Manufacturing Properties and Applications of Nonwoven Fabrics – A Review

Anil P. Athane, Saurabh R. Prasad* & Anushka D Kadage

Dept. of ETC, DKTE Society's Textile and Engineering Institute, Ichalkaranji, India

Abstract

This paper reviews various techniques for producing nonwoven fabrics made from natural and synthetic fibers. The overview of different types of nonwoven fabrics is also considered as per the requirements. It has been shown that needle piercing is widely used in the manufacture of nonwoven fabrics for industrial use. The various physical, mechanical, and functional properties of the different kinds of woven fabrics are discussed here. The different properties nonwoven such as oil absorption, thermal insulation, air permeability, noise reduction, compressibility, water absorbency, acoustic insulation, etc. are discussed here.

Keywords: *functional properties, industrial applications, nonwoven, textile, needle punching, physical properties*

***Corresponding Author:**
Dr. Saurabh R. Prasad
Assistant Professor
Department of Electronics and Telecommunication Engineering,
DKTE Society's Textile and Engineering Institute,
Rajwada, P. O. Ichalkaranji,
Dist: Kolhapur – 416 115
E-mail: saurabhprasad21@gmail.com

1. Introduction

1.1 Nonwoven Fabric

Nonwoven fabrics are one of the oldest and simplest textile fabrics. Applications of the nonwoven fabrics are multifold, such as geotextiles, dry filtration, Acoustic and thermal insulation, personal hygiene, healthcare, clothing, home, automotive, construction, home furnishing, etc. are discussed here. One of the frequent applications of nonwoven fabrics is for home applications, such as cleaning cloth. Nonwoven fabrics are highly porous material, and therefore found suitable for cleaning cloth. For cleaning cloth, among the others the important end-usage properties are softness and strength.

Nonwoven fabrics are formed by joining together or by wrapping textile fiber by machine, heat or chemicals. They are flat or perforated sheets made directly from different fibers, molten plastic or plastic film. They are not made by weaving or knitting and do not need to be twisted into threads. The important properties of nonwoven fabrics include absorbance, dehydration, durability, elasticity, softness, strength, fire resistance, etc. These structures are often combined to make fabrics suitable for specific tasks, while obtaining a good balance between product life and cost. They can mimic the look, texture and strength of woven fabric and can be as large as very large pads. In conjunction with other materials they supply a wide range of products with different properties, and are used alone or as parts of clothing, household goods, and health care, engineering products, industrial goods and consumers.

Mechanically blending fibrous wool is known as a needle piercing [1]. The threads are machine-bound to produce fabric by repeating sharp needles (attractive needles) with a moving batter of threads on the needle thread. The needle piercing process is well suited to produce intermediate and heavy nonwoven weight from 300 gsm to 3000 gsm. So using needle piercing is the best way to produce nonwovens.

2 Overview of Types of Nonwoven Fabrics

As shown in Fig. 1, the nonwovens can be categorized in three types- viz. natural fiber, regenerated fiber, and synthetic fiber.

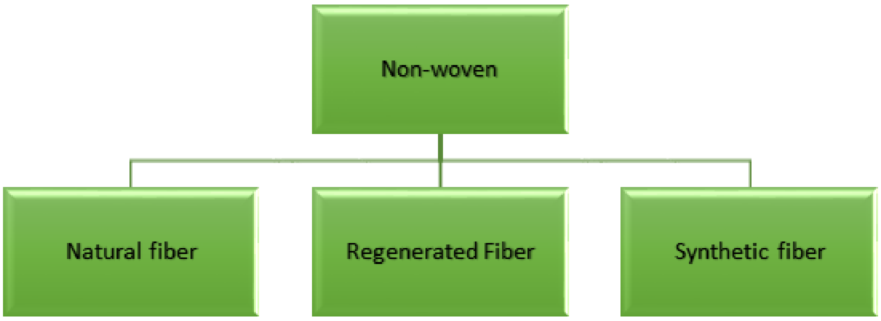

Figure 1 - Types of Nonwoven Fabrics

The nonwoven fabrics can be divided into 8 types according to different manufacturing processes [16].

2.1 Spunlace Nonwovens

The spunlace nonwoven is a category of nonwovens manufacturing that employs jets of water to entangle fibers and thereby provide fabric integrity.

