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An Aesthetic Approach of Seamless Garments: A Review

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Abstract
The manufacturing of garments without laying, cutting and sewing of fabrics is called seamless garments. It's not a new phenomenon but a furtherance of the apparel industry which also reduces the manufacturing cost by 40% if differentiated with the conventional garment production processes and time, furthermore provides greater comfort and fitting to the wearer. A comprehensive literature survey has been done on this area and discussed in the article. Seamless garments production, use of raw materials, advantages, disadvantages and applications are discussed in this review article after a comprehensive literature survey.

Keywords: Seamless Garments, Apparel, Fabrics, Comfort.

1. Introduction

The seamless technique dates back to the fourth and fifth centuries AD. At that period it was absolutely used in socks making in Egypt throughout the Coptic era. Later, the fisherman and their women on the northern coastlines conjointly created over body cloths except any prominent seam. In the early 1990s, the seamless technique was restricted in the socks and hand gloves assembly, however no longer more. The seamless technology has transformed the apparel sector, and it is currently the new craze in worldwide fashion. This is turning into a fashionable trend in western countries, as there are benefitted to wear a seamless item [1]. The seamless technology can manufacture nearly finished products directly, with no side seams and lessens ancient method of the assembly. So, this technology can scale back the traditional
method of garment production and price goes up to 40% compared to the ancient knitting [2]. The various types of techniques are used to produce seamless garment. Such as knitting, weaving, braiding, basketry, crochet, and molding [3-5].

Figure 1. Some photographs of seamless garments.

2. Discussion

Choi provided a clear information about the history of seamless garments (Table-1) [12].

Table 1. Chronological development of seamless technique [12].

Year	Chronological Development of Seamless Knitting
1589	First flat-bed frame was invented to create hosiery by William Lee in England.
1863	The first operational V-bed flat knitting machine with the latch needles was invented by Issac W.
1864	Rotary-driven machine was patented by William Cotton of Loughborough that used a flat bed to produce fully-fashioned garments.
1800	To knit single jersey tubular items such as gloves, socks and berets, the flat knitting machine fitted with sinkers was used which controlled stitches.
1940	In the United States making of shaped knitted skirts using a “flechage” technique was patented.
1955	The automatic knitting of traditional berets through the shaped sections was reported in Hosiery Trade Journal.
1960	Tubular-type knitting principle further explored by Shima Seiki company to produce gloves economically.
1960	Courtaulds established British patents on the idea to produce garments by joining tube knitting.
1995	At ITMA Shima Seiki first introduced seamless entire apparel knitting.

Good moisture and drying properties are important factors for clothing used near the skin, especially for sport wear, underwear etc. [6]. Sena reported in 2012 that seamless technology can give improved versatility in the designing of such clothing with optimized comfort properties compared to the circular knitting technology. This is achieved by using Ne 40/1 cellulose fibres (namely cotton, viscose and bamboo) as face yarn, while 33 denier 34 nylon filament was used as a plaiting yarn which was intermingled with 17 detox spandex yarn. The samples were dyed in industrial circumstances and finally repeated laundering processes which was done with half of the samples. They concluded that fibre types and stitch lengths had a major influence on liquid transfer characteristics and properties of materials.

Seyam et al., published an experiment based research article where they developed seamless woven garments with preset shape and sizes [8]. Total 33 tubular woven fabrics with differential shrinkage and constructional parameters (different weave structure, using variable weft yarn tension, densities, count and shrinkage) were established by employing a Tsudakoma shuttle weaving machine.

After completing subsequent washing, drying and heat setting, samples exhibit that the finished fabric dimensions varies from 34.4-62.0 cm corresponding to finished fabric shrinkage ranging from 7.5 - 48.7%. A straight forward relationship between finished fabric dimension, off loam fabric and weft yarn parameters also comes forward. Here finished fabric dimension decreases, on the other hand shrinkage percentage increases by reducing the weft yarn density, increasing tension in weft yarn, and adding 0.2% spandex.

Gorea et al. used biomimetic design, produced total 14 sports bras and assessed performance (responsive behavior) using college athletes [9]. The obtained results found approachable behavior in terms of support of breast and comforting different conditions. Figure 2 shows significant compression of the breast found in dry conditions from the prototype sports bra, slice circumference became larger because the patches got wet after running. But slice circumferences after rest conditions came back to dry condition measurement with minimum differences (0.8 inch) which was not significant actually.

