UTILIZATION OF TEXTILE WASTES IN NONWOVENS.

Part I: Properties of Industrial Needle Punched Nonwovens Out of Textile Wastes.

الاستفادة من العوادم النسيجية فى انتاج الاقمشة الغير منسوجة ميكانيكيا

الجزء الاول : خواص الاقمشة الصناعية المنتجه من العوادم النسيجية .

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الخلاصة : بناء على تقدير الجهاز المركزى للتعبئة العامة والاحصاء لتعداد السكان ، واحتساب معدلات زيادة السكان بنسبة ٢,٣٣٪ سنويا فان تقدير احتياجات الملابس عام ١٩٩٠ يقدر بـ ١٩١٠٣١ الف قطعة أى ١٠٣٢٦٠ طن تقريبا ، وباعتبار متوسط نسبة العوادم فى مصانعنا ١٨٪ يكون مقدار العوادم الناتجة هو تقريبا ١٨٥٨٥ طن سنويا يمكن تحويلها الى شعيرات تصلح لاغراض مختلفة .

كذلك فان اعادة استخدام عوادم مصانع الملابس الجاهزة لانتاج شعيرات تصلح لانتاج أقمشة غير منسوجة أو غيرها يعطى الفرصة لمزيد من الدراسة للموضوعات التالية :-

١- استنتاج الطريقة التكنولوجية المثلى للحصول على الشعيرات الناتجة من تفتيح العوادم .

٢- توجيه مصانع تفتيح العوادم الى الضبطات المثلى للماكينات وملائمتها لنوعيات العوادم المختلفة .

٣- دراسة الخواص الميكانيكية للشعيرات الناتجة من تفتيح العوادم .

٤- دراسة طرق تحسين الخواص الميكانيكية لهذه الشعيرات بحيث تلائم استخدامها فى أغراض متعددة .

وقد أعطى البحث وصفا تفصيليا للخطوات الصناعية لتحويل عوادم مصانع الملابس الجاهزة الى شعيرات نسيجية ، ثم تم اختبار الخواص الطبيعية والميكانيكية لهذه الشعيرات المفتحة ، وتم ترشيح طريقة تحويلها الى أقمشة غير منسوجة ، ثم قيست وسجلت خواص هذه الاقمشة فى مجالات حشو الملابس الجاهزه حيث ثبت تفوق الاقمشة المصنعة من العوادم من حيث الانفعال الانضغاطى ، والطاقة الممتصة أثناء الانضغاط وكذلك معامل أستخدام الشعيرات .

ثبت أنه بزيادة عدد مضارب التفتيح يقل طول ومتانة الشعيرات القطنية وينخفض معامل الجودة وتزيد نسبة التلف الميكانيكى .

ABSTRACT- The rag waste has been opened using "CGC" processes to be used in the production of nonwoven fabrics for various end uses. It is clear that as the fibre length decreases the compression characteristics will be improved. It was found that as the number of beater increases the quality number and (%) damage increased also.

The survey of the methods of production of nonwoven out of textile waste is given. It was found that the coefficient of exploitation (K') for nonwovens out of textile waste ranges between 8% and 12%. The coefficient of variation of nonwoven fabric thickness which is a measure of the uniformity of the nonwoven textiles, range between 1.22% and 4.2%.

The strength anisotropy of waste nonwoven fabric is better than that of virgin fibre interlining nonwoven fabrics. The stitch bonded nonwoven interlining show high value (0.70), while needle punched nonwoven interlining show less anisotropy (0.19). The most intersting results are from the fabric out of waste fibres, which show less strength anisotropy value (0.21) than others tested fabrics.

1- Aim of the Present Work

The work described in this paper aims towards the presentation, prediction, and understanding of the physical properties of nonwoven fabrics out of textile waste which must precede attempts to modify and control the properties to meet the demands of the user. As a first step in gaining this knowledge, the properties of several commercially available fabrics have been examined. In this way, we shall help to place nonwoven fabrics out of textile waste on a firm basis of physical engineering design. The paper describs measurements of the physical properties of typical commercially available, stitch bonded nonwoven interlining.

2. INTRODUCTION

Nonwoven webs out of textile waste have good tensile strength in both machine and cross directions. Weight can go as high as 70 grams per square meter the hand is generally firmer and more bulky than wet-laid staple fibre webs.

References 2 points out that a nonwoven plant can pump out up to of 1-3 million meters of fabric per year. Therefore, you must engineer a product that will either satisfy a large market or vary the product so that it will appeal to numerous smaller markets.

Marketing has been a problem to nonwovens, as they are new products to both the manufacturer and the user.

A production line can easily cost 1.348-1.566 million DM, and it takes a time before you can make a commercially acceptable fabric.
Ref. 2 points out also some of the wide capabilities of the nonwovens out of textile waste process. It points nonwovens:-

....are producable from hard and soft textile wastes
....have good tensile strength, usually less than woven or knitted fabrics of similar weights.
....are comparatively inexpensive.
....can take a wide variety of surface treatments.
....put up in extra-wide widths and large rolls.
....are usually finished products when they come off the line.

Initial attempts for the manufacture of unconventional fabrics of the nonwoven type started some 70 years back 1. But the research continues for diferent raw materials for nonwovens, for increasing production, improving quality, and reducing cost. Here attempts have been made to utilize rags, cutting both woven, knitted and nonwoven for making nonwovens. Cutting room waste actually constitutes about 93.2% by weight of yarn to garment total waste in Misr Company, Mehalla 2 .

Row materials used in garment industry are subjected to one or all the following three major types of production phases of apparel manufacturing.

