Performance of Air Filter fabrics Produced From Scrim Woven and Nonwoven fabrics

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Abstract: In this paper, 4 air filter needle-punched nonwoven fabrics have been produced. 3 filters are produced using needle-punching technique only and the fourth is produced from needle punching plus a woven scrim fabric. 3 filters are produced from new polyester fibers (100%) while one filter is produced from blended new and recycled fibers (40% new polyester and 60% recycled polyester fibers).Air filter fabric properties have been investigated such as tensile, tear resistance, compression properties, moisture transport and air permeability.

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Key words: Air filters, needle-punched, nonwoven filter fabrics, scrim woven filters, Eco-friendly textiles.

1. Introduction

1-1 Filtration:

Nonwoven filters for dry and wet filtration can be characterized as high-tech products. Due to strict environmental protection laws, the major share of these filters is obviously in the USA, Europe and some other highly industrialized countries. It is obvious that cleaning of polluted air or liquid costs money and only by valid and effective laws a contamination of our breathing air and drinking /bathing water can be avoided. Needle felting offers economic and technical superiority over conventional woven/knitted filters. The major use of needle-felted filters is in dry so-called aerosol filtration and liquid filtration. In addition to that there are so many other uses in day-to-day life like heating, ventilation, air-conditioning, vacuum cleaner, chicken exhaust hoods, car engines and car interiors, etc. [1, 2].

The applications of needle-punched fabrics are extensive and extend into many niche product areas including, for example, medical wound dressings, composite breather felts, capillary mattings for horticulture, fire barriers and ballistic-impact-resistant fabrics. Some of the main product applications are given below but this list is not exhaustive [3]

The types of filter materials, fiber types used and methods to manufacture them is so vast that the theme can be handled in numerous papers. In short, one can say that the filtering properties of a filter medium depend equally on fiber properties and on the bonding process. A combination of these two factors enables to achieve a defined product profile. One of the special features of filter felts is their 3-D construction [1, 2]

Anandjiwala and Boguslavsky [4] have carried out an exploratory study on the production and measurement of the air permeability, mechanical properties, pore size distribution and filtration efficiency of different nonwoven fabrics produced by systematically changing the machine variables to influence the physical parameters of the fabrics. Only flax fiber waste was utilized for this trial.

Of the several different groups of materials used for filter media, textile fabrics constitute the most important and widely accepted. Growing environmental considerations, such as the demand for cleaner air, play a major role in the expansion of this market. While woven fabrics from mono and multi-filaments have dominated both dry and wet filtration markets for a considerable time, needle-punched nonwoven fabrics have also established a market share and have had considerable impact, particularly in dry filtration applications, due to their ease of production, lower cost and disposability. Natural fiber based products offer further advantages due to their renewable nature, excellent biodegradability and the ease of disposal without adversely affecting the environment. The porosity of textile structures is an attribute which is exploited in applications, such as filtration. Nonwovens have played a significant role in dust and liquid filtration due to their loftiness, porous structure and lower cost of manufacturing. Filtration may be broadly divided into two major categories:

1. Dry filtration, for air, gas and particle.
2. Wet filtration, for liquids.

Needle-punched nonwovens represent the largest segment of filtration materials used as dust filters [4].

The field of filtration is tremendously diversified. There are more than 1,000 different applications characterized by different profiles and conditions and consequently requiring different filter materials. Also in addition to industrial fabrics paper, soft foam, sand, sintered materials and ceramics are being used just to name a few.

One of the most important segments of filter materials are nonwovens. Due to their variability and their economical manufacture they can be easily adapted to nearly all kinds of filtration jobs. This explains that already in 1994 such products had a share of the world filtration market of 89% (836 million m2).

To manufacture filter media economically it is important to consider a number of properties which are present in the carrier or scrim fabric and also related to the type of particles being separated [5].

Factors related to the carrier or scrim material are among others:

– Temperature
– Humidity
– Degree of turbulence
– Mass flow
– Chemical composition

Factors related to the particles are among others:

– Their size
– Particle composition
– Type of material
– Particle concentration

Based on these demands a suitable filter material is selected. Usually this often includes a compromise due to the many different requirements which may include high pressure drop or sometimes relatively short running time. To tailor the filter medium to these requirements a wide range of designs of textile elements are available. One of the first aspects is to choose the right fibre material. The kind of fibre has to do with the thermal, physical, chemical and biological conditions. Fibre fineness as well as cross section are important properties which influence the performance of the material. The type of fibre structure and also effective filter surface may influence the efficiency. To manufacture such filter materials a wide range of fibres showing different properties are available. Selecting filter materials for the different applications depends also on the type of equipment being used, let alone economical aspects. In the early years natural fibres like wood, cotton, cellulose and asbestos were used in filtration. They are virtually all substituted by manmade and glass fibers.

In the family of synthetic fibers we see more and more fine fibers as well as bi-component fibers. Fibers with different cross sections to enlarge the fiber surface enhancing the performance are increasingly being used. Very important is the worldwide trend to use finer and even micro fibers with a variety of cross sections. Fibers which show a profiled cross section possess a wider specific surface which makes the separation of very small particles more effective. Factors influencing these characteristics are the cross section, shape and micro fibrillation of such materials [5]

Both finest and micro fibers are, because of their filter surface, preferably arranged and used to enlarge the effective filter surface. With depth filter media they should be found at the flow-out surface in order to refine the pile labyrinth separating finest dust particles. Static charge is sometimes found a problem in filtration which could create danger when parks ignite a dust cloud which may lead to an explosion. To neutralize and sometimes 'ground' such materials metallic fibres and carbon fibres or fibres with metallic coating are mixed with such synthetic fibres and being used [5].