To knit seamless garments, polyamide (PA) yarn or poly urethane (PU)/polyamide (PA) core-spun yarn are mostly used as the base yarn, and PA, cotton, tencel, modal, etc. are used as the face yarn. Polytrimethylene terephthalate (PTT)/polyester (PET) bi-component filament can also be used as base yarn instead of PU/PA core-spun yarn to develop

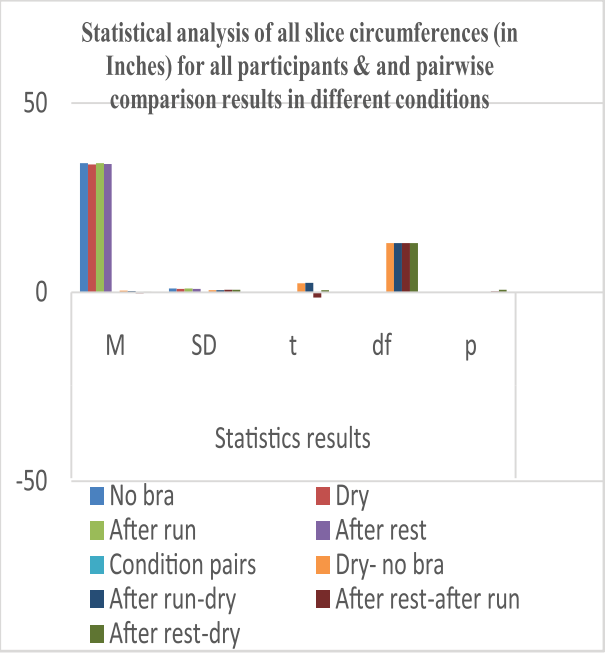


Figure 2. Statistical analysis of all slice circumferences (in inches) for all participants & and pair wise comparison results in different conditions.

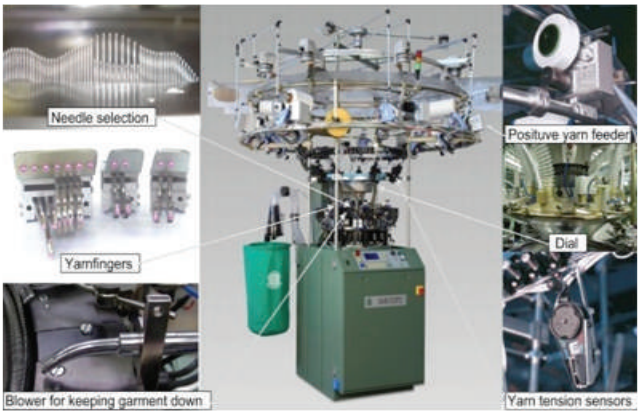
seamless garments because of its excellent flexibility seamless and elastic recovery property. Li Zhao et al. (2012) manufactured both types of fabrics keeping PA filament fixed as face yarns and PTT/PET & PU/PA as base yarns by using single circular SANTONI SM8 TOP 2 seamless machine (guage E28). After knitting pre-treatment, dyeing and finishing were also developed. Evaluation and comparison were done by end use performance of both the seamless products. The results show that the fabric manufactured from the PTT/PET bi-component filament has much better dimensional stability, excellent elastic recovery and better wrinkle resistance than the fabric made of PU/PA core-spun yarn [10].

F. Lauet al, discussed on different aspects (benefits, limitations, knitting parameters and machine's working procedures) on seamless knitting of intimate apparel [11]. They state that there are a wide range of benefits of using seamless garments for designers, manufactures and consumers (Table 2).

Table 2. Benefits of seamless intimate apparel [11].

Designer's benefits	**Manufacturers benefits**	**Customers benefits**
Design remains digitals that's why unlimited design creation possibilities.	Reduces inventories, machine involvements, labor cost and energy.	Provides natural look, very soft and smooth to look, greater comfort can be achieved.
Easy to modify designs with minimum human interventions.	Faster and just-in-time production have achieved.	No irritating stitches, no bulkiness on seam, perhaps support like a second skin.

Figure 3. Various working parts which are present in Santoni SM8-Top 2 circular seamless knitting machines [11].



Wonseok Choi et al. [12] discussed on different types of V-bed flat knitting machine (Shima Seiki and Stoll) used to produce seamless garments (Figure 4-5) which also provides a comparison chart of both machines depend on different knitting parts

and parameters. The only major difference between Shima Seiki and Stoll machines is that three different needles (latch needles, compound needles & slide needles) can be employed in Shima Seiki machine on the other hand only one needle (latch needle) can employ in Stoll machine to produce fully fashion knitted items.

In another report, Madhumathi et al., discussed on the need of seamless garments [13]. They mentioned that seamless garments are very much needed to avoid labor intensive process in traditional cut and sew garment production, avoid fabric, fibre or yarn damage due to the needle hole, reduce concentration of stress, save human potentiality as well as fabric wastage percentage of these products in different sectors such as ladies' underwear (78%), men's underwear (13%), outerwear (2%), swimwear (2%), sportswear (4%) and sanitary products (1%).

It is possible to knit with different yarns inside and face side of a garment by WHOLEGARMENT®machines (Figure 6) [14]. Cotton can be knitted on the inside of coarse yarn which makes it more comfortable to wear. On the other hand silk can be knitted inside and a textured yarn on the outside of a garment. The loose knitting can be done on the outer layer and fine knitting on the inside layer. The holes can also be created highlighting the beautiful inside yarns.