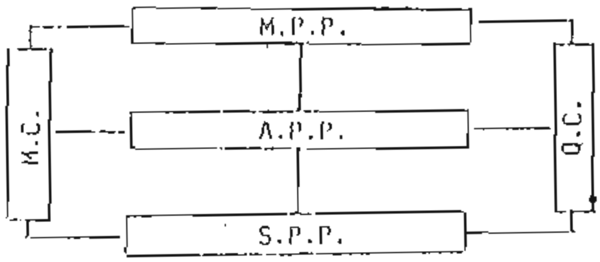
1- Cutting. Severing the row material into shapes for assembly/and or finishing sewing/and or pressing operation. This process is considered the main point which gives textile waste. The percentage waste in fabric cutting varies between 16.71% to 22.81% for wool fabrics and from 12.9% to 15.54% for cotton fabrics (see Table 2).

   By increasing the number of production units, the percentage of cutting room waste increases also. Therefore cutting room waste will be the main scource of row material, which will be recycled in this work.

2- Sewing. Assembling/and or finishing the cut or pre-made pieces with stitches for cutting, pressing, packing or shipping operations.
   This process gives less percentage of waste than cutting room waste. It was found that the overlock machine gives waste not less than 1.4 Kg/shift for cotton Denim Jeans trouser size 50. This type of fabric waste is suitable for recycling and is better than cutting rooms waste from "CGC" processes point of view (3 and 4).

3- Pressing. Shaping cut or sewed material with pressure, with or without heat/and or moisture, for further processing or marketing. In such process the percentage of expected waste must be minimum.
   There are three main processes in garment industry:
   - A- Min Production Process (M.P.P.),
   - B- Accessory Production Process(A.P.P.) and
   - C- Secondary Production Process(S.P.P.).

Figure 1 Shows block diagram of garment production processes.



Q.C. = quality control

M.C. = material control

Fig. 1: Shows the type of manufacturing processes in garment industry.

In Misr-Company El-Mehalla El-Kobra for spinning and weaving the woven fabric waste represents 29.1% of the total company waste (about 1029.6 tons/year), from this amount about 1000 tons/year is considered hard waste. This could be directed to nonwoven fabric mills. 2 .

In El-Noor Company El-Mehalla El-Kobra the above mentioned quantity of the hard waste reaches about 52 tons/year 6 .

In El-Nasr Company Kabo Elexandria, the percentage of hard waste reaches 700-2000 tons/year 2 .

3. Machines Requirements For Recycling of Fibres and Waste Textiles

3.1 Cutting Machine

Taking for granted that rag is available from multiple resources, the first machine required is a cutting machine to cut the hard waste in a suitable fibre length. Such machines work generally with 2 or 4 knives.

3.1.1 Technical data 11

- Length 5000 mm,
- Width 1600 mm, area = 800,000 mm^2
- Feed speed 0-56 m/min,
- Cutting strokes 90-280 per min.,
- Approx. input 1.1 KW,
- ROLANDO Machine Tossili - Italia, SCHIRP - Maschinenbau - Entstaubung Stechnik - Bissingstra Be 5, Wupperta 5600 (11) 7 .

3.2 Tearing and Opening Machine (fibre reclaiming machine)

These machines possess big drums mounted with a large number of pin legs. The no. of drums vary between 1 and 6 drums whereas the no. of pining becomes higher and higher from 1st to subsequent drum. At the same time the pin size becomes finer. In fact the no. of drums depends on the available waste and the required opening grade.

3.2.1 Technical data 8

- Length 7700 mm (2 drums)
- Width 1600 mm, area 123,2000 mm^2
- Input 50 - 350 KW, and
- Alforimex, S.A.ASPAIN 8 .

3.3 Carding Machine

Woolen cards with workers and strippers are most suitable for proper web maker, Modern cards are high-production cards for hourly production of 300 - 500 Kgs/hour. The card production depends on the working width and fibre fineness. It is recommended to install a card with a working width of 2000 or 2500 mm. In this way it is possible to balance the production of a card with that of a needle loom plant.

3.3.1 Technical data 9

- Length 5395 mm,
- Width 2850 mm, area = 15375750 mm^2
- Approx. Working width 2500 mm, and
- Approx. input 14.4 KW.
- HERGETH KG Dülmen, Halterner Stra Be 70, 4408 Dülmen 9 .

Principally it is also possible to use an aerodynamic method of web making. The blending, fibre opening is, however, not comparable with carding process. This process is more suitable for heavy weight felts and shorter fibres. The production rate is also much higher of these machines.

3.4 Rando - Feeder and Rando - Webber

A Rando - Feeder and Rando - Webber nonwoven fabric machines based on a system of air-laying of short fibres were used. It has three main stages = rando - prefeeder, rando - opener blender, and rando-webber.

3.4.1 Technical data 10

- Length 5055 mm,
- Width 1537 mm, area = 7769535 mm^2
- Hight 1930 mm,
- Approx. weight 3588 Kg, and
- Approx. input 7.6 KW.
- RANDO Machine Corporation, The Commons Macedon, New York 14502 10

3.5 Cross - Lapper Machine

The web made of a card, irrespective of its width, can be laid now in any desired width with the help of a cross - lapper. Due to large difference between web delivery speed and running speed of the cross-belt of the cross -lapper, many layers can be laid over each other. The batt weight depends on this speed difference and the area weight of the web.

3.5.1 Technical data 11

- Length 4625 mm
- Width 2616 mm, area = 3139200 mm^2
- Hight 1300 mm
- Approx. Weight 1500 Kg, and
- Approx. input 1 KW.
- ASSELIN - 41 rue Camille - Randoing 76504 El-Beuf Cedex - France 11 .

