Coated and Laminated Textile Materials and Process

By:
Harun Venkatesan and
V.N. Gowrishankar

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Abstract

Textiles are made impermeable to fluids by two processes, coating and laminating. Lamination consists of bonding pre-prepared polymer film or membrane with one or more textile substrates using adhesives, heat, or pressure. Coating is the process of applying a viscous liquid (fluid) or formulated compound on a textile substrate. .In this paper we have gone through several methods of production used to manufacture a wide range of coated or laminated fabrics. Broadly, they are knife coating, lick roll coating, transfer, rotary, Zimmer, melt coating, and flame lamination & hot melt lamination. A review is made on Coated and laminated textiles applications in Defence, transportation, healthcare, space, environmental pollution control, sports, architecture, and many other diverse end-product uses.

Introduction

There are two definitions of a 'coated fabric'. The first one is, 'A material composed of two or more layers, at least one of which is a substantially continuous polymeric layer and at least one of which is a textile fabric. The layers are bonded closely together by means of an added adhesive or by the adhesive properties'. The second definition is, 'A textile fabric on which there has been formed in situ, on one or both surfaces, a layer or layers of adherent coating material'.

Textile Terms and Definitions defines a 'combined fabric' or 'laminated fabric' as, 'a material composed of multiple layers, at least one of which is a textile fabric, bonded closely together by means of an added adhesive, or by the adhesive properties of one or more of the component layers'.

Historical Background

What is regarded as being a coated or laminated fabric decides how long ago the coating and laminating of fabrics began; some writers see the fabric wrapping the Egyptian mummies as a coated material.

People must have sought ways of making the material less permeable to wind and water, for increased weather protection, comfort and survival. Natural oils were applied to the fabric. Then the fabric was dried in the sun and then more oil applied in a repeat process. Water-repellent fabric was obtained after this process had been done several times. This would afford better protection against the elements.

The New Shell Book of Firsts attributes the first 'raincoat' to Francois Fresnau who was the Chief Engineer at Cayenne, French Guyana. In 1747 he proofed an old overcoat by smearing latex over it. Hancock was a manufacturer of rubber goods in Manchester. He became an associate of Macintosh in 1830 and together they produced inflatable. Apart from garment, these included air beds, pillows, pontoons for floating bridges, etc. It is interesting to note that Hancock patented the use of inflatable bags to raise sunken ships. Nitro-cellulose was discovered later, in the mid-nineteenth century. It developed as a fabric coating material for cotton. The material became known as 'gun cotton'. It was also known as 'pyroxylin', 'collodion' or 'schoenbein'. It had many applications and was used extensively.

Several other new polymers and synthetic rubbers were invented in the first half of the twentieth century. After some development they came to be used as fabric coatings. Polyvinyl Chloride (PVC), polyurethane, polychloroprene and acrylates were the most important ones. These polymers along with several other specialist materials have been used in the modern industry. Research and development has been carried out to improve properties. Recently, effort is put in the field of research and development to produce environment friendly methods and materials.

Fabrics Used for Coating

Polyester and nylon have strength and general resistance to micro-organisms, oils, common chemicals and moisture. Therefore they are mainly used fibres. Polyester is more resistant to light and ultraviolet (UV) degradation than nylon while nylon is more resistant to hydrolysis. Because of its better dimensional stability and shrinks resistance, lower extensibility and generally lower cost, polyester has grown at the expense of nylon. High tenacity nylon and polyester yarn are used in coated articles for extra strength. Acrylic fibres are used for some applications where very high UV resistance is necessary, example, in car roofs and hoods for convertibles, for awnings. Aramid fibres are used where more specialist properties are required, such as high strength to weight ratio and resistance to high temperatures. In applications where strength is required, nylon and polyester have replaced cotton which was the first fabric used in textile coating and it is still used in large quantities. Nylon and polyester have considerably higher strength to weight ratios. Cotton has certain advantages over synthetic fibres in spite of being vulnerable to wet rotting and microbial attack. It has a better polymer adhesion. The smoother, continuous filament synthetic fibres frequently require more specialist means of promoting fibre–polymer adhesion. However, cotton or fabrics produced from spun yarns cannot in general be direct coated to produce coated fabrics, especially waterproof materials, lightweight, because the fibre ends may cause pin holing. It may even be 'scraped or teased up' causing a raspy surface with poor abrasion and waterproof performance. Glass woven fabrics are use as bases for PTFE coatings for industrial uses, such as calendar belts and building structures. Specific use of the glass properties of very high strength with very low elongation and excellent flammability resistance are made in these applications. Because of their poor flex resistance, glass fibres cannot be used in applications that involve significant flexing.

