FIBERS FOR NONWOVENS

Wo Kong Kwok
E. I. DuPont de Nemours and Co.
Wilmington, DE

Introduction

The selection of fibers used for nonwovens is based on the final product requirement, and performance expectation. For example, the fibers used for high strength, flame retarded products are different from those used for insulation. Basically, the intrinsic fiber properties such as strength, size, flammability, surface friction, cross-section, etc. determine, or have major influence on, the properties of the final end products. There are many natural, regenerated and synthetic fibers that can meet most of the performance requirements. One should also consider the process elements such as opening, carding, cross-lapping, and needling before deciding what fibers to use.

This talk will discuss the characteristics and properties needed for nonwovens, specifically for needlepunching, fiber preparation, description of fiber used in various end uses. Most of the discussions will concentrate on synthetic fibers.

Characteristics And Properties Needed For Nonwovens

Before we discuss this subject, one should define the terms that are often used to describe fibers:

Denier:	The number of grams in weight per 9000 meter length of fiber
Crimp:	The fiber's configuration consists of peaks and valleys due to mechanical or chemical means vs. straight or linear fiber
Crimp per inch:	The number of crimps (peaks and valleys) per inch of fiber at extended (uncrimped) length
Crimp-take-up:	The difference in length between crimped and extended conditions, expressed as a percentage of the extended length
Tenacity:	The tensile strength of fiber expressed in gram per denier
Elongation:	The difference in length between fully extended to break and extended to straight fiber, expressed as a percentage of extended length

To make an acceptable web or batting for needlepunching, one must be able to process the fibers successfully through the opening, carding and cross-lapping steps. Adequate crimp and crimp-take-up are required to provide good openability, cohesion to maintain width control and production speed, and final product thickness or loft. Too high crimp level and tight crimp can make separation of fibers from the bundle very difficult during the opening step. The resulting feed batt to the card can have various density and, therefore, form non-uniformity web with poor appearance and variable weight. But, too low crimp level can cause web breaking as the result of low cohesion which may be corrected, although it is not desirable, by slowing down the production rate. The key is to fine tune the crimp and crimp-take-up to balance the properties meeting all requirements.

Because the fibers have to go through a series of mechanical workings and needling, the tenacity of the fiber should be able to withstand stress without breaking. Otherwise, flies and powder formation (from broken filament) will result. In general, the tenacity greater than 1.5 g/d is minimum. At tenacity, about 1 g/d will definitively create a housekeeping problem and unacceptable products with low tensile strength.

Other important properties of the fiber are closely related to the finish applied on the surfaces of the fibers. The finish should provide antistatic chemicals to eliminate or conduct static that is generated during processing. Excessive static can create conditions in which fibers are sticking to equipment: opener, apron, doffer, etc. to make production throughput reduction necessary, or even completely shutting down the line. Although process room conditions and the weather (temperature and humidity) can also influence the process performance, finish plays a major role in controlling the static. The second property that finish can control to some extent is the surface friction of the fibers. The lubricant component provides low fiber-to-metal friction for easy release of fibers from processing equipment without forming deposits on card wires or on needles. These deposits can affect the quality of the product and the productivity of the line. In more severe cases, the fiber deposits on needles can punch serious holes on products and breaking needles resulting in contaminated products.

The selection of the denier (size) depends on the cover, surface characteristics, and thickness (loft) of the final product desired. Fine denier fibers and or modified cross-section (non-round) give the appearance of better cover, softness and more uniformity at a given weight. However, not all equipment can handle very fine denier fiber with no defects (neps) or non-uniformity. For needlepunching, the denier range is about 1.5 to 15, as majority of fibers used. In fact, the 3 to 7 denier fibers are commonly used in the industry.

Fiber length can control the processability and the product strength. As usual, the longer the cut length beyond 3 inches, the more difficult the fiber is to be opened, or separated from each other. However, the longer length, normally provides more tensile strength of the final products because more entanglement points are formed per

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fiber. But if process problems create neps or unopened fibers, the effective fiber length is shortened and, therefore, does not utilize the potential of the fiber.

Fibers Used In Needlepunch

A. Fiber Cross-Sections

There are many fibers that are suitable for needlepunch. Naturally, re-generated and synthetic fibers are used commercially. Let's discuss the different elements that are used as selection criteria.

Solid round:	Most commonly used, especially synthetic fibers
Round hollow:	Single hole, multiple holes: 3, 4, 7, etc., for lower density and resiliency
Odd cross-section:	Trilobal, scalloped oval, dog bone, ribbon, irregular, etc. for more surface area
Bicomponent:	--Sheath/core:as binder fiber --Side-by-side:to generate spiral crimp

B. Polymer Composition

Homopolymer:	Polyester, nylon, polyolefin, acrylic, aramid, etc.
Copolymer:	Reduce the melting point as binder fiber, or enhance some properties
Bicomponent:	
Sheath/core:	Sheath component has lower melting or softening point than the core component for thermal bonding
Side-by-side:	One side has different molecular weight, or different chemical composition than the other side. Can form spiral crimp or helical crimp vs. mechanical crimp with other fibers

C. Fibers Used in Needlepunch and Reasons

Polyester

It is a very versatile fiber with good strength, 3-6 g/d, chemical resistance, bulk retention, moisture resistance, and heat resistance, m.p. 249-252° C., boil off shrinkage 1%. This fiber is suitable for cover stock, personal hygiene products, thermal and acoustic insulation, filtration, and many other applications.