The batt made on a cross - Lapper is yet voluminous and unstable and has to be fed to a needle loom (mechanically reinforced)/and or spray-bonded webs (chemically reinforced).

3.6 Spray - bonding Machine 12

HERGETH supplys spraying cabins for bonding of webs and also suitable equipment for preparing the spraying liquid. Spraying may be done by various types of nozzle systems either by the compressed air nozzle system the two-components nozzle system for air and liquid and the low pressure nozzle system. The choice of the suitable system depends on the quantity of spraying agent to be applied. For almost all types of filling webs a two-components spraying system will be required.

3.7 The Dryer 12

The spray-bonded web normally is dryed in the top section of the dryer and is then led through the second spraying cabin to the central passage of the dryer. Heating may either be direct or by gas or oil but steam heating or thermo oil heating are equally suitable. The dryer normally allows working of different temperature in the different passages 12 .

3.8 Needle Punching Machine

The machine should be a downstroke machine, i.e. the needling takes place from top to bottow. For degree of consolidation, parameters like needle size, depth of needle penetration and advance per stroke are determining factors. Following formula is valid for adjusting the punching density 13

$$\text{Punching density} = \frac{\text{no. of needles/1 m working width}}{\text{advance/stroke (mm)} \times 10} \ (\text{punches/cm}^2)$$

3.8.1 Technical data

a) Needle parameters
- needle 15 x 18 x 36 x 2RB (wool and virgin fibres),
  15 x 18 x 25 x 2RB (cotton and waste fibres)
- needle pentration 2-13 mm
- Punching density 60-80 stitch/cm^2

b) Loom parameters
- max. no. of needles/1 m 4000
- Liner speed 4.83 m/min. (in case of waste)
  14.49 m/min. (in case of virgin)
- Production 850 m^2/h (waste fibres)
  804 m^2/h (virgin fibres)
- Strokes 300-450 r.p.m.,
- Length 2500 mm, area = 6250000, mm^2
- Input 13.4 KW.

Needle punched textile find successful applications practically in all classes and subclasses as shown in Fig. 2 15

4. Fibrous Raw Materials

Fibres are the basic and in the majority of cases the starting raw material in the production of nonwoven fabrics. Their proportional content in the finished fabric varies largely; it ranges usually between 30 and 100%. It is evident, therefore, that the properties of the fibres will have an important effect on the properties of nonwoven fabrics produced from them.

4.1 The Function of the Fibres in nonwoven fabrics 16

The function of the fibres in nonwoven fabrics may vary depending upon the type of the binding or bonding system used in the fabric. From this view point, we may consider the following cases:

- The fibres form the skeleton of the nonwoven fabric and the fibrous structure of the whole system.
- The fibres form the binding element of the fabric.
- The fibres form the bonding element of the fabric due to:-
  1- their swelling or dissolving properties,
  2- thermoplastic properties,
  3- shrinking properties.
- The fibres form the filling material for the whole system.

4.2 Effect of fibre properties on the properties of nonwoven fabrics

As far back as in 1959 Nicely 17 discussed in his detailed study the effect of the most important fibre properties, i.e. their type, staple length and fineness, on the properties of nonwoven fabrics.

4.3 Choise of Fibre

The properties of a nonwoven fabric are very strongly dependent on its fibre content. In making a range of fabrics for different purposes, almost all types of fibre have been used, and blends of fibres are very common.

In passing, it may be noted that requirement for fibre length, uniformity and so on may be less stringent in the production of some nonwoven fabrics than they are in the spinning of yarns . Consequently, it is often possible to use second-quality or waste fibres; the latter may be short fibres removed during other processes or fibres recovered from rags. This comment applies particularly to the cheaper uses. High-quality nonwoven fabrics are made from first-grade virgin fibres.

4.4. Measurement of Physical Properties of Fibres Recovered From Rags

Textile garment wastes and textile rags are opened by using Laroche Opening Line using differcht number of beaters. Also virgin fibres are used for comparison.

To study the influence of "CCC" processes on cotton fibres, ten samples of recycled cottons were selected and examined according to the following tests:-

4.4.1 Testing of Recycled Cotton Fibres Using Microscopic Measurements

A light microscope with heating disc was used. All the measurements were conducted at constant slide temperature of $62^{o}C$ (18,19 and 20).

The quality number (Q.N%), which is used as a microscopic measure for quality is calculated by proportion from the following equation:

$$Q.N\% = \left(\frac{n1}{n} + \frac{n2}{2n} + \frac{n3}{3n}\right).\ 100 \qquad ......(1)$$

The % damaged fibres is calculated from the equation:

$$\%\ D = \frac{n3}{n}\ .\ 100 \qquad ......(2)$$

where

$n = n1 + n2 + n3$,

$n1$ = undamged fibres, $n2$ = half-damged fibres, and

$n3$ = damaged fibres.

4.4.2 Fibre Bundle Strength

The tensile strength was measured using Pressley Strength Tester at zero gauge. The % drop in bundle strength "L%" was calculated from the equation:

$$L\ \% = \left(1 - \frac{(P.I)waste}{(P.I)virgin}\right).\ 100 \qquad ......(3)$$

where

(P.I) waste = Fibre bundle strength of recycled cotton fibres.

(P.I) virgin = Fibre bundle strength of untreated cotton sample.

4.4.3 Fibre Length

The Mongo fibre length has been measured by measuring the average of 200 fibre length of random sample by gently straightening them using parafine oil on a glass plate. While cotton fibre length was measured according to the ball's sorter tester 21 .

