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Chapter 1

Introductory Chapter: Engineered Fabrics

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1. Introduction

Engineered fabrics have become the need of present era because the application field of engineered fabrics have spread from automobile sector to aeronautics, marine to geo-engineering, sports items to packaging materials, etc., The present popularity of engineered fabrics is not an incident but it is a long journey which engineered fabrics have completed from triple layer fabrics to three-dimensional fabrics. Engineered fabrics also consists of solution-focused and custom-designed fabrics [1]. These products are also utilized in process industries outside of papermaking such as nonwovens, corrugators, building products, tannery and textile industries.

The growth of engineered fabrics is linked with application of both natural as well as man-made fibers. Engineered fabrics are becoming the base for various product developments for wide variety of applications [2]. Engineered fabrics are reaching to touch the 40–45% share of total fabric production in developed nations.

The supply chain of engineered fabrics follows a long route, starting from manufacturing and selection of appropriate fiber to manufacturing of specialty fabrics for engineering applications [3].

Although, the financial importance and justification of engineered fabrics spreads from conventional textile industry to almost all facets of human life still investors and manufacturers are not getting enough confidence to expand the production capacity at large scale. In spite of all these challenges, the field of engineered fabrics is very promising and only need to keep freshness in product development for better end uses.

Engineered fabrics cannot be developed by using only one type specialty fiber, yarn, weave and finish. This chapter belongs to consider various factors: commercial, technical and global which are major driving forces of this industry. Engineered fabrics have got attention from both side of Atlantic but China has registered remarkable growth in this sector and India is emerging at slow pace [4].

The engineered fabrics are used as raw material to serve various segments of technical textiles viz., agrotech, buildtech, cosmetotextiles, clothtech, hometech, indutech, mobiltech, sportech, packtech, meditech, protech, and others. The automobile textiles (mobiltech) segment is demanding highest amount of engineered fabrics followed by industrial textiles (Indutech). Various types of engineered fabrics like spacer fabrics, multilayer fabrics, needle punched nonwoven fabrics, melt blown nonwoven fabrics and warp knitted fabrics are highly demanded by various sectors of technical textiles [5].

The engineered fabrics are able to cater the needs of wide spectrum of present market starts from awnings, airbags, automobile filters, floor covering, fabrics used in erosion suppression, hoses, road construction, safety belts, thermal and sound insulation and upholstery, etc. Engineered fabric manufacturing industry is already established in strong position in China, India, Korea, Thailand and Taiwan. The engineered fabric market is continued to grow in coming years also. The growth of automobile, industrial sector and infrastructure sector are the major driving forces for engineered fabrics [6]. Being the world's second largest producer of textiles and apparel, India's engineered fabrics manufacturing sector is also growing at fast rate and creating both direct and indirect employment. The textile and garment industry is the root of Indian economy which provided employment to 105 million citizens. Indian textile industry will grow up to $223 billion by 2021 in which engineered fabric's sector will play major role. High transportation and energy cost and lack of labor reforms are some major hurdles in traditional Indian textile industry which force to shift its focus from conventional textile to engineered textiles. Export of engineered textiles is increasing with annual growth rate of 18%. Now, Government of India developed new policies for rapid growth of industry which will make remarkable change in engineered textiles. There are few steps taken to promote the engineered fabric manufacturing in India.

- Market development support to stabilize both domestic and international markets
- Investment promotion
- Exemption in custom duty for raw materials
- Implementation of uniform goods and service tax across the country
- Establishing standards for various types of engineered fabrics.

2. Definition

The Engineered fabrics are defined as "The fabrics which are produced by some modified fabric manufacturing techniques than conventional for unconventional engineering applications". Various critics and scientists will coin some other definitions in future also but the basic theme of engineered fabric may remain unchanged. Basically the engineered fabrics covers the 2D, 3D fabrics, belts, braided items, aerospace automotive textiles, industrial textiles, high performance textiles, etc. [7, 8].

The engineered fabrics can be comparable with composite materials also where two materials having different nature are combined together to extract the merits of both the materials in a single product, similarly two or more than two types of fibers, yarns, weaves or laying techniques are combined to engineer the targeted fabric [9]. In fact at this stage it is safe to say that any effort to define the engineered fabrics will prove insufficient because the development in this sector is in neonatal stage.

