



CHAPTER II

LITERATURE SURVEY

The Use of Silk and Other Natural Fibers in Nonwovens

There have been many publications surveying nonwoven fabrics made from natural fibers and their waste, mostly cottons and their uses, and an extensive patient literatures, but little quantitative information on silk and its waste has been published. Almost the only exceptions to this are a study on nonwoven fabric production using waste silk of Ananthakrishnan et al. in 1992, and a study of possibility in utilization of waste silk for nonwoven in Thailand by Wongwiboonporn, Pattanathabutr, and Tanakornnuwatn in 1992.

Ananthakrishnan and others (1992) carried out a production of nonwoven fabrics using traditional waste silk processed on a nontraditional technique like needlepunched nonwoven fabric forming. Noil waste used for manufacture of coarse noil yarns and degummed reeling waste were cut into staples of 33-35 mm length. The waste was sandwiched by polypropylene staples of 33-35 mm. Laying and mixing were carried out by hand as volume involved was quite low. Bale opener was used to pre-open the stock, and then followed by a fine opener. material delivered from fine opener was fed through a feeder box to roller and cleaner card, having three cylinder in tandem. Then the delivered webs were crop laid using cross lappers on

conveyor lattice, and fed to needlepunching process. The weight of web was adjusted by laying 15 layers on conveyor lattice. The waste silk polypropylene blanket were tested for certain physical and functional properties, and compared for its merit against commercial variety polyester blanket and could be shown by Table 2.1 :

Table 2.1 Physical properties of the waste silk propylene blanket compared to the commercial polyester blanket (Ananthakrishnan et al., 1992).

Characteristics	Waste silk propylene blanket	Commercial polyester blanket
1. Thickness, 10^2 mm	157	329
2. Weight, gm^{-2}	212	346
3. Specific weight, kgm^{-3}	135	105
4. Tensile strength, N (Specific strength)		
25.0 % extension	333 (1.57)	93 (0.27)
37.5 % - do -	542 (2.56)	249 (0.72)
50.0 % - do -	753 (3.55)	548 (1.58)
62.5 % - do -	818 (3.86)	1000 (2.89)
5. Abrasion resistance (%loss in weight per 1000 cycles)	3.5	3.4
6. Flexural rigidity, g	1.907	4.652
7. Bending modulus, kgcm^{-2}	5913	1567
8. Air permeability, $\text{cm}^3 \text{s}^{-1} \text{cm}^2 \times 10^{-4}$	31	24

They concluded that the product has shown diversified usage like blanket and cover fabrics. The waste silk can be produced at lower thickness with higher rigidity. Till 50% extension, the strength of silk propylene blend is more than that of polyester blanket, indicating that at least 50% polypropylene blend is built to a better cohesion in the fabric. Furthermore, the lower flexural rigidity of silk propylene blanket indicated the easy bending, a desirable feature for blanket. At the same time, the higher bending modulus goes in favour for the developed product, ensuring longer wear life. The most important requirement, namely the air permeability and moisture vapour transmission both is high for silk propylene blanket thus improving the breathability of the fabric offers better comfort.

They also found that nonwovens from waste silk could be effectively produced by the needlepunching technique. However, the needlepunching technique was limited for the production of this nonwoven fabrics. Generally, products made by this better drape and much higher extension, but lower tensile and bursting strengths, stiffness and resistance to deformation (Ozsanlav, 1994). A recently initiated project at the Southern Region Research Center worked by Moreau in 1990, subjected to investigate the cotton-containing nonwoven textiles with properties acceptable for consumer uses. Thermalbonding was selected as the technique for consolidating fabrics. Ozsanlav stated that it was the major technique used by the industry to produce coverstock, the most widely used disposable nonwoven fabrics. In an initial trial run, two cotton and polypropylene (C/PP) blends were prepared and the properties compared with a 100% polypropylene fabric. Table 2.2 indicated, the properties of cotton fabrics related to synthetic fibers are the same for nonwoven fabrics as they are for woven fabrics.

Table 2.2 Physical properties of cotton nonwoven fabrics at optimum bonding temperature, machine direction except as indicated (Moreau, 1990).

