Fashion DIET

Sustainable Knitting Production

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Learning Objectives

After this lecture you should be able to:

- Get familiar with the general trends regarding the sustainable textile production
- Describe the principle and categories of knitting
- Presents the methods of producing knitted products
- Understand the sustainable aspects of knitting technology
- Learn about digital solutions for the knitting industry.

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Content

General trends in sustainable textiles production
Definition and classification of knitting technologies
Manufacturing methods of knitted fabrics
Sustainable development of knitwear production
Digitalisation of knitting industry
Conclusions
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General trends in sustainable textiles production

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EU trends for a sustainable development of textiles production

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1. Increased usage of textile waste as raw material for European textile production

- Economic incentives are needed to keep textile materials in the EU, as it is the basis for industrial circular production.
- Illegal shipments of textile waste to countries outside the OECD need to be preemptively monitored through innovative tools and practices.

2. Eco-adjusted fees for non-recyclable textiles

- Materials that cannot be reused or recycled must become more expensive for manufacturers and consumers.
- Information in the digital product passport (DPP) must be simplified for consumer decision making.
- Consumers need to be empowered with information to identify good quality.
- Manufacturers must indicate the estimated useful life of clothing (https://www.aalto.fi).

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EU trends for a sustainable development of textiles production

3. Promotion of the social justice and human rights

- Human rights violations should be the focus of both EU-level and non-EU production.
- Smaller European manufacturers are a real alternative to fast fashion as usually already have a sustainable business model.

4. Exploitation of the traditional sustainable and alternative raw materials

- Incentives to increase local cultivation and production of sustainable fibres such as linen, hemp and nettle. This would also improve the carbon footprint of logistics through short and transparent supply chains (https://www.aalto.fi).

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Definition and classification of knitting technologies

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Definition and classification of knitting technologies

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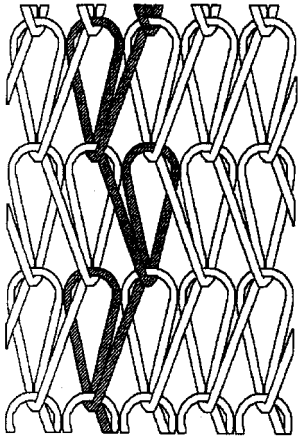
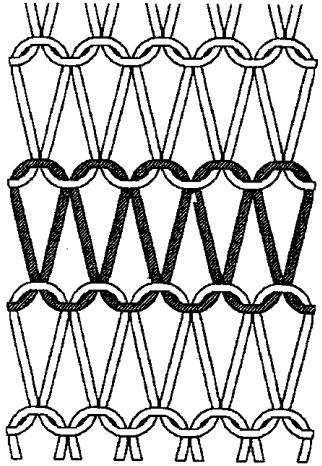
Knitting is a process in which yarn is transformed into a fabric by a series of interdependent stitches. According to this principle, a textile fabric is made with only one set of threads. A vertical set of yarns (warp) can be used to produce a warp knitted fabric and a horizontal set of yarns (weft) can be interlaced to produce a weft knitted fabric (Spencer D.J., 2001).

Warp knitted fabric





Weft knitted fabric

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Knitted fabrics are used worldwide for a variety of apparel, household, and industrial purposes, with apparel purposes being the most common.
Some properties of knitted fabrics are: formability, wrinkle resistance, excellent elasticity and comfort. The two basic knit structures have different properties that must be considered when developing a product (Ray, 2012).

Weft Knitting	Warp Knitting
Loops are made by each weft thread that runs across the width of the fabric	Loops are made from each warp thread along the length of the fabric
Fabric can be formed with a few yarns supplied in the form of a cone	Fabric can be formed with a large number of yarns supplied from a warp beam
There are limited variations in the structure in a weft knitting machine	A wide range of structures can be made in a warp knitting machine
Fabric possesses low dimensional stability	Fabric possess high-dimensional stability
Fabric possesses high stretch in width direction	Fabric possess low stretch in both the directions
Suitable for innerwear garments (ex. plain, 1x 1 rib, purl, interlock fabric)	Suitable for outerwear applications (ex. lock knit and sharkskin)

