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A SIMPLE TECHNIQUE FOR MEASURING THE COMPRESSIBILITY OF A MASS OF LOOSE FIBERS

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Abstract

A simple technique for measuring the compressibility behaviour of loose fibres under automatic cycling has been developed. It consists of a compression cagein which a cylinder and plunger have been fixed, to press a certain mass of fibres in a certain volume. This cage can be attached to any tensile apparatus to measure the pressure-height relationship of fibre volume under automatic cycling. The same relationship but under manual loading has been obtained by using the thickness meter by putting certain mass of fibres in a fabric casing to give the fibres sample a cetain volume.

1. Introduction

Loose fibres used in furniture, padding, mattresses and quiltes are subjected to different static and dynamic loading. Thus the compression characteristics of these fibres are thought to be the most important property required to be measured, to give a comparative guide to their behaviour in practical use. Till the present time there is no available standard method to measure this property for loose fibres. Thus a simple technique has been developed for measuring the compression characteristics of the fibres of a certain mass in a certain volume resembling the practical packing density of matresses and quites.

There are no researches in the study of the compression behaviour of loose fibres, while there are several researches on fabrics and floor covering such as Brown [3], Kasswell [6], Dorothy [4], Dorothy [5], Onions [7] & Robinson [8].

In addition, the American standards of testing of materials (A.S.T.M.) [1] and the British Standards (B.S.) [2] have established standard methods and definitions of the technical terms, measuring the compressibility of fabrics and carpets which can be used also for loose fibres in this work.

2. Experimental Procedure for Measuring Pressure/Height Relationship

2.1 Manual Test

The pressure/height of fibres relationship under loading has been obtained by using Fruzier thickness meter. A sample of the fibres of certain mass (8 grams) is put inside a certain fabric casing, which has dimensions of one inch height and three inches diameter (as the used foot pressure of the thickness meter) to give the practical packing density (0.07 gms/cm^3). The sample is placed between the base and foot pressure of the meter to measure its thickness at minimum pressure of about 0.20 lbs/in^2. Then the pressure is increased gradually every half minute intervals by increasing the deflection of the pressure spring by 0.01" on the pressure gauge (which can be easily translated to pressure, from the deflection/pressure curve of the spring of the apparatus). The height of the sample is read for each pressure till a maximum pressure of only 3 lbs/in^2. Then the pressure is decreased gradually till the minimum pressure is obtained again. Then the pressure/height of fibres relationship for compression and decompression cycling can be obtained.

The manual test has some disadvantages with respect to the automatic test such as the test is time and effort consuming, and also the height measurement for a given pressure is somewhat arbitrary and very dependent on the time allowed for settling.

For these reasons it has been decided that further measurements should be made on the more versatile developed automatic test.

Also, the effect of a static load on the height loss of the fiber sample by time is measured by using maximum pressure (3 lbs/$in.^2$) for one hour and the height of fibres is measured every 10 minutes to give the height loss by time and then during unloading, the static load is removed and the thickness is measured every 10 minutes for another one hour to give the fibre height recovery by time during unloading.

2.2. Automatic Test

The pressure-height relationship of fibres under automatic cycling has been obtained by a developed apparatus. The apparatus shown in Figure (1) could be atached to the Goodbrand tensile tester instead of its clamps as shown in Figure (2). It consists of a compression cage of two parts (A) and (B) to change the tensile load of the tester to a compression load. In between (A) & (B), a perforated cylinder (C) of 5 cm. diameter, in which a sample (E) of certain mass (5 gms) of the fibres is placed to give the same practical packing density (0.07 gms./cm^3). Then the plunger (D) having a mass of 173 gm is put to give the minimum pressure on the fibres sample of 865 Newtons per square meter (8.65 g.f./cm^2) which is found to be just sufficient to press the fibres without compressing. The upper plate of cage (B) compresses the fibre sample by the plunger (D) as cage (A) moves upwards. The pressure-height relationship of fibres sample can be obtained on the recorder chart as shown in Figure (3). The recorder's pen continues tracing until it reaches 20 kgs., which gives approximately the maximum pressure on the fibre sample of 100 K.N/m^2 calculated as it is typical of the pressure exerted by a person on the funiture. After this pressure the cross-head must be stopped and returned to its starting position which is an arbitrary distance to measure the heights of fibre sample and then five automatic cycles can be obtained.

