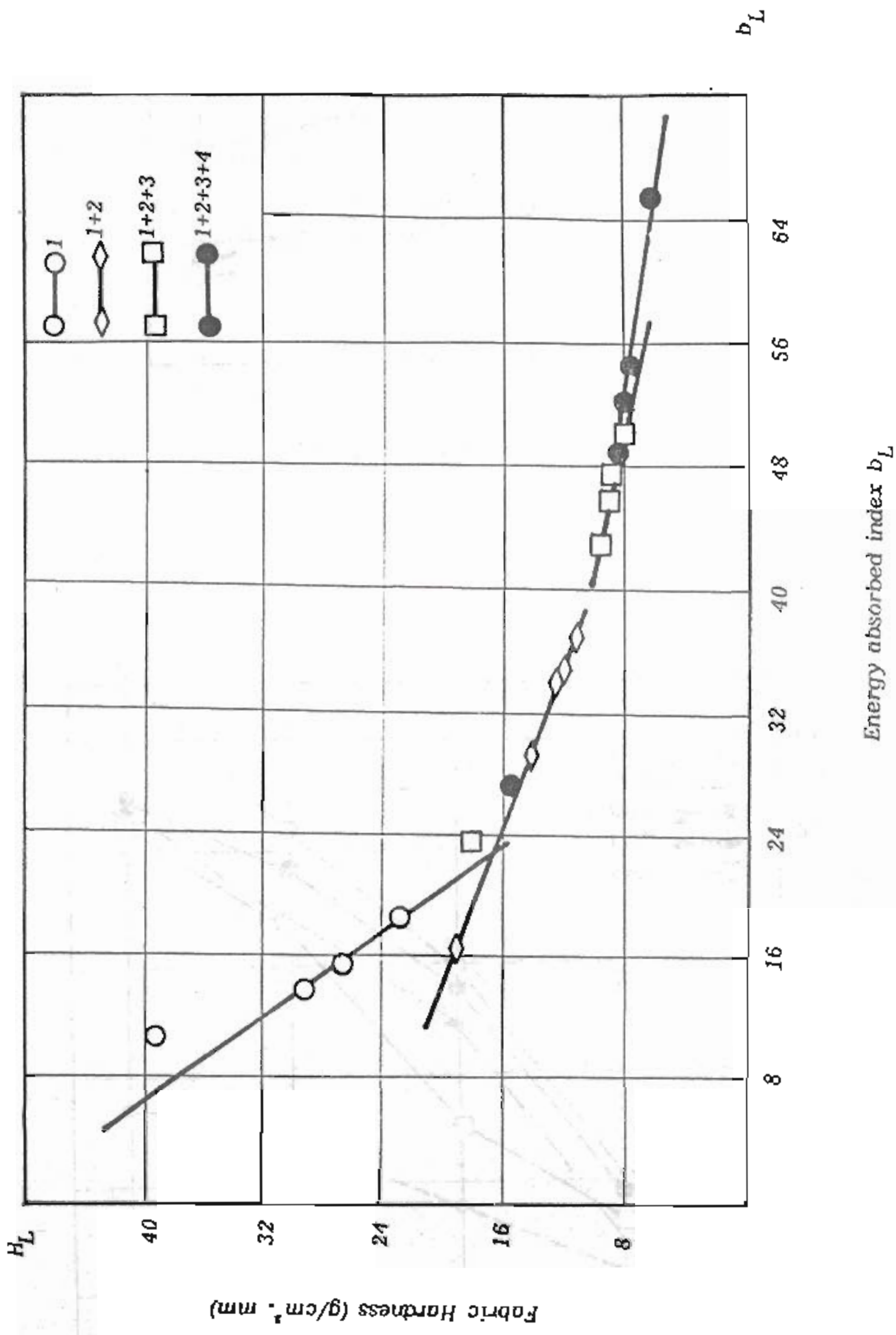


Fig.5: Shows H_L versus b_L