Properties	100%	50/50	75/25
	PP	C/PP	C/PP
Breaking strength, N	48.5	20.0	14.2
Cross direction	7.6	5.8	1.8
Elongation, %	79.8	28.7	17.0
Abrasion, cycles	165	118	34
Cross direction tear strength, mN	1569	1442	981
Bursting strength, kPa	84.8	73.8	43.4
Stiffness, Nm x 10 ⁻⁵	5.8	7.6	4.3
Air permeability, cm ³ s ⁻¹ cm ⁻²	182	132	133
Wicking time, s			
To 2 cm	9	9	6
To 3 cm	21	16	16

Schmalz and Böttcher (1994) studied in the stitch-knit nonwovens made from natural fibers, and gave the reason why there is growing interest in the use of natural fibers amongst product manufacturers, converters and users, namely environmental awareness, available at low cost, and significant raw material resources in many countries. It is therefore not surprising that aspects of ecological use and waste disposal were prominent in almost all papers. These ecological debates relate to avoidance and minimisation of pollution, recycling and energy recovery, and waste dumping. It is also important to improve the machinery suitable to produce a nonwoven from waste.

Wongwiboonporn, Pattanathabutr and Tanakornnuwatn (1992) studied in the utilization of waste silk for nonwoven product by using parallel-laid carding process and thermalbonding technique. Waste silk was blended with bicomponent polyolefin fibers used as binder fibers. The content of binder fibers and areal densities of the products were varied. It was found that the moisture regain of the prepared samples decreased as blending percentages increased. Lack of good carding machine and thermalbonding machine resulted in deficient correlation between binder percentages and mechanical properties.

Further studies were reported by Atsawahem and Wiraset in 1993. They surveyed the disposable underwear products available in Thailand's market. Sontara of Dupont, U.S.A. and Skawol which was made in Thailand, were collected. The mechanical and physical properties of the available products were compared with the nonwoven products made from waste silk produced by Wongwiboonporn and others. They found that the available underwear products had better mechanical properties than the waste silk products. This must have been because the available products composed of synthetic fibers, i.e., polyester in Sontara and cupramonium rayon in Skawol. In any case, tearing strength of the waste silk products brought close together with Sontara products for comparison, but Skawol had rather lower values.

Nowadays, all sectors of the textile industries are becoming more ecologically aware. Producers of technical textiles are beginning to be concerned with the eco-labelling, with the first trends becoming apparent in sportswear, protective clothing and disposable products. Lennox-Kerr said that there was a clear trend

towards creating new materials which are either biodegradable or which may be recycled (quoted in Fisher, 1994). Silk fibers have both of these desirable characteristics.

Few now doubt the exciting properties of natural fibers and their potential in certain technical applications. However, the basic hurdle is that those in industry do not trust agriculture, given its dependence on short-term political decisions. Probably more than price, continuity and consistency of supply will be the main preconditions for the increased use of natural fibers in technical products.

Nonwoven Fabric Manufacture

Nonwovens are defined by the American Society for Testing and Materials as fabrics constructed of fibers held together "by bonding or the interlocking of fibers or both, accomplished by mechanical, chemical, thermal, or solvent means, and the combination thereof" (ASTM D123-91a, 1991).

1. Methods of Manufacture

The processing and manufacture of nonwoven fabrics vary with the fibers, methods of laying the fibers, and the bonding agents used.

1.1 Fiber Description Considerations. In selecting fiber for use in nonwoven fabrics the fiber description, i.e., the crimp, length, denier per filament, and finish, is fully as important as the type of fiber.

1.1.1 Type. The fiber include cotton, wool, rayon, acetate, nylon, polyester, acrylic, modacrylic, polypropylene and polyethylene. A combination of fibers may be employed. It may be noted that the requirements for fibers length, uniformity and so on may be less stringent in the production of some nonwoven fabrics than they are in the spinning yarns. Consequently, it is often possible to use second-quality or waste fibers; the latter may be short fibers removed during processed or fibers recovered from rags (Cusick et al., 1963). This comment applies particularly to the cheaper uses. High-quality nonwoven fabrics are made from first-grade virgin fiber.

1.1.2 Crimp. It is impossible with most equipment to produce a nonwoven fabric from a completely straight staple fibers. The natural fiber have varying amounts of natural crimp, and just as the cut filament must be crimped for spinning, a crimp is necessary for formation of a manageable web for nonwoven production. Curly fibers are better than straight, and usually the curlier the better. Highly crimped fiber tend to form a more uniform mat which will retain its original structure during subsequent processing. In the man-made fiber, a "sawtooth" crimp with a frequency of 5 to 11 "teeth" per inch is commonly available. A given weight per area of fabric made from highly crimped fiber will be more opaque than that made from slightly crimped fiber and have many of the qualities of a heavier fabric (Buresh, 1962).

