Nonwovens in fashion apparel applications

Vaibhav K. Dhangé¹*, Lynne Webster², Amrita Govekar³

¹DKTE Society’s Textile & Engineering Institute, Ichalkaranji, Maharashtra, India
²School of Design, University of Leeds, Leeds, United Kingdom
³Oxfordshire, United Kingdom

*E-mail: profvkd@gmail.com

Received 02 June 2012; accepted 22 June 2012

Abstract
Nonwoven materials offer many advantages over traditional woven and knitted fabrics, cost savings being the most important. When we think of fashion apparels as creative instincts, most of us relate them with the traditional classifications – woven and knitted. We would be loath to consider nonwoven fabrics for the scope of fashion outfits. The aim of this paper is to review various problems associated with nonwoven fabrics with special reference to apparel applications, and sum up various efforts taken by researchers, manufacturers and fashion designers to assure nonwoven start gaining ‘respect’ in fashion apparel products. The paper also discusses various requirements in designing personal outfits such as, physical, physiological, biomechanical, and psychological needs of consumers. The paper establishes a knowledge base to further the product development with particular reference to nonwoven applications in fashion apparel products.

Key words: nonwovens for apparel, fashion, fashion industry, garment

1. Introduction
Primarily nonwoven fabrics were utilized in technical applications like geo-textiles, medical & healthcare, agriculture and horticulture, filters, packaging, home furnishing, etc. But, sadly only 1% nonwoven fabrics is utilized for apparel applications.

Nonwoven offers a number of advantages over woven fabrics, cost savings being the most prominent, due to its direct fiber to fabric process, high volume of production, and less labour compliment. This difference in cost, in fact, is large enough that nonwovens might easily have completely banished woven fabrics for fashion apparel applications, if they were not endured by the distinct disadvantages, mainly in their mechanical properties, poor drape or flexibility. In the late 1960’s there were a few efforts to market disposable nonwoven outfits but with little success due to undesirable properties [1]. Since last few years, with innovative developments in nonwoven field, this unconventional fabric produced with better drape, hand, durability, comfort, stretch and recovery, has now also started finding its application into the fashion apparel products.

2. Manifesting fashion apparel requirements.

Woven fabrics designed for apparel usage manifest characteristic like thermal comfort, heat balance, heat loss, air permeability, water vapour permeability, insulation, wind proof, moisture transport, warmth, feel, hand, drape, fabric shear, compression, surface friction, bending and tensile properties. The recommendation, when interested in designing a nonwoven fabric to imitate a woven cloth for apparel uses, is to meet the following requirements [2].

2.1 Physical requirements

Physical comfort is the sense of well being brought about by 3D shell of a garment or need of the body to feel comfortable in a clothing system. It is related to the human anatomy – size, shape, height, mass, and strength of the body. The extent to which these needs are satisfied is determined by material characteristics, shape, size, feel, bulk, and weight, ease of use, dress in and removal of the garment.

2.2 Thermo-physiological requirements

Thermo-physiological comfort refers to maintenance of thermal balance: The proper relationship between body heat production and loss, and it’s response to internal and
external stimuli. Thermo-physiological comfort is governed by thermal properties of fabric like thermal resistance, water vapour permeability (breathability),wickability, sorption of water, water resistance, water repellence, water proofness, drying rate; and the ambient climatic conditions.

2.3 Biomechanical requirements
Biomechanics deals with postures and movements of a person. As clothing acts as an intimate envelope for the human body, mechanical interactions take place between clothing and skin, muscles and tissues at different parts of the body, while the body is moving or working. Compared to a semi-nude body, the movement, speed, and range of motion are reduced in a clothed body, while muscular exertion may be increased. This is because depending on the structure, all garments exert some pressure and friction on the body. Therefore, the mechanical characteristics of clothing should match the motion, range of motion, movement of human joints, the working posture, degree of freedom of the human body. All these aspects, along with the size and fit of the garment should be considered while developing the style, cut and design features of fashion garments. Otherwise, the clothing that is too loose can get entangled and may impede the movement, but that which is too tight will be uncomfortable to work in.

2.4 Psychological requirements
Psychological aspects relate to how human beings feel, think, act and interact under a given set of circumstances. Psychological comfort implies that individuals demand specific garments, fabrics, colors, patterns and design features like necklines, sleeves, silhouette, etc. to help them feel more secure, confident and at ease. As clothing is an extension of one’s persona, strong feelings are often attached with its appearance and aesthetics. Considerations in terms of users’ psychological and social behaviour in response to events, people, pride, and identification becomes prime important. Clothing items which are perfect in terms of comfort and function may be completely rejected by the user if they are not perceived as conveying the ‘right’ image.