Notes

1. The cross-head returns with the heighest speed and cannot be

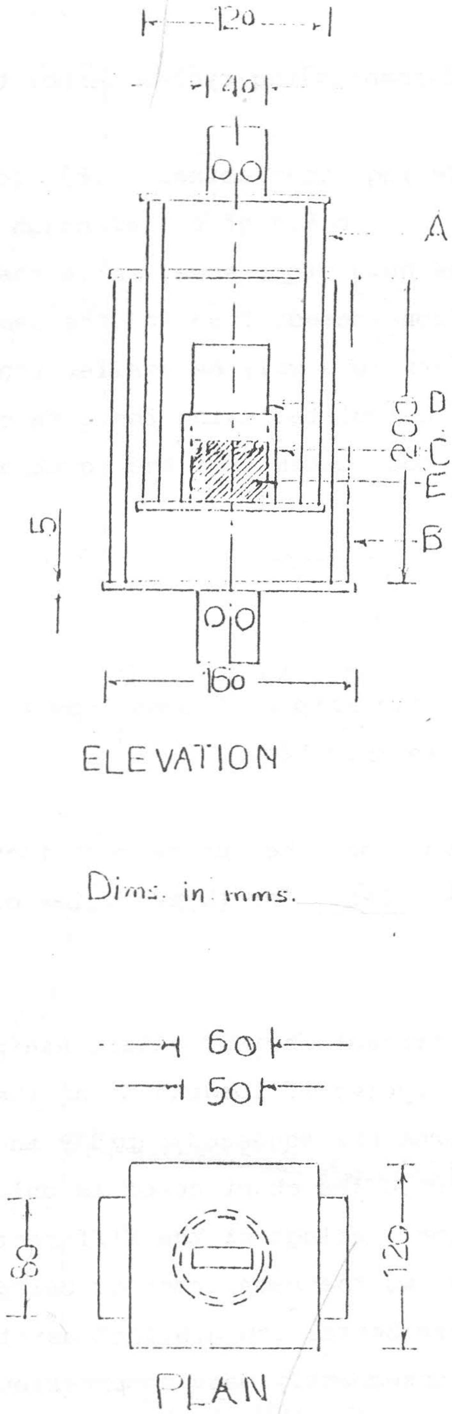

Fig.(1) The developed apparatus for measuring the pressure/height of loose fibres relationship

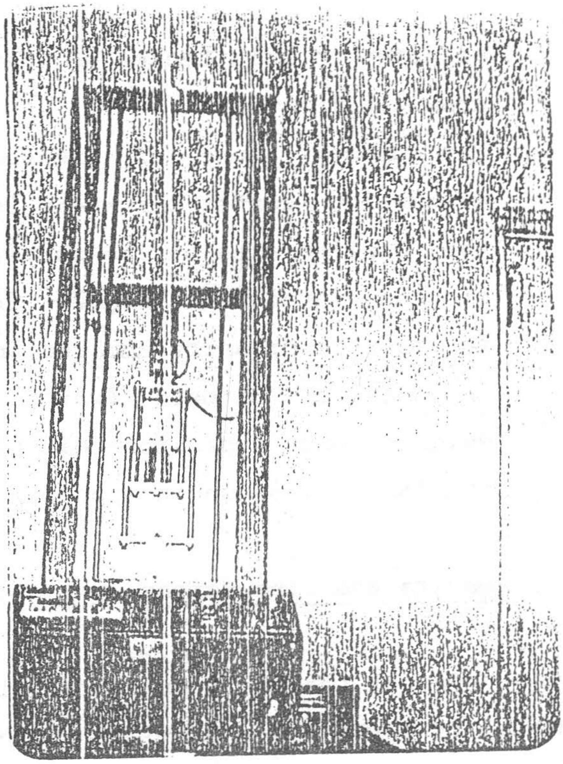

Fig.(2) The photogragh of the developed apparatus

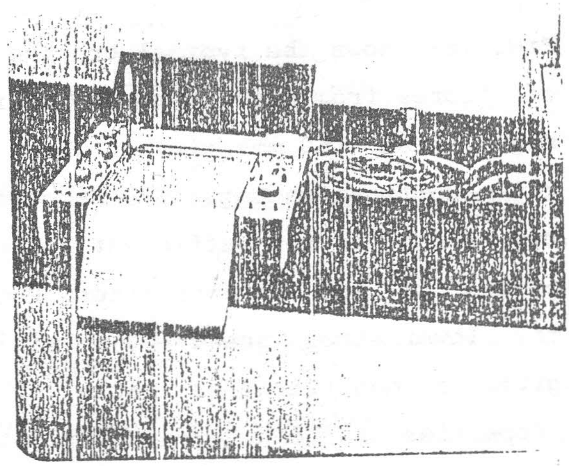

Fig.(3) The pressure/height of fibres relationship on the recorder chart.

adjusted in this tester so that the decompressing cycles cannot be drawn in the chart.