In the case of a hazardous gas or to attack odours or taste carrying substances activated carbon fibres are increasingly being used in so-called combination filter media. Due to their filtering properties mineral fibres are sometimes of great importance for such filter media. In particular they are applied in hot gas applications. For special uses high performance fibres such as polyamide, aramide, polyphenylen-sulfide and melamine resin are available. After selecting the fibre material the principle of web formation and the mode of bonding is determined which will influence the consistency, thickness, permeability, tenacity and strength of the nonwoven. One has to take into consideration the economic aspects as well in manufacturing such product that cannot be regenerated and have to be disposed of after use. On the other hand filtration takes place in three dimensional due to the fibre labyrinth if the material is highly porous [5].

1-2 Filter media

Fabric density and permeability are properties relevant to the filtration of gases and liquids, and depth filters are particularly suited to needle punched fabrics because of their substantial thickness. Woven scrim reinforcement is needed in industrial bag house applications, whilst staple glass, silica or aramide fibres are utilized in high-temperature conditions. For general filtration applications, PET, PA and PP are found, but for high-temperature or corrosive environments other high-performance organic and inorganic fibres are needle punched to make chemically or thermally stable filter fabrics including PTFE alone or in blends, polyimide, basalt and stainless steel amongst others [3].

Electret filters are also needle punched based on drylaid blends of staple Fibers selected for their relative position in the triboelectric series. The surface of needlepunched fabrics may be coated, singed or calendered to adjust the surface structure and therefore both the cleaning and filtration efficiencies of the media. The fabric density may also be graduated through the fabric cross-section by adjusting needle penetration and needlepunching density, which influences filtration efficiency in use. Both roll products and tubular needle punched fabrics are used as filtration media [3].

Mechanisms of particle capture

Most theories concerning nonwoven filter medium are based on a depth filtration effect. This is more complicated than simple screening or sieving where the particle is simply bigger than the hole in the medium and cannot get through. Depth filtration and separation theories are more concerned with other mechanisms for particle capture. These are:

1. **Inertial impaction** occurs when the particle inertia is so high that it has sufficient momentum to break away from air streamlines and impact the fiber.
2. **Interception** occurs when a particle does not have sufficient inertia to break away from the streamline, however comes close enough to the fiber so that natural forces will attach the particle to the fiber.
3. **Diffusion** is based on the Brownian motion of very small particles. This random and probabilistic motion will cause a particle to vary from the streamline and possibly engage a fiber.
4. **Electrostatic attraction** is based on an electric or electrostatic charge on the particle and/or fiber that will force the particle to be diverted from the streamline and attracted to the fiber.

The dominant capture mechanism is related to particle size. Very small particles exert Brownian motion and are subject to capture by diffusion. Large particles have more momentum. They are more likely to break loose from the fluid streamlines and be captured in accordance with the inertia mechanism[6].

1-3 Filtration Theory - Flow dynamics

Nonwoven filter media are porous media and the theories concerning flow through porous media apply. There are two major avenues of theory concerning nonwoven filter media: channel theory and cell model theory. A variation of cell model theory is drag model theory. The original channel theory was based on filtration through non fibrous packed beds such as sand. Often referred to as the capillary tube model, it assumes that the media is a bundle of cylindrical tubes passing from one surface of the media to the other surface, and not necessarily perpendicular to the surfaces. Channel theory can be applied to nonwoven filter media used in liquid filtration, particularly if the medium is a tight structure with a high packing density.

Much of cell model and drag model theories were developed for fibrous air filter media. They are based on flow past a single fiber and the organization of fibers that compose the media. They are best applied to open structures of low packing density.

For nonwoven media, the fibers are represented as cylinders. Cell model theory assumes an array of circular cylinders, each cylinder contained in a cell of fluid surrounded by cylindrical envelopes. Each cylinder with its fluid and envelope is treated as a cell. Drag model theory, the variation of cell model theory, analyzes the drag on each envelope [6].

1-4 Functional requirements properties

The different filter designs are of great importance for the selection of suitable nonwovens. Process related properties and textile technological requirements often lead to so-called combination nonwovens. There may be process or design specific requirements which have to be met in the use of nonwovens in filtration.

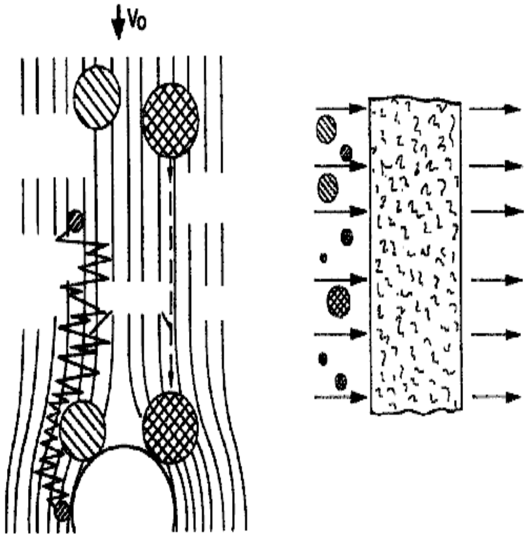

Figure 1 Sketch of physical separation mechanism [5]

Due to the wide range of applications and their attributable design of nonwovens, the following are differences between surface and depth filtration taking into consideration the different types of separation and their process and the design specific requirements [5].

1-5 Deep filtration - Surface filtration

The use of nonwovens in filter technology as well as the range of technological problems to be solved is so wide that we would only like to concentrate on a few examples of applications, designs and types of nonwovens.

In dry filtration as in industrial textiles in general the functionality of nonwovens depends on how the single fibres are designed and arranged. Desirable is an isotropic position of the fibres or filaments in the web. The essential physical separation mechanisms are inertia separation, interception, diffusion and electrostatic forces (Figure 1). They are strongly influenced by velocity, the fibre and particle diameters, the density and thickness of the filter medium.