3. How does an engineered fabric differ from technical fabrics?

Since decades of years technical textiles was widely used to explain the unconventional textiles which includes bunch of fibers, ropes, cabled yarns, woven and nonwoven fabrics, finished fabrics, stitched textiles, etc. The term technical textiles is used to encompass all textile products other than those intended for apparel, household and furnishing end-uses, however, the term "engineered fabrics" is limited to various woven, nonwoven, knitted and braided fabrics manufactured by some unorthodox manufacturing techniques for special engineering applications. Various fabrics engineered for specific applications like medical, hygiene, sporting, transportation, construction, agricultural and many other purposes [10].

Engineered fabrics are used to provide the base for filters, machine clothing, conveyor belts, abrasive substrates, geofabrics, fabrics for acoustic and thermal insulation, etc. It is essential to mention that the composite materials made of polymeric membrane as reinforcing material with matrices, highly loose structured materials such as chopped strand mat, milled glass and pulped organic fibers cannot become the part of engineering fabrics [11].

4. Suitable raw material for engineered fabrics

Various natural fibers have enough potential to become the part of engineered fabrics. The major natural fibers have been used as basic material in engineered fabrics is cotton, flax, jute and sisal. These fiber are used to manufacture various heavy engineered fabrics like canvas, needle punched nonwoven fabrics for geo applications, ropes, belts and other multilayer fabrics, etc. [12]. However, some limitations of these fibers restricted the growth in engineered fabrics in which higher rigidity, prone to fungal and microbial attack; poor water resistance and lower flame retardancy are remarkable. Jute is cheaply available fiber which has ample potential to be used in engineered fabrics in gray and treated form. Sisal fiber is suitable material for ropes, nets and twines manufacturing [13].

Wool is another natural option with merits of higher limiting oxygen index value, thermal insulation but its limited availability and versatility has restricted its applications in engineered fabrics [14]. Silk fiber is another rare option for engineered fabrics due to its low availability and higher cost [15].

4.1. Regenerated fibers

First commercially manufactured manmade fiber developed 1905–1910, is still suitable material for manufacturing engineered fabrics like tyre cords, preforms for conveyer belts and hoses, etc. Some other regenerated fibers like acetate rayon and cuprammonium rayon also have found its place in engineered fabrics [16].

4.2. Synthetic fibers

4.2.1. Polyolefins

Polyethylene (PE) and polypropylene (PP) are two major fibers of this group which have registered its valuable presence in the manufacturing of engineered fabrics. Low density, easy manufacturing techniques, high moisture and abrasion resistance have secured its rapid growth in engineered fabrics. The major engineered fabrics made of these fibers are used to manufacture bags, carpet bases, furniture linings, sacks, nets and other marine textiles. PP Fiber has good wicking with poor moisture absorption potential and this characteristic make this fiber appropriate for use in engineering of high performance diapers. The PP fiber has low spinning temperature (210–220°C) have proved ideally suited material for meltblowing and spun bonding techniques to manufacture engineered nonwoven structures quickly [17].

4.2.2. Polyamide

Polyamide fiber group containing various nylon fibers like nylon 6, nylon 66, nylon 6.10, etc. have good abrasion resistance, high strength, remarkable elasticity and excellent impact absorbing potential proved very useful in manufacturing various engineered items like parachute fabrics, spinnaker sails, reinforced tyres and geofabrics for high performance road construction. Western Europe and North America are more strongly inclined towards nylon 66 while Asia and Eastern Europe produce predominantly nylon 6 [18].

4.2.3. Polyester

Polyester is low cost fiber with plenty of merits like high abrasion resistance, high strength, low moisture regain and excellent uniformity. Recycled polyester fiber is another cost effective alternative fiber for manufacturing of engineered fabrics like spun bonded structures, needle punched structures, etc. [19]. A modified polyester fiber is used widely in manufacturing of flame retardant fabrics, waterproof breathable fabrics and canvas fabrics.