2. The chosen range of pressure refering to Robinson [8] for measureing carpet thickness is from 17.6 to 844 gf/cm^2 although the applied area on the carpet is the human foot area, while that on the furniture, bigger area is considered. Thus for the same forces the pressure applied on the furniture will be smaller than in case of carpets (which can be calculated using the data of weights and dimensions of the human body taken from the Egyptian standards as shown in Appendix (I)).

3. Results and Discussions

The typical traces of pressure/height relationship of fibres from the manual test and the automatic test are represented.

Figure (4) shows the typical tracing of the pressure/height relationship of fibres from the manual test for three cycles of loading and unloading.

Fig. (5) shows the typical tracing of the pressure/height relationship of fibres from the automatic test for five cycles of loading using the high speed (50 mms/min) at which the fibres are squeezed rapidly and the magnification ratio of the strain speed to the chart speed is only two which is not sufficient and causes the tracings of the different cycles to lie on each other. Fig. (6) shows the same tracings using the lower strain speed (10 mm/min) which is better and distinct as it gives a magnification ratio of ten, consequently many compression properties can be determined from them.

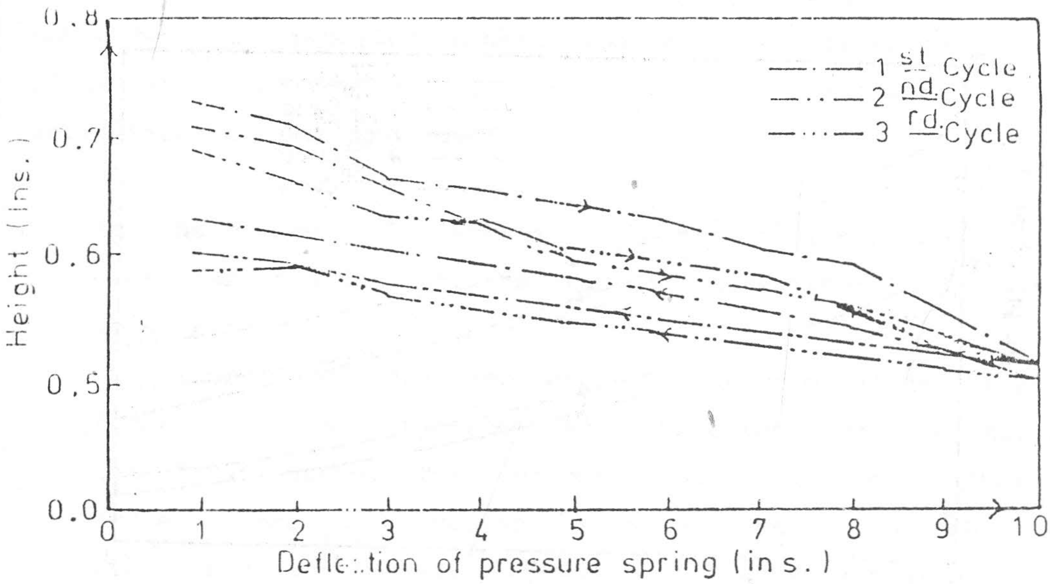

Fig.(4) Actual tracing of pressure / height relationship

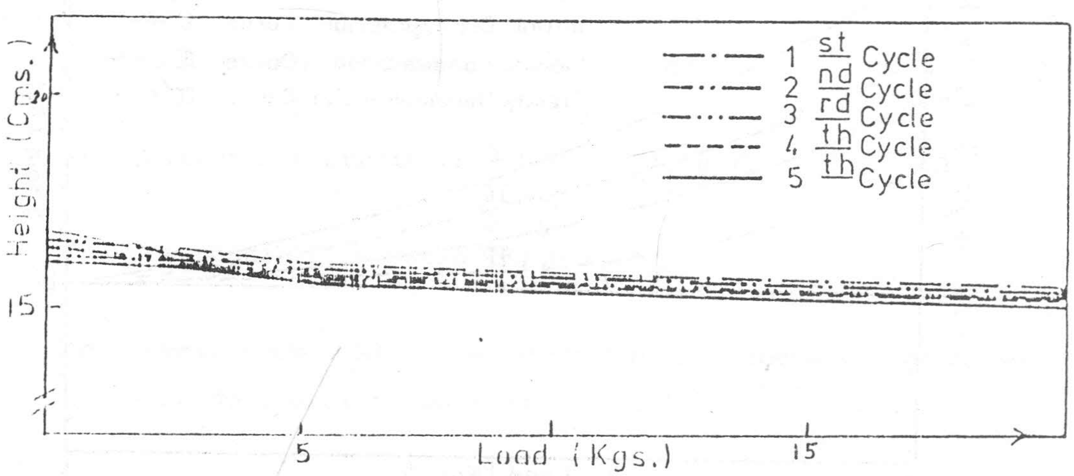

Fig.(5) Actual tracing of pressure/height relationship at 50 mms / min.)

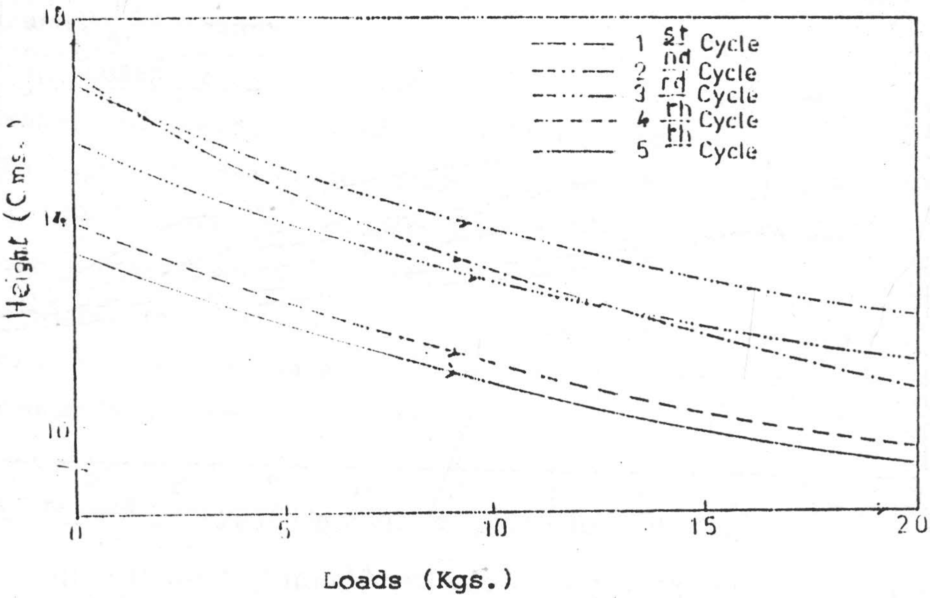

Fig. (6) Actual traning of pressure/height relationship at 10 mns/min.

