STRUCTURE OF NEW TYPES OF FILTER BAGS
OUT OF TEXTILE WASTE

By

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ABSTRACT: The structure of needle punched nonwoven fabrics out of textile waste has been studied in terms of packing density coefficient (\( \theta \)), proportion of pore (\( % \)), energy absorbed index (\( b \)), fibre orientation, i.e. local vector \( \mathbf{0}_x \), \( \mathbf{0}_y \), \( \mathbf{0}_z \), and inclination angle of filtration channels resulted from needles punching (\( \phi \)).
The results indicated that the increase of punching density was accompanied by a drop in inclination angle ($\phi$) and/or filter efficiency. It was found also that the nonwoven filter bags are better than woven filter bags from the following points of view: cost of 1.0 m², air permeability, working temp., energy absorbed index, proportion of pore, packing density coefficient, and filtration efficiency. On the other hand the woven filter bags are the best of all tested filter bags from service life point of view.

1. INTRODUCTION

1-1. General:

Attention is presently directed to open the waste obtained from the cotton and/or wool garment manufacturing and utilized as suitable material for furniture padding, mattresses and quilts. Lung/3/ and Panner/4/ show the economic of utilization of textile waste.

Pederson/5/ suggest that the garment waste can be used for pressed felts, padding, packing wall papers and also for upholstery.

The recycling of fibre and waste textiles provides an important contribution to world textile output. The last decade has been a move in the fibre-re-cycling industry from the U.K. to Italy, India, and South Korea, while the quality of many Italian products (woollens) produced from recycled fibre has made them very competitive. Problems of sorting and dyeing mixtures of recovered fibres have increased with the increasing use of synthetic fibres/6/.

A number of publications/7/ and/8/ relating to nonwoven fabrics and their uses are available, but information on the use of rag wastes, and related fibres for nonwoven is scanty.

The present work is a furtherance of the above studies in different aspects and given some details (know how) of the process.

1-2. Typical Sources of Waste:

- soft and hard waste from spinning, weaving and knitting mills.
- manufacturers waste coming from man-made fibre plants.
- regenerated waste out of edge-cutting of nonwoven industry.
- reclaimed waste out of used apparel fabrics, (so-called shoddy).
- miscellaneous waste.

The properties of any material depends on its constituents and distribution of basic molecules; this is what we call structure. According to the size of these constituents the structures are divided to: (a) micro-structure, and (b) macro-structure. The properties of non-woven depend primarily on the properties of the raw material from which it has been formed, the properties of the adhesive used, the type and form of the binding points or bonds, also the shape of these points.

Many investigations have been carried out by different authors to examine the effect of these parameters on the properties of the non-woven fabric/1,2,9,10,11,12,13 and 15/.

This means that till now no objective method is available that could be used to define the non-woven structure, without intermediate relationship that describes the physical and mechanical properties of non-woven fabrics.
The industrial fabrics represent about 25-30% of the world fabric production /15/, and it serves the following fields: agriculture, building industry, civil engineering, sports, medical purposes... etc.

Filter fabrics are considered one of the best examples for the use of nonwoven fabrics in the industrial applications, especially it serves the following scopes:

a) chemical and medicine industries.
b) food industries (sugar, milk, canned food, fats...etc).
c) ceramic and porcelain industries.
d) paper industry.
e) cement industry.
f) filtration of mineral oils.
g) workshop machines industry and others.

The textile fibres used in the manufacture of industrial fabrics (filter fabrics) may be natural fibres such as cotton and flax, also synthetic fibres such as polyester and polyamide, and this is according to end use.

In filter fabrics besides it should be strong it should be also of high resistance to abrasion, high filtration efficiency (high air and water permeability in the case of gas and liquid filtration), high retention of soil particles, low deformability, of smooth surface and of high chemical and thermal resistance.

1-3. Our Main Objectives Are:
1- enhance the capabilities of Mansoura University, Textile Dept. members involved in applied research.
2- assist the textile industry in solving the technical and economical problems facing this industry, and
3- strengthen the tie between academic researches and industrial specialists.