'Behind comfort, seamless garments can also be sustainable'- besides good feeling seamless garments these are also good for the environment [15]. Its production process is more sustainable and eco-friendly than conventional cut and sew garment manufacturing processes. It not only reduces the production cost and time than conventional process but also reduces a huge amount of fabric wastage, so that this method can save large quantities of yarn/raw materials. Uses of seamless products are more ethical as it minimizes intensive use of human labor compare to the conventional cut and sew system.

Kumar reported important information on seamless garments where he compared between cut and sew garments making and fully fashioned/seamless garments making systems [16] shown in Table 4 also gave a loop transfer mechanism in a V bed knitting machine (Figure 7).

N. Nawaz et al. mentioned discussion on a vast information about seamless garments like seamless technique, advantages, disadvantages, application and so on [17]. Seamless products can be used as upholstery like chair seat cover, automotive, industrial textiles, sports textiles, sports bras, medical textiles and protective clothing. Some disadvantages of seamless garments are mentioned below;
- Fabric takes down keeping tension equal in each loop is the major problem in seamless garment technique [18].

- Problem also arises during alternate needle selection. Effect appears mainly in welt and cuff areas [19].

- Initial capital investment is higher than conventional cut and sew system. The machinery cost is high and skilled operators are needed to operate the machinery [20].

- Seamless garments belong to light weight and remain next to skin thus they are very much popular for innerwear but for outerwear these are less popular compared to regular cut and sew garments [20].
- Seamless garments are also costly comparing to regular garment [20].

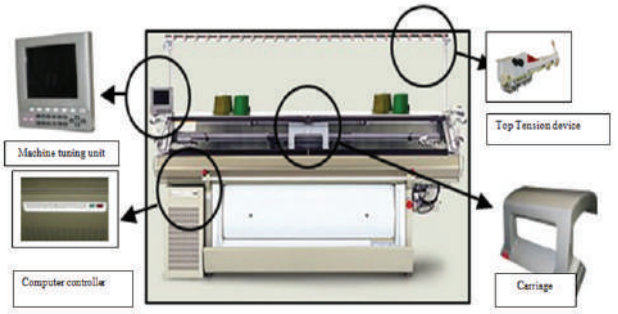


Figure 4. SWG- V® machine [12]

Figure 5. Stoll knit and wear machine (image collected from https://www.stoll.com/en/machines/).

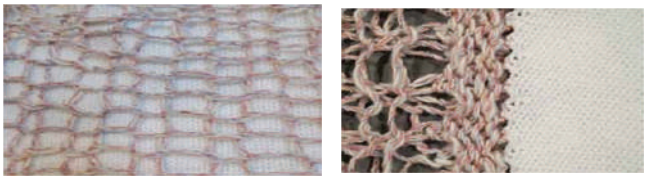


Figure 6. Whole garment making by knitting different yarns on inside and outside of garment by using WHOLEGARMENT®machines [14].

Table 4. A comparison between cut and sew garments and fully fashioned seamless garments [16].

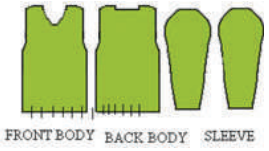
Cut and sew garments	Seamless garments
In cut and sew garments making system the fabrics are cut by using cutting machines after that sewing is carried out.	Shape of the Garment can be achieved by widening and narrowing of loop transfer mechanism.
Cost added for cutting and sewing.	Reduced cutting and sewing cost.
	

Figure 7 . Loop transfer on V-bed knitting machine [12].

3. Recommendations

-Till now seamless garment is used as a special purpose like intimate apparel, sweater, medical textiles and so on but in this era of first fashion or 4th industrial revolution it is necessary to think about seamless garments seriously as inner and outerwear/regular wear from every end of stakeholders (buyers, manufacturers & consumers) as it's a sustainable process.

- More research works should be done in this field both in manufacturing and marketing fields thus it may become more affordable and popular.
- Besides, seamless knitting, seamless woven fabrics should be included more in seamless garment productions, vast research works are required is this field also.
- Selection of yarn to produce seamless garment is limited till now, more innovation should be done in this area to reduce the cost of such product.

4. Conclusion

If we think about sustainable garment production by saving raw materials and least wastage of fabric with minimum involvement of manpower there is no alternative of fully fashioned garments/seamless garments. No doubt it's a pioneer technique in apparel sector because of smooth fitting, comfort feelings, easy handle properties and consistent quality throughout the garment production. That's why demand for seamless items also increases day by day and will remain unchanged for the time being. There is a potential possibility, this new vogue which is very popular especially among the youth will grab 50% of industrial sales by next few years. In this article we tried to uplift some basic

information about fully fashioned garment production system, raw materials used, design possibilities, machinery used to make such garment, its demand at present market, applications, potential benefits, some limitations and recommendations which are given after studying a numerous number of articles published on seamless garments over last two decades. We believe it will be a great help to the future young researchers who have interest on these products.

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