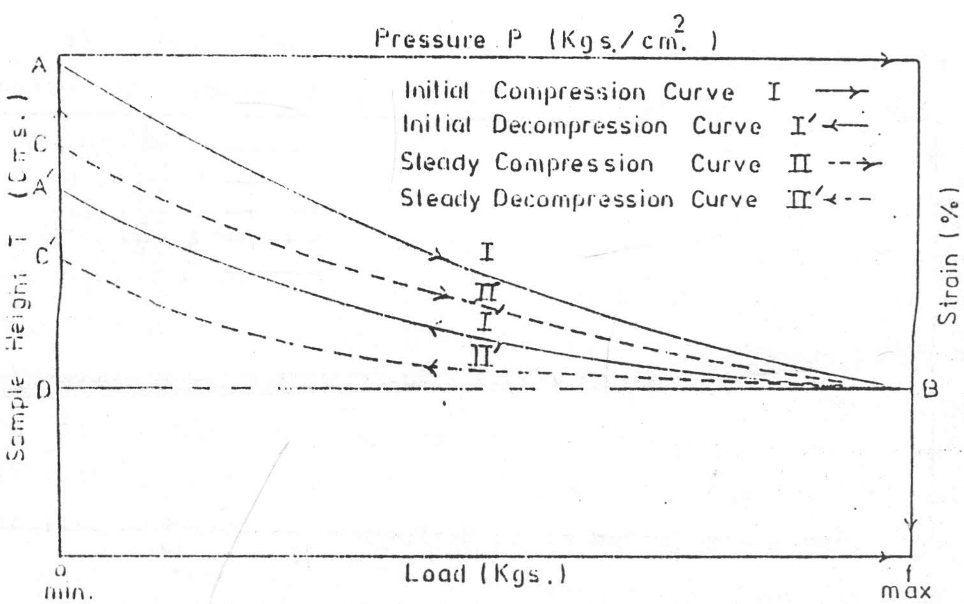

Fig. (7) The pressure/height relationship under repeated compression and decompression cycles.

Generally the behaviour of loose fibres, packed in certain volume, subjected to repeated compression and decompression cycling is illustrated by Fig. (7), from which the following notice and definitions can be concluded:

1. As the pressure (P) increases, the height (T) of the fibre sample decreases rapidly at the start and after that it decreases at a lower rate.
2. The fibre sample does not return to its original height after the *first cycle* and the recorded compression curve does *not fall on* the first curve. This process continues, until after several cycles consecutive curves begin to be nearer to each other. The first curves (intial compression (I) and initial decompression (I')) and the final curves (steady state compression (II) and steady state decompression (II')) are indicated in Figure (7) from which the following definitions [3] & [6] can be obtained:

(a) Hardness (H) = $(P_o - P_f)/(T_o - T_f)$ kgs./cm^3

(b) Compression modulus (C) = H. T_o Kg/cm^2

(c) Compression strain (S)%= $(T - T_o)\ 100/T_o$

(d) Compressibility ratio (K) = T_f/T_o

(e) Resilience (R) % = [work done in recovery (decompression)/ Work done during compressing] x 100

Therefore, R_{II} % (steady state)
= [area under curve II' /area under curve II] x 100

(f) Hysteresis (A) = [work done during compression - work done during decompressing]

Therefore, A_I (intial) = area ABD - area A'BD

= area ABA'

(g) Crush factor (F) is the reduction of work done from intial to the steady state during compression expressed as a percentage of the work done of the steady state compression. Therefore; F % = [area ABC/area CBD) 100.

All these compression behaviour experimental results can be found in [9] for different fibre characteristics using the developed technique. Figure (8) shows the effect of a static load on the fibres sample height loss or recovery by time. It is clear that the effect of time is negligible, that is to say has no considerable effect.