2- Recycling of Cotton Fibres in Soft/and Hard Waste Form:

The recycling of fibres from soft/and hard waste presents several possibilities. This requires the breakdown of finishing wastes into constituent fibrous materials by the cutting, garnetting, scouring and bleaching, drying, aerodynamic web formation, and then chemically reinforced. Having done this, and knowing the chemical nature of the mixture, several processes for nonwoven formation are available. Considering the quantity of waste cotton and viscose available this could make a major contribution of the reuse of cellulosic materials in sheet form. The scheme of cellulosic fibre recovery from both soft and hard wastes can be summarized as shown in Figure 1.

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.
Various textile wastes
  Sorting and Cleaning
  Cutting
  Garnetting

Wet Processing (1.5 - 3.5 mm) --- Carding
Aerodynamic web formation --- Lapping (20 - 150 mm)
Reinforcing

Chemically bonded NW
- using binders
Mechanically bonded NW
- using needle felting m/cs
- stitch bonded m/cs

- Regenerated Fibres
- Paper making
- Others

Finishing

Nonwoven fabrics for various end uses.

Fig. 1 shows fibres recovery from soft and hard waste out of natural fibres.

Table 1

Physical and Mechanical Properties of Cotton Raie
- Mass/area 200 (g/m²)
- Fabric Structure Plain weave 1/1
- Density/inch. 42 x 82
  30/2 x 30/2

Physical and Mechanical Properties of Recycled Cotton Fibres:

<table>
<thead>
<tr>
<th></th>
<th>Length (mm)</th>
<th>Strength (P.I.)</th>
<th>% Damage (%)</th>
<th>Quality Number (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virging Fibres</td>
<td>37.5</td>
<td>9.9</td>
<td>4.6</td>
<td>93</td>
</tr>
<tr>
<td>Recycled Fibres</td>
<td>15.0</td>
<td>4.3</td>
<td>43</td>
<td>55</td>
</tr>
</tbody>
</table>
3- Experimental Arrangement and Technique:

In advanced industrial countries such felt production is done by needle punching. This technique eliminates some of the deficiencies of conventional woven felts, such as low dimensional stability, low water permeability, watermarks in the paper sheet and last, but not least, rather short service life.

The support of the needle felt is usually a loosely set woven fabric, made preferably of carded yarns, into which a fibrous web is needled. The fabric weave is a 1:1 warp rib which provides firm interlacing of yarns. The support fabric is fed, well tensioned, to a needle-felting machine where a fibrous web is laid on it by a horizontal laying system. The fibres in the web are arranged crosswise to the direction of the run of the felt. The support fabric carrying the fibrous web passes through the needling machine to be reinforced by needling. The fibres in the web are oriented horizontally and the needles penetrate the composite vertically. Thus the fibres caught by the needle barbs are needled vertically in the web structure and anchored in the support fabric. The usual needle density is 60 to 90 needle puncher per 1 sq. cm, and possibly more, depending on the desired stiffness and strength of the felt.

The finishing of needle felts, confined earlier to dimensional setting and singeing of the back and exceptionally slap of the top of the parameters felt, has been improved recently. The felts are now bonded with polymer dispersions, most often with acrylics. Such bonding agents must be applied very uniformly and this is a very difficult task, considering the dimensions of the felts whose width reaches up to 10 m. The impregnated felts are dried, while stretched out at about 120°C and set at a temperature between 150 and 160°C.

Structure of Industrial Nonwoven Fabrics in three dimensions:

Till now there is no theory that could be used to describe the structure of nonwoven fabrics in three dimensions. It is known that many of the physical and mechanical properties of nonwoven fabrics depend to a large extent on the method of arranging the fibres within the fabric.

The first trial made to study mechanically the structure of nonwoven fabrics in three dimensions is that made in 1984 by U.K. Since the properties of industrial fabrics in general, and especially the nonwoven fabrics, have various applications and serve many industries, therefore it is essential to study the structure of this new raw material, but it has not been studied till now.