1-5-1 Surface filters

Surface filters are mainly used in the context of industrial exhaust gas with a high mass concentration (larger than 5–1 mg/m3) minimum (dust separation equipment).

1-5-1-1 Filter bags

Worldwide needle punched nonwovens predominantly are being used for filter bags. They can be used in a wide variety of designs, they are very flexible and can be combined using all kinds of different textiles including nonwovens.

To improve the integrity of the material physical requirements during cleaning most needled felts, notably in Europe, use a scrim. In the United States approximately 50–75% of the filter materials from needled felts are used without scrim. The incorporation of a scrim in needle punched nonwovens increases its stability. Some people feel that a scrim also contributes to the better efficiency of certain dusts resulting in better process technology.

In order to achieve the highest possible efficiency it is preferable to use fine fibres, preferably microfibers, finer than 1 dtex or, respectively, apply a special surface to the needle punched product. Certain characteristics are determined by the applications in which filter bags are being used [5].

1-5-1-2 Cartridge filters

In order to use filter cartridge the filter medium may be pleated or folded sometimes into a star. This allows for a larger filter area in a given dimension resulting in a more compact filter element.

Consequently the filter media need to be pleatable. Important quality criteria are high quality pleats, high pleat stability and sufficient mechanical and thermal resistance, preferably thin, stiff nonwovens of mass per unit areas arranging from 80–300 g/m2 are often used as filter materials. Currently the use of paper-like wet laid nonwovens which sometimes are thermally bonded and in some cases from polyester or polypropylene and can also be made from impregnated cellulose papers. They provide high stability at very low thickness (from 0.1 to 2.0 mm) [5].

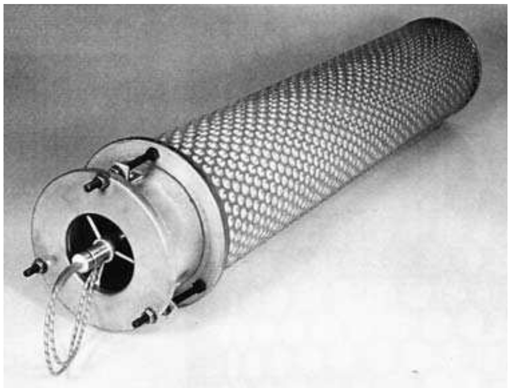

Figure 2 Combined filter cartridge, general view [5]

1-5-2 Depth filters

Depth filters are used in the context of low mass concentration from larger than 1–5 mg/m3 which means mainly in the field of general air filtration. In the field of such application filter media use is completely different from dust filtration. Above all the major reason is substantially lower dust concentration and also particle size present. The air-flow velocity, however, is much higher, filter media show a much more open structure and surface and elements are often in V-shape and also pleated. This results in a considerably higher flow velocity within the filter material. This filter type is not being cleaned due to the dust fineness and low mass of dust. The latter may require special solutions often addressing surface filtration and depth filtration depending on dust concentration and particle size. In process air applications nearly all different filter media are being used. A progressive structure of the filter media leads to longer life cycle often requiring several layers of fibres in varying fineness across the cross section (Figure 3) [5].

Thus, blocking effects may largely be avoided. An important aspect is the rise in pressure drop, and to keep the pressure drop as low as possible at the same time offering high filter efficiency to separate the aerosol. Such filter materials are often represented by filter mats, filter cells, pocket type filters for coarse and also fine dust [5].

Current nonwoven composites could be for example:

- One of several layers of fibre nonwoven plus a layer of spunbonded
- Several layers of meltblown of varying fibre fineness with a carrier material mostly heavier than the filter layer from filament-spunbonded nonwoven
- Thermally bonded nonwovens plus meltblown layer
- Mechanically manufactured stitch-bonded nonwoven Kunit with compacted loop surface [5]

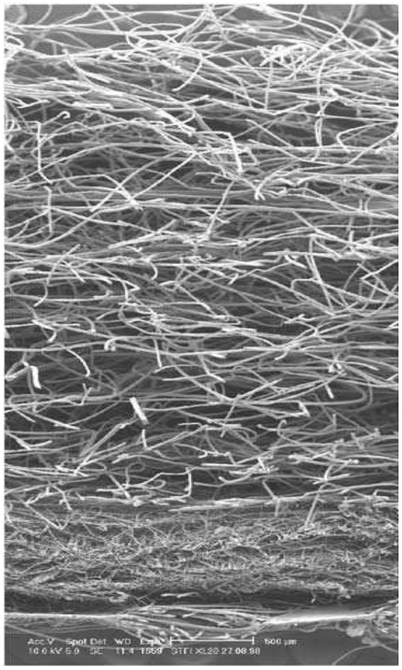

Figure 3 Nonwoven for deep filtration) with progressive structure of cross-section [5]

2- Experimental Work:

Production of fabrics & Fabric structures:

In this research, 3 nonwoven filter fabrics have been produced from virgin and recycled fibers (fabrics 20, 21 and 22). Fabrics 20 and 22 are produced from 100% polyester fibers but fabric 22 has a compressed structure. On the other hand, fabric 21 is produced from blended fibers, new polyester fibers (40%) and recycled polyester fibers (60 %). In addition, one nonwoven with a scrim of woven filter fabric is also produced (25) from 100% polyester fibers. Table 1 shows the specifications of the fabrics produced for air filters.

3- Testing:

In this paper, the tests included the strength, tear resistance, air permeability and moisture transport properties of these fabrics in have been conducted. The tests have been carried out according to standard testing methods [7- 12].

