Assembling technologies for functional garments—An overview

Prabir Jana

National Institute of Fashion Technology, gulmohar Park, New Delhi 110 016, India

Functional garments have higher functional properties and lesser aesthetic properties. They can be workwear, active sportswear, medical wear, personal protective garments, and smart garments. The fibre contents used are mainly polyester, polyethylene, kevlar, and spandex blends which can be woven, knitted and nonwoven, albeit the list is increasing day by day to include speciality fibres like bamboo, banana to name a few. These garments are made up by joining several pattern pieces together and the pieces, in turn, are joined with accessories comprising membranes, linings, buttons, zippers, tapes and waddings to create a composite garment. While fabric can be joined by sewing, seam welding or bonding technique, accessories can be joined by sewing, welding, pasting or using combination method. Some functional garments are made seamless thus requiring little or no assembling technologies. Different new technologies for joining fabric pieces and assembling of accessories have been explored so far. There is a distinct shift towards use of welding and bonding technologies in functional clothing because of the reduced bulk and weight, cleaner appearance and sealing qualities offered by them. Some challenges still continue to exist. This paper reports the distinguished characteristics and developments in assembling technologies, such as sewing, welding and bonding along with the challenges ahead in this area.

Keywords: Assembling technology, Bonding, Garment, Sewing, Welding

1 Introduction

According to Cambridge dictionary ‘functional’ means designed to be practical and useful rather than attractive. Garments designed especially with their needs in mind have been called functional clothing or functional fashions. The term functional garment is generally used when describing garments and accessories that protect the body or increase physical body function, to achieve a high degree of mobility, thermal comfort, etc. Some examples of functional garments are scuba diving suits, bulletproof vests, fire fighting suits, gloves that help paraplegics propel their wheelchairs more effectively, anti bacterial clothing, anti nuclear biological clothing, air cooling vests worn under military clothing and other garments, garments for skiing, mountain climbing, windsurfing, high visibility garments, swimwear/athletics/dancewear, waterproof and water repellent garments, and extreme cold weather clothing.

The functional apparel design process begins with a thorough analysis of the anticipated user, and the identification of the physical, emotional, and situational needs of that user; climate and other hazards in the environment; and physical needs of the wearer for movement, e.g. sight, hearing and psychological factors such as potential for claustrophobia or distraction from work.

Functional garments need various accessories to be associated with them to perform desired functions. What types of accessories can be used for various functions, how these accessories are fixed with the garments, and how they can perform the desired function without affecting the performance of the garments are the important areas. New technological developments in the raw material and assembling technologies play a significant role in the evolution of functional clothing. This paper reports the distinguished characteristics and developments in assembling technologies, such as sewing, welding and bonding along with the challenges ahead in this area.

2 Assembling Technologies

Functional garments, like conventional garments, are made up by joining several pattern pieces together. These pieces, in turn, are joined with accessories comprising membranes, linings, buttons, zippers, tapes and waddings, to create a composite garment. The quality of seam in terms of strength, flexibility, elasticity, appearance, comfort and permeability can have a significant effect on the quality and performance of the garment assembly.

E-mail: prabirjana@gmail.com
The correct choice of seam is therefore critical in case of performance wear. Garment assembling technologies therefore include those that are used for joining fabric to fabric or those that join fabric to accessories. Some of functional garments with accessories are shown in Fig. 1.

The most common and conventional method of joining fabrics is by sewing with needles and threads. These seams can be used in garments made from porous fabrics. However, if the garment is made from non porous materials such as those used for water proof, fire resistant or chemical resistant clothing, then the perforations caused by a conventional sewn seam will compromise the integrity and performance of the garment. For example, a water proof garment will leak at the seams or dust particles will be able to pass through a dust proof garment. For such applications, therefore, either the sewn seams are sealed with tapes or entirely new technologies based on welding and bonding of layers are being employed to create fully sealed seams.

As mentioned above, sewing includes those processes where needle(s) and thread(s) are used to join two pliable materials. Some newer methods of sewing being used to join technical textiles include one-sided sewing technologies such as blind-stitching.

While conventional sewing requires access to both sides of fabric, one-sided sewing and blind-stitching require access to only one side of the fabric, thereby allowing immense flexibility in joining of tubular and other parts having complex 3D shapes.