3. Nonwoven Performance from Apparel Perspective
During garment manufacturing process and day-to-day wear, fabric experiences deformations of different nature, i.e. tension, bending, compression, shear, torsion. Moreover individual parts of apparel are deformed in various directions with forces of different intensity and frequency. To what extent a fabric can withstand these mechanical forces is determined by the type, thickness, surface area density and other structural properties of the materials. A fabric desired for apparel applications, therefore, must have sufficient dimensional stability in its day-to-day usage, laundering or dry cleaning. It must also have low bending rigidity, ability to drape under its own weight, without any limp. It must have high area deformability to accommodate curvatures in three dimensions. It must have good recovery from extensions and bends, but not rubberlike recovery. It must be durable and resistant to tears and stress concentrations.

Stanley Backer and Dewitt R. Petterson (1960) compared mechanical behaviour of woven and nonwoven fabrics from apparel point of view. They found out that transforming a fabric sheet from two dimensions into the third dimension is accomplished by two principal actions: bending and area modification [3].

3.1 Bending
One of the major differences between woven and nonwoven fabric is the low bending rigidity of woven. The woven structure can accommodate bending strains in the direction of its yarns with nominal fiber strain, and meets desirable softness, drape and dimensional stability. The high bending rigidity of the nonwoven fabric can be ascribed to the high degree of bonding between individual fibers to impart adequate strength to the web structure. The nonwoven calls for fiber straightening followed by fiber extension. The resultant work required to stretch the fiber at a very early stage of fabric extension disturbs the wearer’s feeling of softness or drape.

3.2 Area Modification
The ability of a fabric to fit smoothly on three-dimensionally curved human body, to hang and drape freely, and to recover from bends and tensile extension, is greatly decided by a multifaceted interaction between fiber properties, and structural geometry which is drastically different in both the cases. In case of a woven cloth, the initial stress application causes a high degree of slippage and dislocation of yarns in the woven structure. This movement forces neighbouring yarns to share the stress pattern well before the initial yarn has reached its limit of stress bearing capacity. The structure of the woven fabric lends itself easily to in-plane compression e.g. at the shoulder sleeve seam. An inherent mechanism of rotation of warp & weft relative to each other, crimp interchange, yarn flatter, fiber rotation and fiber extension provide local reductions in areas necessary for proper fitting of fabric on a three dimensional body.

In the nonwoven, the collective involvement of adjacent fibers depends entirely on the extensibility of fiber and bond and is therefore quite limited. The mechanism of nonwoven fabric fitting is governed by the fiber rotation, fiber straightening, bond rotation, bond extension and fiber extension. The nonwoven cannot easily accommodate in-plane compression without buckling or wrinkling as it lacks the easy shear avenue. The inability of nonwovens to spread the stress at a tear or snag, leads to their early breakdown in outer wear.

In short, the nonwoven structure is not in a better position to withstand needle punctures, tears, stitch gatherings, and stress transfers in a fabricated garment and other forms of stress concentration met in day to day service.

4. Making nonwoven durable and resilient
There is a traditional conviction that nonwovens cannot replace traditional fabrics for fashion outfits, though they have enjoyed a tremendous popularity in the field of
apparel applications as fusible interlinings, reinforcements for shirt collars and cuffs, or front interfacings for suits. Many Researchers have been trying to find out answers to overcome weaknesses of nonwoven and suggested some solutions to improve performance of nonwoven for apparel applications.

1. The introduction of highly elastic and tough fibers and equally elastic and strong bonds has to make nonwovens more durable and resilient.

2. Darting of the fibers between the two surfaces of the fabric and introducing bonding only at the midplane. The fabric will have adequate tensile strength with significantly increased flexibility. The fibers away from the midplane, near the fabric surfaces, would have increased freedom of relative fiber motion, and it is these outer fibers which, for the most part, determine total nonwoven fabric rigidity.

3. Excess fiber length between bond points should permit greater deformability and hence decreased fabric rigidity. Generally decreasing packing density could significantly increase fabric flexibility.

4. The opportunity of achieving greater degrees of filament freedom of motion would be enhanced with increasing distance between bond points.

