MODULE 5
Sustainable yarn, fabric and garment/assembly production

Unit 5.2 Knitting and weaving processes in circular economy

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Unit 5.2 Knitting and weaving processes in circular economy

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5.2.1 Knitting and weaving processes - from the beginning to present day

Woven fabrics are known since the Palaeolithic era, i.e., more than 25,000 years ago.

The first weaving looms were vertical, as presented in a picture of ancient Egyptian civilization more than 5,000 years ago.

Such weaving was really completely wasteless, as all yarns were woven into a fabric and even small ends of yarns were used for manufacture.

Figure 1. Weaving in the ancient Egypt[1]

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5.2.1 Knitting and weaving processes - from the beginning to present day

The history of knitting is believed to have begun in Egypt in ~400th years of our era. Until the 16th century, knitting in Europe was exclusively male work - men were the first official knitters.

By the 13th century, socks were mostly knitted, initially as flat products with a seam, and from the 15th century as circular knitting using five knitting needles.

Figure 2. Early knitted Spanish gloves made with red and yellow silk, worn by a bishop, 16th century / Victoria & Albert Museum[2]

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5.2.1 Knitting and weaving processes - from the beginning to present day

The first mechanical stocking frame knitting machine was invented only in 1589 by William Lee in Nottinghamshire, England. Its principle of operation is still used today in weft knitting machines.

The stocking frame knitting machine allowed larger quantities of garments and household goods to be produced in shorter periods of time, combined with lower labour costs.

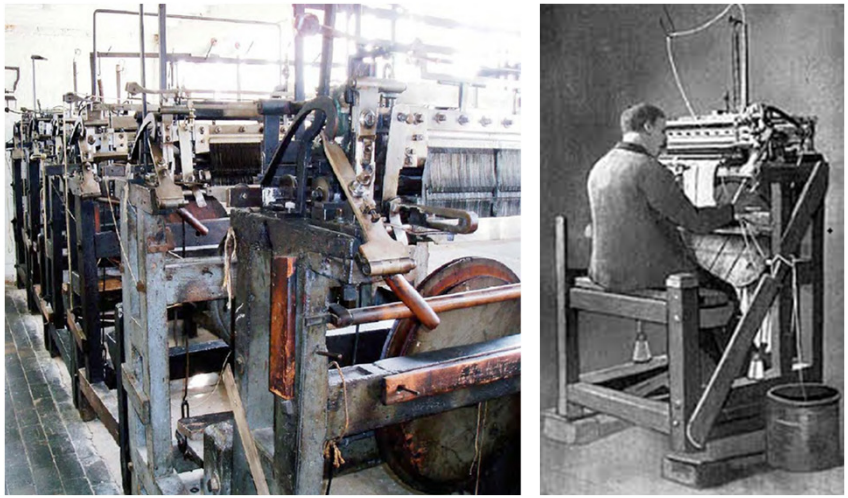

Figure 3. The first mechanical stocking frame knitting machine invented by W. Lee[3,4]

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5.2.2 Monitoring and control of process parameters that can reduce waste, cost and environmental impact

One of the factors that is controlled during knitting or weaving is yarn consumption.

If two garment samples are knitted with the same yarn and structure but have different dimensions, it indicates a difference in the length of the loop or the density of the stitch. In this case, the knitting machine settings need to be adjusted.

In knitting, yarn consumption can be minimized by effectively analyzing yarn feed through the computerized system on the knitting machine, for instance, DSCS (Digital Stitch Control System) on Shima Seiki (Japan) machine