4.2.4. Glass and ceramics

Glass fiber was very difficult handle for many years, been one of the most underutilized fibers. This fiber is used in various engineered nonwoven structures to be considered as a cheap insulating material and reinforcement preforms for relatively low performance composites like fiber glass and heat-resistant materials. The applications of glass fiber increasing day by day in the form of engineered structures for sealing materials, rubber reinforcement, as well as filtration, protective clothing, packaging metal body parts and components [20]. Some ceramic fibers have found limited applications in engineered structures due its high cost and poor bending performance.

4.2.5. High performance fibers

4.2.5.1. Poly(amide-imide) fibers

Successful polyamide-imide fiber was produced by Rhone-Poulenc Inc. with a trade name of Kermel. The limiting oxygen index (LOI) of Kermel fiber is 32. It remains safe without any degradation up to 250°C for a exposure of 500 h to heat. This fiber does not have melting temperature Tm but is carbonize. Kermel fiber can be blend successfully with other commercial fibers like viscose and polyester. A wide variety of engineered fabrics with Kermel fiber can be produced for air forces, army, navy and firefighter dresses [21].

4.2.5.2. Polybenzimidazole (PBI) fibers

The PBI fiber was invented by Celanese Inc. This fiber is highly stable at 300–350°C. Its limiting oxygen index (LOI) value is 41, which is quite safe and higher than threshold value 25. This fiber offer equal heat protection to asbestos with half density. It has moisture regain. The PBI fiber based engineered fabrics are used as reinforcing material to produce fire protection in aircraft seats, firefighter suits and racing-car driver suits. It found its smart applications in in rocket motors and boosters to provide safety against ignition [22]. The engineered fabrics made of PBI fibers offer excellent resistant to puncturing, tearing and ripping.

4.2.5.3. Phenolic or novoloid fibers

Phenolic or novoloid fibers fiber is manufactured by spinning and postcuring of phenol formaldehyde resin precondensate. Kynol is a well-established novoloid heat-resistant fiber of GUN EI chemical industry. Kynol fiber is golden in color, soft feel with moisture regain of 6%. It slowly carbonized at very high temperature without any smoke. It has poor strength and abrasion resistance which suppresses it application in apparel sector. It can be easily blended with aramid fibers like nomex to make it suitable for flame retardant apparel applications. Philene is another important fiber member of this group with moisture regain of 7.3% and LOI 39% [23].

4.2.5.4. Modacrylic

The modacrylic fiber still has first choice of manufacturers to engineer flame-retardant fabrics. Modacrylic fibers are produced under various commercial names, such as SEF (Solutia Inc.), Velicren FR (Montefibre, Italy), Elura (Monsanto Fibers), Dynel (Union Carbide) and Verel (Tennessee Eastman). Modacrylic fiber and is a copolymer of acrylonitrile, vinyl chloride or vinylidene chloride in the ratio of 60:40 (w/w) along with a sulfonated vinyl monomer. Modacrylic fiber has LOI in the range of 26–31%. Kaneka Corporation has also developed Kanecaron, an FR modacrylic with an LOI value in the range of 30–35%. Fabrics from Kanecaron with commercial name of Protex M has LOI 33% blended with cotton, while maintaining the softness and comfort similar to cotton fabric.

5. Engineered fabrics

Engineered fabrics are textile materials manufactured primarily for technical and functional performances. Most of the engineered fabrics are manufactured by assembly of fibers, yarns and/or strips of material which have a very high surface area in comparison to their thickness and have sufficient mechanical strength. Engineered fabrics are commonly manufactured by weaving, knitting, felting, lace making, nonwoven processes, net making and tufting or a combination of these processes. Most of the engineered fabrics are two dimensional structures but recently three-dimensional structures have become very popular structure in this segment. The knitted structure consist one set of thread, woven consist two set of threads in the form of warp and weft but three-dimensional structure consist three set of threads: warp, weft and stuffer thread.

5.1. Weave structures

The two dimension engineered fabrics consists various weaves in which plain and leno weaves are widely used. There are some others weaves which can be proved functionality in engineered fabrics. All threads do not follow the straight path in woven structures and consist a crimp [24].