Copolyester

This fiber can be used as binder fiber to provide dimensionalstability and moldability of the needlepunched products.

Polyolefin

This fiber has lower melting point than polyester, can be used as load bearing fiber or as binder fiber. End use is for cover stock, geotextile, filtration, and other applications.

Nylon

Because of its strength and abrasion resistance, it can provide high tear strength, good bonding and fold endurance to nonwoven used in everything from interlining to scouring pads.

Kevlar® Aramid

Aramid is organic fibers within the family of aromatic polyamides. Kevlar® is a lightweight fiber with a unique combination of high strength, high modulus, toughness and thermal stability. To put this into perspective, Kevlar® filament yarn is five times as strong as steel on an equal weight basis. Its primary area of use centers around replacement for asbestos, glass and steel based on its high strength, high temperature resistance and excellent frictional properties. Current end uses include protective apparel, high temperature industrial protective fabrics and friction products such as brake pads.

Nomex® Aramid

This fiber retains strength, flexibility, and resistance to abrasion and stretch at continuous operation temperatures up to 260 C. Fabrics of Nomex® exhibit high tensile strength, tear strength, and abrasion resistance as well as excellent flame resistance and good retention of tensile properties at elevated temperatures. Typical end uses are hot gas filtration, protective apparel and miscellaneous uses requiring heat resistant fibers such as paper maker felts, ironing and pressing machine covers, etc.

Teflon® Fluorocarbon Fiber

This fiber provides low friction for excellent release properties, abrasion resistance, high temperature stability and chemically inert. Major applications are air filtration, pump and valve packing, bearing, chlor-alkali cells.

Acrylic Fiber

Acrylic lends itself to applications in the nonwoven field because of its excellent moisture transport properties, resistance to acids, and resistance to alkalis. Unlike cellulosics, acrylic does not collapse when wet, thus maintaining its bulk and giving increased capacity to an absorbent structure. Typical applications are absorbent pad and wiper.

Cotton and Rayon

These fibers have high moisture regain and high absorbency. These are excellent fibers for absorbent pads which require to keep the moisture and liquid in the structure. The moisture transport properties can diminish as the fibers are swelled and blocking some of the passageway between fibers. In many cases, blending in other fibers can maintain the moisture transport properties if required.

Fiber Preparation

Most of the fibers are packed in a bale at very high density for storage and shipping. Therefore, fibers are matted down into bundles for a period of time. In order to make a uniform feed batt to the card or garnet, breaking and opening these bundles gently is required. The adequacy of the preparation will determine the quality of the final product uniformity and performance. If the opening system is too aggressive, which can pull out or damage the crimp of the fibers, low fiber cohesion and product loft may result. The processing speed from the card may have to be reduced to compensate the cohesion loss. In the worst case, too much working of the fibers during breaking, opening and blending steps, can generate fiber entangled pieces commonly called rat tails. These rat tails are difficult to break down and straighten by carding and become permanent defects in the final products. So gentle but adequate opening of fiber bundles into individual fiber is key to successful operation.

A. Conditioning of Bales

It is recommended to keep the bales in the carding area, ideally at 75°F and 55% relative humidity, for at least eight hour to come to equilibrium. At this condition, the moisture content on the surface of the fibers in combination with finish on fibers should provide trouble free processing. If the imbalance occurs, either high static generation due to low moisture level, or fiber sticking to card wires due to high moisture level, processing problems often become an issue. Some of the solutions are adjusting the humidity level, and slow down the production rate.

B. Bale Breaking

This is the first step of the whole opening system to prepare the fibers for carding and web formation. The objective is to break down the big pieces of matted down bundles into manageable size and feed to the opener to further separate into individual fiber. The cleaning and maintenance of the bale breaker, especially the opening (beating rolls) is important. Fiber building up on rolls can start creating rate tails and clumps.

C. Blending and Opening

This step further breaking down the small bundles of fibers into individual fibers and presenting the fibers to the card. Gentle opening either by single opening or multiple opener is the key for successful web formation. Defects can be generated in this step if aggressive opening is used. Depending on the degree of the opening, and the feed batt density to the card, the uniformity of the web is determined. Significant amount of unopened bundles will give high feed batt density resulting in heavier web weight at a given feed roll speed. The unopened bundles will also form thick spots (or cloudiness) in the web affecting the uniformity in weight distribution and appearance. If the rat tails are formed in this step or previous steps, the defects (neps or lumps) will show up in the final product. Static generation should be minimized in this process. Non-uniform flow of fibers to the chute or weight pan resulting in various density of the feed batt, which in turn, makes variable and non-uniform webs.

Table I. Fiber Properties

Fiber	Tenacity g/d	Elongation at Break %	Melting point °C	Specific gravity	Moisture Regain (%)
Polyester	3-6	20-50	250	1.38	0.40
Nylon	3-6	20-70	252	1.14	4.50
Polyolefin	3-5	60-100	120-170	0.90	0.01
Acrylic	2-3	30-50	200-250*	1.17	1.50
Rayon	2-3	10-20	180-240*	1.54	11
Cotton	3-4	3-8	200-240*	1.27	7
Kevlar®	22-26	3-4	480*	1.44	4
Nomex®	4-5	20-30	425*	1.38	4.50
Teflon®	2-3	30-40	400*	2.12	0
Glass	15-19	3-5	1120	2.60	0

* Does not melt, decompose

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