4.5 Compressional Properties of Recycled Fibres and/or Needle Punched Nonwoven Fabrics Out of Textile Wastes.

The compressional properties of needle punched nonwoven fabrics out of textile wastes were measured at two pressures ranging between 5 and 50 (gm/cm^2) using the Shirley Thickness Gauge with the largest foot (Area = 50 cm^2) and fibre attachment according to Ref. (22,23,24,25 and 26).

The absolut compressibility (S) could be determined according to the equation:

$$S = T_{(1x)} - T_{(10x)} \qquad \text{......(4)}$$

Where T_{1x} is fabric thickness at 5 (gm/cm^2)

T_{10x} is fabric thickness at 50(gm/cm^2)

While the relative compressibility (S_t) may be calculated according to the formula:

$$S_t = \frac{S}{T_{(1x)}} \, 100(\%) \qquad \text{......(5)}$$

Also the compressibility ratio (CR) is given as the ratio of fabric thickness at 50 (gm/cm^2) to fabric thickness at 5 (gm/cm^2) respectively, i.e:-

$$CR = \frac{T_{(10x)}}{T_{(1x)}} \, 100(\%) \qquad \text{......(6)}$$

According to Peirce 27 the hardness (H) of textile fabric could be determined from the equation:

$$H = \frac{P_{(10x)} - P_{(1x)}}{T_{(1x)} - T_{(10x)}} \quad (gm/cm^2)/mm \qquad \text{......(7)}$$

Where $T_{(1x)}$ and $T_{(10x)}$ are fabric thickness measured at two pressures $P_{(1x)}$ and $P_{(10x)}$ respectively.

The equation of thickness-pressure proposed by Bogaty 28 was used and found suitable. This equation is in form of;

$$T_{(1x)} = T_{(10x)} + b/(P_{(1x)} + c) \qquad \text{......(8)}$$

Where $T_{(1x)}$ = thickness of fabric at 5 (gm/cm^2), (mm)

$T_{(10x)}$ = thickness of fabric at 50 (gm/cm^2), (mm)

$P_{(1x)}$ = Pressure at 5 (gm/cm^2),

c = correction of pressure, according to Ref. (2 and 3)

b = parameter describes the energy absorbed per unit, area of fabric.

As the pressure (p) increases, the high (h) of the fibres (fabric thickness) decreases rapidly at the start and after that it decreases at a lower rate.

The fibres sample (fabrics) not return to its original height (thickness) after the first cycle and the recorded compression curve does not fall on the top of the first curve. This process continues, until after several cyclea consecutive curves begin to be near to each other.

The first curves (intial compression (I) and initial release of compression (I') and the final curves, (steady state compression (II) and steady state decompression (II') are indicated in Figures 3 and 4 from which the following definitions can be obtained:

a) Compression modulus (CM)

$$CM = H.T_{(1x)} \ (gm/cm^2) \qquad ......(9)$$

b) Compression strain (%)

$$\% = (T_{(1x)} - T_{(10x)}/T_{(1x)}).\ 100 \qquad ......(10)$$

c) Exploitation Compressibility coefficent (K)

$$K = \frac{CM_{fibre}}{CM_{fabric}}\ .\ 100 \qquad ......(11)$$

Where CM_{fabric} and CM_{fibre} are the compression modulus of tested fabric and fibre in the same weight respectively.

4.6 Measurement of Physical Properties of Industrial Nonwoven Fabrics out of Textile Wastes.

A range of commercially available nonwoven fabrics, including random laid, and performated fabrics, was obtained and tested in the ways described below. All tests were carried out in an atmosphere of 20°C and 65% R.H. after a conditioing period of not less then 24 hours.

4.6.1 Dimensional Characteristics

Ten specimens 10 cm x 10 cm were cut from different parts of the material using a template and weighed individually. The average mass per square meter was calculated. The same specimens were tested for thickness between anvils of area 50 cm^2 under a compressive stress in range of 5 to 50 gm/cm^2. At least 10 thickness measurements were made on each fabric, and the coefficient of variation of thickness gives some indication of the uniformity of the fabric.

The density of the fabric in Kg/m^3 was calculated from the mass per unit area and the thickness.

4.6.2 Tensile Strength

In order to cut specimens for tensile testing a brass 25 x 15 x 1 cm was placed on the fabric and then a brass strip of the required width was held on the fabric against the edge of the plate. The fabric was cut along the edge of the brass strip with a knife. The test specimens, when monunted, were 20 cm long and either 1 cm or 2 cm wide: it was found that within these limits, the results were unaffected by the width of the specimen. Load-extension curves were obtained on an Instron tester at a constant rate of extension of 10% per min. 3

4.6.3 Anisotropy of Fabrics

The fabrics have different properties in different directions. In order to take account of this, the various parameters mentioned above were, where appropriate, measured in the direction along the length of the fabric (long), perpendicular to the length of the fabric (cross), and at 30° to the length of the fabric (30°), in order to obtain complete polar diagrams of strength of nonwovens. 3

5. RESULTS

5.1 Compression Properties of Recycled Cotton Fibres

Figure 3 Shows the relationship between sample high (h) mm and applied pressare (gm/cm^2) for raw (ginned cotton), Opened cotton fibres using 6 beaters, opended cotton fibres using 12 beaters and mongo cotton fibres out of textile waste (rag). It was found that as the fibre length decreases the compression characteristics will be improved. It is clear that as the number of beater increase both compression ratio and fabric hardness increases (see Table II).