Fabric welding is the process of joining pieces of fabrics using heat and pressure. Thermoplastic coatings, such as polyvinylchloride (PVC), polyurethane (PU), polyethylene fabric (PE) and polypropylene (PP) are used for heat sealing. It is done when the product needs to have special functional properties like water resistance, abrasion resistance, resistance to thread decay, and fine appearance. Bonding is a process used to join two fabrics that are non thermoplastic such as cotton or wool or blends with little synthetic content. In this process, a heat activated materials is placed between the two layers, and as heat is applied, this heat-activated material begins to flow into the fibres of the fabric, joining them together. Quality parameters and management of welded joints are limited so far in comparison to conventional seams. No external feature is visible at welded joints to determine their functionality due to absence of a sewing thread. Some details and distinguishing characteristics of these methods are discussed hereunder.

3 Conventional Sewing

Modern day sewing machines are highly automated and programmable and can form seams at very high speeds. However, the basic mechanism of stitch formation remains similar to that created during the late nineteenth century— that of interlacing threads through or around textile materials. Stitch formation involves the carrying of needle thread to the reverse side of the fabric, where it is interlaced or interlooped with the under threads. The process is made continuous by a mechanism that feeds the material over a defined distance, through the needle head. When a stitch is used with a defined geometry of fabric positioning, a seam is formed. Standard classification of stitches and seams is available in international standards, as shown below:

- ISO 4915, 1991-08 (Stitch types—classification and terminology).
- ISO 4916, 1991-09 (Seam types—classification and terminology).
- BS 3870 Part 1 (Stitches and seams—classification and terminology of stitch types).
- BS 3870 Part 2 (Stitches and seams—classification and terminology of seam types).
Figure 2 shows the 2D and 3D representation of some seams as per British standard, as shown above. Garments that eventually undergo seam sealing operation, use superimposed or flat and fell seam, as these are among the strongest and most secure seams. Garments made with bulkier fabrics (like scuba diving suit) generally use 607 stitch type and butt seam or overlap seam as these yield some of the flattest seams possible with good stretch and strength. The two fabric pieces are butted against each other, edge to edge. The stitch goes to and fro across the seam, creating a flat stitch (Fig. 3). The seam is without bulk and comfortable but slightly less strong than overlocked one due to formation of needle holes on either side of the seam. Cost of the seam can also be a consideration in its choice. For example, Overlocked seams, though strong and cheap to produce give a raised bead on the inside of the garment which can be irritating in the armpit or crotch areas of close fitted garments. The seam is also not watertight.

Stitch types are classified into 6 classes (100-600), depending on the configuration and the mechanism of entanglement of threads. The most commonly used stitch types are lock stitch (Class 300) and chain stitch (Class 400). The two classes differ in that, the lock stitch is formed by interlacement of the needle thread with the bottom shuttle thread, while chain stitch is based on inter-looping of the top with bottom thread (Fig. 4). Other important classes for functional clothing are overlock (Class 500) or top and bottom cover stitch (Class 600). Blind stitch based on the principle of 103 stitch type is used to make one sided stitches (Fig. 5). A curved needle of 25 mm radius is used with a blind looper at the other side to form chains at the back of material. As the needle does not puncture the material, no holes are introduced. Figure 6 shows the KSL blind stitch stitching devices and stitch architecture. The various stitch types differ from each other in terms of the strength, elasticity and security offered. A judicious selection of type has to be made based on the requirements of the seam.

Aerodynamics and comfort are key factors in high performance sportswear like swimwear, speed skating and cycling activities. This trend has resulted in...
replacement of conventional lapped or superimposed seams, which introduce drag, with flat seams which give absolutely smooth and bulk free joints.

For body hugging sportswear and inner wear the preferred stitch is flatlock stitch that gives a stronger, smoother and less irritating seam that does not rub and fray between the legs. Blindstitching is used in garments which are waterproof like surfing suits. The fabric pieces are butted against each other, glued and blindstitched to create a waterproof seam. Single blindstitched seam is not strong enough, therefore the seam can be blind stitched on both sides for extra strength. The seam may even be taped for complete sealing. Such seams are the best for insulation and protection from water or cold winds but are quite expensive.