Raw materials and technique used to measure the structure of nonwoven fabrics in three dimensions:

Three types of industrial fabrics manufactured locally from cotton waste have been selected for the study. Given in Table I, the physical and mechanical properties of these samples, also given the properties of the fibres. The technique described in Ref. 19/ has been used for the study of the previously mentioned specimens.
Five cubes of nonwoven fabrics has been prepared after immersion in PVC and heat setted at 115°C, and the apparatus in Ref./19/ was used to cut it in three directions.

Using the light microscope (X 100), the number of fibres in each face of the cube has been counted to obtain n(0) and from that it was possible to obtained the function of the distribution:

\[ \bar{J} = \frac{n(0)}{N} \]  

where N is the total number of fibres in each face of the cube. This has been repeated in the various directions from 0° to 190°, and by a step of 15°.

4. RESULTS

Sodomka's /18/ equations were used to measure the anisotropy(s) of the specimens tested in this work:

\[ S_y = \frac{n_{\text{max}} - n_{\text{min}}}{n_{\text{max}} + n_{\text{min}}} \]  
\[ S_4 = \frac{n_{\text{max}} - n_{\text{min}}}{n_{\text{max}}} \]  

It is known that the structure is compact and close to the structure of metals when \( S = 0 \), at which we reach to isotropic or arithotropic properties. Plotted the block diagram for specimen No. 1 this is for the function distribution \( \bar{J} \) and n(0) for six class-intervals for each of the five specimens.

The importance of studying the structure of NW fabric in three dimensions appears when testing it’s performance when used for the purposes of filtration or artificial leather or shoe linings. For this purpose these types of fabrics of NW fabrics made from waste (recycled fibres) have been designed and the best of it is tested in the time being an air filter in the production line in Taikha Mill (No. 1) for fertilizers. The results of this experiment including a comparison between woven fabrics (local and imported) and NW fabrics (virgin and recycled fibres) are given in Table 1 and Table 2.

Fibre distribution in three dimensions may be described using the local vector \( \theta_f \), where:

\[ \theta_f = (0_x, 0_y, 0_z) \]  

\( 0_x \) is partial fibre orientation in x axis as shown in Fig. 2_{11} - 2_{26} \n\( 0_y \) is partial fibre orientation in y axis as shown in Fig. 2_{12} - 2_{34} \n\( 0_z \) is partial fibre orientation in z axis as shown in Fig. 2_{13} - 2_{55} \n
In case of surface fibre orientation the range of values \( 0_x \), \( 0_y \), \( 0_z \) are:

\( 0 \leq 0_x \leq 1 \)  

\( 0 \leq 0_y \leq 1 \)  

\( 0 \leq 0_z \leq 1 \)
<table>
<thead>
<tr>
<th>Filter thickness (mm)</th>
<th>Woven Filter</th>
<th>Nonwoven Filter Bags</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imported 2.360</td>
<td>2.680</td>
<td>Virgin 5.720 POP 5.460</td>
</tr>
<tr>
<td>Local 0.119</td>
<td>0.145</td>
<td>0.020 POP 0.047</td>
</tr>
</tbody>
</table>

| Proportion of Pore (%) | 88.0 | 86.0 | 97.2 | 95.4 | 95.0 | 95.8 | 78.0 |

| Energy Absorbed Index (g.cm^-2.mm^-1) | 9.61 | 6.65 | 9.70 | 9.58 | 11.51 | 18.62 | 7.98 |

| Maximum Temp. °C | 90 | 90 | 250-260 | 163-175 | 80 | 80 | 80 |

<table>
<thead>
<tr>
<th>Air Permeability</th>
<th>Per i sq. m of filler/min</th>
<th>19.5</th>
<th>21</th>
<th>39</th>
<th>27.5</th>
<th>28</th>
<th>25</th>
<th>30</th>
</tr>
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| Filter Efficiency (%) | 22.1 | 2.2 | 37.3 | 34.8 |

| Total Cost of Filter Bag 1.0 m^2 (L.E.)* | 70 | 25 | 12 | 10 | 4 | 6 | 11 |

| Reduction of Cost (%) | 0 | 64.3 | 82.9 | 85.7 | 94.3 | 91.4 | 84.3 |

| Service Life (month) | 12 | 2 | 1 | 1 |

*The prices given here are those of 1980.
\[
0 \leq \theta_y \leq 1 \\
0 \leq \theta_z \leq 1
\] ....... (6) ....... (7)

"\( \theta \)" value means there are no orientation of fibres in this direction, while value (1) represents the total orientation in measured direction.