2.2 Heat-Bonded Nonwoven Fabrics

Heat or Thermal bonding is the most popular method of bonding used in nonwovens manufacture. It offers high production rates. This type of nonwoven fabric is produced mainly by adding adhesive materials to the fiber network, and then strengthening the network into fabric by heating and cooling.

2.3 Pulp Air-Laid Nonwovens

Nonwovens that are air-laid are also known as dust paper or dry paper nonwovens. It employs air-conditioned technology to change wood pulp fiberboard into a single state fibre, then an air flow method to turn fibre agglomeration into a net curtain, and finally fibre web into fabric.

2.4 Wet-Laid Nonwoven

Wet-laid nonwovens are prepared by dispersing the short fibers of 30 mm length in water and deposited on the wire mesh, allowing the water to drain from the web. The fibers within the web were entangled by means of either fiber-to-fiber friction or binding agent.

2.5 Spunbond Nonwovens

Spunbond is a nonwoven fabric made from 100% pure polypropylene. The polypropylene pellets are melted and extruded, then spun into fine fibers which in turn are laid and bonded by heated rollers to form spun bond fabrics.

2.6 Meltblown Nonwovens

Melt-blown nonwoven fabric is made by extruding melted polymer fibre through a linear die with hundreds of microscopic holes to generate long thin fibres that are stretched and cooled as they fall from the linear die. This type of nonwoven fabric is usually combined with spunbond to create SM or SMS webs. Meltblown cloth mainly uses polypropylene as the main raw material, and the fiber diameter can reach 1 to 5 microns.

2.7 Acupuncture Nonwovens

Acupuncture nonwoven is a form of nonwoven fabric that is used for acupuncture. Needle penetration reinforces the fluffy fibre into the textile.

2.8 Stitch-bond Nonwovens

Another type of dry nonwoven fabric is stitch-bond nonwoven. A stitch-bond nonwoven fabric is made on a weaving machine that bonds the web, or holds the web in place, with longitudinal yarns.

The market size of nonwoven used for various applications is given in Fig. 1.2.

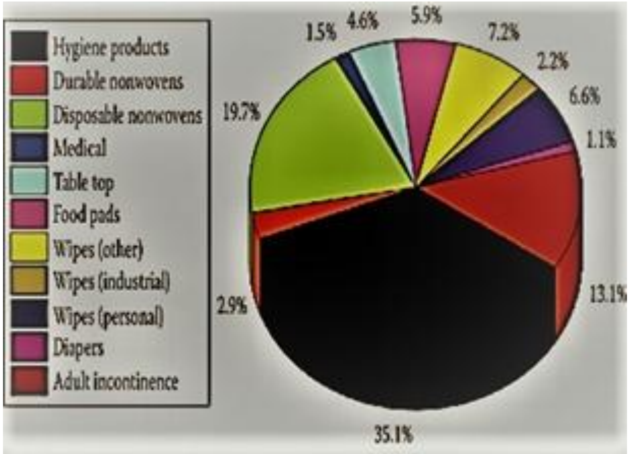

Figure 2 - Distribution of Nonwoven Based Product in 2014-2015

3. Methods of Manufacturing

There are three major bonding methods for nonwoven fabrics- chemical bonding, thermal bonding, and mechanical bonding. Hydro entanglement and needle punching/ needle felting are the two main methods used in mechanical bonding.

3.1 Hydro Entanglement

Hydro-entanglement is the process of producing nonwoven fabric that involves bonding together textile and high performance fibres and their blends by using very fine, high pressure water jets.

3.2 Thermal Bonding

Thermal bonding is one of the most common method of bonding used in manufacturing nonwoven fabrics. It offers high production rates because bonding is accomplished at high speed with heated calendar rolls or ovens. At the point where two or more fiber strands meet, thermoplastic powders are burnt which melts to join the fiber strands.

3.3 Chemical Bonding

The process of chemical bonding involves the application of a “chemical binder” to join polyester and rayon fibers to impart unique and beneficial characteristics to nonwovens. In chemical bonding, chemical bonds (adhesive materials) are used to hold the fibers together in a non-woven fabric. Chemical bonds are polymers formed by emulsion polymerization. The most widely used binder today is water-based latexes. They are used in many different ways in nonwovens and because their viscosity is close to that of water. They can easily penetrate into nonwoven structures with emulsion. After applying the binder it is dried and water evaporates. The binding then makes the adhesive film between or between the fiber crossings and the fusion of the fiber occurs.