4 Seam Sealing

Conventional stitched seams have small needle holes, these seams can be sealed and made water and wind proof by taping. Fabrics which have been ultrasonically or laser cut and sealed are also taped for reinforcement and a smooth comfortable finish. Typical applications of sealed seams include outdoor gear (skiing, hiking, climbing, marine and fishing gear), sports wear, diving suits, military gear and hazardous material suits.

4.1 Principle of Seam Sealing

Seam sealing tape has a thermoplastic adhesive coating on one side. Hot air at precisely controlled temperature is applied to the hot melt adhesive which is activated. In the activated form, the tape is applied on the fabric seam under pressure. On cooling, a strong bond is formed between the tape and the seam which prevents wind or water from penetrating, thus making the assembly waterproof (Fig. 7).

4.2 Types of Sealing Tape

Sealing tape fabric can be woven or nonwoven depending on the requirement. Tapes can be made of a single, double or triple layer. Tapes are attached by pressure sensitive adhesives which are either rubber or acrylic based, solvent based, heat activated or fire retardant.

Single layer seam sealing tape is used for PVC and PU rain garments which are produced directly by welding and seam sealing machines. Double layer tape is used with previously sewn seams to prevent water and air transfer through stitch holes. It is used when seam sealing is performed directly on waterproof membranes. A typical 3 ply tape could be made of nylon/polyester backer fabric, a PU waterproof primer film with a hot melt adhesive film on top. Such tapes are used on thick or heavy duty fabrics like those used in heavy industrial work, like fire fighting, chemical protection, military, medical clothing and dry/wet suits and offer excellent dry cleaning resistance and washability.

Nonwoven tapes consist of a layer of nylon coated with a layer of adhesive. They have many advantages such as low application temperature, strong adhesive force, high flexibility and good cold resistance. These are generally used in medical or anti-bacterial clothing and other nonwoven fabric products.

5 Welding Technology

The term welding refers to the thermal bonding and sealing of seams in knitted, woven, and nonwoven thermoplastic materials without adhesives, chemical binders, staples, needle, or thread. The three principles for welding are heat, speed, and pressure. The precise combination of these principles allows one to achieve a properly welded seam in thermoplastic materials either by point bonding of fabric or continuous sealing of film. The efficiency of welding of a woven fabric is affected by yarn density, thermoplastic content, tightness of weave and uniformity of material thickness while the random orientation of fibres in nonwovens gives them excellent bond strength. In knits, the style and elasticity of construction affect the bond strength. Coated materials are often welded to seal the seams. The nature of coating, film thickness and other substrate properties are important parameters in such cases.

Materials suitable for processing with the welding technique include 100% synthetics such as nylon, polyester, polypropylene, polyethylene, modified acrylics, some vinyls, urethane, film, coated paper, and synthetic blends with 35-50% non-synthetic fibre content. Several methods of generating heat are employed. The most popular methods are hot air welding and hot wedge welding. In hot air welding, a
hot air nozzle is used to deliver heat, while in hot wedge welding, a precisely controlled high temperature wedge is injected between two or more layers of thermoplastic material, thus heating the thermoplastic and preparing the two surfaces for molecular bonding. Other methods include ultrasonic welding, laser welding and RF welding. Some less common methods include impact welding techniques.

Usually, each heat system can be used in place of the other. However, there are certain applications and scenarios when one heat system may be better than the other. Speed is the amount of time the heat is applied to the thermoplastic material. This is controlled by the rate at which the material passes through the system. Pressure is used to compress the heated thermoplastic materials together during the sealing process to complete the molecular bond between two or more surfaces. Variable air pressure is applied to the weld rollers creating the necessary strength. Driven weld rollers advance the thermoplastic material through the system at a precisely controlled variable speed. Welding produces sealed edges and seams with no stitch holes, thus preventing penetration of chemicals, liquids, blood-borne pathogens, or particulates, providing a benefit over conventional stitching methods.