Polymers Used for Coating:

- **Butyl rubber (isobutene-isoprene copolymers):** Good resistance to heat aging, UV light, general chemical attack, oxidation, ozone. Low permeability to gases. Serviceable temperature range -50 to +125.C. Difficult to seam. Low to moderate cost.
- **Hypalon (chlorosulfonated polyethylene)**: Similar to neoprene. Moderate cost. Relatively poor low temperature resistance.
- **Natural rubber (polyisoprene)**: Good tensile strength and b flexibility. Tear strength and abrasion resistance improved by reinforcing fillers (e.g., carbon black). Unaffected by dilute acids, alkalis, and water. Insoluble in all organic liquids when

vulcanized. Highly swollen by hydrocarbons and chlorinated solvents. Susceptible to oxidation; less so to ozone. Contains 2–4% of protein, which enhances susceptibility to biodegradation. Moderate cost. Serviceable temperature range-55 to+70.C. Sewn or glued seams required.

- **Neoprene (polychloroprene)**: Good mechanical properties. Inferior low temperature properties to those of natural rubber. Swollen by chlorinated and aromatic solvents; resistant to most chemicals and organic liquids. Excellent weathering properties.
- Upper temperature limit about 120.C. Low to moderate cost.
- **Nitrile rubber (acrylonitrile-butadiene copolymers)**: similar to natural rubber except for improved resistance to swelling in organic liquids and improved resistance to light, oxidative aging and heat. Moderate cost.
- **PTFE (polytetrafluoroethylene)**: Exceptional resistance to chemicals, micro-organisms, heat, solvents, oxidation and weathering. Difficult to seam. Excellent electrical and non-stick properties. Serviceable temperature range -70 to +250.C. Very high cost.
- **PU (polyurethanes)**: Very variable compositions; properties range from inflexible, hard plastics to elastic, soft coatings. Some grades have good resistance to fuels and oils. Plasticizers not required. Excellent strength and resistance to tearing and abrasion. Moderate to high cost. Thermoplastic grades available.
- **PVC (polyvinyl chloride)**: naturally rigid material; requires careful formulating to produce durable, flexible coatings. Good chemical properties, although solvents tend to extract plasticizers and stiffen the polymer. High plasticizer content (up to 40% by weight). Good weathering properties and flame resistance. Unless special plasticizers are used, poor low temperature performance. Thermoplastic and can therefore be seamed by hot air, ultrasonic welding techniques and radio-frequency. Low cost.
- **PVDC (polyvinylidene chloride)**: Low permeability to gases. Similar to PVC. Low to moderate cost. Better flame resistance.
- **SBR (styrene butadiene rubber)**: Similar to natural rubber except for improved flex and abrasion resistance. Resistant to biodegradation. Inferior tear resistance and serviceable temperature range. Moderate cost.

PVC is an extremely well researched material that can be compounded to produce very many different properties. It is economical, has a high degree of inherent FR properties and is the most used fabric coating. However, due to environmental concerns alternatives are being researched. FR properties can be improved by blending PVC with Polyvinylidene chloride (**PVDC)** resins. PVDC lacquers are used on polyester bottles to prevent the loss of carbon dioxide which would cause the drinks inside to go flat. PVDC have good impermeability to gases. Styrene butadiene rubber (**SBR**) latex is used in place of and in combination with some of the above when economy is required.

Compounding of Polymers (Resins)

Note that, the word 'resin' has become almost interchangeable with coating compound or polymer, within this context. Resins are supplied as emulsions or as solutions in water or solvent.

The overall task of the compounder is to formulate a mixed compound which will process without problems. It should also be able to produce the coated fabric properties required by the customer – at the correct price. Material selection and formulation of recipe is where the compounder's task starts. It also includes the physical mixing of all ingredients to produce uniform mix. This mix has to be stable during coating process as well as storage. Sometimes because of premature cross linking, poorly formulated compounds can develop lumps or go thick. A typical recipe is given in the below table:

Base Coat	
PVC polymer: (E.K value 68-70)	100
Stabilizer liquid: Ca/Zn containing (e.g. Irgastab CZ 57)	1.5-3.0 phr
Co-stabilizer: epoxidized soya bean oil	6.0-8.0 phr
Plasticizer: DOP	85 phr
Filler: Whiting	20 phr

Polymeric Materials for Lamination

Films can be used to produce reflective surfaces with efficiencies much higher than can be produced with a fabric. Clear unsupported PVC film made by calendaring is sometimes used in automotive door casing construction. In a separate process, it is laminated to car interior trim fabric, as a barrier against wetness and dampness within the door casing. The PVC film is also a useful processing aid because of its weld ability. The market leaders are Gore-Tex which is a PTFE film, Sympatex (Acordis) which is made from polyester, and polyurethane based Porelle (Porvair). There are also several other branded waterproof and breathable films made from polyurethane. The largest outlet for polyurethane foam is in textile laminates. It is mainly used for automobile seats covers and for other coverings in the car interior.