5.1.1. Plain weave and derivatives

The simplest weave to manufacture engineered fabrics is plain weave which is produced by alternatively lifting and lowering one warp thread across one weft thread. The performance of engineered fabrics has plain weave will depend type of fiber used: either staple or filament, type of yarn: flat, textured and twisted, yarn linear density and fabric set. The bending rigidity of engineered fabrics depends on the stiffness of the raw materials used and by the twist factor of the yarn and thread density in woven fabric [25]. Amount of twist in constituent yarns of engineered fabrics is used to impart specific features like extensibility, surface roughness and texture, etc. By changing the areal density (fabric grams per square meter, GSM) and cover factor affect the abrasion resistance, dimensional stability, filtration potential, porosity, stiffness, strength and thickness of engineered fabrics can be altered [26]. Square sett plain woven fabrics that are fabrics have nearly the constant number of ends and picks per unit space and warp and weft yarns of the same linear densities are produced with similar cover factors. Light weight plain woven fabrics with lower areal density and low cover factor with open weave construction are used as bandages and cheese cloths while highly open cloths are used in geotextile stabilization fabrics and heavy closely woven fabrics include cotton awnings.

Plain weave can be modified in the form of Rib and Matt weave. These weaves are produced when two or more than two adjoining warp or weft threads are considered as one unit and lifts or downs simultaneously. These weaves gives a higher cover factor, without jamming the weave structure [27].

Simple matt (or hopsack) woven fabrics offer a similar texture to plain woven fabric. The simplest matt weave is a 2/2 matt where two warp ends are lifted over two picks (unit of two warps and two weft act as a unit in plain weave). The unit of lifting threads can be increased to 3 or 4 to create 3/3 or 4/4 matt weave structures.

Some typical matt weaves, like a 4/2 matt, are produced to obtain special engineered effects.

Plain weave can be modified in another way in which either the ends or picks keeps more with higher crimp is called rib structure. If the number of ends is more than picks per unit length with high warp crimp, it is called as warp rib and vice versa for weft rib fabrics [28].

5.1.2. Triaxial weaves

Almost all two-dimensional woven structures have been developed from plain weave fabrics in which warp and weft yarns are interlaced at 90° or at nearly 90°. The triaxial fabrics are the only exception, where two sets of warp yarns are generally inserted at 60° to the weft. In case of tetra-axial fabrics, four sets of yarns are inserted at 45° to each other. Triaxial fabrics are manufacturing on commercial machines. The first triaxial weaving machines were developed by the Barber Colman Co. and further developed by Howa Machinery Ltd., Japan. Triaxial fabrics can be defined as set of threads where the three sets of threads form a multitude of equilateral triangles in which two sets of warp yarn are interlaced at 60° with each other and with the weft. The tearing and bursting strength of triaxial fabrics is remarkable higher than conventional fabrics. The shear rigidity of triaxial fabrics remains superior due to locked intersection points. Triaxial woven engineered fabrics have found a wide range of technical applications in, balloon fabrics, pressure receptacles, sailcloths, tyre fabrics and laminated structures [29].

5.1.3. Three-dimensional woven engineered fabrics

Three-dimensional woven engineered fabrics are produced to enhance the strength, thickness, extensibility, porosity and durability in woven engineered fabrics.

The performance of 3D woven fabrics can be engineered by making some alteration in weave used, the thread spacing, raw materials structure (filament or staple), linear density (or count) and twist factors of the warp and weft yarns. There are countless possibilities in 3D woven engineered fabrics to manufacture engineered fabrics of desired properties [5].

Engineered fabrics manufacturing processes: the essential operations in the weaving of a cloth are:

- Shedding, i.e. the separation of the warp threads into two (or more) sheets according to a pattern to allow for weft insertion
- Weft insertion (picking)
- Beating-up, i.e. forcing the pick, which has been inserted into the shed, up to the fell of the cloth (line where the cloth terminates after the previous pick has been inserted).