5.1 Hot Air Fabric Welding

Hot air welding is used to thermally bond (melt) foils and textiles. In this method, a hot air nozzle is used to deliver heat (Fig. 8). Since there is no contact with the product, the impressions and soiling on the surface of a product can be eliminated. The machine is equipped with a pneumatic tape cutter, a temporised tape feeding system and an electronic temperature control regulator with digital display to allow the monitoring of working temperature. Fabric transport is provided by two rollers, speed and pressure of rollers is controlled by specific electronic/pneumatic device and can be adjusted to cope with all different fabric types and thicknesses.

5.2 Hot Wedge Fabric Welding

In hot wedge welding, a small metal wedge is used to deliver heat to the fabric immediately before it passes between the drive wheels where pressure is applied to seal the fabric together (Fig. 9). PFAFF 8320-010 is a highly sophisticated programmable fabric joining hot-wedge welding equipment. Equipped with a touch screen, it allows electronic control of all parameters with 100% accuracy. An integrated control board monitors the sealing temperature, air volume, sealing power and the two motors for controlling the speed of the top and bottom rollers. Proportional valves enable the dynamic adjustment of air volume and sealing power while two precision-controlled motors enable a very accurate differential feed. A revolutionary new two-axis engaging system allows the wedge to be adjusted accurately without tools.

5.3 Ultrasonic Welding

Ultrasonic energy is used to seal, slit, form and convert textiles into garments or other products. An ultrasonic welding system contains a power supply which takes line power at 50-60 cycles and changes it to high ultrasonic frequency at 20,000 cycles/s, while a converter containing piezoelectric crystals dissipates the incoming electrical signal into mechanical vibrations with the same frequency. These mechanical vibrations, applied to fabric under pressure are absorbed and reflected at the interfaces. This vibration energy is delivered to the fabric or film with the help of a horn. The horns having a maximum width of about 25 cm are made of titanium with a carbide coating. The resulting molecular and interfacial-friction produces heat which causes the material to soften and adjacent layers to fuse. The anvil is a backup part used to support the work piece. When equipped with a cutting edge, the anvil can cut and seal the edges at the same time. Advantages of this
threadless sewing technique include speed, width of seam (up to 5mm), versatility of material movement (left, right, mechanical or electronic on/off), programming and cutting, sealing and welding in one step.

Plunge welding or cutting is a batch process in which the material is placed over a fixed anvil and the horn descends on it and fuses the layers together in the pattern of the stationary anvil. Cutting and sealing of edges occur simultaneously. For example, a plastic stiffener is inserted into a folded nonwoven fabric and the edges sealed using a plunge welder for a first aid splint; tapes and eye shields are attached to a surgical face mask and ties are attached to a nonwoven medical gown, all using the plunge welding technique. Other applications include punching of buttonholes, bra straps, darts, buckles, collar stays, belt loops and zipper stops (Fig. 10).

Continuous welding can be performed by use of machines which are similar to sewing machines. Feed off the arm machines equipped with a cylindrical bed, a rotary stitch anvil and an ultrasonic system above the wheel are used for making tubular parts, such as sleeves, pant legs or continuous tubes. The fabric is fed through a folder beneath a stationary horn to give a lapped seam or a double felled seam. Stitch patterns produced by an etched anvil include solid lines, dots, single stitch, double stitch, zigzag, knurl, slant, rope, serpentine, flower and leaf patterns (Fig. 10).

Ultrasonics produce smooth, durable, and clean edges with no discoloration of the fabric. Typical applications include disposable hospital gowns, protective garments, infants’ nursery garments, shoe covers, face masks, filters and curtains.

5.4 Laser Welding

This process is based on the knowledge that most polymeric materials transmit near infrared wavelengths. Thus, there is a need to introduce an IR absorber at the interface between the materials to be fused. Carbon black has been extensively used for this but results in a black weld. Now other sophisticated absorbers are used which yield a clear and colourless weld. The absorbing material, generally applied by spraying, absorbs the laser radiation and generates a weld which seals the contacting fabric surfaces. Pressure is applied during the process, to provide intimate contact between the two surfaces and fuse them together. This results in a joint that has a greater flexibility and softer feel than is made with other welding methods. The outer texture of the fabric is also retained. The beneficial features of the process include:

- Control of melt volume and hence seam flexibility
- Sealed seams in one operation, avoiding use of tapes - curved seams become possible
- Potential for high speed seaming and automation
- A novel appearance to the seam - new design opportunities
- Welding may be achieved through several layers, so closed products with internal welded structures are possible.
- The process is suitable for automation.

