Chapter 24
Current Status and Future Outlook for Nonwovens in Japan

Osamu Yaida

Abstract More than half a century has already passed since the production of nonwovens began in Japan. In January 1996, the Ministry of International Trade and Industry (presently the Ministry of Economy, Trade and Industry) modified the contents of production dynamics, and statistical surveys of nonwovens have come to be independently reported.

Up to 2000, the nonwoven industry in Japan had been developing steadily. After the industry experienced a slowdown, it began to grow again and marked historical records consecutively in 2007 and 2008. However, the industry stopped growing and decreased in 2009 due to simultaneous declines of the world's economies. At present, there are certain signs of a recovery, but people engaged in the industry are uncertain whether the business will continue to grow in the future.

Keywords Nonwovens • Technical textiles • Web forming • Web bonding • Spunbonding • Melt blowing • Spunlace • Needle punching • Wet laying • Dry laying • Thermal bonding • Chemical bonding

24.1 Definition of Nonwovens

According to ASTM D-1117-80 of the USA, it is defined as a fibrous structure manufactured by having fibers mutually adhered or entangled or by both, mechanically, chemically, or by using a solvent or by a combination thereof.

ISO 9092:1988 defines it as follows: A manufactured sheet, web, or batt of directionally or randomly oriented fibers, bonded by friction and/or cohesion and/or adhesion, excluding paper and products which are woven, knitted, tufted, stitch bonded incorporating binding yarns of filaments, or felted by milling. The fibers may be of natural or man-made origin. They may be staple or continuous filaments or be formed in situ. Notes: (1) To distinguish between paper and wet nonwovens, nonwovens are defined as fibers having a length-diameter ratio (aspect ratio) exceeding 300 by 50 % or more or as fibers exceeding an aspect ratio of 300 by

O. Yaida (✉)
Adviser, All Nippon Nonwovens Association (ANNA), Osaka, Japan
e-mail: o_yaida@sutv.zaq.ne.jp

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30 % or more, with a density of 0.40 g/cm^3 or less. In all cases, chemically decomposed vegetable fibers are excluded.

After reviewing ISO 9092-1988 mentioned above, because of its complicated and ambiguous definition, the second edition of ISO 9092-2011 defines it as follows.

Nonwovens are structures of textile materials, such as fibers, continuous filaments, or chopped yarns of any nature or origin, that have been formed into webs by any means and bonded together by any means, excluding the interlacing of yarns as in woven fabrics, knitted fabrics, laces, braided fabrics, and tufted fabrics.

Note: Film and paper structures are not considered as nonwovens.

Simply speaking, however, nonwovens may be regarded as a fibrous sheet manufactured by entangling or adhering fibers by some means. It is a mutually interdisciplinary field existing in and among the fields of film, leather, paper, weaving, knitting, and wool felt.

24.2 Manufacturing Method of Nonwovens

Manufacturing methods of nonwovens are roughly divided into two processes: web forming and interfiber adhering/bonding. In particular, in web forming, it is divided into dry-laying method (producing in air) and wet-laying method (producing in water).

24.2.1 Web-Forming Method

Web forming is classified by fiber length as follows:

Fiber length: 6 mm or less

Wet-laying process and dry-laying process (synthetic fiber, pulp):

Fiber length: 15–100 mm

Dry-laying process:

Fiber length: Continuous

Spunbonding, melt blowing, and others

Due to the web fiber array, consequently, there is a difference in the characteristic values (tensile strength, heat shrinkage, etc.). The random laid web is most preferable, but the parallel laid web is generally used depending on the application where the difference between machine direction and cross machine direction is not important.

In the wet-laying process, the fiber array is random in papermaking process, but, in spunbonding process, the characteristic values are not always equal between the machine direction and the cross direction.

In the dry-laying process using staple fibers, the random laid web is preferred; however, web uniformity is impaired due to the crimp action of fibers when the fibers are departed from the metallic wire of the carding machine and scattered into air in the screen at the suction, and in the case of low-weight web, the product width is broad, and the characteristic value gets stronger in the cross machine direction (CMD), but since the fiber is expanded by the drafter or in the next processing step in the machine direction (MD) and in the final product, the aspect ratio is sufficient, and the dry-laying process is widely used.

24.2.1.1 Wet-Laying Process

The manufacturing equipment in wet-laying process is based on the papermaking technology and is modified and revised depending on the raw materials and applications of products. In the process, raw materials, that is, short fibers and pulp, are uniformly dispersed in water, and the prepared fiber suspension is filtrated on the various types of wire screen belts; then, a thin sheetlike web is formed. Since fibers are dispersed in water, the usable fiber length is limited, and generally it is 10 mm or less, but 20–30 mm may be applicable. Formers include the cylinder mold wire mesh type and the inclined wire conveyor type capable of web forming at low-suspension concentration in order to form a web with comparative long fibers. The formed web is processed such as dewatering and so on and dried by a dryer, and normally the webs are bonded through these processes. The sheet characteristics vary significantly depending on the web-forming method, the web-bonding and web-adhering method, and the drying method.