3.4 Needle punching/Needle Felting

Out of the four knitting methods, the needle piercing is found to be the most effective.

4. Mechanical Properties of Needle Punched

4.1 Thermal Insulation

The thermal insulating properties of textile fabrics depend on their thermal conductivity, density, thickness and thermal emission characteristics. Thermal insulation material is one of the most important materials for technological fabric use. The most commonly used methods of measuring thermal insulation value (TIV) are disk method, the constant temperature method, and cooling method. Temperature resistance and stiffness increase but air permeability and air permeability are significantly reduced by increasing the weight of the fabric at all levels of jute content [6].

4.2 Fabric Density, Percentage, Compression, and Thickness

Fabric thickness is one of the most important factors determining thermal comfort. It was found that fabric thickness had a direct effect on thermal transmittance, where the thicker the material, the lower the thermal transmittance [1].

4.3 Air Permeability

Air permeability is a measure of air passage through the fabric. This parameter highly affects the comfort obtained from a particular fabric. Different products require different amount of air permeability. For example, the amount of air permeability is distinctly different for various products like clothing, parachute, bag, packaging textile, agro-textiles, etc. Also the air flow resistance increased with decreased fiber width and porosity [1]. The air permeability of the fabric increases with the increase in the amount of polyester compound in the composite. It is observed that air permeability decreases sharply with increasing fabric weight in case of polyester and jute fibers. The inflow of air also follows the same process with the weight of the fabric [11]. As expected, with a growing number of layers air permeability is reduced and, as a result, air flow resistance increases [14].

4.4 Water Absorbency

The water absorbency of the textile material is very important, and especially it is of paramount importance in case of diapers. Jute fabrics are used for a variety of applications like floor covering, wiping, suction, agro-textile, where water absorption is an important parameter. The nonwoven structure manufactured with porous needles is expected to improve the water holding capacity of the fabric. The density of the fabric plays a significant role in the absorption [8].

4.5 Acoustic Characteristics and Sound Absorption Coefficient

Sound absorbents are highly used at various workplaces like auditorium, theatre, class room, etc. Various natural and artificial products are used to enhance sound abortion. The capacity of the sound absorption of a material per unit surface area is given by absorption coefficient. Higher the value of absorption coefficient, higher is the amount of absorption.

A study on the effect of various fabric parameters such as fiber filtration, surface effect, punch congestion, area congestion, and chemical bonding on the amount of sound absorption was performed. The results show that fiber fineness has a strong effect on the absorption of sound by nonwoven fabrics [4].

4.6 Bulk and Physical Properties

The bulk and physical properties of the fabric determine the performance of the fabric during the use. The physical characteristics of the fabric are directly or indirectly influenced by the fiber material, manufacturing process, and quality of raw material. The physical properties of needle fabric determine its suitability of the fabric in its various uses. Typically, a thin nonwoven fabric exhibits low air penetration, and high strength. Large incorporation of nonwoven fabric is usually achieved by high needle and needle penetration. Compressibility is reduced but pressure recovery is improved by increasing the penetration depth of the needle [3].

4.7 Oil Sorbents

Oil spills on water are removed using various techniques such as skimmer, chemicals, bacteria, etc. But these techniques are time-consuming. Similarly, the chemical method is dangerous for the environment. So, to overcome these drawbacks fibrous assemblies called sorbents are being studied for improved removal of oil spills. They possesses oleophilic and hydrophobic properties. Sorbents are natural or synthetic materials with high capacity to absorb oil and repel water. They are spread over the oil slick to absorb the oil. Milkweed and kapok fiber-based nonwovens showed the highest oil sorption rate. Thirumurugan et al. (2011) reports that cotton fiber based nonwoven was found to absorb 26 g of oil per g of fiber. It exhibited a small water sorption capacity of about 1.67 g/g. The oil and water soaked sorbent didn't show any chemical degradation or microbial attack even up to 10^{th} day in the sea water. The two natural fibers- Milkweed and cotton had shown good selective sorption of oil over water. Milkweed and cotton could replace around 90 % and 85 % resp. of the previously imbibed water by oil [17]. This indicates that natural nonwovens should be developed as potential oil sorbents to eliminate oil spills [13].