Table 1: Specifications of fabrics used

Sample No.	Fiber composition	Fiber type	Weight	Type of fabric	Fabric Density
20	Polyester fibers	Virgin fibers	331 g/m^2	Needle-punched nonwoven	0.046
21	40%, 60%, polyester virgin fibers and polyester waste fibers	Virgin and waste fibers	416 g/m^2	Needle-punched nonwoven	0.065
22	100% polyester fibers	Virgin fibers	191.6 g/m^2	Needle-punched nonwoven (compressed)	0.089
25	100 % polyester fibers	Virgin Fibers	401 g/m^2	Nonwoven with woven scrim fabric	0.24

4- Results and Discussion:

In this paper, the results obtained from testing some produced filter fabrics are presented. The results are obtained for the strength, tear resistance, air permeability and moisture transport properties of these fabrics in relation to their fabric structure and fiber composition.

4-1 Compression properties:

In figure 4, the compression results for fabrics 20, 21, 22 and 25 are presented. It is important here to mention that fabrics 20, 21 and 22 are made of nonwoven fabrics, whereas fabric 25 is made of nonwoven with scrim woven filter fabric.

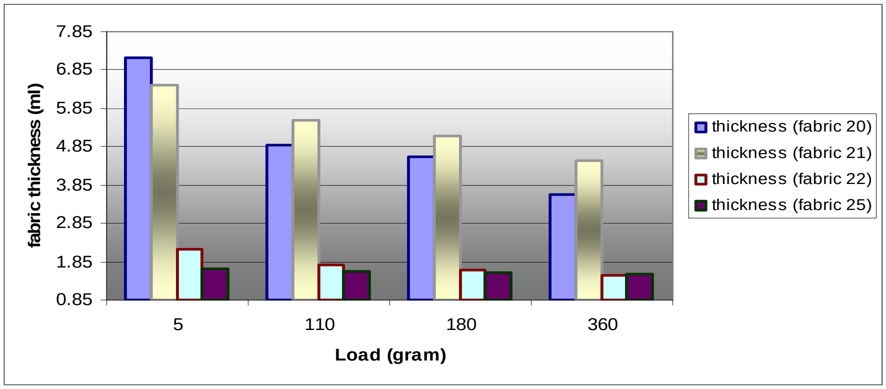

Figure 4: Loads Vs Thickness of fabrics

The fabrics are applied to different loads, 5, 110, 180 and 360 grams respectively. It is recognized that the decrease in fabric thickness according to these different loads is various. For example, fabric 25, the thickness is decrease by 4.79% after increasing the load from 5 to 110 gram. Then the thickness decreased by 1.88% after increasing the load from 110 to180 grams. Followed by a decrease of 2.56% after increasing the load from 180 up to 360 grams.

For fabric 20, the thickness is decrease by 31.6% after increasing the load from 5 to 110 gram. Then the thickness decreased by 4.31% after increasing the load from 110 to180 grams. Followed by a decrease of 21.73% after increasing the load from 180 up to 360 grams.

For fabric 21, the thickness is decrease by 14.13% after increasing the load from 5 to 110 gram. Then the thickness decreased by 7.23% after increasing the load from 110 to180 grams. Followed by a decrease of 12.67% after increasing the load from 180 up to 360 grams.

For fabric 22, the thickness is decrease by 18.05% after increasing the load from 5 to 110 gram. Then the thickness decreased by 7.34% after increasing the load from 110 to180 grams. Followed by a decrease of 9.14% after increasing the load from 180 up to 360 grams.

After a quick comparison between the nonwoven fabrics (20, 21 and 22) and the industrial bag filter fabric (25), it is easy to recognize that the decrease percentages in fabric thickness for the nonwoven fabrics are generally much higher than that of the nonwoven with scrim woven filter fabric.

This can be explained as the scrim woven filter fabrics are structured of yarns which provide more compact structures than that of nonwoven fabrics which structured directly from fibers. Most of nonwoven fabrics are relatively loose compared with woven fabrics, which allow more compression. These results can be observed more obviously in figure 5.