Polyolefins can be fabricated by vacuum forming and moulding techniques to produce smooth and well defined contours in articles like automotive interior components. They have excellent solvent, microbial, oil and chemical resistance.

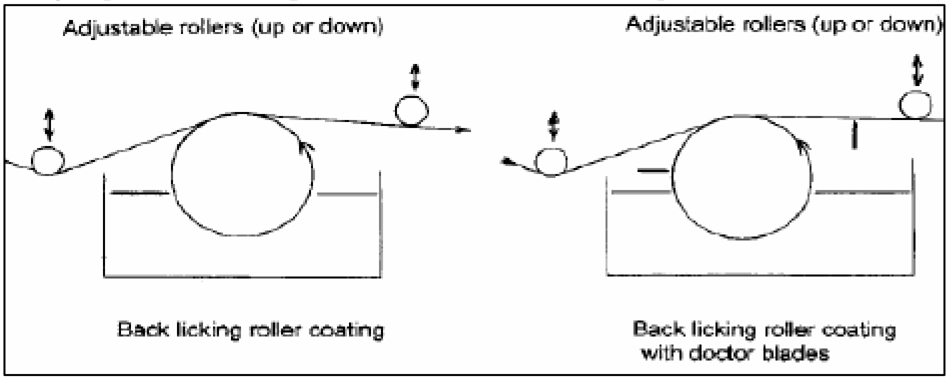
General Principles of Fabric Coating

Coating techniques simply try to control resin add-on and preserve fabric aesthetics and properties as much as possible. The total fabric weight increases after one layer has been applied. The surface layer of one side of the material also changes significantly. This makes coated fabric handling difficult. Various methods achieve control of resin add-on in different ways as it is one of the fundamental principles of fabric coating. The machine characteristics and geometry are also relevant, along with the properties of polymers used to control add-on. The fabric properties should not be adversely affected while achieving control. The direct method uses blades of different profile as means to control add-on. It uses gap separation of blade over table or blade angle and gap separation of blade over roller. Roller methods use gap separation between rollers, contact angle and speed of rotation; doctor blades applied against the rollers to scrape off excess resin are sometimes used for more accurate control. Foam processing, gravure roller, the rotary screen and die extruder are the most effective ways of controlling very low add-ons. The slot die extruder and rotary screen have other novel advantages. Producing a product which consistently passes all quality tests provides customer with satisfaction which should be the prime aim. The technical considerations dictate what the add-on should be to achieve this and any resin add-on more than this amount is excessive cost. Lamination process also has this same principle. Excess adhesive produces bonds greater than the standard required which in turn generates excess cost.

These aspects are further reasons why precise control of resin or adhesive is crucial to the success of the business. The ability to stay adhered to the base fabric throughout the life of the product is the fundamental requirement of any coating.

Coating Techniques

The original methods of coating were largely based on various impregnating techniques based on an impregnating trough followed by a pair of squeeze rollers to ensure a constant pick-up. Usually on a stenter, the material was then air dried at constant width and rolled. When the coating was required on one side of the fabric then total immersion of the fabric in the coating liquor was not possible and other techniques had to be developed.

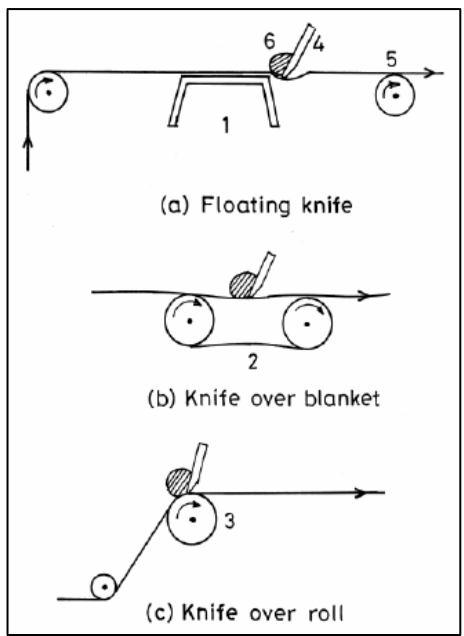


Lick roll

In this method the fabric was passed over the coating roll which was rotated in a trough of the coating liquor. Several variations developed to ensure a more even application of the coating by metering the coating onto the fabric. Two main approaches were used to do this. The first was to use a second roll on the primary coating roll which picked up a fixed amount. So that again only a fixed amount of liquor was transferred to the fabric, the second approach was to use a doctor blade on the primary roll.