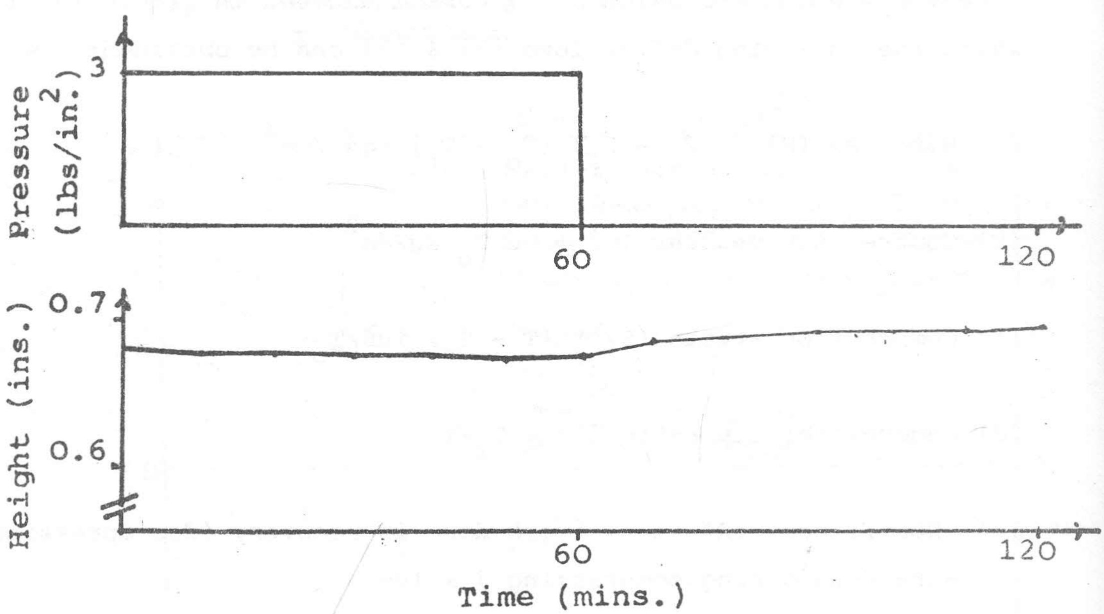

Fig (8) The effect of static load on height loss or recovery by time

4. Conclusions

The developed technique for measuring the relationship, between the height of fibre sample for the manual &automatic tests is found to be sensitive enough to determine the fibre compression characteristics.

The developed apparatus for the automatic test saves time &is easy and very usueful to be a comparative guide for evaluating the fibres used as padding materials for furniture materesses and quiltes.

References

[1] A.S.T.M. Standards of American Society of Testing Materials, D. 117, 1959.
[2] B.S. British Standards Institution 4051, 4052 & 4939 : 1973.
[3] Brown P., "Thickness testing of Fabrics Using the Instron", Ph.D thesis, Leeds University, 1966.
[4] Dorothy, G.C., and Anderson, S., "A test for the assessment of carpet compression during wear , J.T.I., 1962, 53, T. 347.
[5] Dorothy, G.C., "Compression of carpets and underlays"; J.T.I., 1967, 58, T. 573.
[6] Kasswell, S.R., "Textile Fibres, yarns and fabrics", The wool Bureau Inc., 1953.
[7] Onions, W.J., "An assessment of methods of test of carpet flattening, degree of appearance and long term wear", J.T.I., 1967, 58, T. 487-516.
[8] Robinson G., "Carpets" Textile Book Service, 2nd edition 1972.
[9] El-Hawary, I.A., and Sheta, A.H., "Study of Fibre Mass Compressibility Behaviour" Under Publishing.

Appendix I
Calculation of Human body Projected area

Figure (9) shows an outline sketch of a human body from which the total projected area T can be calculated as follows:

The total area T = A + 2B + 2C + D + E

$$= \left(\frac{a+b}{2} \times h\right) + 2\left(\frac{g+e}{2} \times f\right) + 2\left(\frac{l+c}{2} \times j\right)$$

$$+ (a \times d) + \left(\frac{m+k}{2} \times n\right).$$

Table (1) shows the minimum and maximum human body dimension for Egyptian men and women.

Table (1): Dimension of human body

item	men		women	
	min	max	min	max
a (cms.)	43	49	36	42
b "	42	54	46	61
c "	10.5	12.5	9.5	11.5
d "	17	19	15.5	19
e "	9	9.5	8	9
f "	60	60	56	60
g "	17	19	15.5	19
h "	30	30	25	26
j "	101	101	97.5	102
m "	19	21	17.5	21
n "	25	25	22	25
l "	26.5	29.5	32	32
k "	13	15	10	12
$T(m^2)$	0.7703	0.8908	0.6550	0.8718

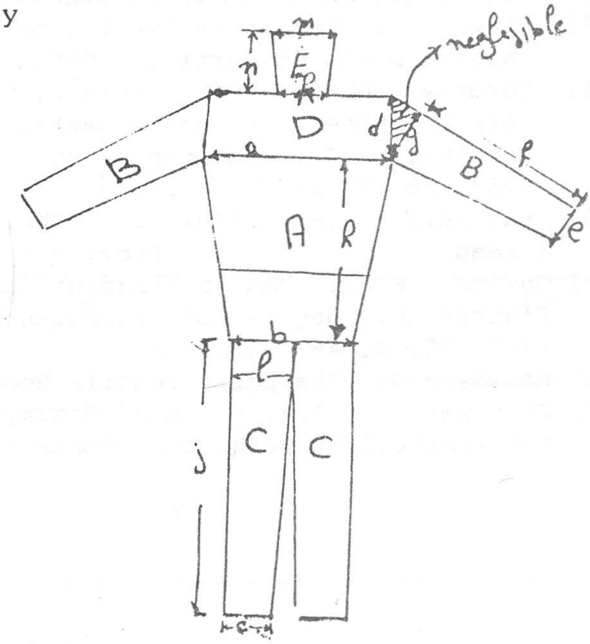

Fig. (9) The human body projected area