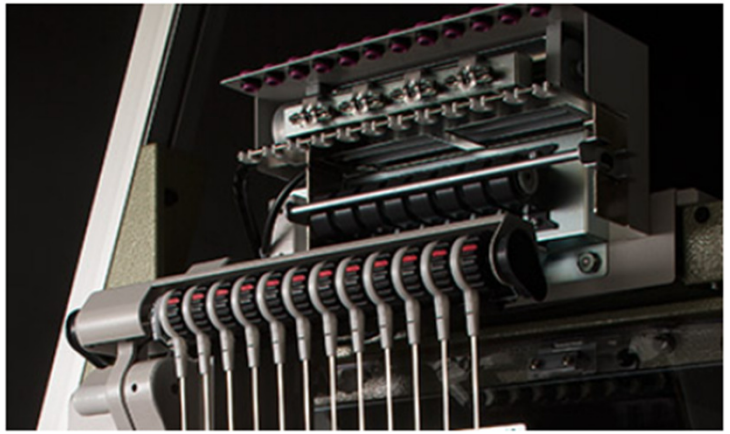

Figure 5. DCSC by Shima Seiki

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5.2.2 Monitoring and control of process parameters that can reduce waste, cost and environmental impact

For managing time and yarn waste, it is very important to control possible knitting defects such as broken needle, yarn fly, hole, barre, and thick or thin yarn segments.

Defects in a knitted fabric mean that these defected pieces of the fabric will increase the total amount of a knitting waste.

In fully-fashion and seamless knitting, such defected pieces usually are disassembled and the yarn is reused for knitting. It helps to reduce the amount of knitting waste significantly.

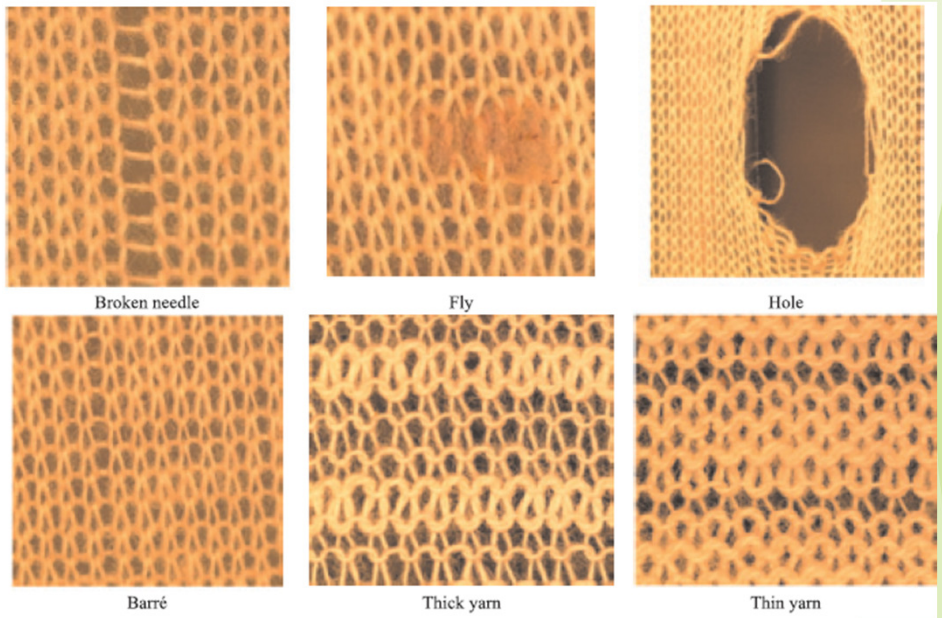

Figure 6. Defect in knitted fabric structure[5]

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5.2.2 Monitoring and control of process parameters that can reduce waste, cost and environmental impact

Cutting and sewing is a labour intensive process that creates human error, and then the cutting process creates more fabric wastage.

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5.2.2 Monitoring and control of process parameters that can reduce waste, cost and environmental impact

The seamless knitting technique creates entire garments with minimal intervention of the cutting and sewing processes, leading to substantial **savings in cost and time, higher productivity, quick response, and rapid production in time**.

Figure 7. Seamless dress

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5.2.2 Monitoring and control of process parameters that can reduce waste, cost and environmental impact

Seamless knitting eliminates processes, such as fabric laying, cutting and sewing, which create human errors and quality problems, e.g., needle holes in the sewn product or additional stress in the seam portion.

Figure 8. Seamless knitting

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5.2.2 Monitoring and control of process parameters that can reduce waste, cost and environmental impact

The virtual **yarnbank** reduces the need for manual yarns scanning and improves the accuracy of simulations and the efficiency of product planning.