24.2.1.2 Air-Laying Process

It is one of web-forming processes of dry-laid nonwovens. Pulp sheet, short cuts of fiber with a length of 3–12 mm, synthetic fibers called chops, and other short cut fibers are mechanically opened into single fibers in dry-laying process, and webs are continuously formed on wire mesh running in air as medium and dried to make nonwoven fabrics by employing various adhering methods.

This process was first started by the development of “dry-laid pulp nonwoven” manufacturing process using pulp as the raw material (around 1965), and the demand is high, and dry-laid pulp type is now a representative name of air-laid nonwovens.

Dry laid pulp nonwovens is most excellent in water absorption and oil absorption capacity, and owing to the features of the pulp fiber that is lowest priced among fibers, the bulky and soft touch (apparent density 0.04 to 0.09g/cm^3) is characteristic.

It is used around the world, as absorbing materials for sanitary napkin or other hygienic products and wipes. In Japan, it is mainly used as a cigarette filter, a cooking paper, a paper towel, a food tray mat, sanitary goods, an inkjet printer, adeodorant and aromatic volatile products, and other household goods. Still more, the air-laid nonwovens are composed of short cut or chopped fiber of 100 % synthetic fiber which is called "dry short-fiber synthetic fiber air-laid nonwoven," and its commercial productions began around 1980. These nonwovens are used as automobile filter, insole, wipes, molding, and others.

Webs formed by the air-laying method are high in air contents and are excellent in liquid-holding property, filtering performance, air permeability, touch, and softness, and their pores can be filled with functional powder such as SAP (superabsorbent polymer), activated carbon, and other powders, not to spoil their own functions. The demand field is expanding in the disposable products used for absorption, holding, filtering, evaporation functions of liquid, gas, drip, waste liquid, excrement, and others.

Japan is the first to establish the air-laying method and to start commercial productions of air-laid nonwovens. The manufacturing method of dry-pulp nonwovens was inaugurated by Honshu Paper of Japan, after studies on dry papermaking and cigarette filters using wood pulp, for the first time in the world (Honshu Method 1965), and the company started commercial productions of dry-pulp nonwoven products (1967) (the technology is presently inherited to Oji Kinocloth Co., Ltd. a group company of Oji Paper Group). Other representative methods include Kroyer method of Denmark (presently called M&J method) and Dan-Web method, and together with Honshu method, these are known as the world's three major air-laying methods. Commonly in these methods, pulps are opened by using hammer mill or refiner, sent to a web-forming machine by airstream, and passed through a screen, and a web is formed. Other methods are also patented, for example, a pulp sheet is hooked by a picker rotor and opened, and opened fibers are formed on a net as a web.

Recently, it is a characteristic attempt to introduce only the head of the air-laying process combined with other processes (spunlacing, melt blowing, spunbonding, etc.) to design the equipment and realize multiple functions by combining manufacturing processes such as "high strength + hydrophilic + original hand feeling." Ever since, Honshu has newly developed the TDS process capable of combining high-weight (about 3500 g/m^2) and thick nonwovens (about 40 mm), high blending of powder, and other materials. Furthermore, they developed the air-laid composite type laminated with other low-weight nonwovens composed of long fibers such as rayon and others on one side or both sides. An original field using air-laid nonwovens is built up.

24.2.1.3 Dry-Laying Process

This process is the oldest method; this is still the main process together with spunbonding at the present. Using staple fibers for spinning (fiber length usually

25–76 mm), a conventional spinning machine is used to form nonwoven webs. By the introduction of synthetic fibers, transfer from wool-spinning machine has been promoted from the viewpoint of productivity.

In nonwovens, basically, the synthetic fibers are mainly used, and the machine width is at least 1.5 m or more, and presently carding machines of 2.5–3.5 m in width are used.

A spinning machine mixes raw materials, opens them, bundles webs, twists thinly and gradually, and finally forms spun yarns. In nonwoven processes, raw materials are mixed, opened, and formed into webs, and the subsequent process is directly linked to the bonding process between fibers. At the present, the mainstream is the broad-width machine with high-performance and high-speed production.

24.2.1.4 Spunbonding Method

Spunbonded nonwovens are manufactured by direct coupling of the spinning, drawing, and opening processes with the accumulating process and are significantly different from the staple fiber nonwovens.

Initially, spunbonded nonwovens were patented by DuPont in 1956, further developed, and enterprised. The spunbonded nonwoven "Reemay" was launched by them in 1965, and later in the 1970s, American and European synthetic fiber makers and chemical makers and Japanese synthetic fiber, chemical, and petroleum makers started commercial productions one after another.