Laser welding uses transmission of energy to weld without melting the outer surfaces. In laser welding of thermoplastics, sometimes referred to as laser transmission welding or transmission IR welding (TTIr), transparent and absorbing parts are bonded together. The laser beam penetrates the transparent plastic and is converted to heat in the absorbing plastic. Since both parts are pressed together during the welding process, heat is conducted from the absorbing to the transparent plastic, allowing both materials to melt and create a bond. Internal joining pressure is also generated through the local warming
and thermal expansion. The internal and external joining pressures ensure strong welding of both parts. Almost all thermoplastic materials and elastomers as well as glass fibre reinforced plastics can be welded with the laser beam (Fig. 11). Its areas of application include three-dimensional interior and exterior automobile components, as well as large technical components and continuous applications from the broad field of industrial textiles. Numerous additional applications, including those in medical technologies, are conceivable.

5.5 Radio Frequency Welding
Radio frequency or high frequency welding is a proprietary plastics welding technology that enables sealing of polyethylene, polypropylene and nearly any low-loss polymer or phthalate-free material. This technology is ideal for manufacturers needing to transition away from PVC or polyurethane for ecological, financial or regulatory reasons. This technology works in 27.12 MHz (+/- 5%) frequency range. Hot air, hot wedge, and ultrasonic welding are generally categorized as rotary welding, where the fabric moves continuously through the machine while it is being welded. Radio frequency welders are a stamping type machine similar to plunge ultrasonic machines. The fabric pieces don't move but are held in place while they are being welded. Advantages of radio frequency welding are opportunities for cost savings, increased product performance, great versatility in the selection of plastics materials, and meeting of regulatory and environmental standards.

5.6 Impact Welding
There are other lesser known welding technologies available like impact welding technologies which are still at experimental stage and their use as of now is restricted to non-apparel applications. In impact welding, pressure is applied to the seam area by two impulse-heating bars. Heat is created by pulsing energy through the heating element in the top and bottom bars for the duration of the weld. After a set weld time is completed, liquid is flushed through the bars to allow a cool down cycle, helping eliminate wrinkles.

6 Bonding Technology
Bonding technology is different from welding in the sense that while welding is based on thermal bonding, the former is based on chemical or liquid glue bonding. It uses an adhesive between two layers of materials and bonding occurs through the effect of heat, pressure and moisture. Depending on the type of textile to be welded, different types of adhesives such as hot-melt adhesives and spray glues are also used in some systems. Sufficient adhesion between the textile surfaces is important for durability. This technology is also used to seal the insertion holes made by the needles. Applications are mainly in medical use garments, protective clothing and sportswear.

7 Joining Fabric to Accessories
Accessories also can be joined by sewing, welding, pasting or using a combination of these methods. Some common accessories used in functional garments are zippers, hook and loop fasteners, laminated/fluorescent/reflective tapes, buckles, labels and so on.
7.1 Attaching Zippers and Hook and Loop Fasteners

Automatic cutting of zipper tapes and hook-n-loop fasteners from a roll can be done by programming the length and loading into the holding clamp. The operator loads the garment over the pre-positioned tape, which is underneath the garment. After the initial start, the rest of the sewing is fully automatic.

Zippers and fasteners can be attached to fabric by ultrasonic welding with a seam structure according to customer’s requirements. Ultrasonic bonding with special adhesive tapes or coated elastic tapes can also be done. Some manufacturers use spot welding with ultrasonic machines (Fig. 12).

7.2 Attaching Labels and Logos

Thermal welding is used to attach thermoplastic labels on garments. For seam free labels, the label is directly printed on the fabric by thermal transfer printing. Logos and other design details can be incorporated by flock printing technique.

8 Conclusion

With advancements in material science and increasing use of coated and laminated fabrics in functional clothing, the technology for joining and assembling of these materials has also advanced. There is a distinct shift towards use of welding and bonding technologies in functional clothing because of the reduced bulk and weight, cleaner appearance and sealing qualities offered by them. Some challenges continue to exist like joining of deep curves, seam elasticity and flexibility and also in joining of non compatible materials.

References