1.1.3 Denier. The choice of denier per filament for fiber used in nonwovens is governed primarily by the requirements of the end products. The use of finer fiber results in greater density, strength and softness, and at the same time

produces a more opaque sheet. Generally, the man-made fibers are 1.5 to 6 denier; however, for some specialized surgical and industrial purposes, the range may be from about 5 microdenier to 10 denier (Bernard, 1985). Nonwovens for cushioning and paddings require about 25 to 40 denier fiber for a resilience equivalent to that of animal hair (Buresh, 1962). Heavier deniers are easier to open for production of a uniform web at higher speeds than fine deniers.

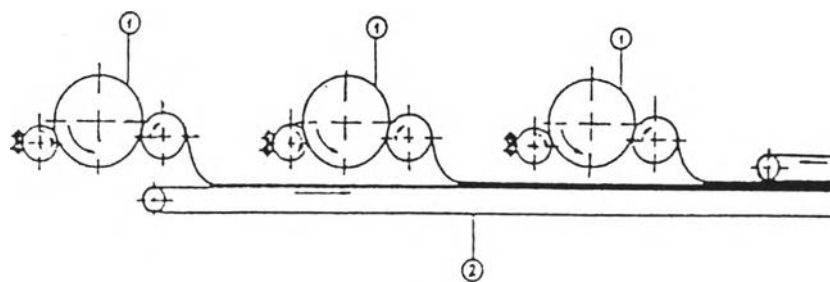
1.1.4 Length. The staple length of fiber to be used in nonwoven production depends upon the type of web-forming equipment selected for the production line. In most cases longer fibers can be used in cards and garnetts better than in air-laid machines, but there is no advantage in fabric strength derived from the longer fiber (Buresh, 1962). Generally, the staple, which is usually not waste, ranges from about 1/12 to 6 inches (2-150 mm) in length can be used (Bernard, 1985).

1.1.5 Blending. The blending of fibers of different properties and chemical nature is an important factor in the designing of many nonwovens. Economy, ease of processing, and desired combinations of chemical and physical properties may be the result of scientific blending of various fibers, deniers, lengths, and crimps. A great deal of research often goes into the formula for a satisfactory blend and result is usually a closely guarded secret of manufacturer. The exact fiber blend is a major factor in the performance and price of the end product. For example, an expensive synthetic used in a blend may give a fabric washability and fast drying characteristics while a carefully controlled amount of a much cheaper cellulose will facilitate binder pickup and at the same time bring down the cost. Although very low grade waste, very short staple recycled material or organic fibers such as asbestos can

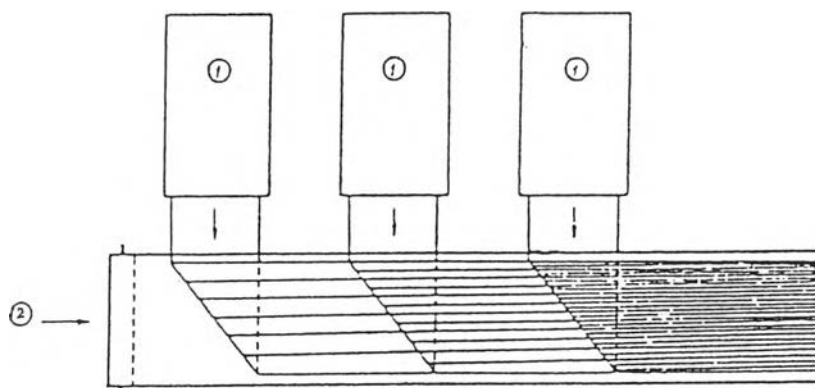
be successfully processed by blending with a good quality staple of 1 to 1 1/2 inches (Buresh, 1962). In addition, a blend may contain as many as five components although two or three are more common.

1.2 Web Formation. The fibers are processed through a series of opening, conditioning, and blending operations. In general, the more effective the opening of the fiber material has been, the better will be the nonwoven fabric produced. For cheap low-quality products, the raw stock will be used; but for high-quality products, the raw stock will be subjected to a longer sequence of opening machines, and the fibers may be carded before feeding to the web-forming machine. Conventional textile machine, such as cards and garnetts, may be used to make webs. The object of the carding process is to reduce the raw material to a state of the greatest possible subdivision, thereby exposing and removing the bits of trash and foreign matter enclosed by the unopened fiber aggregates, and form the cleaned, disentangled fibers into convenience form (Bogdan, 1965). But more important still is the necessity for ensuring a thorough mixing of all the fibers. However, a single card web is too fine to make a nonwoven fabric, so several particular techniques has been employed for uniformity of web.