The manufacturing method of spunbonded nonwovens (web-forming method) is based on the usual synthetic fiber spinning method and combined with high-speed fiber drawing method such as high-speed airstream. By the way, the process of fiber spinning directly combined with web forming is recently so-called spun-melting process which includes melt-blowing method, flash spinning, and in addition spunbonding. In addition, in the bonding process of the spun web, new methods have been developed, including the thermal-bonding method, mechanical interlacing by needle punching, adhesive agent bonding with resin, and water entangling.

In the aspect of the spunbonding process, many kinds of fibers are used, such as polyester, nylon, polypropylene, and their composite materials.

In the history of production amount of synthetic filament nonwovens, a drastic expansion has been achieved.

24.2.1.5 Melt-Blowing Method

In the 1950s, the US Navy Research Laboratories studied filters of high performance and started basic researches of ultrafine fibers, and in the middle of the 1960s, Exxon began to study melt-blown nonwovens by using polypropylene resin, but Exxon was specialized as a resin supply company and was divided into a company promoting the business by introducing the technology of Exxon and a company promoting development by the own technology.

In the manufacture of melt-blown nonwovens, the polymer is spun and blown from the outlet of a spinning nozzle with high-pressured airstream of high temperature, and the blown fibers are opened and collected on a capturing conveyor.

Its features include characteristics, not obtained in ordinary nonwovens, such as softness, thermal insulation, and high filtering performance because of the microfibers. At present, in the melt-spinning technology of synthetic fibers, a filament of 0.1 dtex is known as the thinnest filament, but the fiber thickness of the melt-blown ranges from submicron to several microns (ordinary fiber diameter 10–30 μm).

The problem was the low productivity in the initial stage of the development, the melting flow rate (FMR) of raw polypropylene resin was low, about 50–100, but recently a high rate of about 1000 is reported. (FMR is an index of start of flow of melted resin in heated state; a higher value shows a better resin fluidity and the productivity.)

Raw materials are mainly polyolefin derivatives (including polypropylene), nylon 6, polyester, low melting point PBT (polybutylene terephthalate), etc. Polyurethane materials are also used partly. The demerit of melt-blown nonwoven is an insufficient strength of sheet, because of its undrawn ultrafine microfibers, and some reinforcement is needed. Since the fiber diameter is very thin, in the case of low fabric weight, for example, at 5 g/m^2, the number density of fiber accumulation is very high; therefore, it is used for such high-performance filter at low fabric weight.

24.2.1.6 Flash Spinning Method

In the 1950s, DuPont developed this technology, and the products using polyethylene resin (TYVEX®) based on this technology were commercialized in the 1960s. Thereafter, Asahi Chemical Industry originally developed a technology and commercialized products (LUXER®). In 1995, in Japan, a joint venture of DuPont and Asahi Chemical Industry was organized as DuPont-Asahi Flash Spun Products Co., Ltd. and started manufacture and sales.

Flash means a sudden gasification phenomenon of liquid polymer solution, and flash spinning is a kind of dry spinning, and a fiber-forming polymer and a special solvent are used basically. The solvent is a liquid and solvent at high temperature and pressure but is a gas and nonsolvent at ordinary temperature and pressure.

In flash spinning, the polymer is dissolved with the solvent to form a uniform solution at high temperature and pressure, and this solution is separated in phase before flashing from the nozzle. This phase-separated solution is flashed from the nozzle into the atmosphere of room temperature and pressure; then by suddenly gasifying and drawing, because of the low boiling point of the solvent, the polymer is drowned and solidified, and a unique structure composed of mesh-like continuous ultrafine filaments is formed.

The jet flow containing the mesh-like continuous filaments is injected against a collision plate and spread. The spread mesh-like ultrafine filaments are charged by corona discharge and electrostatically charged in order to collect stably and uniformly the web on the moving conveyor net. The gas including the solvent used in this process is collected and recovered. The web is sent to a next bonding process and formed into a product. Depending on applications, improvements are needed in print, adhesion, and others, and the specific surface treatment is carried out by additional converting process. Where permeability is needed for such as house wrap, the condition is changed in the bonding process, and the permeability is assured.

24.2.1.7 Tow Opening Method

When producing nonwovens of synthetic filaments, the direct spinning method is employed usually, but this method is to form a web from synthetic filament bundle (tow). In Japan, the process was developed by Unisel Co., Ltd.

24.2.1.8 Film-Drawing Method

In burst fiber method, the raw material polymer mixed with the foaming agent in an extruder is melted and kneaded, and the polymer containing gas is extruded from the slit die and is simultaneously drawn quickly. Then, the compressed gas in the polymer is swelled and ruptured (foaming: bursting) at the die outlet, and extreme micromesh-like continuous fibrous sheet (burst fiber) is formed. This burst fiber sheet is laid up, spread, and finished into a product.