5. Increased fabric flexibility might also be achieved by the use of binders with improved mechanical properties, i.e., lower moduli with maintenance of elastic recovery and strength.

6. Lamb and Costanza [4] suggested that nonwoven to which a convoluted and crepe-like structure is imparted, exhibits excellent permanency of structure, flexibility, and good wrinkle recovery.

7. The durable and launderable nonwovens by necessity must be hydro-entangled. Hydro-entangling produces fabrics that are flexible, soft and conformable, similar to traditional woven fabrics [5].

Freudenberg Nonwovens, Germany based leading nonwoven producer, introduced Evolon®, a spunlaced, bi-component nonwoven, made from polyamide and polyester polymers, one of the first high-tech nonwoven to be used as an apparel outer fabric. Evolon offers ultraviolet protection, wind resistance, thermal insulation, washability, breathability and quick-drying. It also posses better mechanical characteristics and will not lose its uniformity or shape, even after heavy use. In addition, it has a soft hand, drape and is lighter-weight. Evolon provides increased comfort for the wearer through perspiration as it is permeable to water vapour. The very fine microfilaments create thousands of micro-channels to provide breathability, perspiration absorption and wicking away from the body, and quick drying of the fabric [6]. Students from North Carolina State University (NCSU) College of Textiles introduced this noble fabric for their fashion apparels.

Precision Custom Coatings LLC, a major U.S. manufacturer of nonwoven and coated fabrics for apparel and industrial applications, has recently introduced the Comfort Stretch Thermal Bond Nonwoven, which offers excellent stretch, recovery and comfort. PCC’s new products are coated with the manufacturer’s proprietary KF Resin, which provides softness, along with durability, washability and drycleanability under a wide range of conditions. Moreover, no special fusing conditions are required [7].


5.1 Disposable fashion garments

The paper disposable dress craze began in 1960s. When the demand for paper dresses exceeded supply in 1965, nonwoven fabrics quickly entered the disposable fashion market. Styles in disposable mini dresses changed

Fig. 1: Nonwoven creativity of NCSU students
Fig. 2: Spray-on dress

with breathtaking speed in the 1960s. After all, paper and nonwovens can be made into almost any fashion style. Throw-away fashion dresses suddenly started experiencing downfall due to a high concern about pollution and waste. By 1970 they had almost disappeared from the market. The demise of the disposable dresses was not simply due to the environmental crises. At that point of early stages of technology, nonwovens had an adverse position due to its poor drape or flexibility, causing low acceptability in apparel uses.

5.2 NCSU nonwoven fashion garments

During spring 2005 North Carolina State University (NCSU) College of Textiles demonstrated that nonwoven fabrics can produce aesthetics that are as good as traditional textiles. Under the guidance of Dr. Istook [8], students designed a variety of fashion outfits and accessories, constructed with at least 95% nonwoven fabric. Freudenberg fabrics as well as fabrics donated by PGI and DuPont were used to construct these garments. Unlike woven and knit fabrics, nonwovens do not ravel; therefore, seams were not surged, facilitating incorporation of shaped hemlines into the garment design. Seams within the garments also did not require finishing. Automatic cutters and industrial sewing machines were used for this work. The drape of the garments was found to be fairly good and improved after finishing. To platform the work, a fashion show was organised at the opening dinner of The 13th National Textile Center Forum and the 84th Textile Institute Annual World Conference, in Raleigh, NC on March 22. These garments were designed to target the 18-26 year old urban sector, since it was supposed that they would be more likely to hold close this unconventional nonwoven fabric and its exceptional features. Figure 1 illustrates a variety of nonwoven outfits developed by NCSU students.

5.3 Nonwoven woollen apparel

Another organization that has been working towards nonwoven garments is Wool Research Organization of New Zealand. The aim for pursuing research in the field of nonwoven fashion apparel was to dismiss the long held perception that wool apparel is expensive and created to appeal to the more rich and elite customer. For the last three years the nonwoven team at Canesis has been working on developing lightweight apparel fabrics with greater elongation and recovery. Researchers have recently designed a special collection of beautiful 100% wool and wool rich nonwoven fabrics. Fabrics with special finishes were used to produce a collection of elegant garments [9].