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5.2.2 Monitoring and control of process parameters that can reduce waste, cost and environmental impact

The biggest attention in weaving modernization in front of sustainability and waste-less manufacturing is given in a non-stopped procedure of weaving when one beam is changed by the similar next one and ends are tied directly in a loom. While the ends of the yarns in the bobbins after beam formation could be used for the manufacture of woven fabric as warps.

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5.2.2 Monitoring and control of process parameters that can reduce waste, cost and environmental impact

In weaving, minimization of yarn consumption can be achieved by minimizing the length of side weft waste.

In the Picanol (Belgium) weaving loom, the EcoFill system was introduced with the main focus on applications where high-value weft yarns are used.

The EcoFill system completely eliminates the catch-cord system and reduces the filling waste.

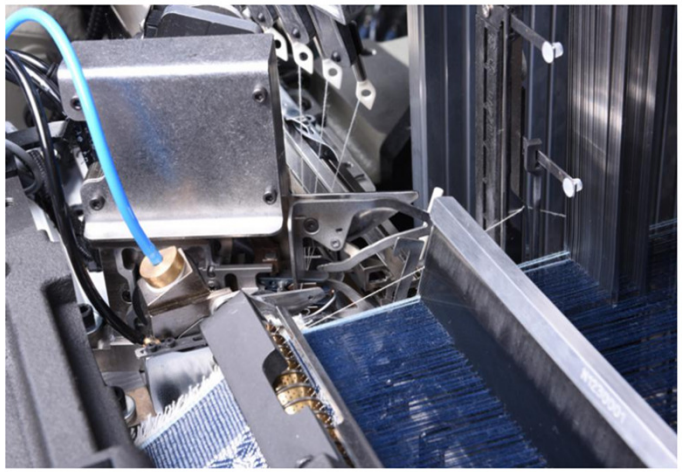

Figure 9. EcoFill system by Picanol[6]

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5.2.2 Monitoring and control of process parameters that can reduce waste, cost and environmental impact

CordLess by Picanol:

At the end of the insertion, the filling yarn is stretched and guided into a suction mouth. The remaining ends of the filling yarn waste are then removed and ready for recycling.

An additional advantage of the CordLess is the reduced workload for the weaver, by eliminating catch-cords.

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5.2.2 Monitoring and control of process parameters that can reduce waste, cost and environmental impact

The Picanol AirMaster allows measurement of air consumption. This makes it possible to offer the following features:

- Continuous measurement of the air consumption,
- Fully automatic diagnosis of leakage and clogging detection
- Manage the length of the filling to reduce waste.

The design of the Blue22 and Blue11 prewinders makes the waste adjustment quick and simple, fully electronically without stopping the machine.

Figure 10. Blue prewinders by Picanol[7]

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5.2.3 Circular weaving in the context of waste management and production efficiency

Ancient vertical weaving looms were really wasteless, as warps and wefts were used up to the very end.

Horizontal weaving is not fully wasteless, even in the case of hand looms, as some part of warp yarns from the beam are not used for fabric weaving – the beginning and the end of warps on a beam cannot be used for weaving. Also, there are ends of wefts left on both sides of a woven fabric.

In many cases catch-cords are used which also create additional amount of yarn waste.

Figure 11. Horizontal hand weaving looms[8]

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5.2.3 Circular weaving in the context of waste management and production efficiency

Picanol (Belgium) manufactures high-tech weaving machines based on airjet or rapier technology. The difference between these to types in regard of reduced amount of waste is in the principle of wefts insertion.

Using rapier of shuttle weaving technology, ends of wefts left on both sides of woven fabric are very short.

In airjet technology, there are relatively long ends of wefts left on both sides of woven fabric which are cut directly in a weaving loom and it is a pure waste of yarns.

Figure 12. Modern rapier weaving loom of Picanol[9]

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5.2.3 Circular weaving in the context of waste management and production efficiency

Even modern technologies of classical weaving did not fully solve waste problems in weaving. In modern technologies waste rises not only in weaving looms but also in a process of beam manufacture – not all yarns from bobbins in a creel are used for beam manufacturing.