While Fig. 4 shows the same behaviour but for raw wool, wool mongo, and wool raising waste.

Table II shows the microscopical measurements of tested cotton samples, i.e. quality number (Q.N%), and % damage (%D). It was found that as the number of beaters increases the quality number decreases and % damage increase. Inspit of these poor results, the recycled cotton fibres could be used to produce some types of nonwoven fabrics, as examples; interlining, disposal, cotton padding., soil felt for agriculture, interlining padding for garment, wall covering, cleaning felts and others.

5.2 Results of Tensile Properties

For the tested cottons, the general trend obtained is that fibre strength tends to decrease after "CGC" processes. The decreased or drop in strength relative to that measured for virgin cotton fibres, ranges between 39.4% and 59.6%.

The degree of exploitation of the fibre strength in nonwoven fabrics out of textile waste may be characterized by the either % or ratio of the strength of the nonwoven fabric to the total strength of the elementary fibres in it lying in the direction of the applied load. The coefficient of exploitation may be expressed:

$$K' = \frac{\sigma'_{nw}}{\sigma_f \cdot n} \cdot 100 \qquad \ldots\ldots(12)$$

where

K' is the coefficient of exploitation,
σ'_{nw} is the tensild strength of nonwoven, fabrics out of textile waste,
σ_f is the absolute tensile strength of, recycled single fibres, and
n is the number of fibres in a 1 sq. cm.

According to Ref. 16 ; it was found that, $K' = 40 - 50\%$ for woven fabrics, 20% for chemically bonded nonwoven fabrics, and 30% for needled fabrics.

It was found that K' value for nonwovens out of textile wast ranges between 8% and 12%.

5.2.1 Tensile Strength of Different Interlining Fabrics.

The stitch bonded interlining as a know interlining textile was compared with needle punched nonwoven fabric out of texile wastes.

The stress strain measurements were carried on 20 cm x 5 cm strip using Instron tester at speed rate of 10 cm per min. Specimens were cut at angular interval of 30^o to the long direction. All tests were carried out under the standard conditions (65 R.H. and 20^{o}C).

The tensile strength and extension at break for two tested fabrics are illustrated in Fig. 5. The corresponding rupture strength are obtained by dividing the load in grams for one mm test strip by the fabric weight in grams per square meters. The units of stress may then be expressed as grams per tex. since fabric weight is equivalent to tex per mm, that is the weight of strip of fabric 1 mm wide and 1000 m long.

Regarding the given values in Fig. 5a, it is apparently seen that the anisotropy of tested fabrics is better using needle punched nonwoven fabric than that using stitch bonded nonwoven in both strength and extension values.

5.3 Results of Tested Nonwovens

The results of the physical tests, are given in the following points:-

5.3.1 Density and Uniformity

The densities of the industrial nonwoven fabrics out of textile waste, ranged between 542.7 and 1549.3 gm/cm^3. (see Table III).
The lower end of this range is for denser than the lofties nonwoven fabrics, which can be made; typical binded polyacrylic wadding used for insulation. The upper end of the range, used for interlinings.

The coefficient of variation of thickness which are a measure of the uniformity of the nonwoven fabrics, range between 1.22% and 4.2%.

4.3.2 Anisotropy

On the basis of the strength anisotropy, the random web fabrics appear significantly oriented in the machine direction. The strength anisotropies of needle punched interlining (virgin fibres) and stitch bonded interlining lie mainly in the range 0.19 to 0.70, while those of another group (nonwoven out of textile wastes) is 0.21, i.e. the strength anisotropy of waste nonwoven fabrics is better than that of virgin interlining nonwoven fabrics (see Fig. 5_a and 5_b). The stitch bonded nonwoven interlining show high values (0.70), while needle punched nonwoven interlining show less anisotropy (0.19). The most intersting results are from the waste fabrics, which show less values (0.21).

5.3.3 Compressional Properties

Experimentally, it was found that all the nonwoven fabrics, out of textile wast, listed in Table III give high energy-absorbed index of 8.6 to 17.03 compared to 4.99 to 10.15 for the exported and local no-woven interlining fabric. Also it was found that the product of fabric hardness and energy-absorbed index is constant and equal to 387.

For some uses, such as interlining, the energy-absorbed index of nonwoven fabrics is an advantage, but, for more genral textile purposes, greater energy-absorbed index would be an asset.

The same behaviour was found during compression ratio measurements.

The fabric hardness of the nonwoven fabrics, which give a measure of their inherent structure, lie in the range 22.73 to 45 ($gm/cm^2 . mm^{-1}$). Those values are less than that of exported and local production nonwoven fabrics 30.14 to 77.59 (gm/cm^2)$.mm^{-1}$.

In Fig. 6, the shoulder pads thickness (mm) is plotted against pressure (gm/cm^2). The shoulder pads out of textile waste, compression characteristcs mainly depend on the original fibre properties, length and degree of opening. The shorter the fibre length the better the compression characteristics sach as relative compressibility (S_L), energy absorbed per unit area of fabric (b), and exploitation compressibility coefficient (k). This is previously known from the practical use that the short cotton fibres (Afreta and Seking in Egypt) are used for furniture and upholestry as they give better compression characteristics than the long staple fibres which are used in spinning 25.

CONCLUSIONS

The use of industrial nonwoven fabrics out of textile waste is highly recommended as:-

- Shoulder pads and interlining padding for garments
- Filter felts for dust collector 29 .
- Underlay, roofing felt, insulating felt, floor covering, carpets and wall covering for construction textile 30
- Shade and soil felts for agriculture 31 .
- A subgrade reinforcement for highway construction in the Delta region 32 .