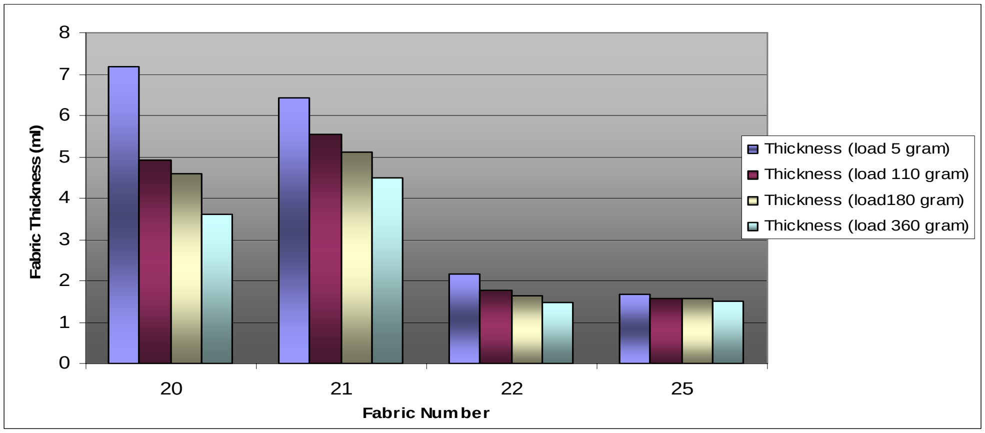

Figure 5: Fabric number Vs fabric thickness under different loads

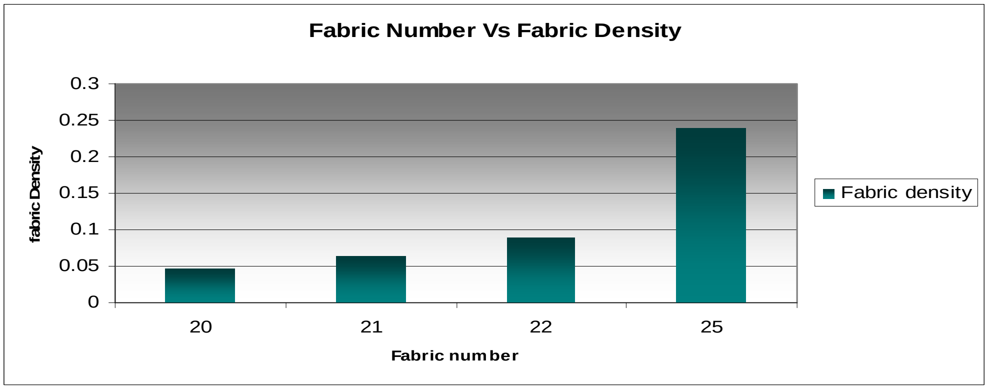

Figure 6: Fabric numbers Vs fabric density

4-2 Density Properties

Figure 6 represents the values of densities for all the fabrics under testing.

In figure 6, it can be recognized that the nonwoven with scrim woven filter fabric (25) has the highest fabric density compared with the all the other nonwoven fabrics (20, 21 and 22). This can be explained as the woven fabric 25 has a more compact structure than the nonwoven fabrics which results in higher density. The nonwoven fabric 22, followed the industrial bag filter fabric 25 in density value, this can be regarded to the compression of fibers in its fabric thickness because of fabric filter 22 has a compressed structure whereas the other two nonwoven filter fabrics (20 and 21) are not. It is important here to mention that the density of these fabrics may affect their efficiency of filtration.

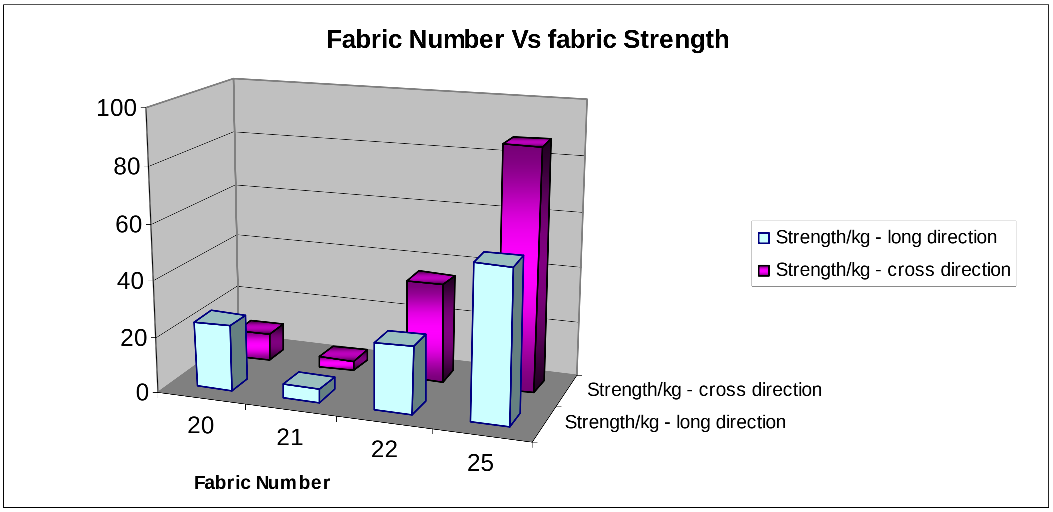

Figure 7: Fabric number Vs fabric strength in both long and cross directions

4-3 Strength Properties

In figure 7, the strength values of the fabric filters strength are represented. In this figure, it can be recognized that strength values for fabric filter 25 (nonwoven with scrim woven filter fabric) is the highest compared with fabric filters 20, 21 and 22 (nonwoven fabrics). This can be as a reason of the compact structure of the woven fabrics compared with the nonwovens. Also, the strength values obtained can be regarded as a result of type of fibers used. For example, the highest strength value obtained was of the nonwoven with scrim woven filter fabric 25, which is made of 100% polyester fibers. Followed by the nonwoven filter fabric 22 and then fabric filter 20, which are also made of virgin 100% polyester fibers. And at the end, the nonwoven filter fabric 21 which is made of blended virgin and recycled fibers (Table 1).

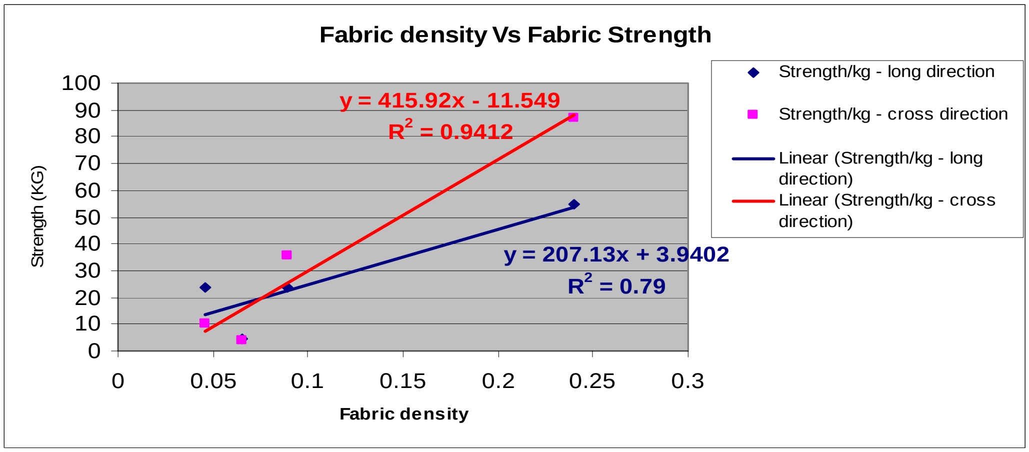

Figure 8: fabric density Vs fabric strength in kg

Figure 8 represents the values of the filter fabrics strength against their densities. In figure 8, it can be seen that there is a relationship between the density of the filter fabrics and their strength. The higher the density, the higher the filter strength for all the filters whether they are made of nonwoven with scrim woven filter or nonwoven fabrics only. Regression linear lines are obtained and their R-squares. These results can be explained as when the density increase, more compact structures can be achieved. And accordingly, more strengthened filter fabrics can be obtained.