1.2.1 Parallel-laid Web. Fibers are passed through carding machines that put them into parallel alignment. Thin webs of parallelized fibers, produced by successive machines and running in the direction, are laid on each other to form a multilayer web as shown in Figure 2.1. This technique produces a fabric which has high lengthwise strength but low crosswise strength. The fabrics in parallel-laid technique are used chiefly for disposable products.



(a) 1. cards 2. condensing conveyor



(b) 1. cards 2. condensing conveyor

Figure 2.1 Production of parallel-laid webs (Krcma, 1971),

(a) laying of webs coming from cards arranged in tandem

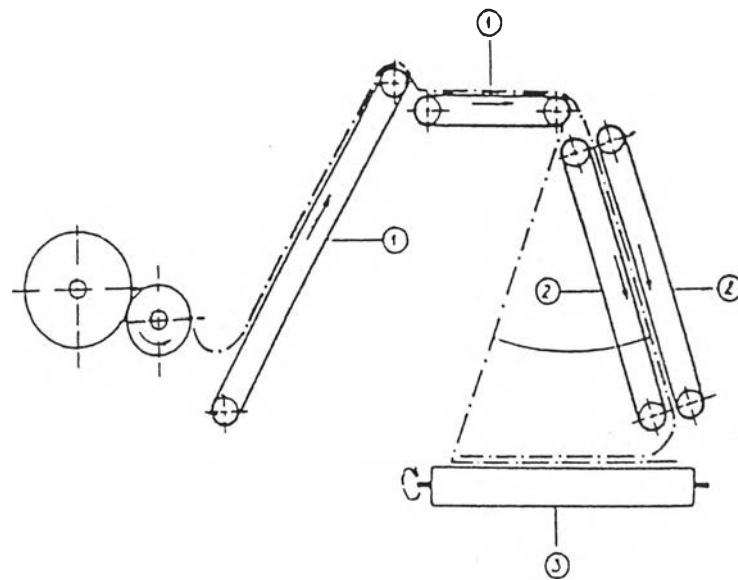
(b) laying of webs coming from cards arranged side by side

1.2.2 Cross-laid Web. After fibers are passed through a carding machine to form thin webs of parallelized fibers, the webs are crisscrossed successively on each other as shown in Figure 2.2. This technique is more costly to produce, but the fabric has greater crosswise strength than the parallel-laid web type.

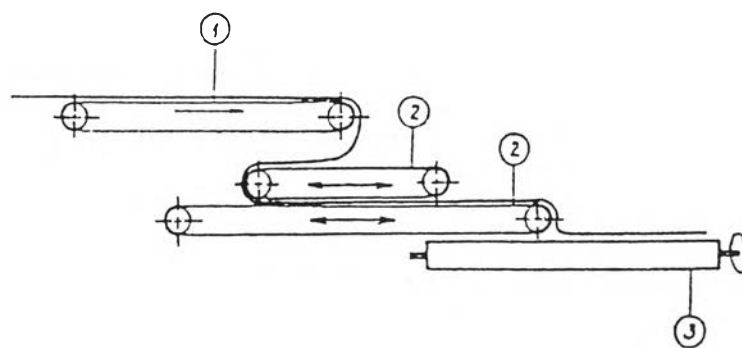
1.2.3 Random-laid Web. Loose fiber is blown onto a rotating, perforated drum. Internal vacuum causes the fibers to adhere to the drum, forming a heavy mat that is then passed to a licker-in, or rotating drum with teeth, which breaks up the web. These particles are blown onto a second vacuum drum, forming a highly uniform web of randomly placed fibers. The thickness of the web can be regulated as required. Fabrics from these random-laid webs have uniform weight.

1.2.4 Air-laid Web. Fibers from either a card, sliver, or tops are pulled by a high-velocity air stream into a collector which directs the fiber flow onto a moving screen. Fiber placement and orientation may be directed by vacuum controls and/or grid bar so that specific densities and patterns, such as stripes and snowflake designs, may be formed by the fibers.

1.2.5 Wet-laid Web. This method is based upon paper-making technique. Fibers are mixed with certain chemicals, processed through beaters and pulpers, and then passed onto a wire screen. The excess moisture is drawn off, leaving a web that is then compressed in a manner similar to other nonwoven fabrics.



- (a) 1. feed conveyor 2. swinging horizontal conveyors
3. delivery conveyor



- (b) 1. feed conveyor 2. swinging horizontal conveyors
3. delivery conveyor

Figure 2.2 Production of cross-laid webs (Krcma, 1971),

(a) web laying on a vertical web layer in a continuous production line

(b) web laying on a horizontal web layer in a continuous production line

1.3 Bonding the Web. There are several methods of bonding the fibers in the web to form fabrics. Because the method used and the particular binder applied affect the characteristics of the finished fabric, the intended use of the fabric must be anticipated.