Film split method is said to be developed and commercialized as a result of years of research and development by Polymer Processing Research Institute, Ltd., Japan. The film is drawn, split, and spread at high speed, same as in the burst fiber method above, and the split films are plied up orthogonally to each other in machine direction and cross machine direction. This technology is inherited by JX Nippon ANCI Corporation and commercially produced and is widely sold as Claf®; also the technology is licensed to Amoco of the USA.

24.2.1.9 Electro-spinning Method

Basically, this is a solution spinning method by using electrostatic force. Electric charges that are induced and accumulated on the solution surface by a high voltage repel each other to resist the surface tension; when the electrostatic force exceeds a limit value and the repellent force of electric charges exceeds the surface tension, a jet of charged solution is injected and spun.

The injected jet is larger in surface area as compared with the volume; therefore, the solvent is evaporated efficiently, and the charge density elevates as a result of decrease of volume, and it is divided into a further thinner jet. In this process, a nonwoven of uniform filaments in the diameter of tens to hundreds of nanometers is formed on the collector. In principle, this is a traditionally known technology, but recently application in filters and other examples are realized, and the production technology for practical use has been intensively studied in many research laboratories and companies.

24.2.2 Web-Bonding Method

Various methods of web bonding have been developed, and recently the use of thermal bonding and spunlacing is increasing from the viewpoint of environment and energy saving, but along with the advancement of automobile industry and environmental improvement, the needle-punching process is also dominating.

24.2.2.1 Chemical (Binder) Bonding

Earliest in history, it is still widely used at the present. Tending to be decreased in use gradually from the viewpoint of product safety, hand feeling, environmental pollution, and energy-saving policy, it is being replaced by thermal bonding which is easier in process. Chemical-bonding method includes dipping method, foam-bonding method, and spray-bonding method.

Latex adhesive is mainly used for the bonding. Evaporation of moisture is needed except for powder-bonding system. In the dipping method, it is important not to disturb the web uniformity when dipping the web in the adhesive, and various methods are invented. In the method of holding the web with wire mesh and dipping in latex bath, clogging of wire mesh with the binder is a problem. In the foam-bonding method, the web is dipped with binder latex so as to be coated from one side or both sides, but in the case of heavyweight web, the inner layer is hardly immersed, but it is effective because it is less in contamination of binder or residual liquid. In another method, the strength of the web is increased by coating only one side of the web with the foam binder. To increase product durability, a dryer or heat-treating machine is needed to dry and cure the binder. In print-bonding method, the binder resin is printed and bonded partly the web, and the products are widely used in disposable application. The spray-bonding method is effective for production of products of bulkiness and surface fluffiness-preventive property, which is produced by spraying and bonding both sides of the web by spray nozzle. The prevention of the scattering of binder was difficult, but the countermeasures are recently improved, and efficient scattering is realized. The products are used in production of wadding for clothing, air filter, etc.

24.2.2.2 Thermal Bonding

Thermal bonding is used widely instead of chemical bonding method. Recently, along with the development of various thermal-bonding fibers, its use is expected to be increased more and more in the future, from the viewpoint of excellent hand feeling of the product, energy-saving, and environmental advantages. This is the method of bonding between fibers by heating and fusing lower melting portions, and two types are known as follows.

Using heat roll: Divided into the smooth type (contacting with the entire roll surface) and the protruding type (contacting partly with the embossed surface). The embossed type is more used.

Using hot air: Also known as air-through type. Sheath lower melting parts of sheath/core-type bicomponent fibers are fused and adhered by hot air, and bulky products can be produced. When a certain precision in thickness is required, the web is held, and the fibers are adhered between wire mesh nets having a clearance.

In the recent advancement in productivity, wider webs (more than 2 m) are produced, and in the case of low-weight webs, the uniformity of weight, density, and thickness in cross direction is necessary. Accordingly, various methods are developed to apply the pressure uniformly in the entire width. In the case of product width of 4–5 m, and the fabric weight is 50 g/m^2 or less, the gauge uniformity of rolls is very important. Usually, after pressing at room temperature, the uniformity is checked by passing a pressure-sensitive paper. Whether the roll-heating method is steam, oil, heat medium, or electric heat is selected depending on the fiber or final product.

24.2.2.3 Needle Punching

Traditionally used for needle-punched felt and recently owing to the improvement in the machines and the needles, this method is widely used in relatively heavy-weight products. Recent machines are high in speed, low in vibration, low in noise, and possible in safety operation. In particular, in heavyweight products, in other bonding methods, bond strength between fibers is not sufficient, and interlayer abrasion is likely to occur. But the problems can be solved easily by needle-punching method. On the other hand, in lightweight products, it is not suitable because the uniform web array is disturbed.

By the development of new fork-type needles, other than plain-tone surface, cord-tone or pile-tone surface products can be also manufactured.