Secondary motions are incorporated to make the provision for the supply of warp and weft warp yarns and for the cloth. The warp yarn is usually supplied from warp beam(s) and the weft yarn from the pirn on shuttle looms only or cones on shuttles looms. Most of the single phase weaving machines uses same kind of motions and an almost horizontal warp sheet between the back rest and the front rest. Such kind of system is utilized in common shuttle looms, rapier looms, projectile looms, air jet looms and water jet looms [30].

6. Engineered fabrics by nonwoven fabric manufacturing

It is difficult to define the nonwoven fabrics because country wise definitions of nonwoven are available which have very poor coherence with other. However the most acceptable definition was coined by the American Society for Testing Materials (ASTM D 1117-80). Although this definition solved the limited purposes to define the nonwoven. The nonwoven fabrics can be redefine as “A nonwoven textile structure can be produced by bonding, interlocking, intermingling, pressing of textile fibers or in combination by means of mechanical, chemical or thermal techniques and their combinations by shortening of conventional fabric manufacturing processes” . The nonwoven fabric manufacturing can be divided into two sections. The first section is dedicated for fiber web manufacturing and second section for bonding or interlocking of constituent fibers, the layering of various webs one over another in various fashions which decides the nonwoven structure properties up to major extent is called batt. The batt is subjected to bonding or interlocking process for final product manufacturing [31].

7. Batt production by carding machines

The main objective of carding process is individualization of fibers after removing short fibers up to some extent but the carding machines for nonwoven batt production have some modifications like two cylinders in place of one in conventional cards. In case of nonwoven engineered fabric production carding process is nearly final process because after carding the chances of fiber blending goes to zero. Generally short-staple revolving flat cards are most suitable for nonwoven industry due to its high opening potential with high production rate. These cards are equipped with autoleveller facility to improve the uniformity in mass per unit length of web. The card web has very low web density and high degree of variation in mass per unit length which is not suitable to be used directly in a nonwoven. There are three main way to lay the web during batt formation: parallel laying, cross laying and bias laying [32].

7.1. Parallel laying

The parallel laying is the basic, cheapest and simplest way of batt formation. In this system numbers of cards are situated one above another or side by side slightly above the main conveyor belt. The webs from each card came down onto the batt forming conveyor lattice with number of times (number equals to the card numbers) the mass per unit area. The card webs are turned through a right angle with the help of a guide which turns the web at 45°. These techniques provide maximum number of fiber lying along the batt direction which is called machine direction and very few remains across the batt direction. This type of web can be converted to engineered nonwoven fabric by opting anyone way of either bonding or entanglement. The strength of bond in parallel laid nonwoven remains less than individual fiber strength. The parallel laying process suits to manufacture narrow tapes and medical textiles while cross laying suits to filter and wipe fabrics. However randomized doffer cards neutralize the situation up to major extent by distributing the fibers randomly together with 'scrambling rollers'. Both parallel laid and cross laid laying shows anisotropic behavior, however by combining both parallel laying and cross laying isotropic nonwoven structures are engineered.

The final width of nonwoven engineered structure is a challenge and it can be overcome by combining various laying techniques [32].

7.2. Cross laying

In order to result cross laying of webs to form batt, the cards are kept at right angles to the main conveyor lattice M and the card web is moved backwards and forwards across the main moving conveyor lattice.

The speed of main conveyor lattice is kept slow to accommodate many layers of card web in desired order. The cross laying systems suffers with two major problems; first, this system prone to form heavier batt at the edge due to overlapping. This issue can be solved by moving the of direction of batt at the edge of lattice. The second is to match the input speed of cross laying with card web speed. Generally input speed remains less and card web speed must reduce to match with input speed.

7.3. Wet laying

This technique of batt formation is influenced by paper making industry. The fibers are dispersed into water and water content is kept sufficient to prevent fiber aggregation. This system promotes the blending of fibers and laying them successfully. Wood pulps can also be blended with fibers to form the batt. This system is suitable to the batt of wooden pulp and fibers used in sanitary napkin manufacturing. The wet-laid batt is used in some other disposable engineered products like drapes, gowns, sometimes as sheets, as one-use filters, and as coverstock in disposable nappies [33].