1.3.1 Resin Bonding. If the fibers are absorbent, the web may be saturated with a suitable bonding agent either by spraying, printing, padding, or by immersing in a bath just before it is passed between two rollers that compress the web and squeeze out the excess liquid. The web is then dried and heat-cured at temperatures ranging from 200 to 400° F (93 - 204° C), depending upon the material used.

1.3.2 Latex Foam Bonding. Latex foams may be used for bonding fibers into nonwoven fabrics. The latex may be applied to web of fiber by pressure-spreading, spraying, rotary screening, roller dipping, or by spreading through perforated drum.

1.3.3 Thermalbonding. This technique was used for produced the fabric integrity of the waste silk web in this thesis. Three key components of thermalbonding are carrier or base fiber structure, heat-activated binder, and bonding process.

1.3.3.1 Carrier Fiber. Carrier fiber is the skeletal structure of the nonwoven fabric. It gives the fabric integrity, strength, surface coverage, and certain basic properties inherent in the polymer that make up the fiber. Usually, the

carrier fiber is homogeneous. Natural fibers, synthetic fibers, and mineral fibers are commonly used.

1.3.3.2 Heat-activated Binder. Binder for thermalbonding technique is thermoplastic materials that can come in many forms such as fiber, sheath-core bicomponent fiber, powder, film or hot melt. The physical form of the thermal binder affects its distribution throughout the fiber matrix (Hoyle, 1990). As a result, the choice of binder affects product properties just as much as the process used to thermally bond these materials. The amount of binder also plays a large part in determining the properties of the resultant nonwoven fabric. If the binder content approaches or exceeds 50% of the total blend, the product is a material that has the properties of a reinforced plastic. Conversely, at binder contents of 10%, the product is an open, bulky, porous material with some integrity but low strength (Hoyle, 1990).

1.3.3.3 Thermalbonding Processes. These are hot-roll calendering, belt calendering, through-air oven bonding, ultrasonic bonding, and radiant-heat bonding. These processes share two common features : (a) heat is applied, and (b) the binder's melting temperature is lower than that of the carrier fiber. All thermalbonding methods provide strong bond points which resist to hostile environments and to solvents. The advantages include greater process simplicity, reduced production cost, and improved fabric properties (Hoyle, 1990).

1.3.4 Spunbonding. A web of polymeric fibers may be deposited in a random manner onto a moving screen or belt by any one or a combination of methods and subsequently bonded by either a physical or chemical process.

The production is a continuous operation, going from fluid polymer to fabric.

1.3.5 Spunlaced Bonding. As an air-laid web of fiber is blown on a moving screen, extremely fine jets of fluid cause the fibers to entangle and adhere in a predetermined lacelike design. When the material dries, the firmly entangled fibers retain the pattern to provide a lacelike fabric.

1.3.6 Needlepunching. Nonwoven fabrics are also produced by inserting barbed needles in fiber webs as shown in Figure 2.3. As the needles penetrate the web, they force some fibers downward and thereby entangle them with the randomly laid horizontal fibers. As the needles then are pulled up, the entanglements increase, and the depth of penetration, as well as the kind of fiber used, determine the characteristics of the fabrics. Needlepunched fabrics may be reinforced with scrim or scrim impregnated with resin. This method was not suitable for the production of useful materials of less than 200 g/m^2 . Products made generally tend to have greater thickness and air permeability, better drape and much higher extension, but lower tensile and bursting strengths, stiffness and resistance to deformation than the others reported methods (Ozsanlav, 1994).

2. Characteristics of Nonwoven Fabrics

The particular set of properties that a nonwoven fabric may have is dependent upon the combination of factors in its production. The range of characteristics is wide. The appearance of nonwoven fabrics may be paperlike, feltlike, or similar to that of woven fabrics. They may have a soft, resilient hand, or