4-4 Tear resistance properties:

Figure 9 represents the values of tear resistances of the 4 fabric filters produced. Similar results are obtained to those results of fabric strength in figure 7. The nonwoven with scrim woven filter fabric has the highest tear resistance value, compared with the other nonwoven filter fabrics, regarding to its woven structure, fiber composition and fabric density. Same explanation can be applied as in figure 7.

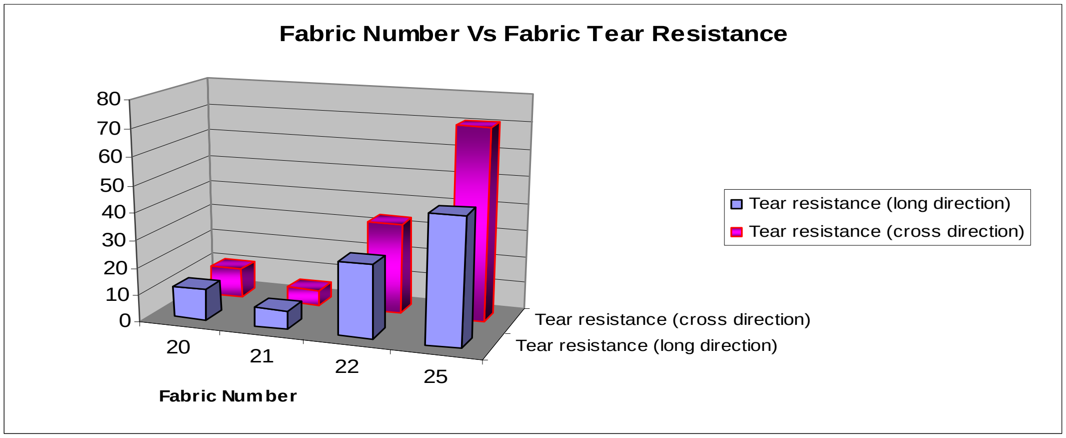

Figure 9: fabric Number Vs Tear resistance

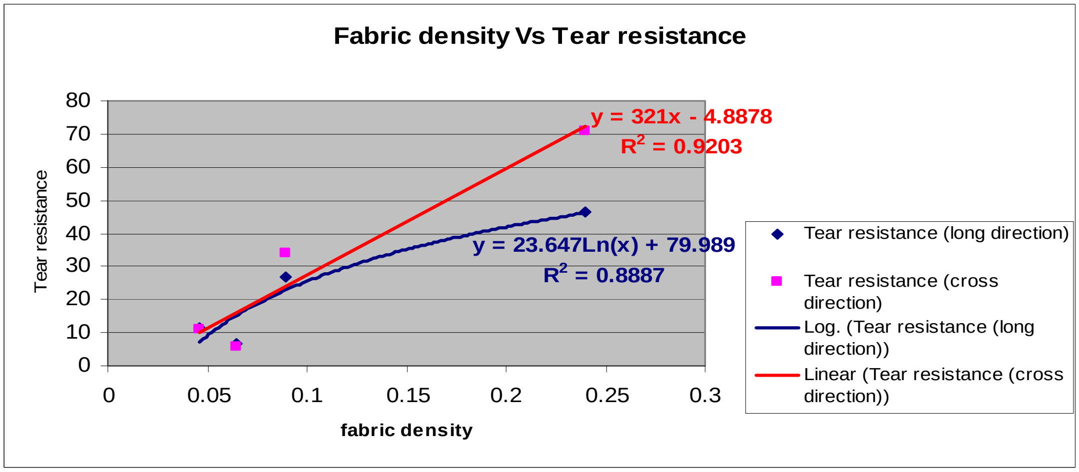

Figure 10: fabric density Vs fabric tear resistance

Figure 10 represents the values of the filter fabrics tear resistance against their densities. In figure 10, it can be seen that there is a relationship between the density of the filter fabrics and their tear resistance. The higher the density, the higher the filters tear resistance for all the filters whether they are made of nonwoven with scrim woven or nonwoven fabrics only. Regression linear lines are obtained and their R-squares. The same explanation can be applied as in figure 8.

4-5 Moisture Transport:

The idea of testing the moisture transport properties of the air filter fabrics here; although they are not used as liquid filters, is that these filters are used inside the company chimneys and sometimes the different vapors which coming through these chimneys are exposed to some changes from vapor state to liquid state. It is important here to check the ability of these filters to transport these accumulated vapors within their structures and take them to the upper point of these chimneys where they will evaporate into the air.