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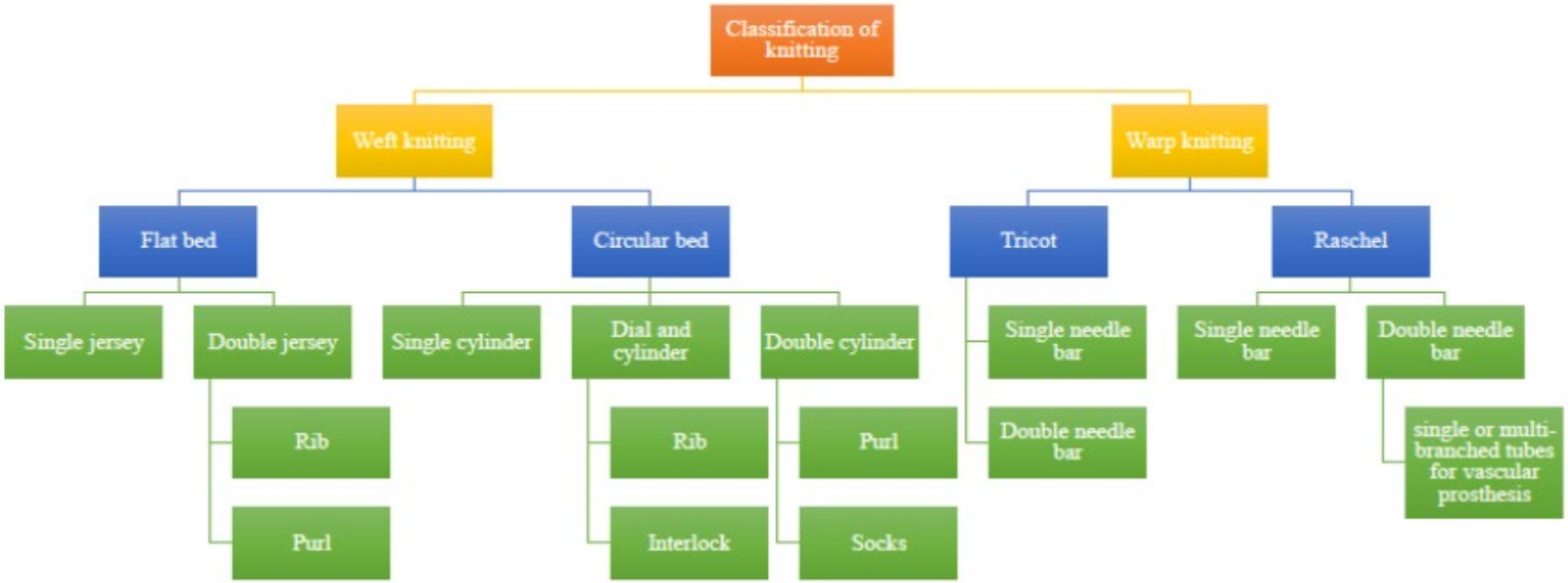
Definition and classification of knitting technologies

The knitting machines can be classified according to the knitting principle (warp, weft), the shape of the needle bed (flat, circular), and the number of needle beds (single, double) as presented in the scheme displayed below (Ray, 2012).



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Knitted materials

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Fabrics range from thin structures knitted on ultra-fine weft circular knitting machines to very strong, stiff, multi-layer, multi-axis structures produced on warp knitting machines.

The quality and serviceability of knitwear depends on the type of knitting process used, the fibre, the fineness and uniformity of the yarn, the tightness of the fabric, and the dimensional stability of the finished product.

The introduction of high performance yarns, the development of industrial products on V-bed machines and the very rapid diversification of the knitting sector have led to the production of products with different properties, from a very high extensibility to high resistances in the mechanical or chemical environment.

The materials can have outstanding properties such as: great flexibility in manufacturing (geometry, shape, and yarns), controlled mechanical properties, excellent formability, and stretchability (Ray, 2012).

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Manufacturing methods of knitted fabrics

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Weft flat knitting technology

The development of knitting technology has been driven over the years by significant breakthroughs in flatbed machine technology and software since the late 1980s. These developments have led to the recognition of the potential of 3D shape knitting for the apparel industry and, more recently, for the non-apparel industry.