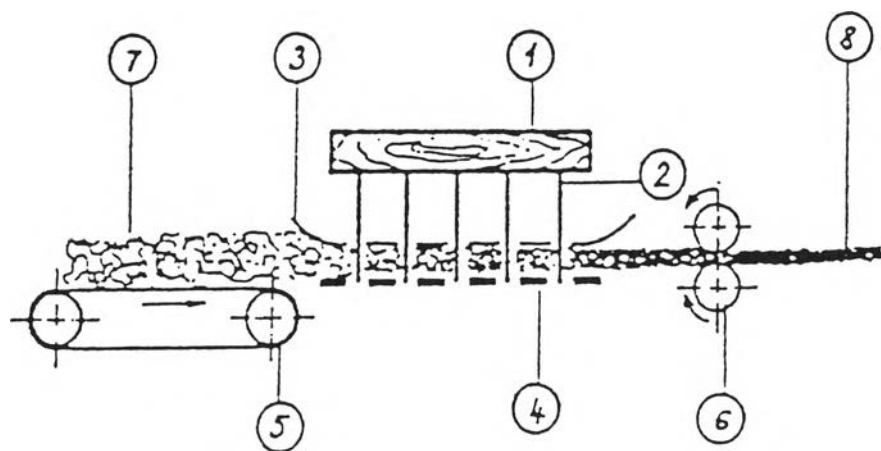


Figure 2.3 Basic arrangement of the main functional parts of a needle punching machine (Krcma, 1971).

- | | |
|--------------------|-----------------------------|
| 1. needle bar | 5. feed conveyor |
| 2. needle | 6. draw-off system |
| 3. stripping grid | 7. transferred web |
| 4. supporting grid | 8. delivered needled fabric |

they may be hard, stiff, or boardy with little pliability. They may be as thin as tissue paper, or many times thicker. Nonwovens may be translucent or opaque. Their porosity may range from high, free airflow to minute to impermeable. Their strength may range from low tear and burst strength to very high tensile strength. They can be fabricated by gluing, heat bonding, or sewing. The drapability of nonwovens varies from good to none at all. Some nonwovens have excellent launderability; others have none. Some may be dry-cleaned.

Nonwovens are engineered to provide particular properties suited to desired end uses. For example, diapers can be constructed of two different layers of nonwoven fabrics. An outer layer composed of a wetting agent treated polyester that will permit rapid fluid penetration, but with minimal lateral wicking, and an inner layer of absorbent rayon (Bernard, 1985). Thin, high-filtration nonwoven fabrics for surgical masks were composed of microdenier fibers. The thick, fluffy, insulating nonwovens for ski jackets can also be made of microdenier fibers. Many researches are continued in order to achieve or perhaps exceed certain properties of conventional constructed cloth.

3. Uses of Nonwoven Fabrics

There are many applications for which nonwoven fabrics are particularly suited. In general, nonwovens may be divided into two groups: durable products and disposable products.

Durable nonwovens have wide applications. These include apparel,

such as for caps, interlinings, and interfacings; home furnishings, such as for draperies, furniture upholstery, mattress padding, and carpet backing; industrial uses, such as filters, insulation, and roadbed stabilization sheeting.

Disposable nonwovens are essentially made for one-time use; but some, such as dust cloths, may be laundered and reused a few times. General application include diapers, sanitary napkins, surgical and industrial masks, medical and hospital wears, bandages, towels, and airline products, such as pillow case, wiping cloth, and many others.

Silk

Ever since its discovery about 7000 years ago by an empress in China, according to legend, silk has retained its fascination with its special charm right up to the present day. Silk is always the leading fabric in fashion collections. Its optical impression, handle and the classic draping of the fabric together with its physical and physiological properties make silk the highly cost material.

Silk is a protein fiber which is extruded as filaments by the glands of the larva of different species of moth. Two types of silkworm and silk are distinguished:

a) Bombyx Mori Silkworm or Cultivated Silk. It is a commercial silk produced by silkworm larvae which are cultivated in special roofed enclosures and fed with freshy mulberry leaves. Cultivated silk is fine, almost white (when degummed) and soft, with a soft luster. "Thai silk" also belongs to the bombyx mori

family, but it differs somewhat in appearance. Thai silk is characterized by coarser filaments and not least by the striated appearance of the fabrics, cause by manual processing, as compared with that of normal silk (Sandoz, 1988).

b) Wild Silkworm (Tussah) or Wild Silk. Tussah silkworms mostly live in the wild on bushes or trees, where they feed. Wild silk filaments are coarser, more irregular and beige-brownish in the nature state when comparing with cultivated silk.

Both types of silk consist of a tribular twin filament, the fibroin, and the sericin which is a gelatinous protein that cements the two fibroin filaments, and can be removed by degumming.

1. Silk Cultivation

Silk cultivation requires the careful breeding and nurturing of the *Bombyx mori* species of moth. The intensive labor requirements of sericulture, combined with the agriculture and harvesting of the mulberry leaves upon which the moth larvae feed, limit silk production to warm temperature regions in which cheap labor is available. China and Japan are the world's major sources of silk, although minor quantities come from India, Italy, Korea and Thailand (Smith, 1982).