Further, in reducing the needle density (penetration needles/cm^2), the pre-punching is also used. A special type includes a cylindrical bed plate.

Generally, a needle-punching machine moves the needle board (the needle anchored board) by vertical vibration motion, and the vibration during motion may cause a problem, but recent machines have been improved to be stable and be balanced sufficiently if only put in place. For realizing a high-speed rotation

(2000–3000 rpm/min.), the stroke amount of vertical motion (cam eccentricity × two times) must be decreased.

Usually, in the production line directly coupled with the card in the dry-laying process, there are many cross laid webs, and the laid-up web is bulky for needle-punching type, and the needle stroke depth is about 75 mm, but when the number of times the punching increases, the thickness decreases consequently, and the finishing punch is about 40 mm in most stroke depth.

An ordinary needle has a triangular section, and each side has barbs, and when the barb interval is regular (2.1 mm), it is called a regular barb (RB). When the barb interval is half (1.1 mm), it is called a close barb (CB). A special interval (1.6 mm) is called a multi-barb (MB). Recently, special needles are developed to be applicable to new fibers such as high modulus of organic fiber, inorganic fiber, and metal fiber.

The important point in needle-punching process is the needling density per unit area. Various terms are used and a uniform term must be defined. Herein, it is called the needling density which means number of needle penetrations per square centimeter.

24.2.2.4 Hydroentangling (Spunlace Bonding)

This process was developed by DuPont, United States. Fibers are entangled by a water steam jet by injecting high-pressure water to the webs from nozzles, and the fibers are not damaged, and a fabric-like hand feeling is obtained without any adhesive agent. Since the expiration of DuPont's original patent, it is rapidly used. Although the equipment is costly, the productivity is high, and the market is expanding in the field of medical and wiper and other disposable products with unique hand feeling-like woven fabrics. As combination with other materials such as SM or SMS, it is used for such as filter medium, and the products composed of split fibers which are split and entangled by this process are used for precise wipers, abrasive bases, and filter materials. In addition, lace-like-patterned products can be produced. This process is used by combining with wet-laying or dry-laying manufacturing process, and it is also used with spunbonding processes.

Depending on the water pressure, the method is divided into low-pressure type (within 10,000 kPa) and high-pressure type (15,000–20,000 kPa).

By using one manifold stage, the fiber entanglement is insufficient, and several manifold stages are provided in the same number of boards of needle punching. Various characteristics are obtained depending on the web-holding mesh screen or wire net or the type of net conveyor. Recently, various patterned nonwovens are developed, that is, on the patterned suction drum, the fiber webs are entangled and simultaneously patterned to form the nonwoven.

At present, Honeycomb and Perfojet are the leading spunlace machine manufacturers in the world, and this kind of machine is highly demanded recently, and many manufacturers are releasing new machines, such as Courtaulds Engineering. More recently, instead of water steam jet, high-pressure steam jet was developed, and the webs are entangled by the steam jet and produced into bulky nonwovens, which is known as steam jet (SJ) type.

24.2.2.5 Stitch Bonding

Using spun yarn or filament, webs are interlaced by warp knitting. This method is developed in Eastern Europe, such as former East Germany and Czech Republic, and this is not classified into the category of nonwovens in the European Disposables and Nonwovens Association (EDANA), but it is classified in the category of nonwovens in Japan. Basically, this is knitting, and it seems to be different from other nonwoven manufacturing methods because the manufacturing line is stopped even if one interlacing yarn is broken.

Besides, in other methods, without using yarn, fibers are interlaced by needles only, just like needle-punching method. However, the needles of stitch-bonding method are needles used in knitting, and the interlacing strength is weak because many barbs are not provided in one needle, different from the needles used in needle-punching method.

24.3 Applications of Nonwovens

More than a half century has already passed since the nonwoven industry commercially started in Japan. Initially, nonwovens were mainly applied as durability substitutes for woven fabric, felt, leather, and others mainly in the clothing field and are later used in other original fields such as disposable hygiene and medical, and these original products are grown to occupy a major demand. As a result of original product development based on the porous and other features of nonwoven, various fibers, and manufacturing methods, the applications are expanding in all fields.

This advancement has been achieved by developing new materials based on efforts of material makers (fibers and resins) and new designs of facility or equipment. While making use of the features of nonwovens, in the competition of other materials, new developments will be further invented to meet with original needs.

The following explains the feature and history of development process in main applications with the latest information and the market trends.

24.3.1 Protective Wear

Protective wear clothes are made of polypropylene spunbonded, SMS, flash spun, polyethylene-coated spunbonded nonwovens, microporous film composite, aramid water-entangled or needle-punched nonwovens, and others.

The protective wear market includes nuclear related, clean room, food preparation, paint manufacture, protection from extreme cold or hot climate, heat or fire, protection bullets or mechanical danger, and protection from harmful microorganisms and chemicals.