Carpets and other articles are also processed using back licking techniques. Woven velvet automotive seat fabric is sometimes processed in this way to lock in the pile. Some reports claim that two different finishes may be applied to the same substrate at the same time – a foam finishing technique on the top of the fabric and a back licking technique for the other side.

The main disadvantage of these systems was that the amount of coating on the fabric was dependent on the surface tension and viscosity of the coating fluid and also the surface condition of the fabric.



Knife coating

In this method the coating fluid is applied directly to the textile fabric and spread in a uniform manner by means of a fixed knife. The gap between the bottom of the knife and the top of the fabric controls the thickness of the coating. The type of machinery is determined by the way in which this gap is controlled. The main techniques used are as follows:

- knife on air
- knife over table

- knife over roller
- knife over rubber blanket

Air knife coating

In discussing knife coating, mention must also he made of the air knife as a method of removal of the excess coating fluid. A blast of air is used to blow off the excess coating fluid in this technique. The viscosity of the fluid is much lower than in the case of conventional knife doctoring and the coating applied follows the profile of the substrate to which it is being applied. The paper industry uses this technique more frequently than the textile industry. There, it is used to coat photographic paper.

Transfer coating

In principle, transfer coating consists of applying polymeric coating on the surface of a support laminating the textile substrate to be coated to the polymeric layer to yield a transferred polymeric layer on the textile. Direct coating is the process of applying coating material directly on the textile. This process has certain limitations as mentioned below:

- It is not suitable for excessively stretchable knitted fabrics. It is applicable to dimensionally stable, closely woven fabrics that can withstand machine tension.
- Penetration occurs in the weave of the fabric. This increases adhesion and lowers tear strength and elongation which results in a stiff fabric.

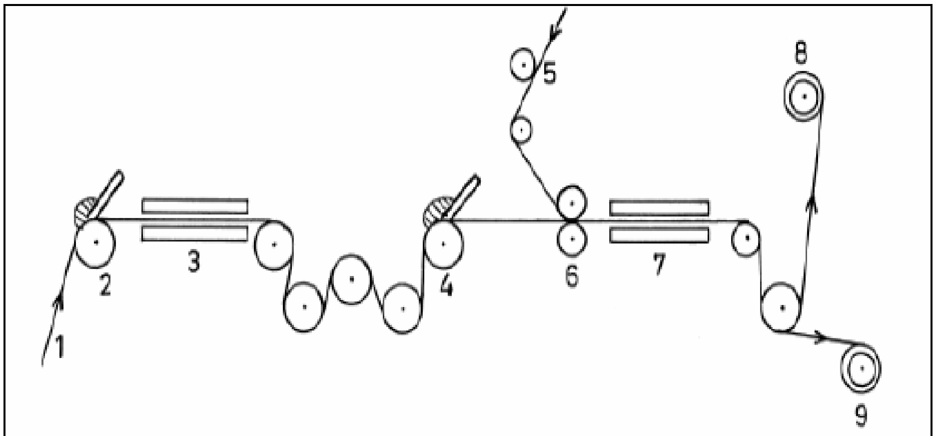
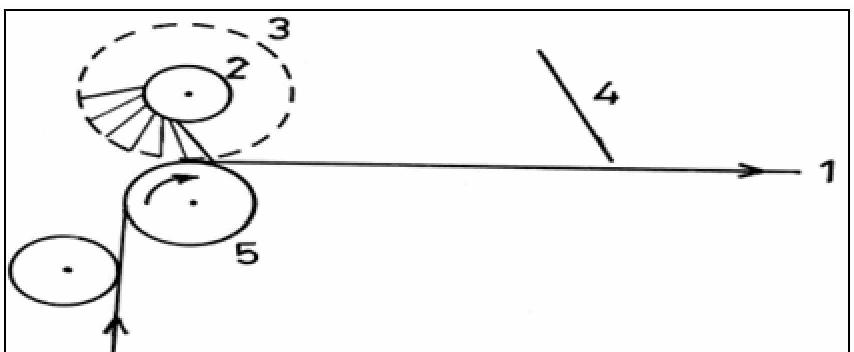


Figure: Layout of Transfer coating process: (1) release paper (2) First coating head (3) First oven (4) second coating head (5) Textile substrate (6) laminating nip rolls (7) second drying oven (8) Coated fabric take off roll (9) release paper wind roll (Adapted with permission from G.R. Lomax, Textiles, no.2. 1992 ©Shirley institute, U.K. [1])

Transfer coating overcomes these limitations. The most delicate and stretchable fabrics can be coated by this process because no tension is applied during coating. The appearance of the textile substrate can be altered to give a much better aesthetic appeal with proper processing e.g. artificial leather for fashion footwear. Fabric penetration and stiffening is significantly low.