The future of the European knitting industry appears to lie in the development of a highly skilled workforce and the production of high value-added textile products in non-traditional market sectors. Knitting machine manufacturers have responded accordingly, focusing on the development of flat-bed technology over the past 20 years to enable the manufacture of a wide range of products, with an emphasis on more cost-effective manufacturing techniques to achieve higher product performance (Underwood, 2009).

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Weft flat knitting technology

Computerized weft flat knitting is one of the technologies used in the production of fabrics. It is characterized by greater process flexibility and a greater variety of fabric structures, all at low manufacturing costs.

In addition to the significant advances in industrial knitting machines over the past 15 years, the software used to program digital knitting patterns has also evolved. Computer Aided Design (CAD) is the preliminary stage of pattern making that aims to design knitting programs in a specific language that can be read by the machine. CAD has brought a revolution in the textile and fashion industry, mainly due to the reduced time consuming process of textile design (Underwood, 2009).

Tools from CAD improve the aesthetics and ergonomics of product design by creating advanced shapes, complex surfaces and patterns for the fashion industry and other demanding industries. These tools enable rapid prediction of design and fabric properties prior to knitwear production.

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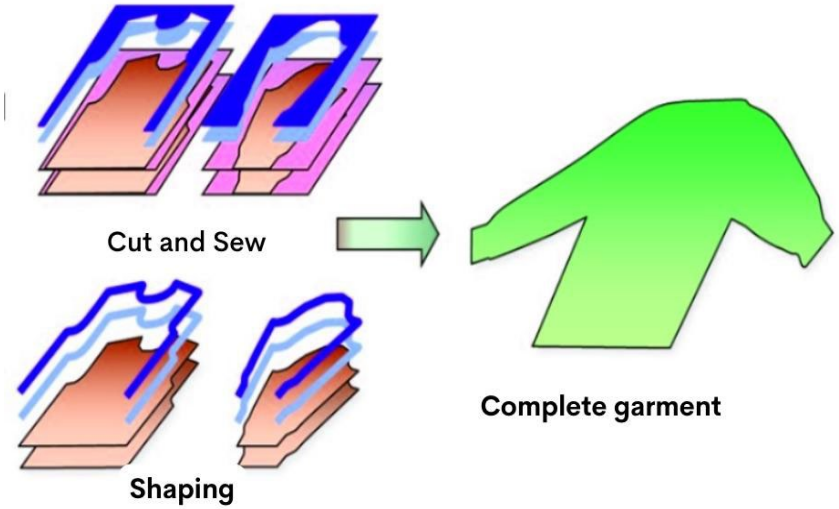
Manufacturing methods of flat knitted garments

1) Cut & sew - front, back and sleeve pieces are knitted in a rectangular shape and then cut to shape

2) Fully-fashioned - front, back and sleeve pieces are knitted in the final shape directly on the knitting machine

3) Integral knitting - design features are knitted directly into the finished pieces, minimising both cutting waste and re-knitting processes.

4) Complete knitting (seamless) - the entire garment is knitted directly on the knitting machine.