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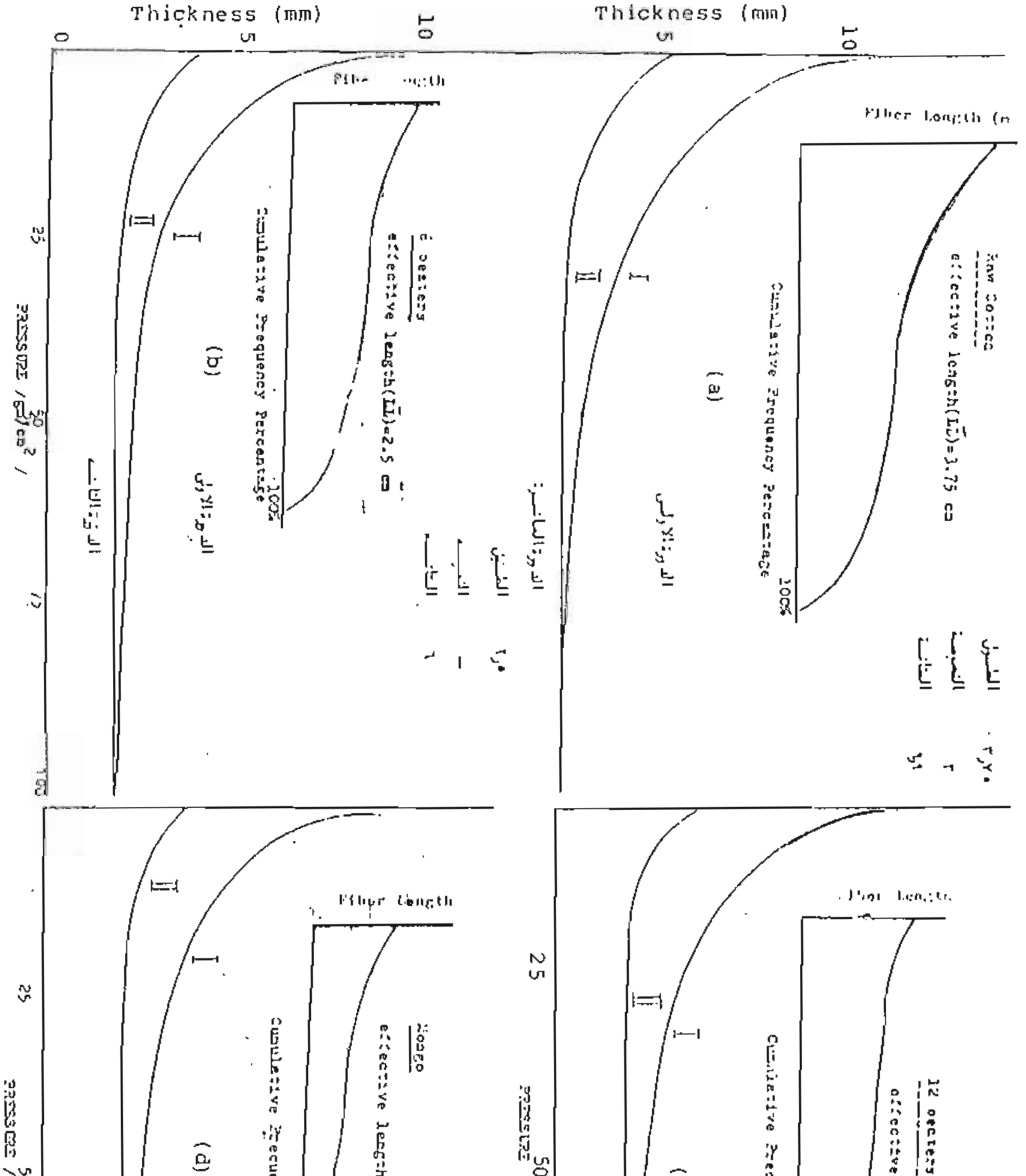


Fig. 3_{a-d}: Shows Initial Compression Curves for Raw and Recycled Cotton Fibres

Table 1

Industrial Waste Distribution During 1986-1989 at Misr El-Mehall and Kabo Alex. (Cutting room wastes)

Yeas	Misr El - Mehalla				Kabo Company	
	Wool Waste (ton)	%	Cotton Waste (ton)	%	Cotton Waste (ton)	
1986 / 1987	201.5	22.8	947.7	15.5	more than	1100
1987 / 1988	120.5	16.7	722.9	13.2	about	1290
1988 / 1989	131.6	21.9	626.7	12.9	more than	715