In particular, when used in manufacture of semiconductor or pharmaceuticals, it is required to protect the environments from workers. In the infection-preventive measure arising as a problem by the incident of SARS, the role of medical-protective wears has been widely recognized and used. This trend has caused to increase the demand for protective masks.

In facility of nuclear power plants, working clothes exposed possibly to low-level radioactive contamination are provided as disposable wears and stored and sealed in special drums after use. In such applications, nonwoven products are used widely. The permeability and barrier properties are important.

24.3.2 Medical Care

In medical care products, products are explained as being classified into medical site and nonmedical site.

24.3.2.1 Medical Site

The use of the nonwoven in the medical and healthcare in Japan is increasing year by year, because of the following reasons:

– Improvement of the usability by increasing variations of items and sizes
– The price down by the increase of production volume with the market expansion and the increase of low-price imported goods
– Increasing the use of disposable or short-life products in medical site, because of the point of view of preventing nosocomial infection

The general characteristics required for medical nonwovens are as follows: bacteria barrier, moderate moisture permeability, water repellency, water absorption, waterproofing, lint-free, drapability, and durability in sterilization.

24.3.2.2 Nonmedical Sites

1. Cataplasm-base material

   Transdermal system is known as a modern cure therapeutic method, and the medicine permeates into the inner parts of the body by way of the skin. It is commonly known as the wet compress or poultice.

   The fiber product used in the cataplasm base was cotton flannel in the past, but the nonwovens are mainly used at present. The usable nonwovens include nonelastic type, lateral elastic type, and longitudinal-lateral elastic type.

   The medicine was formerly a kaolin cataplasm composed of kaolin as the base, mixed with medicine powders and with water. Recently a cross-linking reaction-type ointment is developed, and further the active ingredients are developed in a second generation (including flurbiprofen, ketoprofen, and indometacine as percutaneous absorbing agents), and the coating amount is reduced to less than half. As these result, the nonwoven base materials comes to be used widely.
2. Plaster medicine support-base material

   A therapeutic method of giving medication administration of medicine by way of the skin is highly expected as a new market. By direct administration from the skin of the affected area, the side effects of the internal organ absorbing medicine can be reduced. As the function of nonwoven base material, the medicine adsorption and compatibility are important. In the sealed type, composite with the film is necessary, and as the entire structure, the smaller size and thinner types are demanded.

24.3.3 Architecture

In the field of building and architecture, the nonwoven is used in waterproof roofing, house wrap for prevention of dew condensation, and indoor floor and wallpaper.

The process of waterproof roofing in the building is used in a roll profile of 1 m in product width, for the purpose of roof waterproofing of reinforced concrete building. Waterproofing of a general house (inclined roof) is a method using under-roofing material, and it is not called roofing.

In Japan, from the earlier days, binder-bonded nonwovens, composed of vinylon fibers (PVA fibers) made of its tow, have been used as the base materials. And this technology was exported to Europe and America. Generally, it is divided into new construction and repair, and in repair building, asphalt-melting method has not been used gradually to prevent from environmental deterioration effects due to the malodor and scatter of asphalt particles, and it has been attempted to avoid the harms by the construction method at normal temperature.

24.3.4 Civil Engineering

Nonwovens are very widely used in civil engineering, and the consumption is expected to be increased more henceforth. Mostly, civil engineering works are public construction works, and the quality of works is inspected by the government's board of audit. For the use of new materials, laboratories under direct governmental control are managing, and only the materials approved by the academy can be used in the design. Therefore, this point is radically different from other applications.

Textile products used in civil engineering are called geo-textiles, and including plastic products and others used in civil engineering works, they are called geo-synthetics. Functions of nonwovens include separation, draining, filtering, reinforcing, protection, and water sealing.

24.3.5 Vehicle

Nonwovens are widely used in vehicles. About eight million vehicles are produced a year in Japan, and a half of them is exported. As the overseas productions increase, the domestic consumption tends to be lower recently, but the nonwoven consumption per vehicle is increasing along with the increase in compartments using nonwovens and the increase in the area.

The demand in the automobile industry is in the direction to use nonwovens of easy recycling and lightweight. In the industry, a higher recycling rate of car materials and a higher fuel efficiency are demanded.

As compared with the textiles of the conventional specification, nonwovens were inexpensive and were handled as materials of low-quality level. By overcoming this traditional concept, success and growth has been brought in this field.

In the headlines, visual attraction is enhanced by the print design, Mari-fleece pattern, stitch bond, and other decorations, and the trunk surface material is enhanced in touch by Dilour/shirring process.

By the invention of artificial leather of high quality equal to that of natural leather, choices of materials are expanded in the seat, ceiling, and door panel. It is highly noteworthy that the advanced progress of the nonwoven technology is greatly contributing to the automobile upholstery field.

In the aspect of functions, recent topics are reduction of VOC. New surface materials are developed, such as those not generating VOC or others having functions to take up, adsorb, and decompose VOC.