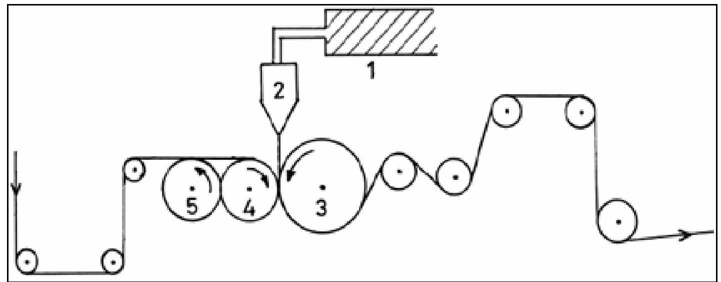
Rotary screen coating

Coating and printing textiles commonly use this method. A screen that is a seamless nickel cylinder with perforations is the coating head. This screen rests on the web. In the screen a squeegee is mounted, serving as supply and distribution pipe of the coating paste. Mounted to this pipe, the squeegee blade pushes the paste out through the perforations of the screen. A whisper



Rotary screen coating: (1) web, (2) squeegee, (3) screen (4) Whisper blade, and (5) backup roll.

blade smooth's the applied coating. A backup roll is provided for counter pressure. The coated material is sent to an oven for fusion of the polymers after coating. The angle between the blade and the screen, the mesh number of the screen and the viscosity of the paste determine the amount of coating applied. Coating of complex pattern, continuous coating and dot coating can be done depending on the mesh size and design of the screen. In continuous coating, by proper choice of the screen, the coating can be up to 200 g/m2.



Extrusion coating: (1) extruder, (2) die, (3) chill roll, (4) Backup roll (5) pressure roll

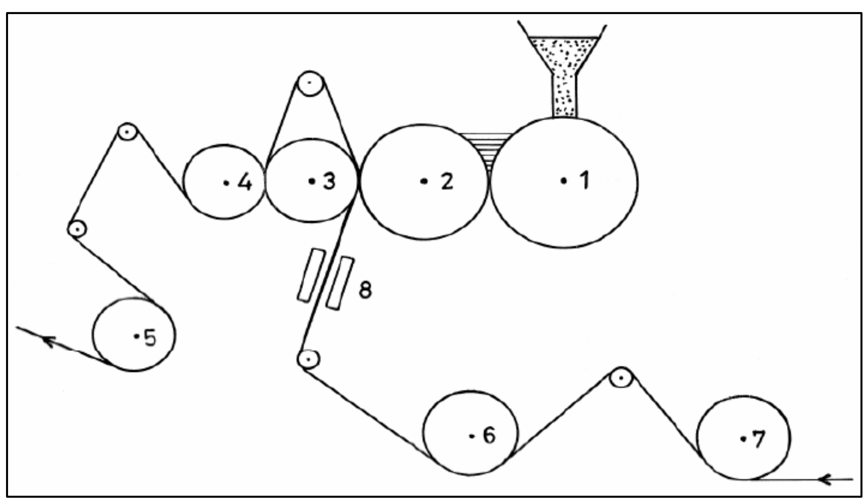
Hot melt coating

Thermoplastic coating material must be used in this technique, so that they melt when heated and in this condition are capable of being spread onto a textile substrate. Paste coating is similar to this technique in some respects. The major difference between thermoplastic coating and paste coating is that the prior has no solvents to evaporate and no water that has to be evaporated giving the process both economic and ecological advantages. The molten polymer is usually calendared directly onto the textile or in some cases extruded directly from a slotted die. If a smooth surface is required the coating or a patterned roll if a patterned effect is required, it is followed by contact with a polished chill roller.

One further process needs to be mentioned in the area of hot-melt coating i.e. the use of powdered polymers as a coating medium. In this technique the powdered polymer is sprinkled onto the substrate and heated with radiant heaters in order to melt thermo plastic. The coating is then compacted and rendered continuous by a compaction calendar. The main materials used in this are polyethylene and nylon and these are now being applied in the production of carpets for car interiors. A complete car carpet may be pressed out in one operation because of the mould ability of the thermoplastic.