5. Conclusion

Nonwovens is an important branch of textiles and it accounts for the global market size of $38.3 billion in 2020 and it is expected to reach $68.1 billion by 2030. This sector is growing at average CAGR of more than 6%. Although an extensive research and development has taken place in the field of nonwoven, still there is a room for improvement. The nonwovens finds its presence in a variety of applications such as technical textiles including geotextiles, medical textiles, agricultural textiles, vehicle textiles, etc. By taking an overview of different manufacturing methods of nonwoven fabrics, it is found that needle punching is the most advanced and well-suited technology.

References

[1] Debnath, S., & Madhusoothanan, M. (2010). Thermal insulation, compression and air permeability of polyester needle-punched nonwoven

[2] Sengupta, S. (2010). Sound reduction by needle-punched nonwoven fabrics

[3] Midha, V. K., & Mukhopadyay, A. (2005). Bulk and physical properties of needle-punched nonwoven fabrics

[4] Shahani, F., Soltani, P., & Zarrebini, M. (2014). The analysis of acoustic characteristics and sound absorption coefficient of needle punched nonwoven fabrics. Journal of Engineered Fibers and Fabrics, 9(2), 155892501400900210

[5] Tascan, M., & Vaughn, E. A. (2008). Effects of total surface area and fabric density on the acoustical behavior of needlepunched nonwoven fabrics. Textile Research Journal, 78(4), 289-296

[6] Debnath, S. (2011). Thermal resistance and air permeability of jute-polypropylene blended needle-punched nonwoven.

[7] Yilmaz, N. D., Banks-Lee, P., Powell, N. B., & Michielsen, S. (2011). Effects of porosity, fiber size, and layering sequence on sound absorption performance of needle-punched nonwovens. Journal of Applied Polymer Science, 121(5), 3056-3069

[8] Sengupta, S. (2009). Water absorbency of jute needle-punched nonwoven fabric

[9] Yilmaz, N. D., Powell, N. B., Banks-Lee, P., & Michielsen, S. (2013). Multi-fiber needle-punched nonwoven composites: effects of heat treatment on sound absorption performance. Journal of Industrial Textiles, 43(2), 231-246

[10] Çinçik, E., & Koç, E. (2013). The effect of blend ratio and process parameters on tensile properties of polyester/viscose blended needle-punched nonwovens. Fibers and Polymers, 14(6), 1040-1049

[11] Çinçik, E., & Koç, E. (2012). An analysis on air permeability of polyester/viscose blended needle-punched nonwovens. Textile Research Journal, 82(5), 430-442

[12] Yilmaz, N. D., Michielsen, S., Banks-Lee, P., & Powell, N. B. (2012). Effects of material and treatment parameters on noise-control performance of compressed three-layered multifiber needle-punched nonwovens. Journal of Applied Polymer Science, 123(4), 2095-2106. DOI 10.1002/app.34712

[13] Renuka, S., Rengasamy, R. S., & Das, D. (2016). Studies on needle-punched natural and polypropylene fiber nonwovens as oil sorbents. Journal of Industrial Textiles, 46(4), 1121-1143

[14] Broda, J., & Bączek, M. (2020). Acoustic properties of multi-layer wool nonwoven structures. Journal of Natural Fibers, 17(11), 1567-1581

[15] Shahani, F., Soltani, P., & Zarrebini, M. (2014). The analysis of acoustic characteristics and sound absorption coefficient of needle punched nonwoven fabrics. Journal of Engineered Fibers and Fabrics, 9(2), 155892501400900210

[16] https://www.textiletoday.com.bd/types-non-woven-fabrics-manufacturing-processes-applications/
Md. Tanvir Hossain

[17] Thirumurugan, V., Karthikeyan, S., Reddy, K. V. K., & Murugan, E. (2021). A Study on the Effects of Physical Properties and Thermal Properties of Nonwoven Fabric. International Journal of Recent Advances in Multidisciplinary Topics, 2(5), 8-10

[18] Liao, J., Zhang, S., & Tang, X. (2020). Sound absorption of hemp fibers (Cannabis Sativa L.) based nonwoven fabrics and composites: A review. Journal of Natural Fibers, 1-13