24.3.6 Hygiene

The largest market of nonwovens in the hygiene industry is the diaper market for both infants and the elderly. The nonwoven and the SAP (superabsorbent polymer) perform synergetic effects and are producing various types of hygiene products.

Disposable diaper is composed of top sheet, acquisition distribution layer, absorbent layer, and water-shielding back sheet. Nonwovens are widely used in the top sheet, acquisition distribution layer, and back sheet laminated with film. The absorbent layer is made of fluff pulp and SAP (superabsorbent polymer), and the nonwoven is used for covering them. The water-shielding back sheet is required to have a texture feeling, and the film is laminated with the nonwoven. The most important growth is spunbonded or SMS for disposable diaper in hygiene field.

In diapers for infants, the pant type and the side gather type are highly reputed, and the consumption of nonwovens is increasing. In diapers for the elderly (for incontinence), the production is rapidly expanding.

Recently, by decreasing the pulp amount in the absorbing material and increasing the SAP, the moisture absorbing quantity is maintained, while the weight and thickness are decreased, in order to save the storage and transportation expense. The trend is the same for the adult market.

Lately, along with the increase of incontinence among elderly people, the use of diapers is estimated to be increase more and more.

24.3.7 Wipes

The wipe market is expanding owing to the function of the nonwovens. In particular, characteristics of microfibers such as enhanced dust-holding performance and liquid-absorbing performance are applied to various fields.

Both dry type and wet type are developed widely. The container ranges from cylindrical type to lunch box type, and the takeout port is developed in various shapes. Display storage and refill types are available. Many portable products are sold.

24.3.8 Filter

The filtration is the market conforming to the inherent function of nonwovens. In other materials except nonwovens, it seems difficult to maintain the low apparent density and design to stack up while giving a density gradient in the thickness direction.

On the other hand, in the recent development of nanofibers, ultrafine particles can be removed at a highest level, and a latent application development is expected in the filter medium based on nanofibers.

For the application of nanofibers, higher filtration efficiency than ULPA or HEPA filter is highly expected in the field of air filters. Thinness, low-pressure drop, large dust-holding capacity, and long filter life will be realized. In the liquid filter, invasion of bacteria and virus will be blocked effectively.

Utilization to filter by using/making use of photocatalyst is one of the technologies highly expected as the indoor VOC-preventive countermeasures.

When filtering, generally, dust particles of various sizes must be captured. In the case of a high-efficiency filter, in particular, first-coarse, dust particles are filtered, and the rest is a high-efficiency filter. Accordingly, a prefilter media are used in front of main high-efficiency ones, and the useful life of the high-efficiency filter is extended.

The manufacturing method is mainly chemical (spray) or thermal bonding of staple fibers. In fiber structure, thick fibers are used at the flow-inlet side, and thinner fibers are used at the flow-outlet side. For example, it is used for the cooking range hood in general household.

For industrial use, it is used in the fresh air intake part of a painting booth for automobiles and electric products, so that foreign substance may not get into the air for the painting.

Filter media of extremely high efficiency are known as HEPA and ULPA, composed of ultrafine glass fibers in general, which are zigzag pleated and formed the assemble structure. Recently, melt-blown products are developing. In the market of semiconductor chip manufacture, the ultrafine glass fiber paper was in the mainstream; also PTFE membranes are used recently. PTFE membranes are made of nanofibers, and it has an advantage that it is free from boron volatilization of the glass fibers.

When static electricity is applied to polyolefin fiber, the filter media have higher filter efficiency by dust-capturing force of static electricity *i*. When combined with this effect, a filter capable of high-capturing dust particles without raising the pressure drop is realized.

As the dust-holding feature of this filter, electrostatic-capturing force begins to decline in a certain time after start of use, but since the media pores become gradually smaller because of the dust clogging, and after a certain limit, the filter efficiency is enhanced by the action of mechanical capturing.

In particular, the electret filter using polypropylene melt-blown nonwoven is not only excellent in mechanical filtration efficiency by ultrafine fibers but also low in pressure drop and high filter efficiency owing to its electrostatic effect, and it is used in a household air purifier filter and so on.

A bag filter is used for prevention of dust scattering and collection of dust particles in the powder-conveying site, powder manufacturing plant, power plant, and others.

Depending on the method of separating air mixed with powder, it is divided into the filter air-flow systems, inside to outside type and outside to inside type. Fibers are mainly synthetic fibers, but glass or metallic fibers may be used depending on the purpose. Recently, since heat resistance is required, functional heat- or chemical-resistant fibers are used. For example, in the atmosphere of high temperature and harmful gas, suitable fiber materials are selected.