Zimmer Coating

The Zimmer coater consists of two melt rolls (1) and (2). The rolls are made of diamond-polished, deep-hardened high-grade steel. The material is fed at the nip of the rolls, the temperature of which is about 200.C. The gap between the two rolls is adjusted hydraulically. The coating material melts and adheres to roll (2) which runs at a higher speed and is maintained at a higher temperature. The textile substrate is fed between the nip of roll (2) and the backup roll (3) after heating by passage through one or more ore heater rolls and IR heaters. The hot laminate is either smoothened or embossed by an embossing roll (4) after coating. The coated material is then cooled by cooling drums and wound [6].



The Lamination Process

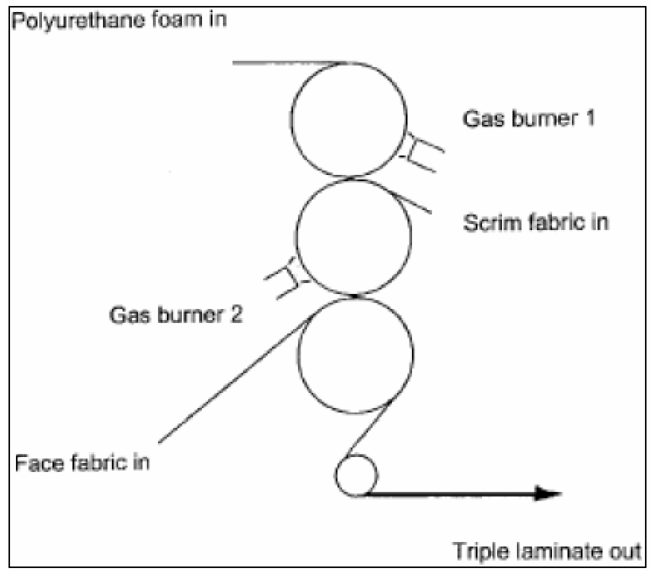
Lamination of Fabric for Apparel

In the apparel industry, drape, handle and flexibility are of major importance. The durability to flexing and to washing is also important. Therefore, finding the best method and adhesive materials for a durable bond and applying them in a controlled manner to maintain the fabric flexibility and aesthetics during the lamination process is where the problem arises. For a bond of high strength, it is generally necessary for the adhesive to penetrate the material and to cover the widest possible surface area.

The challenge is to select the best adhesive and application process which has the least effect on the substrate aesthetics. This factor is especially important when waterproof breathable fabrics are being prepared by lamination of a membrane to a fabric. Ideally, the least amount of a highly effective adhesive should be applied. It is usual to apply the adhesive – hot melt powder or moisture curing polyurethanes – in dot or discontinuous form. The waterproof breathable films are generally very thin and delicate materials and require considerable skill and care to handle without creasing.

Flame Lamination

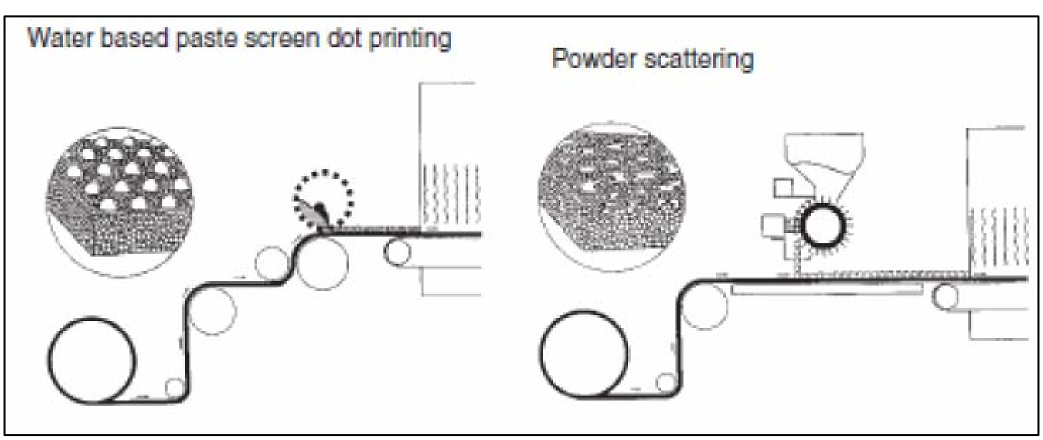
This lamination method was once used extensively to produce laminated fabric for garments, curtains and drapes, and it makes use of the polyurethane foam itself as the adhesive. It is a quick, economical process but requires a certain amount of technical skill, regular maintenance and abatement of the fumes produced. It is used almost exclusively for the production of car seat laminates.