The cultivated silkworm goes through four distinct stages in its life cycle: egg, larva to caterpillar, pupa or chrysalis, and moth. Each stage of the cycle is very carefully and scientifically controlled in the major silk production countries. The silk fiber is produced at the end of the larva cycle. The tiny larva imerges from the egg;

during the following period of 20 to 30 days, it eats mulberry leaves voraciously, sheds its outgrowth skin four times. After the final shedding, the caterpillar of silkworm consumes over twenty times its weight in ten days. Finally, it attaches itself to a convenience stick or piece of straw and commences to spin its silk cocoon.

The silk is produced in two glands which come together in one exit tube in the head of the worm, where a silk glue, sericin is also secreted to bond the silk strands together. Over a period of three days, the silkworm encases itself in a silk cocoon, and spins a continuous filament 400 to 700 metres long (Smith, 1982).

If allowed to emerge from the chrysalis in the normal life cycle, the moth would damage an end of the cocoon, so only those moths desired for reproduction are permitted to cut through the cocoon with the aid of a secretion from their bodies. Others are killed by heat, or are stored under freezing condition to keep the pupae dormant until the silk is to be unwound from the cocoons. Quite often two caterpillars working together produce a double cocoon, the silk from which is called "Dupion silk". It is difficult to unreel and varies much along its length, having thick and thin sports and knots. Dupion silk is used in making slub-textured fabrics.

2. Silk Processing

To unwind the silk filament, the cocoon are usually placed in warm water to soften the sericin, and the outside of cocoon is brushed to locate the end of the filament. Then one or two other filaments are placed together and given just enough twist to hold them. The sericin gum helps to hold the filaments together. This

process is known as "reeling". Great skill is required to handle the filaments without tangling or breaking them. Since the filaments become finer toward the center of the cocoon, as they are unwound, it is essential to start new cocoon at intervals so that the resulting strand will be fairly even diameter. The raw silk may now be used as is. However, it is generally thrown, or twisted, with two or three other strands to form a yarn, which can be used in cloth manufacture. This process is known as "throwing". The number of strands combined and the amount of twisted they are given is determined by the use to be made of yarn (Stout, 1970).

3. By-product of Silk Processing

About two-third of the cocoon filament is not highest quality for making a raw silk filament or grege silk (Sandoz, 1988). Thus, the processing of unreelable filament is also important. This material, as well as scraps from reeling, twisting and weaving, can be further processed in many forms, such as spun yarns and noil yarns. For a long time these valuable materials were simply pulped or used for other purpose in the country of origin, due to the intensive work involved and the high investment costs for machinery. Another waste from silk processing is the cocoon residues that often serve as animal feed, e.g. for chicken or fish.

The by-products of silk processing can be characterized by the followings (Sandoz, 1988) :

3.1 Silk Wadding (Spelaia, Blaze, Keba). Silk wadding is the loose silk mesh around the cocoon which have to be brushed away before reeling. It can

not be used for spun yarns or noil yarns because of its nature and condition, also the noil waste is difficult to spin (Ananthakrishnan and others, 1992). In addition, it has the sericin gum more than the other parts of silk filament. The outer of silk cocoon consists of sericin about 30%, while the middle consists of sericin about 20% (Sandoz, 1988). In silk industry silk wadding seem to be the worthless material. In some cases it may be sold in very cheap price or was left without attention.

3.2 Flock Silk (Frison, Stursa, Kibizzo). It is the outer, irregularly spun cocoon layers (ca. 25% of weight of material), regarded as best raw material for spun silk.

3.3 Bassine (Pelettes, Ricatti, Galettame, Bisou). Bassine is the inner, parchment-like layer of the cocoon skin. The fiber in Bassine are hold together tightly; so it is difficult to card by the normal process.

3.4 Pierced Cocoons (Cocons Perces, Cocons Piques). They are the pierced, damaged cocoons which can not be normally reeled.

3.5 Bourre (Strazza). Bourre is the scraps produced during reeling the skeins, twisting and cleaning the threads.

Unlike cotton spinning, where the small amount of impurities can be removed in the dry state, silk residues require an entire series of dissolving and cleaning operations such as degumming, washing, drying, beating and cutting (opening) before yarn formation process. In recent years these operations have

increasingly been carried out in the country of origin, where the silk is processed into yarns or exported in the form of tops. In general, two types of yarns produced from by-product of silk processing are divided, i.e. spun yarns and noil yarns.

a) Spun Silk Yarns (Schappe). These are wool-like slivers formed by repeated combing and consist of parallel-running filaments of 50-250 mm in length (Sandoz, 1988). An important factor in spinning this material, is the regularity of the slivers. These are processed on a spreader into a single fleece about 3 metres long and then repeated drawing (on an intersetting machine) into a uniform ribbon.