Application fields of liquid filters are roughly classified into general industrial, water purifier, and membrane use and classified by shape into cylindrical cartridge type, bag type, or box type. Usable nonwovens are dry-laid, wet-laid, and melt-blown type, which require safety, insolubility oil-resistant, and chemical-resistant properties. In particular, in the semiconductor field, the filter composition is required to have a more pure water characteristic, non-eluting a trace of additive used in the polymerization process of polymer.

24.3.9 Agriculture and Horticulture

The development of nonwovens in the field of agriculture is long in history. In Japan, in the early 1970s, Unitika Ltd. developed polyester spunbonded nonwoven, and it was first used in the weed barrier sheet, and the application in agriculture expanded. A second application was found in the inner curtain for greenhouse. It is because it is evaluated in the effects of thermal insulation, dehumidifying, and water drop prevention.

The materials have been mainly synthesized polymer compounds made from fossil resources such as polypropylene and polyethylene terephthalate, but recently it is demanded to change the direction from the global environmental problems such as “shortage fossil resources” and “refuse disposal problem.”

In particular, in the field, an active use of bio-based biodegradable resins (polylactic acid, cellulose, etc.) is expected for solving the problems. Yet, at the present, the mainstream is polypropylene and polyethylene terephthalate materials, but biodegradable fibers and spunbonded nonwovens have come to be used widely in direct covering, mulch sheet, slope protection, and greening sheet.

Along with the development of biodegradable resins, the nonwoven application is promoted in the household, hygiene, and medical or automobile materials; the resins are intensively modified and reformed for practical use.

24.3.10 Artificial Leather

Artificial leather started in shoe materials and spread further in wide fields including bags, furnitures, gloves, apparel material-related precision machines, and abrasives. The nonwoven composing the base material is an important constituent element. At present, there are two major surface-making methods such as polyurethane film laying forming on the base material by dry process and a thin film layer forming on the surface of a foamed layer made by wet process.

Artificial leather achieves excellent properties such as touch and strength of surface state emulating natural leather in structure. Accordingly, in a layered structure of nonwovens using ultrafine fibers, a gradation structure is built so as to be similar to that of natural leather, and ultrafine bundle fibers are used as the outermost layer of the grain side. Also, by the raising process of ultrafine fibers, the artificial suede is realizing appearance and structure similar to those of natural leather.

On the other hand, along with the conventional demand increase, there is a mounting need for lightweight, breathability, humidity permeation, flame resistance, softness, antistatic, and water-repellent properties. By adding these functions not realized in natural leather, an advanced artificial leather is developed and promoted.

By using polyurethane together with water-based emulsion, leather in consideration of environment and ecology is accelerated.

Recently, technical levels are advanced in Korea, Taiwan, and China, and the technology is getting into the age of borderless and major competition.

24.3.11 Others

One of the recent best sellers is Kao's Quickle Wiper®. Static electricity generated in nonwoven is utilized advantageously for capturing hair and various dust, and it has become a phenomenal seller. The wiper itself is a staple fiber nonwoven reinforced with mesh. Initially, a long stick was attached to be used for cleaning the floor, wall, and ceiling, instead of a vacuum cleaner, and a one-hand operation product was developed later. Furthermore, combined with a detergent, products of strong cleaning performance are developed for removing stubborn stains, stickiness, or fine dust particles.

"Kairo" disposable pocket warmer is a Japanese unique product. This is a very simple warming tool as the result of the oxidation of iron powder and it can be used in clothes, shoes, or further stuck to clothes. Nonwovens are also used widely as shopping bags.

For electric appliances of high voltage and large capacity, electric-insulating materials excellent in heat resistance, corona resistance, and arc resistance are needed. These materials are generally known as mica tapes which need the reinforcing materials, such as polyester nonwoven, glass cloth, film, or aramid paper. While polyester nonwoven is lower in tensile strength than other materials, it has advantages such as softness and excellent elongation making adherence or less creases in the winding process and the superior impregnation of insulation resin.

Rechargeable batteries are used widely in mobile phones, laptop PC, or portable communication devices, expanding nowadays to hybrid vehicles, and the development competition is keen, aiming at higher capacity, higher output, or higher reliability. The nonwoven separator is manufactured in dry-laying, wet-laying melt-blowing, or combined processes thereof, while microporous film is also used. Nonwovens are used mainly in the nickel-cadmium or nickel-metal hydride batteries, and fine porous film is preferred in lithium batteries.

In the future, for improvement of electric characteristics of separators, in addition to the absolute requirement of prevention of short-circuiting, dense and homogeneous properties are demanded, and development of thinner separators having higher performance is expected.

Battery-related elements are specialties of makers in Japan, and a further growth is expected by global standardization and global located productions.

Glossary It is expected that the Japanese fiber industry develops mainly on technical textiles. For technical textiles, it is important to push forward the development of new high functional fiber and nonwovens.

Based on a technique and results of research provided so far in the fiber industry, it is thought that it is necessary to push forward a study and the development of the nonwovens.