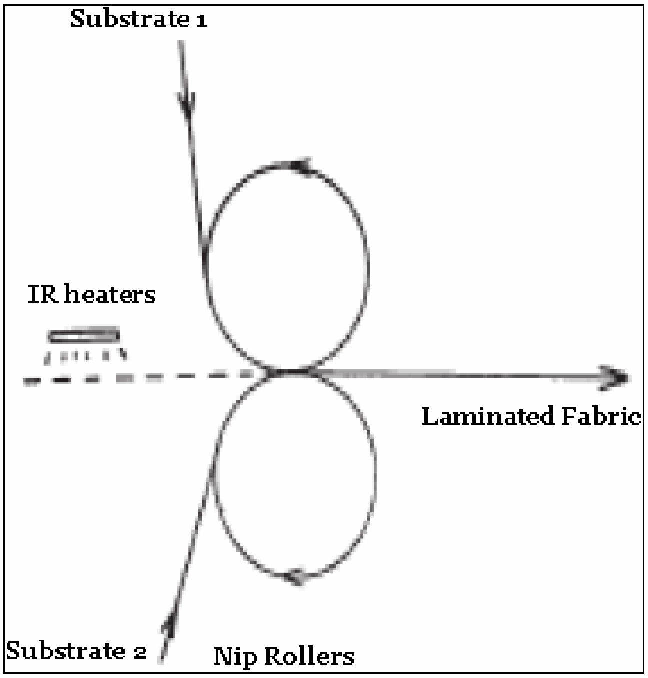


Scrim fabric, face fabric and polyurethane foam are the three components that are fed into the laminator. These three materials joined together emerge at speeds between 25 and 40 meters or more per minute. The surface of the moving foam is melted by a gas flame, which then acts as the adhesive to the fabric which is laid over it. It is possible to flame laminate polyester face fabric to polyester non-woven material (polyurethane foam substitute) using 'mini' foam i.e. polyurethane foam about 1–2 mm thick.

Hot Melt Lamination

When the issue of flame lamination being an environmentally unfriendly process arose, thoughts turned first to calendars and the hot melt adhesives. These have been used in the garment industry for many years. The calendar principle is that the two materials being joined are made into a sandwich with a hot melt adhesive powder, film or web in the centre. Webs or films are available only at fixed weights and widths. The suppliers will normally provide any width required in case of large volumes. This is then fed into the calendar, which heats the materials and melts the adhesive to produce





a laminate. Much higher volumes are required if webs or films are to be specially made at a particular weight. For both short and long production runs of fabric powder is very beneficial. It can be conveniently applied at any weight and at any width.
Infra-red heaters are used widely in hot melt lamination machines to heat or pre-heat materials and adhesives before nipping together.

Various Coated and Laminated Products

Protective Coated & laminated textile

Sports
Fabrics for sports-clothing's are coated or laminated mainly to enhance their ability to protect the human body from the elements, especially rain and wind. The degree of protection is sometimes classified into three levels of performance. They are waterproof, rain-repellent and shower-proof. The first mentioned gives the highest level of protection. Waterproof protective clothing is produced from nylon or polyester fabric coated with acrylic, polyurethane, PVC, or a rubber-based resin such as Neoprene.

Breathable waterproof materials : The concept behind breathable fabrics, which is fabrics that repel water but allow perspiration to escape, are tiny holes in the material that are too small for water droplets to pass through, but large enough for water vapour (perspiration) to escape.

Gore-Tex is a PTFE film with nine billion tiny micro-pores in every square inch (6.45cm^2) these are 700 times larger than a water molecule and 20000 times smaller than a drop of liquid water. Thus they are large enough to allow the passage of molecules of water vapour at the same time too small to allow liquid water to pass through. It is sandwiched between two layers of fabric.

Industrial Protection
Concern for health and safety at workers has led to the development of specialist clothing to protect against chemicals, biological agents, radiation, fire, heat and against mechanical hazards such as sharp edges. Personal protection systems (PPS) and equipment (PPE) is now an essential feature of occupations where a potential hazard exists and they are being continuously improved.

High visibility garments
There are three main categories of high visibility material. Textile coating, through incorporation of the appropriate pigment into either PVC or polyurethane resin which is then transfer coated on to a base fabric readily produces two of these. 'Day glow' or fluorescent pigments which produce a high visibility effect in daylight are available in a number of colours. Orange and yellow are the most used. Photoluminescence materials such as zinc sulphide actually give out light in the dark for a limited amount of time (up

to six hours is claimed), after being 'charged up' by daylight. Alternatively, pre-prepared film containing these pigments may be laminated on to fabric. The third category is reflective micro prisms which are incorporated into a film in such a way that they reflect back the light which falls on to them in the same manner as road signs.