This ribbon is again drawn and made finer on a pre-spinning machine or flyer, resulting in a thin tape which by light twisting is processed into the pre-yarn stage. By spinning, drawing and more strongly twisting, the strong spun yarn itself is formed. Spun yarns are smooth and regular, and have a discreet, soft luster. For warp of sewing threads they are twisted again in most cases.

b) Noil Silk Yarns (Bourette). Short fibers of 10-50 mm which are produced when combing, are used for noil yarn spinning (Sandoz, 1988). These yarns are characterized by the dark, irregular chrysalis residues which even after bleaching and dyeing are still visible as small black specks irregularly distributed over the fabric surface.

4. Degumming of Silk

The sericin coating is generally removed after the yarns has been woven or knitted into cloth by a process known as "degumming", in which the cement, sericin, is removed in hot, soapy water. Degummed silks are softer and more lustrous than raw silk, which still retains its sericin coat.

5. Properties of Silk

The important physical and chemical properties of silk are listed in Table 2.3.

Table 2.3 Properties of silk (Smith, 1982).

Molecular structure.	Extended protein (fibroin).
Macroscopic features.	In cross section, silk is triangular in shape with no specific markings.
Appearance	The smooth, translucent surface of degummed silk gives it a high luster.
Comfort	The hand of silk is often described as smooth, crisp, soft, and dry. The pleasant hand comes about through a combination of smooth surface, finess of fiber, and ability to absorb moisture.
Tenacity (g/den)	2.4 to 5.1
Stretch and elasticity	15% elongation at break. 90% recovery at 2% elongation.
Resilience	Moderate.
Abrasion resistance	Good abrasion resistance.
Dimensional stability	Good resistance to stretch and shrinkage.
Moisture regain	11%
Specific gravity	1.25
Effects of bleaches	Damaged by strong oxidizing bleaches such as sodium hypochlorite. Mild concentration of hydrogen peroxide or sodium perborate may be used.

Table 2.3 Continued.

Acids and alkalis	Concentrated mineral acids will destroy silk; nitric acid will cause silk to yellow. Damaged by strong alkalis and dissolved in hot caustic soda
Organic solvents	Not damaged by organic solvents.
Sunlight and heat	Considerably weakened by sunlight, which accelerates decomposition. Silk will begin to decompose at 150 °C.
Resistance to stains	Easily stained by perspiration; fair resistance to oil and waterborne stains. Requires hand laundering or dry cleaning.
Dyeability	Can be dyed in very deep shades and will absorb dyestuffs at low temperatures. Direct, acid, base, and vat dyes may be used.
Effects of fungi and mold	Highly resistance to fungi and mold, and will not be damaged except under extreme conditions.
Flammability behavior	Burns slowly with sputtering. Usually is self-extinguishing.
Electrical and thermal conductivity	Poor conductor of electricity and heat.

6. Uses of Silk

Silk is so versatile that it may be woven or knitted into the sheerest, most revealing lingerie or the heaviest of velvets. It is cool and comfortable for summer wear yet, because it is a good insulator, appreciate for cool weather. For apparel, silk offers high strength, excellent drape, a comfortable, luxurious hand, a pleasing luster, and beautiful colors. For daytime wear, silk provides comfort, durability, and wrinkle resistance to garments that proclaim the wearer's consciousness of quality. The esthetics of silk for formal wear are unsurpassed.

Silk is rarely used to make heavy fabrics because it is too expensive and too fine. However, to give fuller body to lightweight fabrics, silk is often "weighted" by steeping the yarn into a solution of tin salts followed by drying. This treatment loads the fiber with a dense substance. An addition of salts up to 15% of weight of the fiber improve the body and drape without harming the cloth. However, excessive weighting will damage the fiber and greatly reduce the tear strength and abrasion resistance of the cloth (Smith, 1982).

In home furnishings, silk fabric provide a richness of sense impression. A dry, firm, yet yielding hand give a pleasant tactile sensation; the brilliance of color and the natural luster of the fiber delights the eyes, while the soft rustle, or "scoop", of the cloth as it is rubbed, pleases the ears. No other fiber can delight so many senses. In addition to their esthetic qualities, silk furnishings are comfortable and durable. However, because of their cost and difficulty of maintenance, they should be treated more like art than commodities.