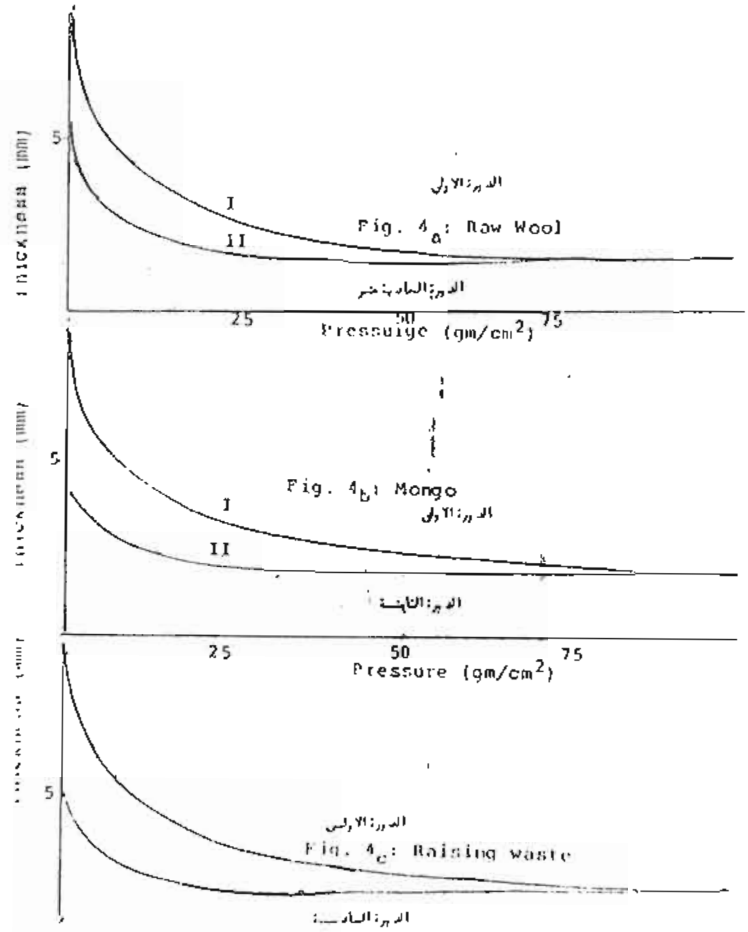


Fig. 4a-c: Shows Actual Tracing of Pressure-Thickness Wool Fibres Relationship for Raw and Recycled

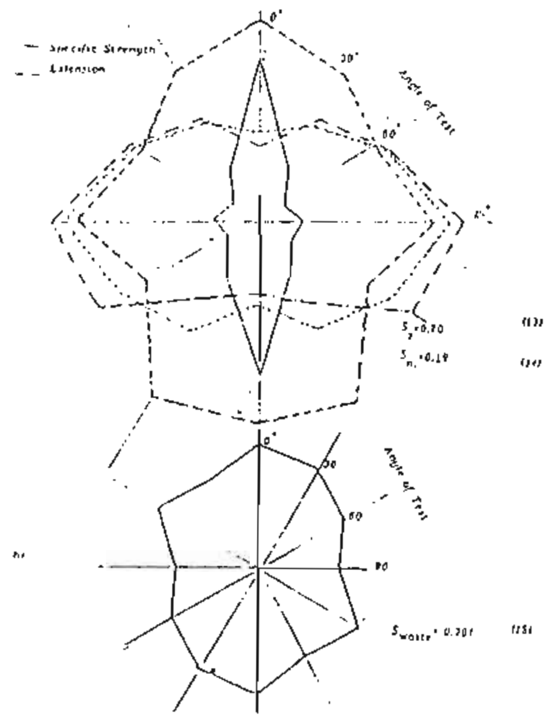


Fig. 5: Specific strength (g/tex) v. Angle of Test.

Fig. 5_a: Stitch bonded NW Interlining and needle punched NW interlining.

Fig. 5_b: Needle punched NW interlining out of textile waste.