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1. Cut & sew

Garments made from jacquard rectangular panels

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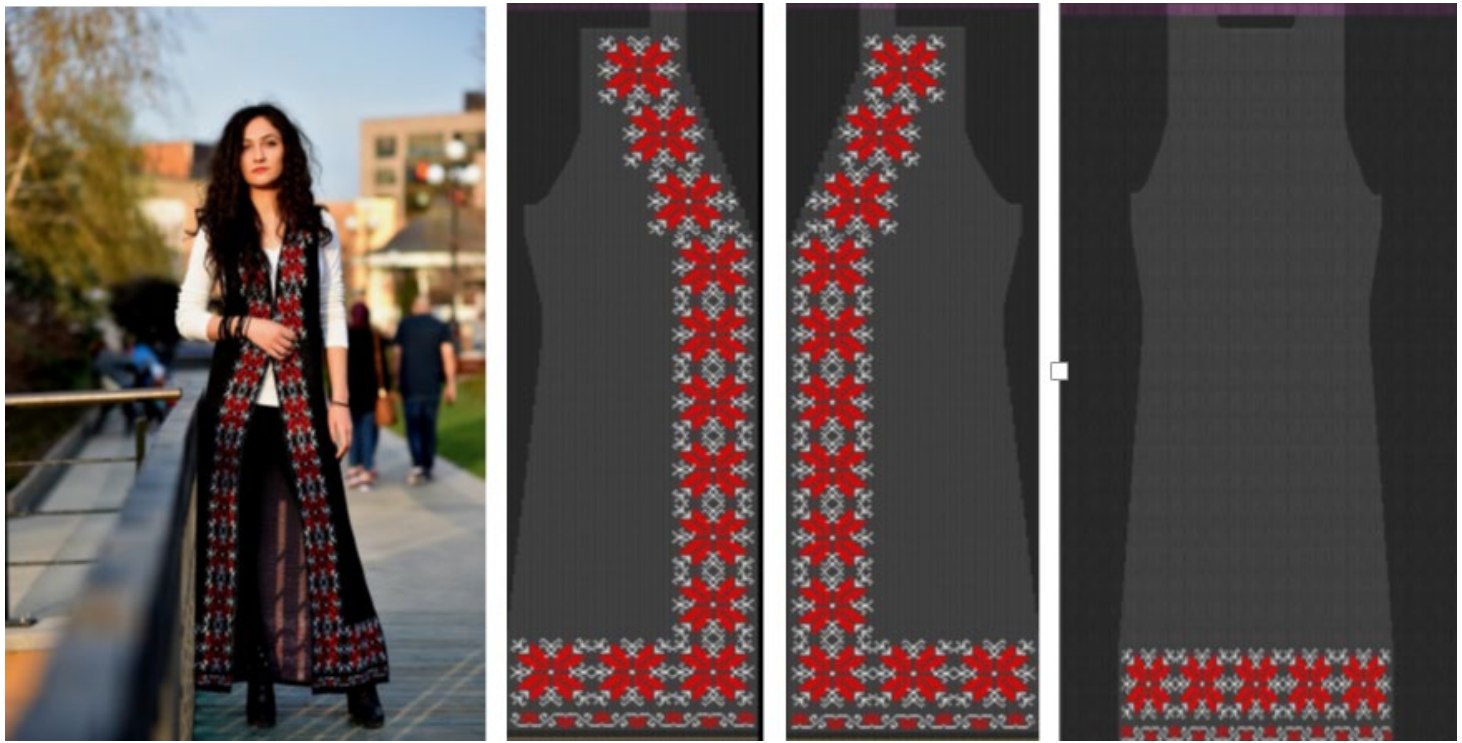
2. Fully-fashioned – front, back and sleeve pieces are knitted in the final shape directly in the knitting machine



Garment made of fully-fashioned panels

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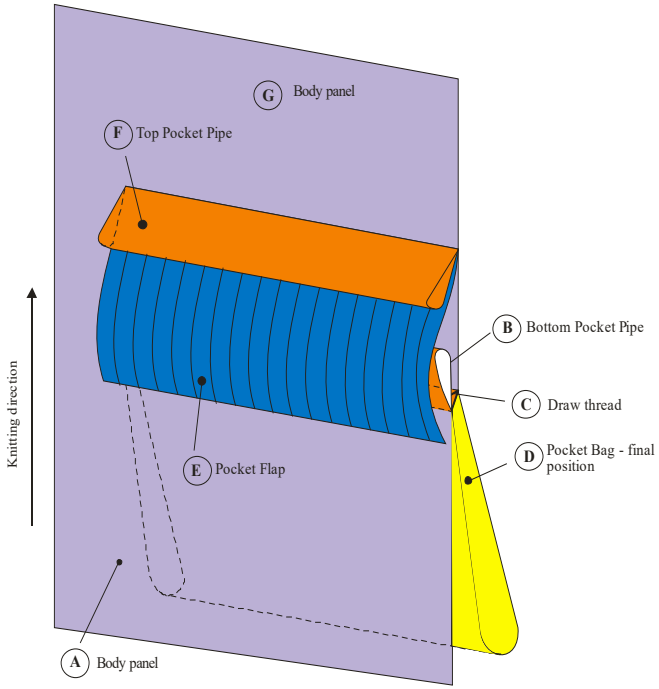
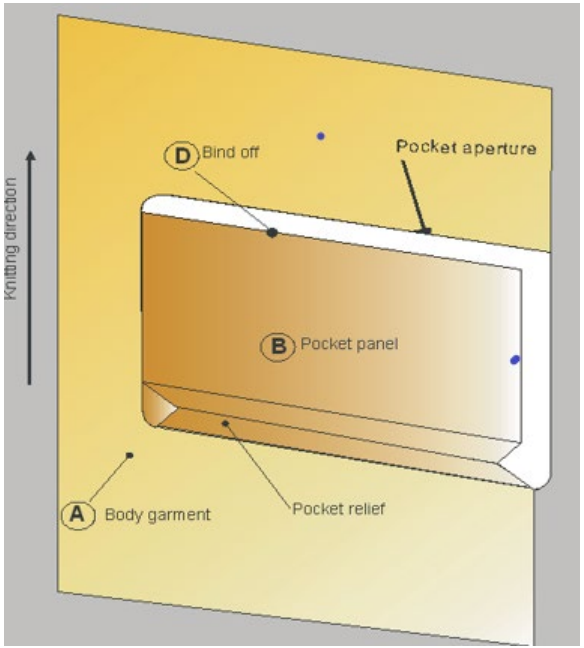
3. Integral knitting is a method in which trimmings, pockets, buttonholes and other design features are knitted directly into the finished produced pieces, but the product still need some linking or sewing operations.