7.4. Spun laying

This technique of batt formation offers shortest route. This includes extrusion of the filaments from extruder, drawing the filaments and laying them in the form of batt. At the same time bonding also takes place which makes this process very economic from polymer to fabric manufacturing cost point of view. Initially, this process was developed for large scale production but at present small size machines are available to cater the need of small scale manufacturers. Initially polyester and polypropylene fibers were spun-laid but presently polyamide and polyethylene fibers can also be processed on this system. The microfiber technology also integrated with this system which enhanced the versatility to produce finer, softer and better filtration engineered fabric structures. The process starts from feeding of polymer chips into extruder which feeds the molten mass of polymer to a metering pump and then to a group of spinnerets which quenched further for quick solidification. The drawing process is assisted by hot air blowing in this system. The fiber orientation is controlled by both the direction of filament delivery tube and conveyor belt to assure uniform distribution of fibers [34].

7.5. Air laying

The air-laying system is capable to offer the desired batt in single stroke at high speed without first making lighter weight web and then by laying. The fiber opening potential of this system is limited and needs ample pre-opening before feed to air laying system. This system consist opening and blending section in back of feed hopper which is used to deliver fiber sheet to the feed rollers. The fibers are then taking-off by consist fine wire metallic clothing on its surface, revolves at high speed. Some optional stripping rollers may attach to enhance the opening potential of the system. The opened fibers are removed by powerful air stream from opening cylinder surface. The air stream carries the fibers to cage like conveyor lattice to form the final batt [35].

7.6. Melt blown

The melt blowing process is another very promising method of manufacturing very fine deniers. This system produces fibers without the use of fine orifice spinnerets at high production rate. In this arrangement polymer is melted and extruded normally as other melt extrusion processes but through relatively large spinneret orifices. After complete melting, filtration, polymer melt extrude out from spinneret orifices it directly comes in the contact of very high temperature (above the melting temperature of polymer, Tm) hot air stream which assist in filament stretching up to maximum extent. The staple fibers of very fine deniers produced in this way are collected on the surface of permeable conveyor to form a batt as in air laying and spun laying.

Bonding is rarely required here and in most of the cases the melt-blown batt is laminated on another nonwoven structure (may be a spun-laid or the melt-blown batt). This type of laminated engineered fabric is used to engineer breathable protective clothing for use in agriculture hospitals and industry. These structures are useful as battery separators, industrial wipes and clothing interlinings with good insulation properties also. If melt blown layered structure is not bonded and directly collected as nonwoven batt then it is used as ultrafine filters for air conditioning and personal face masks, oil-spill absorbents and personal hygiene products. This technique is growing with 10% annual growth rate [36].

7.7. Chemical bonding

Chemical bonding is the process of sticking fibers of batt by treating/modifying either a specific area of batt or whole batt. A variety of bonding agents/adhesives are available in which acrylic latex, styrene butadiene lattices and vinyl acetate latex are the major one. The bonding agent must have ample wettability otherwise it can be maintained by adding appropriate amount of surfactants [37]. After judicious application of bonding agent, the batt is dried then to remove aqueous component and making proper bonding among the fibers of that localized region. Finally, the treated batt is cured at higher temperature to develop crosslinks both inside and between the polymer particles at 120–140°C for 2–4 min.

7.8. Thermal bonding

This technique of bonding is tagged as eco-friendly because the application of any kind of chemical is negligible. Productivity of thermal bonding process remains higher than any other chemical bonding process. Thermal bonding process is energy efficient also because it saves the energy which consumes to evaporate water from the binder and curing. Thermal bonding strategy can be divided into three classes like in first all of the fibers of same type with common melting behavior, second; a blend of fusible (lower melting point) and non-fusible (either the higher melting point or non-melting fibers) fibers and third; by application of bi-component fiber in which one component is fusible and other component is non-fusible. The temperature is applied at a localized area with or without pressure to melt the fusible fiber component and to stick with non-fusible fibers [38].

7.9. Spray bonding

In this technique latex binder is sprayed which act as bonding element to bind the fibers. There may be more number of spray cycles depending upon desired bonding extent and batt thickness because every spray cycle reduces the batt thickness up to some extent. These engineered fabrics can be used as raw material for hometech sector as quilt filling material, duvets and some typical type of filters [39].