In order to reduce the amount of warp yarn waste, bobbins of higher mass and with higher length of yarns on them are used for warp beam formation

Figure 13. Modern creel for beam manufacturing[10]

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5.2.3 Circular weaving in the context of waste management and production efficiency

The biggest attention in weaving modernization in a front of sustainability and waste-less manufacturing is given in a **non-stopped procedure of weaving** when one beam is changed by the similar next one and ends are tied directly in a loom.

These ends of the yarns in the bobbins after beam formation could be used for woven fabric manufacturing as warps. However, not all kinds of warp yarns can be used for wefts; therefore, some amount of waste usually appears in this process.

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5.2.3 Circular weaving in the context of waste management and production efficiency

The most wasteless and sustainable weaving is circular weaving when woven fabric is manufactured like a circle tube directly from a creel, i.e., a warp beam is not used.

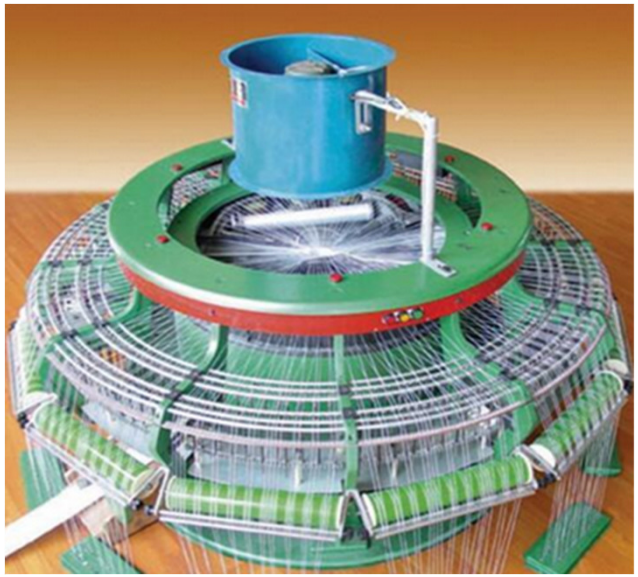

Figure 14. Circular weaving loom[11]

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5.2.4 Fully-fashion knitting in the context of waste management and production efficiency

Knitwear can be produced using three methods:

1. Cut-and-sew method
2. Knit-to-shape (fully-fashion) and sew method
3. Seamless knitting method

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5.2.4 Fully-fashion knitting in the context of waste management and production efficiency

The **fully-fashion knitting** of regular details and seamless knitting technology shortens the manufacturing process and significantly reduces material waste.

A new way of making garments also opens up new ways of thinking, which may lead to new expressions.

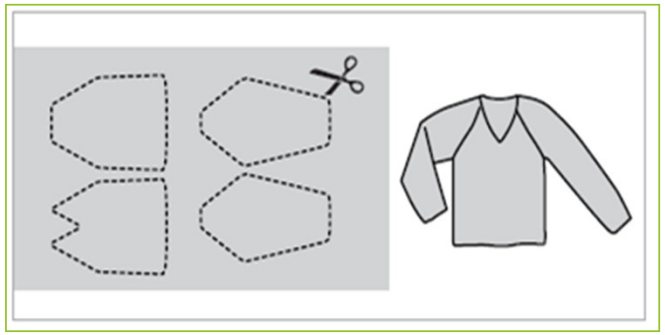

Figure 15. Cut-and-sew method

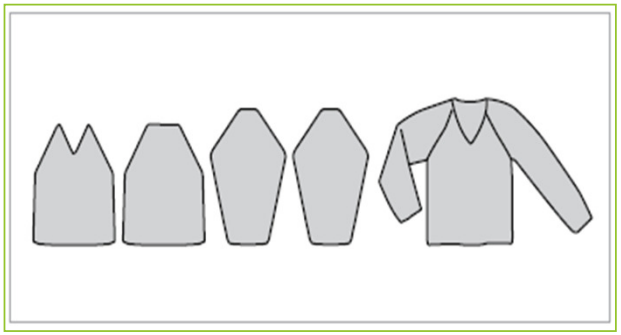

Figure 16. Fully-fashion method

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5.2.4 Fully-fashion knitting in the context of waste management and production efficiency

Fully-fashion knitting allows one to get fully-fashioned panels of garment that do not require cutting operations or cutting is used only for small corrections.