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3. Integral knitting – Fully fashioned shoe upper with knitted on ribbing, open hole knit for breathability, cushioning zones with infill yarn and plated parts with TPU yarn for more stability.

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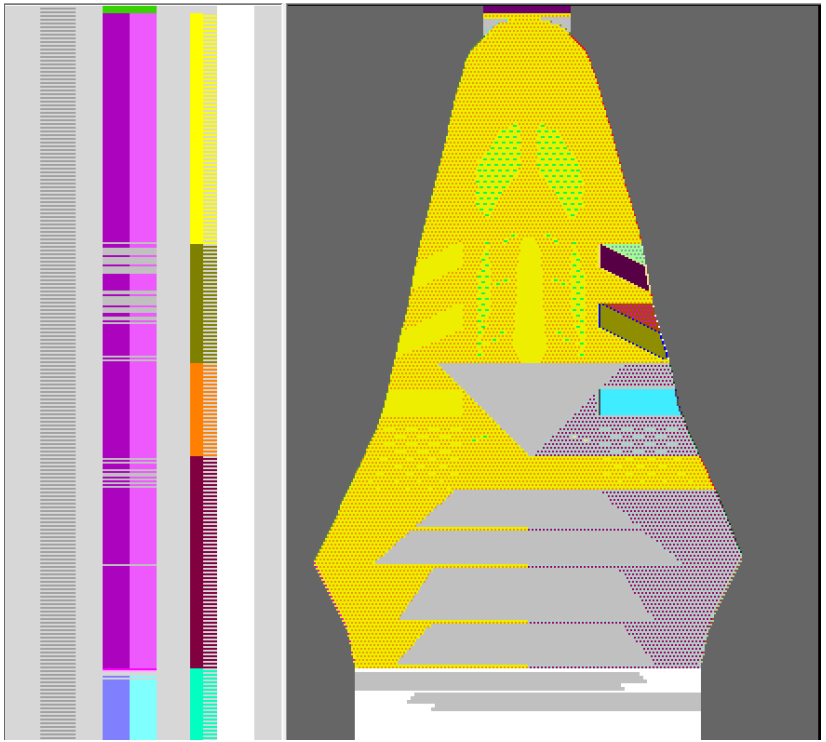
Knitting programme (Stoll M1Plus®)



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Knitted Shoe Upper

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Integral knitting - From the flat shoe upper to the finished shoe