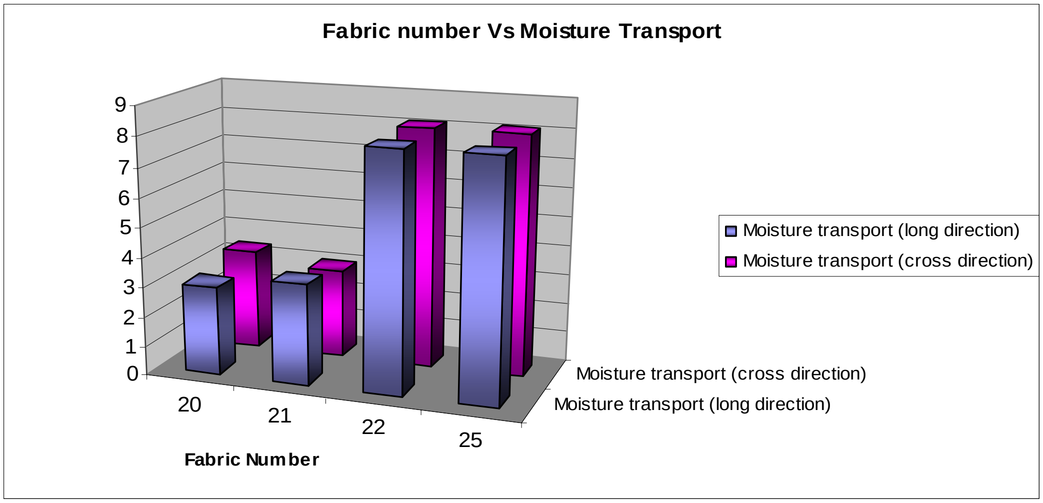

Figure 11: Fabric Number Vs Moisture Transport

Figure 11 represents the moisture transport of all the fabrics under examination. In figure 11, it can be noticed that the moisture transport of the industrial bag filter fabric 25 is very close to that of the nonwoven filter fabric 22. Although it is expected that the nonwoven with scrim woven filter fabric will have higher moisture transport compared with nonwoven fabric according to its structure that are constructed from yarns which work as fine tubes, and hence improve the capillary action of these fabrics.

And this can be explained as a result of the nonwoven filter fabric No. 22 is compressed, where it may affect the moisture transport, as the compressibility of the filter fabric results in increasing the density of this fabric (Figure 6), which will bring the fibres closer to each other and results in constituting what is similar to close pipes and accordingly increase the capillary action of that nonwoven filter fabric (22). And as a result, the moisture transport will increase compared with the other fluffy nonwoven fabrics.

It is important here to notice that the high density of the filter fabric 22 compared with the other two filter nonwoven fabrics (20 and 21) in figure 6.

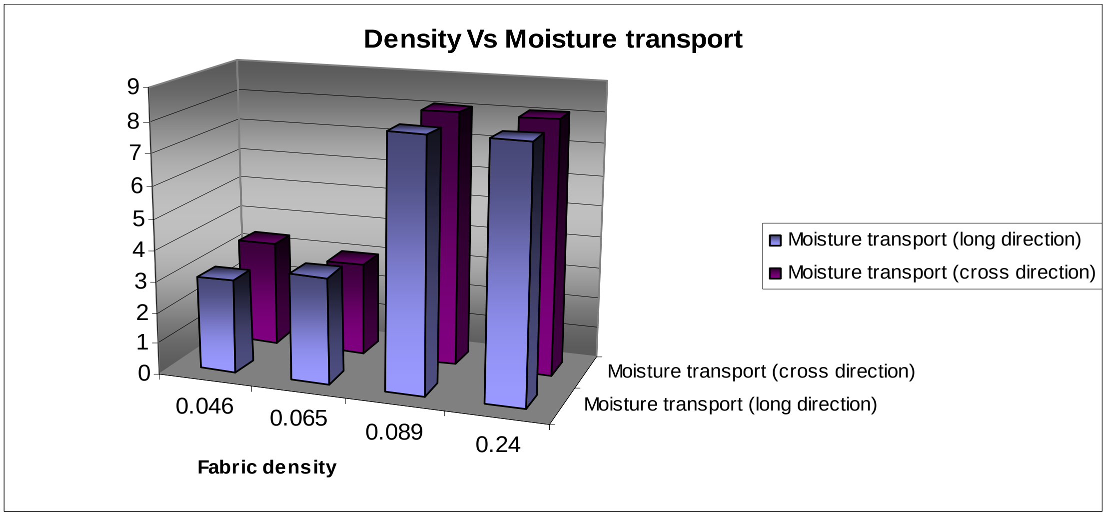

Figure 12: Fabric Density Vs Moisture Transport

Figure 12 represents the moisture transport against fabric densities. It can be noticed that the more the fabric density are, the more moisture transport can be obtained. It can be noticed that both the nonwoven with scrim woven filter fabric (25) and the filter nonwoven fabric 22 have close fabric density as a result of their structures as mentioned earlier. And that can be the direct reason for their higher moisture transport properties. Followed by the filter nonwoven fabrics 20 and 21 which have more fluffy structures and lower densities.

4-6 Air permeability properties:

Figure 13 represents the values of air permeability obtained for all the filter fabrics. It can be noticed that the industrial bag filter fabric 25 has the lowest air permeability according to its compact structure (nonwoven with scrim woven filter fabric 25) compared with all the other nonwoven filter fabrics. Thus, we can predict that the efficiency of the nonwoven fabrics as filter fabrics is higher than the other fabrics because of their ability to pass air through them better than the fabrics that include woven fabrics in their structures (25).

On the other hand, the filter nonwoven fabric 20 has the highest air permeability according to its fluffy structure, its relatively lower weight per unit area compared with fabric 21.

The air permeability of filter nonwoven fabric 22 is higher than filter nonwoven fabric 21 according to its relatively lower weight per unit area and thickness. Whereas the filter nonwoven fabric 21 has the highest weight per unit area and thickness and also made of virgin and recycled fibers which affects the harmony of its structure and hence its ability of transport of air.