In ideal case we can find that:

\[
\theta_x = \theta_y = \theta_z = 0, \text{ means random fibre orientation} \quad ....... (8)
\]

\[
\theta_x = \theta_y = 1, \text{ means cross wise fibre orientation} \quad ....... (9)
\]

\[
\theta_y = \theta_z = 1, \text{ means horizontal fibre orientation} \quad ....... (10)
\]

\[
\theta_x = \theta_z = 1, \text{ means vertical fibre orientation} \quad ....... (11)
\]

\[
\theta_x = \theta_y = \theta_z = 1, \text{ means both cross and horizontal fibre orientation} \quad ....... (12)
\]

It was found that:

the local vector \((\theta_f)\) according to Sodomka is

\[
\theta_f = S_y = (0.75, 0.82, 0.79)
\] ....... (13)

and also

\[
\theta_f = S_6 = (0.85, 0.90, 0.89)
\] ....... (14)

It means that the orientation of fibres in the tested industrial non-woven fabric out of textile waste is a combination of cross and horizontal fibre orientation and is existing in large value.

Figure 3 shows the inclination angle \((\theta_f)\) of filtration channels resulted from needles punching and density of punching /19/.

Both inclination angles and diameter of channels are used in the calculation of the rate of flow of the liquid through the fabric.

From the figure it is evident that as the density of punching increases the angle of inclination \((\theta_f)\) decreases and the efficiency of filtration decreases also. The increase in punching density increases fibre entanglement, hence the channels decreases and consequently filtration efficiency decreases. This coincides with the statement of Iwaa and Smith /20/.

5- CONCLUSIONS AND RECOMMENDATIONS

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

- Filter felts for oil-air-fuel-dust collector, and
- Filter bags for cement works, lime works, metallurgical works, chemical works, flour mills, silos and in foodstuff industry, and contributes greatly to the reduction of air pollution by these works.
Air pollution, which has become a world problem, may be suppressed to a minimum when these new types of modern filters cloth are used. Moreover, no capital expenditure is needed and the efficiency of filters is increased.

The economical analysis which assumed that the weaving surface layer is constant before and after filtration proved that a reduction of filter bag cost, when using nonwoven out of waste, is in the range of 91.1 - 94.3% of the total initial woven filter bag cost.

ACKNOWLEDGEMENT

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Also thanks to General Manager of El-Asmar company for fertilizers Company in Talkha, and the general manager of the mills for their co-operation with the research team in the experiments of using nonwoven fabrics out of waste as filters in Talkha mill No.1 (Uree Salt) and also in air filters in acid mill-Talkha/2.

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/12/ Ref. /11/ p. 292.

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Fig. 1(a)

Effect of yarn density on lightness

FIG. 1(b)

Effect of yarn density on lustre

T. 132

T. 106  El-Hadidy, A.M.


/16/ Krčma, R.: Technologie II, VSSS, Liberec, CSSR. Trans. Technology II, Faculty of Textiles and Mechanical Engineering, Liberec, CZECHOSLOVAKIA.


/20/ Igwe, C.J.I. and Smith, P.A.: "Einfluß der Nadelstichtiefe auf die Stausammlerkapazität und das Filtrierzvermogen von Nadelfilzen", NÆLIA AND TEXTILE IN...
Fig. 3.1 Shows values of \( \theta_y \) versus angle of test (150 stitch/cm²).

Fig. 3.2 Shows values of \( \theta_y \) versus angle of test (600 stitch/cm²).