Military Applications

Camouflage net

The camouflage net consists essentially of two components, a garnishing material, usually coated fabric that is fixed to the netting with clips, netting forming the base. The garnishing material is usually PVC-coated nylon fabric incised in a suitable pattern. The netting is a square mesh of nylon twine, mesh size varying from 50–80 mm with soft vinyl coating or a flame retardant treatment. Lightweight fabric is taken as the base fabric (~70 g/m2) that enhances the strength of the garnishing material. The colour scheme of the garnishing material depends on the terrain of deployment.

Protective clothing

Military waterproof protective clothing – known as 'foul weather' clothing is produced to the highest standards of performance. Protection from the cold and wet is of paramount importance in the field. It is a well-known fact that there are as many casualties from sickness as there are from enemy action.

Automotive Applications

Coating and Lamination of car seat fabric

Woven car seat fabric is sometimes back coated to increase the abrasion resistance and to improve the FR properties of the whole tri-laminate. The back coating resin can be acrylic, polyurethane or SBR based and can be coated on, knife over air as a straight resin or knife over roller or table as a foamed resin. Add-ons vary from about 10 to 60gm2 or more, but the tendency is to put on as little as possible for reasons of cost and also so that the seat cover laminates is as light as possible. Car seat fabric is generally laminated to polyurethane foam by flame lamination which is a quick and economical way of producing the triple laminate in a single process. Under controlled conditions a gas flame impinges directly on to the surface of moving polyurethane foam.

Automotive air bag fabrics

During the last decade, air bags or inflatable restraints have gained significant importance as protection for the driver and passengers in case of a collision. The air bag fabric is made from nylon 66 because of its high weight-to strength ratio and is preferred over polyester because of higher elongation, allowing the force to distribute widely. Until recently, two types of neoprene-coated fabrics were used because of better environmental stability and flame retardant properties of neoprene. One is a heavy fabric made of 840 d nylon and the other a lighter fabric woven from 420 d nylon. The details are given in. The need to enhance the life of the air bag and further reduce the size led to the development of silicone-coated air bags. Silicones are chemically inert and maintain their properties for a long time at temperature extremes. An aging study of both neoprene- and silicone-coated fabrics was carried out at 120.C for 42 days. The elongation of the fabrics prior to aging was about 40%. After aging, the elongation of silicone-coated fabric was 32% but that of neoprene coated fabric dropped sharply to only 8%. Silicone-coated fabrics are more flexible and abrasion resistant than neoprene-coated ones. Moreover, because of better durability and compatibility of silicones with nylon, a thinner coating is adequate.

Household products

- Baby pants fabric
- Furniture upholstery
- Mattress ticking
- Shower curtains
- Aprons
- Wipe-clean tablecloths

Conclusion

The coating and lamination sectors of the technical textiles industry are constantly changing and advancing, although not as fast as some other areas. This section lists some sources of information likely to be useful to all involved with coating and lamination. However, new information, materials and applications continue to be produced and to present new opportunities.

Reaching 655 million square yards in 2012, US demand for coated fabrics is expected to grow 2.1 percent per annum. Sales will be spurred by rising protective clothing shipments and growth in building construction. In value terms, coated fabric sales will rise 3.4 percent yearly to $3.0 billion in 2012. Rubber-coated fabrics will register fastest gains. Non rubber- coated fabrics is the largest, accounting for more than three-quarters of sales in 2007, of the three major fabric types. Vinyl is a relatively low-cost, durable and easy to clean coating. As a result it is utilized in a wide range of applications, including awnings, covers, banners, tarpaulins and upholstery. Within this category, PVC-coated fabrics are the most commonly used material.

Rubber-coated fabrics -- including those coated with natural rubber, neoprene, silicone rubber or butyl rubber -- will post the fastest gains through 2012. Rubber's resistance to degradation and flexibility make rubber-coated fabrics the material of choice for airbags and certain types of protective clothing. Growth in these end-use applications will lead to considerable sales opportunities for manufacturers of rubber-coated fabrics. Fabric-backed wall coverings will post above average gains through 2012 as a result of increasing construction expenditures and product developments.

Through 2012, polyester will remain the most commonly used coated fabric substrate because of its low cost and versatility. Nylon is utilized as a substrate in several high growth applications, including protective clothing and airbags, because of the material's strength and light weight. However, sales of coated nylon will post the fastest gains.

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