5.4 Fabrican Spray-on fabric

Manel Torres, while studying for his MA and Ph.D. during 1995 – 2001, introduced the idea of Spray-on Fabric, a novel way of producing instant garment without any seams directly from of fibers [10]. The spray-on dress is made up of short fibers that are combined with polymers to bind the fibers together, and a solvent that yields the fabric in liquid form and evaporates when the spray reaches a surface. The spray is applied using a high pressure spray gun or an aerosol can. The fabric can be natural, such as cotton, silk, wool, or linen, or synthetic like polyester, nylon, or acrylic fibers. The clothing can also be produced by spraying recycled fibers, for example, a pair of jeans that are not being worn any longer could be milled into fibers and sprayed in a new design. The spray on fabric can also be perfumed. It can be in any colours like black, white, red, blue, gold, platinum, bright fluorescent colours, etc. The material may be washed, re-used, re-styled and re-worn. Its properties can be customized to meet the needs of each user. Dr. Torres, founder and managing director of Fabrican Ltd., spent about ten years working on his invention, to create cheap & personalised dresses. He has also unveiled a collection of haute couture made entirely out of spray-on fabric showcased at the 'science in style' fashion show in 2010; one of these dresses is illustrated in the Figure 2.

5.5 UoL School of Design nonwoven fashion dresses

Students, under the guidance of David Backhouse (Programme Leader, Fashion) & Lynne Webster (Senior Teaching Fellow) in the School of Design at the University of
Leeds (UoL), UK have been involved in researching the use of nonwoven fabrics in apparel since 2005 resulting in a number of unique collections [11].

5.5.1 Fashion synergy

Colbond, a globally active leading producer of high quality industrial nonwovens supplied their Colback® fabric in a range of weights. The challenges with using this nonwoven fabric, originally intended for civil engineering, building and other industrial purpose, for fashion apparel applications were varied; most of the fabrics were transparent, non-drape, harsh to the touch and rigid. Students had to ‘work’ these qualities into their designs and develop ways of ‘patterning’ these aesthetics to create modern, fashionable apparel (Fig. 3).

The real challenge was to consider alternative garment design approaches exclusively suited for nonwoven. One of the major difficulties they encountered was the pattern blocks. Traditionally these include ‘ease’ around the armhole and top of arm to accommodate movement when worn; these were re-engineered to omit any ‘ease’, enabling the sleeve to be inserted into this cylindrical shape using this rigid and non-stretch fabric. The transparency issues were overcome by using multi-layers, pleating and gathering. Colbond’s nonwoven fabrics were inexpensive in comparison to traditional fabrics, using a higher than average meterage in this instance, was viewed as a commercially viable option.

Elements of this first collection of garments, ‘Fashion Synergy’ was disseminated at the EDANA Nonwovens Research Academy held at the University of Leeds in 2007 and at the University of Leeds International Textiles Archive (ULITA) the same year. This initial effort generated a range of remarkable and informative results. It was discovered that nonwovens offered garment making process a range of unique advantages over wovens: they did
not have warp or weft and therefore no grainline, which enabled pattern pieces to be cut more efficiently utilising less meterage, overlocking of seams was not required as fabric did not fray, interlining was not required for collars, seams which normally receive overlocking could be left raw and front bodices which by tradition require facings could be produced without. Ultrasonic and thermal joining techniques allowed stitching to be replaced and localised thermo-forming offered a means of improving fit and simplifying garment assembly.

5.5.2 Fashion: function in action

This initial experimentation generated further research impetus and other imaginative, and what could be termed ‘quirky’ collections followed including ‘Fashion: Function in Action’ (Fig. 4). Students developed creative fashion forward apparel using Evolon and other nonwoven fabrics which included the latest technological advances such as incorporating developments in elastic film composites, thermo-active PCM’s, masterbatch additives, thermochromic finishes, electroconductive fabrics, high temperature protective fabrics, metallised and multi-layer spunbond laminates. This collection, supported by EDANA and its members, was exhibited at INDEX08 in Geneva and at the 7th Nonwoven Network UK annual conference in 2008.

5.5.3 Fashion: transparency

The next collection of experimental research, Fashion: Transparency, merged history with science to create a mix of multilayered new materials with an air of familiarity. Colbond’s unique Colbeck® fabrics were given ingrained imperfections using laser cutting, beading and hand embroidery, adding a sense of story kept up to date in an elegant and contemporary way. The use of high frequency sonic energy to bond the seams around the body and armholes gave the apparel the clean, sharp edge required for the style characteristics. This process of seam bonding requires a high synthetic fiber composition so Colback’s® unique thermally bonded spunlaid nonwoven, made from bi-component filament with a polyester core and a polyamide skin proved ideal using the re-engineered pattern blocks. Here the ‘transparency’ of the nonwoven was exploited to create a mood with many facets, from soft dressing and
feminine ruffles (Fig. 5) through to tailored-inspired looks.