Knitted panels usually have all necessary parts – pockets, buttonholes, even collars, which are also knitted during the same knitting process.

Additionally, fully-fashioned knitted panels can be unknitted if some knitting defects appear, and these yarns can be used for knitting repeatedly.

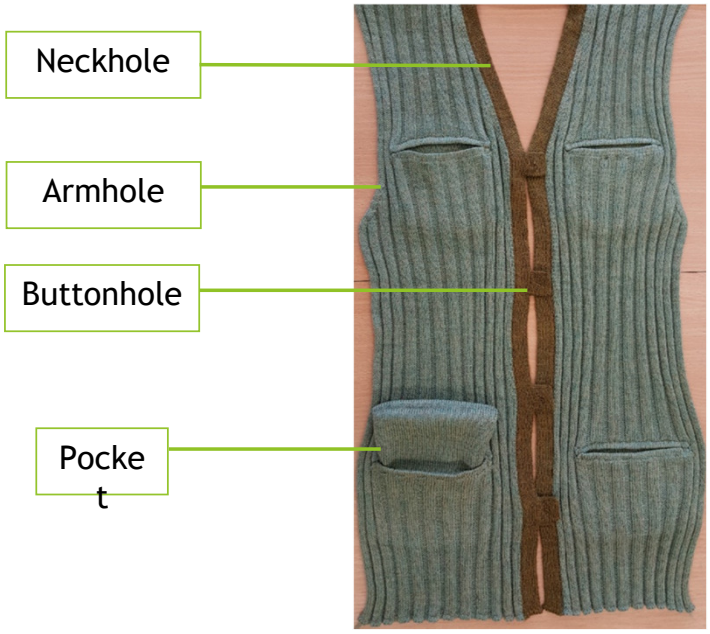

Figure 17. Fully-fashion panel

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5.2.4 Fully-fashion knitting in the context of waste management and production efficiency

Sometimes cutting is still required to trim the fabric area outside the garment panels, and sewing is needed to join components together into a garment.

Figure 18. Fully-fashion panel

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5.2.4 Fully-fashion knitting in the context of waste management and production efficiency

Panels knitted with fully-fashion knitting technology commonly are connected to each other through **locking courses**.

The locking courses helps to avoid take-up of the first courses of each panel and protect the knit from unstitching after detachment of two adjacent panels.

Figure 19. Locking courses

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5.2.4 Fully-fashion knitting in the context of waste management and production efficiency

The shape of fully-fashion knitted pieces can be changed in different ways, including combinations of stitch types, loop formation, yarn types, machine settings, and design processes.

Combination of different patterns in one panel

Combination of different yarn' linear density in one panel

Figure 20. Fully-fashion panel shaping

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5.2.4 Fully-fashion knitting in the context of waste management and production efficiency

Variations in a panel can be obtained due to different loop lengths in multigauge weft-knitting machines or loop transfer.

Panel knitted by using loop transfer

Panel knitted on multigauge weft-knitting machine

Figure 21. Fully-fashion panel shaping

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5.2.4 Fully-fashion knitting in the context of waste management and production efficiency

Fully fashioned garments can be developed by widening or narrowing the fabric through loop transfer or adding new needles at the edges.

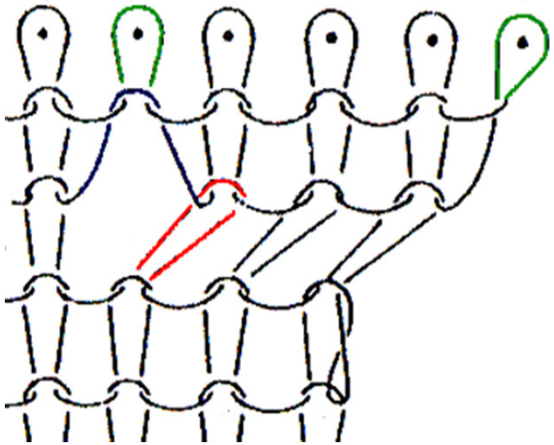

Figure 22. Widening scheme

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5.2.4 Fully-fashion knitting in the context of waste management and production efficiency

Narrowing by transferring one loop onto the adjacent needle.