7.10. Foam bonding

In order to reduce the application of water in various bonding techniques which not only enhances the cost of manufacturing due to essential drying but also the risk of binder migration, the foam bonding is better alternate in this direction. A definite amount of compressed air is passed through binder solution to create foam and then it applied on both side of batt with the help of horizontal nip of the impregnating roller. Foam consist limited amount of binder and negligible water content which suits for targeted application for bonding point of view.

7.11. Print bonding

This technique is used to apply the binder on one or both side of batt to limited portion and in a set pattern. In order to assure penetration of binder well inside the batt, it is first impregnated with water and then binder is printed on batt in defined pattern either a printing roller or a rotary screen printer. The ratio of printed/unprinted area decides the ultimate properties of final nonwoven engineered fabric. The limited application of binder in print bonded fabric keeps fabric soft and pleasant feel. Print pattern and print content decides on the basis of type of fiber, fiber orientation and other properties of fibers used in the batt. Print-bonded fabrics have found its application in disposable/protective clothing, coverstock and wiping cloths.

7.12. Powder bonding

Powder bonding technique is based on the application of thermoplastic powders alternate to thermoplastic fibers. Rest processes remain similar to thermobonding. The powder bonded engineered fabrics show better flexibility and softness with poor bonding strength. These structures are used in protective apparel and coverstock areas where high bulk is desired.

8. Engineered fabrics by fiber entanglements

There are three methods of producing engineered fabric by fiber entanglements; needle punch, hydroentanglement and stitch bonding. These three methods are based on fiber entanglements and frictional behavior of fibers and conceptually known as mechanical bonding. Out of these three techniques needle punch is most popular and simplest one [40].

8.1. Needle punching

The concept of needle punching is quite clear and simple. In this method the batt is passes between two stationary plates, the bed and stripper plates. While between the plates the batt is penetrated. The needle density remains up to about 4000 m^{-1} width of the loom. The design of penetrating needle plays major role in fiber entanglement. Needles are generally made triangular in shape and have barbs cut into the three. As the needle goes down into the batt the barbs traps some fibers and pull them through the other fibers to get it entangled.

When the needles return back in upward direction, the fiber loops formed during downward movement of needles tend to remain in position, because they are released by the barbs. This downward penetration of needles takes place repeatedly which makes the batt much denser and finally needle punched structure manufactured [41].

8.2. Hydroentanglement

The hydroentanglement process of engineered fabrics manufacturing was developed by DuPont in 1960. This process is quite similar to needle punch process. This technique is used to entangle the fibers of lightweight batt. In this process very fine nozzles are used to inject the water in the form of fine water streams or droplets. Number of fine nozzles is situated at the edges of batt. The water stream passes through the perforated screen to remove the used water. The fiber which come in the contact of water get wetted and its total momentum goes compare to other fibers and these fibers get entangles with other fibers of the batt. Water cleanliness, pH and temperature are critical issues to be taken care during the manufacturing. This process is capable to produce engineered fabrics for wipes, surgical gowns, disposable protective clothing and backing fabrics for coating applications [42].

9. Engineered fabric manufacturing by weaving

Weaving is most popular promising technique of engineered fabric manufacturing. Presently shuttle looms are obsolete and out of the international manufacturing scene.

9.1. Rapier looms for engineered fabrics manufacturing

Rapier was the first concept that successfully replaced the shuttle weft insertion system. First generation of Rapier looms did not get commercial acceptance due to its very low speed. With the invention and introduction of precision engineering and microprocessor controls, the weft insertion rates have increased remarkably.

The Rapier loom of 2.5 m width has close competition with projectile loom. The single rapier looms are rigid rapier slow speed looms. However, the invention of double rapier has increased the commercial acceptability because wide variety of threads can be processed on these looms. Both rapier enter from both extreme end of reed and meet at the middle of cloth width to transfer the weft thread from one rapier to other rapier. Rapier looms have two weft insertion systems; one is Gabler and other is Dewas system. In case of Gabler weft insertion system weft is inserted alternately from both sides of the machine [43].