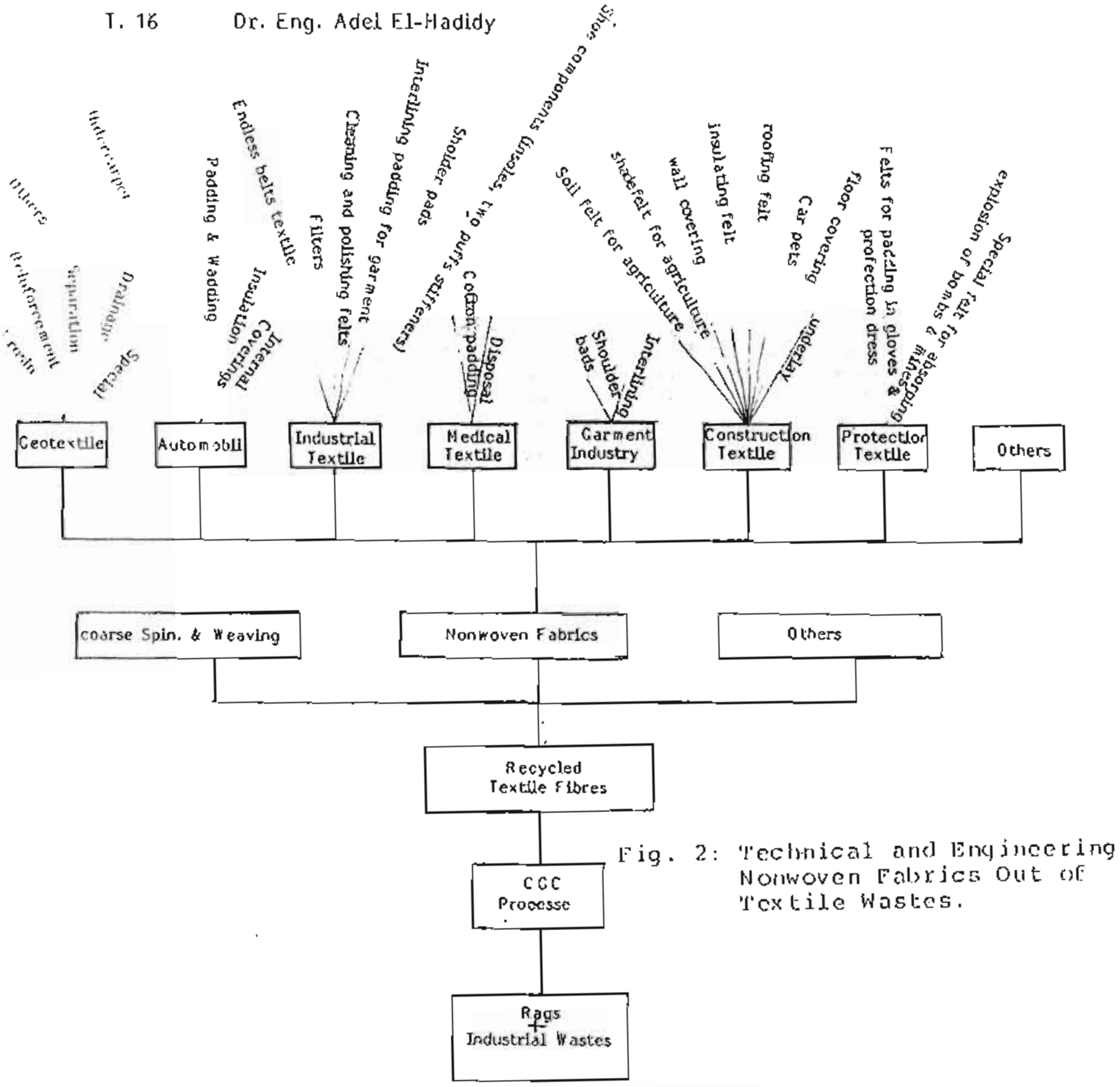
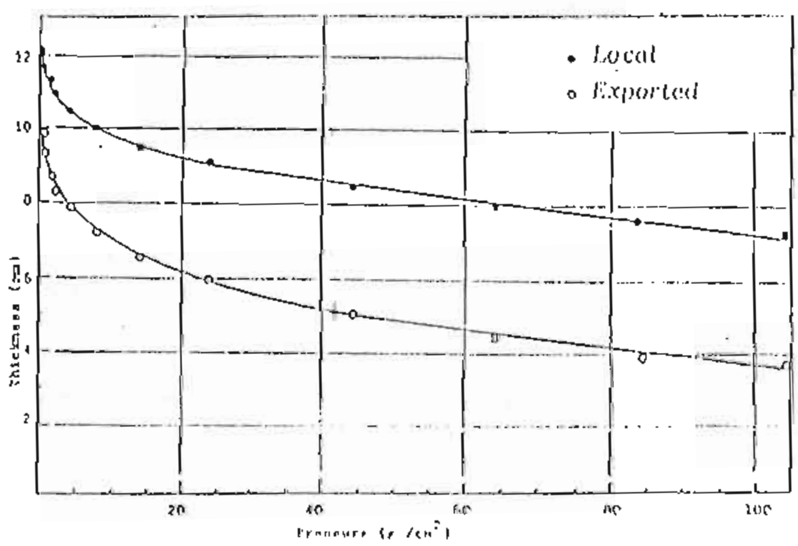


Fig. 2: Technical and Engineering Nonwoven Fabrics Out of Textile Wastes.



Shoulder pads out of textile Waste (Made in EGYPTEX).

Shoulder pads out of virgin Fibres (Made ITALIA).

Fig. 6 Thickness v. pressure (shoulder pads)

Table II

Physical and Mechanical Properties of Recycled Cotton Fibres

Type of tested Cotton	Mechanical Properties							Microscopical Properties	
	strength P.I.	Fineness (micron)	Length (m m)	Compressional Properties S	H	CR %	CH	O.R. %	Damage %
Raw (Ginned)	9.9	3.1	37.5	13.9	123.4	15.0	7.5	93	4.6
Opened (6 beaters)	6	3.1	25.-	7.9	129.-	19.4	13.2	60	32.5
" (12 beaters)	5.5	3.3	22.5	7.4	130.7	20.4	14.1	58	36.7
Mongo	4	3.6	19.-	7.1	136.2	23.7	14.5	55	43.-

Table III

Compressional Properties of Tested Nonwoven Fabrics

Sample	No.	Thickness (mm) $T_{(1x)}$	$T_{(10x)}$	S $T_{(1x)} - T_{(10x)}$ mm	RC % $\frac{S}{T_{(1x)}}$ (%)	H $\frac{P_{(10x)}-P_{(1x)}}{T_{(1x)}-T_{(10x)}}$ (gm/cm2)/mm	CR % $\frac{T_{(10x)}}{T_{(1x)}}$ (%)	CH $H.T_{(1x)}$ (gm/cm^2)/mm	b' 8.65 S_2 (gm/cm^2)	Qv $\frac{Q_s}{T_{(1x)}}$	I.b
Nonwoven Fabrics out of Virgin Fibres	1 (exported)	3.04	2.46	0.58	19.08	77.59	80.9	235.9	[illegible].99	[illegible]42.7	357.2
	2 (local	8.42	7.24	1.18	14.01	38.14	85.9	231.1	10.15	973.9	387.1
	3 (Mongo)	4.80	3.80	1.00	20.83	45.00	79.2	216.0	8.60	833.3	397.0
Nonwoven Fabrics Out of Textile Wastes	4 (Mongo)	4.97	4.00	0.97	19.52	46.39	80.5	230.6	8.34	1569.3	386.9
	5 (Mongo)	5.60	4.21	1.39	24.82	32.37	75.2	181.3	11.95	803.6	[illegible]06.8
	6 (Mongo)	8.26	6.60	1.66	20.10	27.11	79.9	223.9	14.28	726.4	396.1
	7 (Mongo)	8.83	6.85	1.98	22.42	22.73	77.6	200.7	17.03	860.7	387.1
	8 (Mongo)	8.87	6.96	1.91	21.53	23.56	78.5	208.9	16.43	924.5	397.1