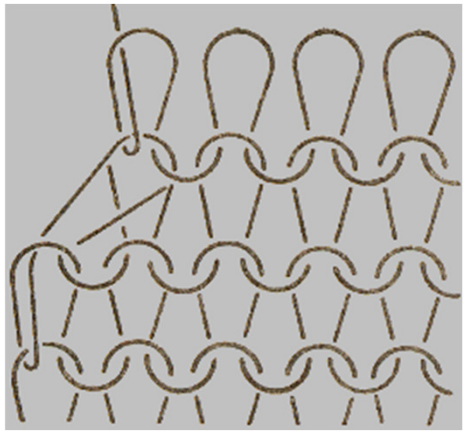

Figure 23. Principle of narrowing

Figure 24. Knitted sample

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5.2.4 Fully-fashion knitting in the context of waste management and production efficiency

Narrowing by transferring group of the loops onto adjacent needles.

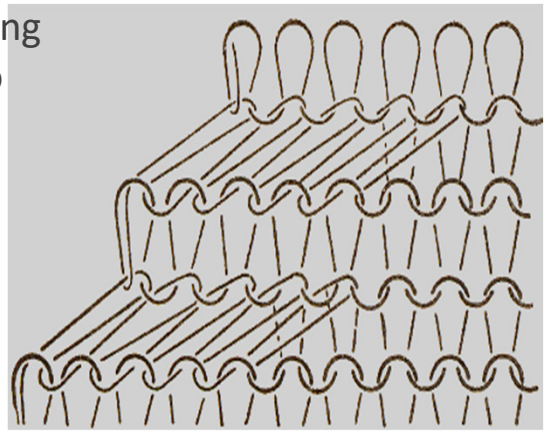

Figure 25. Principle of narrowing

Figure 26. Knitted samples

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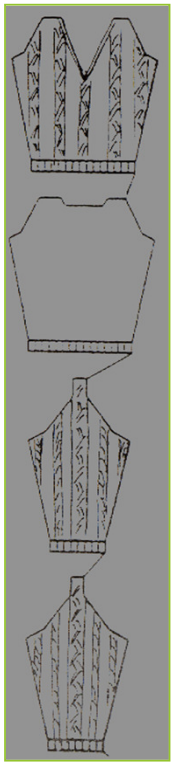
5.2.4 Fully-fashion knitting in the context of waste management and production efficiency



Each panel can be knitted on separate knitting machines, or all panels can be knitted on the same knitting machine.

After knitting, all panels are sewn together into one garment.

The fully-fashion method ensures a much lower amount of fabric and yarn waste, as a well as lower energy and manpower consumption.

Figure 27. Fully-fashion panel knitting principles

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5.2.5 Seamless/whole garments knitting in the context of waste management and production efficiency