The weft thread is cut every second pick with hairpin selvedges being formed alternately on both selvedges but weft is inserted from one end of rapier loom in Dewas system. Dewas system is dominating now a days and most of the looms has weft feeding system on one side. Double rapier weaving machines may have either the rigid or flexible rapiers. Dornier HTV and P19 series Rapier looms are capable of weaving most of the industrial fabrics with weft linear densities of up to 3000 tex, in loom widths of up to 4600 mm and at weft insertion rates of up to 1000 m min^{-1}. Rapier looms are used widely to manufacture wide range of engineered fabrics starts from opencoated geotextile mesh, heavy conveyor belt cloths, home textiles, and canvas and furnishing items. Rapier looms are most suitable weaving machines to carry and run Jacquard shedding device.

9.2. Projectile looms

The first projectile weaving machine was based on single projectile which had provision to strike the projectile from each side of the loom. This machine had weft supply system from both side of the loom. The latest projectile looms have multiple projectiles which are stroked from one side and are returned back to the picking position with the help of a conveyor belt. The contribution of Sulzer Textile to develop projectile loom and enhanced its versatility in terms of improved weft insertion rates, machine efficiency and extended the range of fabrics manufactured is unforgettable. Projectile loom offers facility to use a winding cone directly without rewinding which saves cost and time both. The length of standard projectile is 90 mm with 40 g weight. The weft thread is withdrawn from weft supply cone through a weft brake and a weft tensioning device to the weft feeder which places it into the gripper of the projectile [44].

A torsion rod system is used for picking which transfers the maximum possible strain-energy to the projectile before it leaves the picker shoe. The strain energy can be adjusted by changing the position of torsion bar. Sulzer Textil redesigned the reed of projectile loom which offer more effective and strong beat-up. A weft insertion speed of 1300 m min^{-1} can be achieved on 3600 mm reed width machine. Latest projectile looms are capable to insert six color weft threads, fancy threads and wide variety of material from fine polyester to coarse woolen threads successfully. The machines can be equipped with a variety of shedding mechanism like dobby and jacquard. Machine performance can be monitored with microprocessors. Sulzer Ruti and Jäger are two major manufactures of projectile loom. Jäger have developed a hydraulically propelled projectile loom. Projectile looms are capable to weave wide variety of engineered fabrics of up to 8 m width, for awnings, airbags, conveyor belts, geotextiles, sailcloth, tyre cord fabrics, and a wide variety of filter fabrics of varying area density and air permeability.

9.3. Air-jet loom

The major aim of product development in woven fabric is to engineer new fabric structures having the most appropriate properties to achieve a high level of performance with suitable quality. In air jet loom weft thread is accelerated and passes through the shed by the flow impedance between the flowing compressed air and the weft. The energy creating from compressed air supplied from the compressed air tank to the air-nozzles reserves the kinetic energy in the nozzle, which accelerates and passes the weft through the shed. The compressed air leaving the nozzle combines with atmospheric air, it disperses, and the axial speed of compressed air drops quickly as it moves away from the nozzle. Therefore, in order to achieve wider loom width on air-jet loom, the compressed air speed must be maintained up to carry the weft thread. Three different systems have been adopted by commercial air jet loom manufacturers: single nozzle with confusor guides, multiple nozzles with guides and multiple (relay) nozzles with tunnel reed. Multiphase weaving machines have also adopted air-jet weaving concept. At present, the air-jet looms are very versatile and capable to process wide variety of weft threads. Hence, it become most suitable machine for engineered fabric manufacturing with weft insertion speed of 1000–2500 m min^{-1} [45].

10. Challenges and barriers

Designing and promotion of engineered fabrics is remarkable challenge in this sector. The conclusions can be arranged under following points:

- Protectionist policies of some countries are creating big hurdles in free flow of investment, technology and engineered fabrics products
- Lack of automation and dependency on conventional fabric manufacturing machineries
- Lack of skilled worker
- Lack of promotion of engineered fabrics
- There are enough potential of growth in engineered fabrics because the areas of applications are countless
- Engineered fabrics have found its place from inside the earth, deep under sea to high in the sky.

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