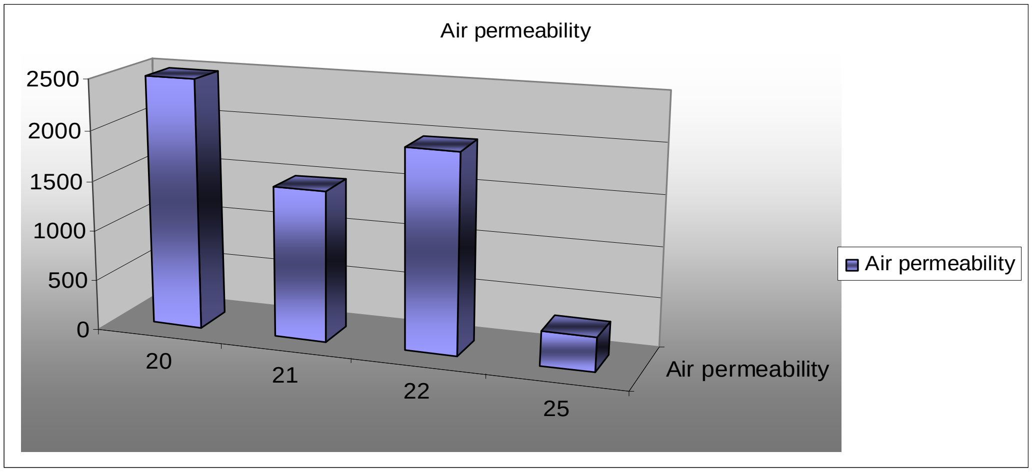

Figure 13: Fabric Number Vs Air Permeability

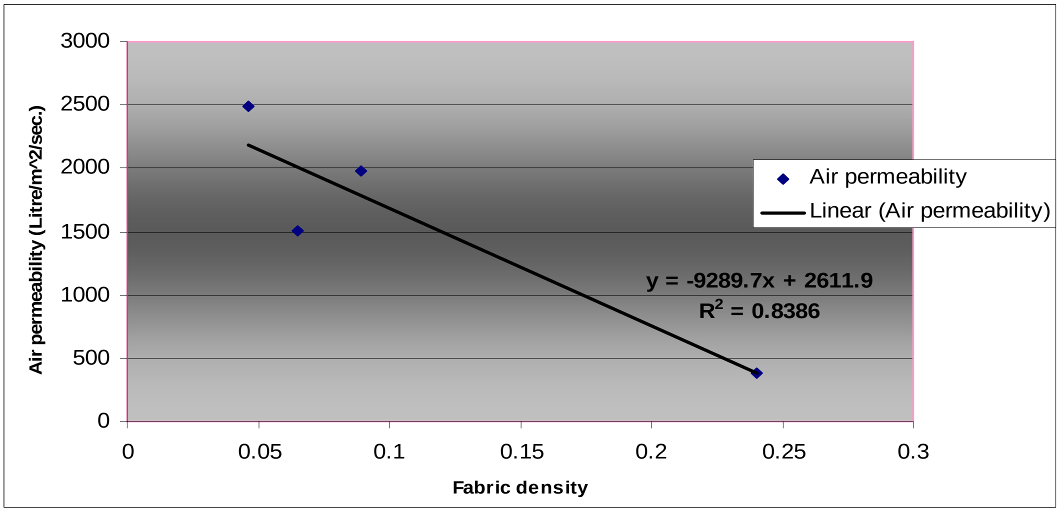

Figure 14: Fabric Density Vs Air permeability

Figure 14 represents the air permeability values against densities of these filter fabrics. The more the fabric density, the less the air permeability of the fabrics whether the fabrics are woven or nonwoven structures. This can be explained the more bonded fibers or yarns in the fabric structure, the more they obstruct the air to pass through them. Regression linear lines are obtained and their R-squares.

5- Conclusions:

1- Nonwoven with scrim woven filter fabrics (industrial bags) have different performance compared with the filters that are produced from nonwoven fabrics only in terms of air permeability, moisture transport, compression properties, strength and tear resistance which affect their efficiency as filters.

2- Regarding the compression properties of the filter fabrics, it can be recognized that the decrease percentages in filter fabric thickness for the nonwoven filter fabrics are generally much higher than that of the decrease percentage for the industrial bags that comprise woven fabrics in their structures. This can be explained as the woven fabrics are structured of yarns which provide more compact structures than that of nonwoven fabrics which are structured directly from fibers that allow more compression.

3- Generally, the densities of nonwoven with scrim woven filter fabrics are higher than that of the nonwoven fabrics for the same weight per unit area. This can be explained as the woven fabrics have more compact structures than the nonwoven fabrics which results in higher density.

4- Generally, the strength and tear resistance of the nonwoven with scrim woven filter fabrics are higher than that of the nonwoven filter fabrics. Also, the higher the filter density of fabrics, the higher the filter strength and tear resistance, and that can be applied for all the filters whether they are made of woven or nonwoven fabrics.

5- Nonwoven with scrim woven filter fabrics and compressed nonwoven fabrics are generally have higher moisture transport compared with the nonwoven fluffy filter structure fabrics. Also, It can be noticed that the more the fabric density, the more moisture transport can be obtained for both woven and nonwoven filter fabrics.

6- The nonwoven with scrim woven filter fabric has the lowest air permeability according to its compact structure (yarns) compared with all the other nonwoven filter fabrics (fibers).Also, it has been found that the more the fabric density, the less the air permeability of the fabrics whether the fabrics are woven or nonwoven structures. This can be explained as the more bonded fibers or yarns in the fabric structure, the more they obstruct the air to pass through them.

7- It is concluded that the nonwoven with scrim woven filter fabrics have higher ability to moisture transport than nonwoven fabrics, and on the other hand, the nonwoven fabrics have higher ability to pass air through the fibers than the filter that are produced from nonwoven with scrim woven fabrics.

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