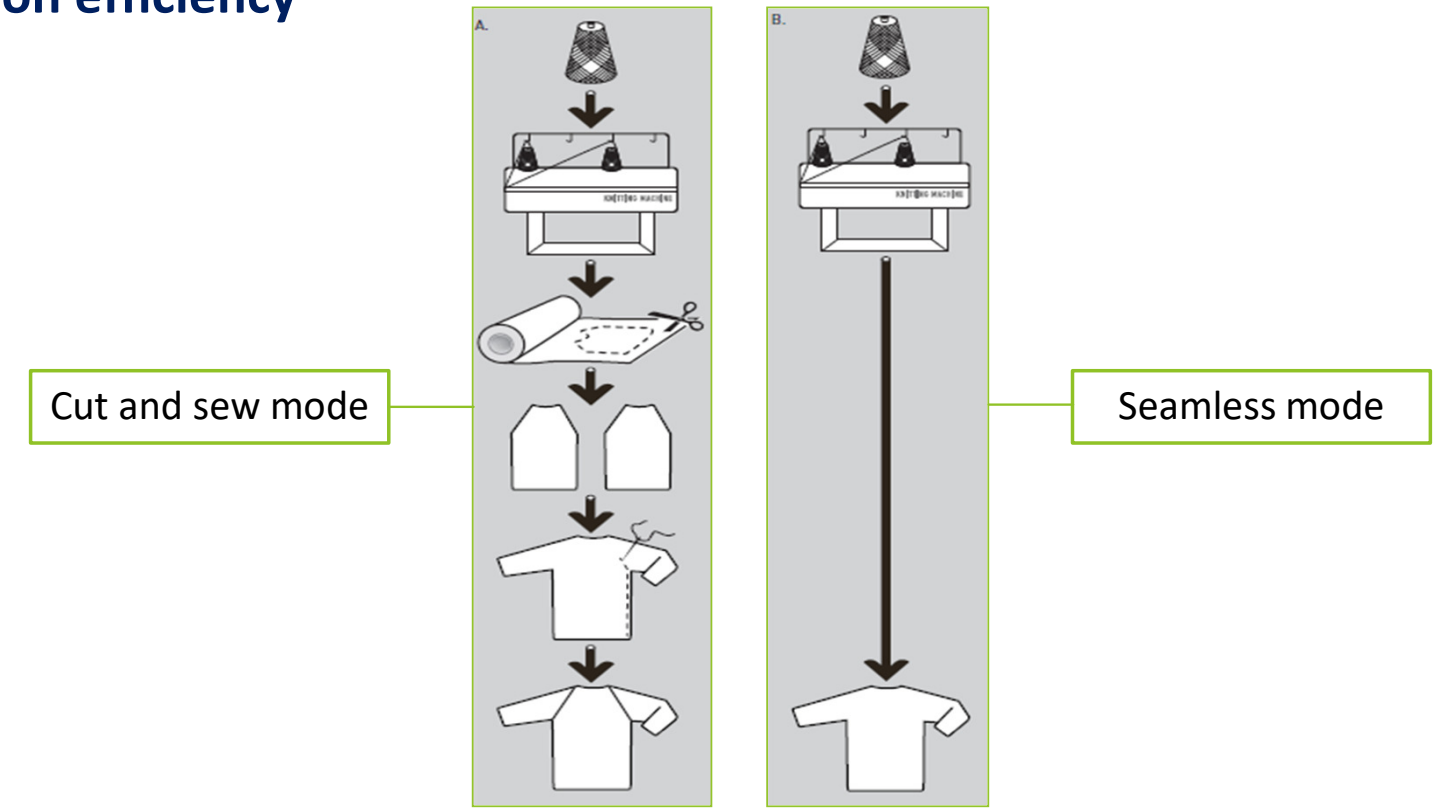

Figure 28. Seamless knitting vice cut-and-sew method

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5.2.5 Seamless/whole garments knitting in the context of waste management and production efficiency

Using seamless knitting, we can minimize the production cost as well as production time by 40% compared to the traditional apparel production system.

Seamless clothing gives more comfort because it does not have a seam in its structure

Figure 29. Seamless knit

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5.2.5 Seamless/whole garments knitting in the context of waste management and production efficiency

Figure 29. Seamless knit

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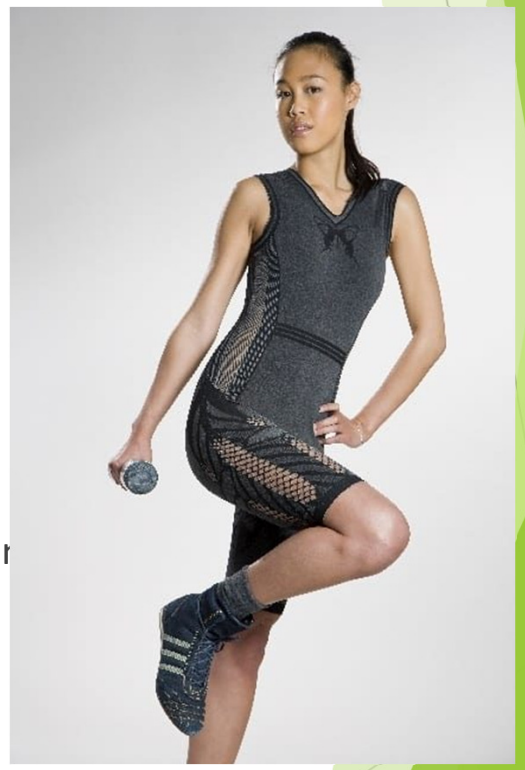
5.2.5 Seamless/whole garments knitting in the context of waste management and production efficiency