5.5.4 Fashion: décoratif

Fashion: Décoratif was the next collection developed by the students, this incorporated exploratory research in beading, embellishment and print and colour techniques. Colour was implemented in a variety of ways, from hand painting with acrylics and water to machine dying and hand dip dying. It was found that these processes changed the handle of the fabrics and these differences were exploited in the design process (Fig 6). Determining best practice in garment construction also highlighted the issue of fastenings. Apparel traditionally uses zips, buttons, hooks and eyes for garment fit and ease of wear, alternatives were explored resulting in a number of highly individual and creative alternatives being found; buttons made from plaited nonwoven pieces, tie fastenings instead of hooks and eyes and elastic inserts as an alternative to zips.

5.5.5 Architectural Colour Clash

In 2010 the Lenzing Group - world leader in marketing and manufacturing man-made cellulose fibers - approached the staff at School of Design with a challenge to create a range of garments using their distinctive brightly coloured fibers. To date, apparel collections using nonwoven fabrics had been
created by the School in either neutral or soft colours such as white, creams, soft greys, blues and pinks. The fabrics sent from Lenzing were soft to touch and came in bold colours; chartreuse yellow and green, lilac, cyclamen pink and tangerine. They were also complex; delivered in rolls 50cm wide. Generally fabrics used for apparel are 100-150 cm wide to allow for shaping around the body and to create the fluid lines customary to apparel. This narrow width presented staff and students with a range of new questions; would full size garment pieces fit? Which pattern shapes would best address the restrictions? How could full and pleated skirts (Fig 7) be evolved using this width of cloth? Taking advantage of the fabrics lack of grainline the pattern pieces could be laid across the both the length and width, enabling the students to make full use of the available cloth. Careful manipulation of large pattern pieces and thoughtful pattern cutting was essential.

To take advantage of the nonwovens non fray properties a unique experimentation with seams was developed, using net fabric both sides of the seam were stitched together using the net as an anchor (Fig. 8). This not only gave the apparel flat seams but also created a new and distinct design focus. The use of colour made an impacting statement, whether it came in colliding or matching colour blocks. Strong, sharp and clean design lines gave a contemporary feel.

Lenzing’s eco-friendly cellulose fibers and ‘on-trend’ colours gave the apparel a soft handle and directly linked to consumer aspiration, inspiring and supporting both product development and the creative process. Bright statements, directional and cutting-edge pattern cutting pushed the boundaries and made an impact into what could be perceived as fashion fabrics. Focussing on clashing colours, architectural and sculptured or rounded shapes (Fig. 9) and simple methods of construction these garments wrap the body in a swathe of ‘cool cocooning’. These nonwoven fashion garments were exhibited at INDEX 11 Palexpo, Geneva April 2011 under the title Architectural Colour Clash.

6. Conclusion

The traditional belief that nonwovens cannot replace regular woven outfits is not strictly correct today. There are nonwoven materials like Evolon® that can function perfectly well as clothing; they are durable, dimensionally stable, launderable, flexible, soft and comfortable, similar to conventional woven fabrics. The research undertaken by various fashion designers mentioned in this paper goes some way to proving that nonwoven could offer a number of advantages over traditional fashion fabrics; reducing assembling cost and allowing recycling at the end of life, thereby reducing the overall life-cycle impact of clothing with obvious cost saving.

In order to ensure that nonwoven gets commercial success in the field of fashion apparels, it is crucial that nonwoven producing and supplying companies understand and appreciate how fashion designers perceive and use new

Fig. 9: Architectural colour clash. Example of cutting edge pattern drafting.
fabrics and technologies to develop innovative products.

The review so far suggests that with current research and developments within the nonwoven industry focusing on improving the creative and aesthetic possibilities of nonwovens, these fabrics could soon be finding a place of pride in the fashion market.

7. **Acknowledgement**

The authors are thankful to Mr. Manel Torres, managing director, Fabrican Ltd., Photographer Mr. Ian Cole, Dr. Cynthia L. Istook, College of Textiles, NC State University, and Mr. David Backhouse, School of Design, University of Leeds for making photographs of their work available for incorporation in this article.

**References**


Source of support: Nil; Conflict of interest: None declared