Seamless knitting technology brings an innovative concept in clothing manufacturing and enables us to have:

- Different pattern structures in different areas
- Different kind of yarns in different areas
- Better and wider range of fit
- Freedom of movement and comfort
- Performance features linked to combination of fibr
- Custom apparel at a good cost



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5.2.5 Seamless/whole garments knitting in the context of waste management and production efficiency

Seamless knitting technology allows functional yarns such as those made from conductive fibres to lay in a garment without interruption for application in smart garments.

Figure 30. A knitted augmented and virtual reality sensor glove from Stoll[12]

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5.2.5 Seamless/whole garments knitting in the context of waste management and production efficiency

Figure 31. Samples of seamless knits

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5.2.5 Seamless/whole garments knitting in the context of waste management and production efficiency

Innovative warp-knitted garments can also be produced in a single sequence, without seams.

Figure 32. An open warp-knit jacquard design produced on Karl Mayer RDPJ 6/2 machine[13]

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5.2.5 Seamless/whole garments knitting in the context of waste management and production efficiency

Table 1. Benefits of seamless knitting

Benefits to designers	Benefits to manufacturers	Benefits to consumers
Design remains in digital form from designer to manufacturer	Reduced labour costs	No irritating stitches and bulky seams
Minimizes human intervention and eliminates communication barrier	Just-in-time production	Natural look, easy fit, and greater comfort
Easier to modify or refine the design and pattern	Fewer machines involved	Is light in weight, has a soft touch, and gives a smooth and sleek body image
Unlimited design possibilities; colored and patterned designs are all knittable	Reduced yarn and fabric inventories	Supports like a second skin without leaving uncomfortable marks
Various knitting constructions are possible for different zones to achieve specific support, ventilation, shaping	Quicker sample creation	No problem with color shading or mismatch between different components
Quick response for size and pattern changes	Lower energy costs	Mass customization for personalized fit

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5.2.5 Seamless/whole garments knitting in the context of waste management and production efficiency

Advantages of seamless technology:

1. Reduced labour cost
2. Minimum yarn consumption
3. Smaller work space
4. Reduced yarn and fabric inventory
5. Quick sampling
6. Fewer product failures
7. Less cost of production
8. Just-in-time production

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5.2.5 Seamless/whole garments knitting in the context of waste management and production efficiency

Seemless knitwear consumes only the material required to produce a single garment.

The combination of virtual sampling and knitting can optimize inventory and minimize leftovers that otherwise go to waste.

Seemless knitting minimizes the need for manual labor.

Figure 33. Shima Seiki's Wholegarment® knitting on MACH2X 153 machine[14]

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5.2.5 Seamless/whole garments knitting in the context of waste management and production efficiency

With this seamless knitting technology, consumers can enjoy a more natural feeling when wearing clothing made from more expensive natural and renewable fibers.

Figure 34. Shima Seiki's Wholegarment®[14]

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CONCLUSION

- The most wasteless and sustainable weaving is circular weaving when woven fabric is manufactured like a circle tube directly from a creel.
- The fully-fashion knitting technology shortens the manufacturing process and reduces material waste as the cutting operation is skipped and the number of sewing operations is significantly reduced.
- Seamless knitting technology is even more eco-friendly as it skips the sewing and cutting stages, saving large quantities of yarn.
- Fully-fashion and seamless technology allows us to significantly reduce the number of technological equipment, technological operations, and energy consumption required for manufacturing of a garment.
- It can also be described as more ethical than alternative technology, as it minimizes the need for manual labor.
- The seamless technology can directly produce nearly finished products. Currently, the most widely available seamless garments in the market are knitted ones. Woven garments are not available.

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