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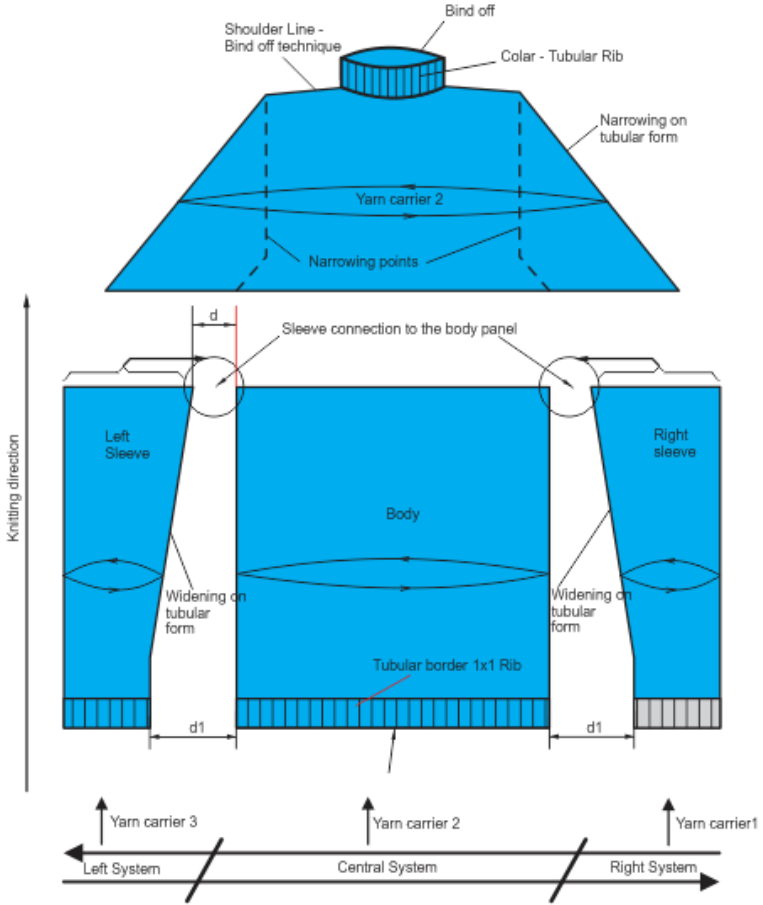
4. Complete knitting (seamless) is the method of knitting the entire garment directly in the knitting machine, without subsequent operations.



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Sustainable development of knitwear production

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Knitting industry context

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Similar to other industries, there are various manufacturing processes in the knitwear industry that have a high demand for electricity, oil, water, and air.

All these resources are provided by nature and are running out day by day. The exploitation of natural resources is a great burden on the environment. In addition, many processes release harmful gases and chemicals that pollute the environment.

Therefore, there is an urgent need for the knitting industry to adopt a sustainable manufacturing process, environmentally friendly production, and chain of custody management for the life cycle assessment of consumer goods to raise awareness and define the role of manufacturers and consumers (Chakraborty, 2016).

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Knitting industry context

Current context in the knitwear industry:

- The excessive consumerism;
- The trend to shift to non-garment production;
- Developments of materials for sectors, such as: automotive, aerospace, footwear, medical, sports, construction.

Key players for the strategic development of innovative products:

- Fashion designers;
- Manufacturers of fibres and yarns;
- Machinery manufacturers;
- Suppliers and retailers;
- Consumers;
- Policy makers (Maity, 2022).

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Solutions for meet sustainability requirements

The knitting industry can make an important contribution to global energy and waste savings through a number of measures:

- Selection of sustainable raw materials for knitting;
- Recycling and upcycling of raw materials and knitted waste;
- Sustainable design and production of knitwear;
- Sustainable finishing processes (Maity, 2022);
- Increasing internal efficiency (reducing downtime);
- The use of indirect technologies (needles and oils);
- The use of new innovations to obtain less waste;
- Reducing the carbon footprint (Cuden, 2022).

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Sustainable raw materials for knitting

Sustainability is about producing greener materials that are environmentally friendly and produced in a way that does not have harmful effects on the physical properties of the environment, i.e., soil, air, and water.

Greener materials are either made from organic raw materials, recycled, or require little energy during the manufacturing process. However, the consumer instinct is to buy a product at a cheaper price, and this discourages manufacturers from pursuing sustainable practices that are costly (Chakraborty, 2016).

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Sustainable raw materials

Natural fibres like organic cotton and wool are non-toxic, biodegradable and renewable.

The cultivation of organic cotton is the sustainable approach to grow cotton without using any inorganic chemicals either as fertilizers or as pesticides

Manmade fibres like viscose, polyester, nylon and acrylic require a manufacturing process that involves many chemicals and release toxic gases into the environment. Though viscose is the biodegradable cellulosic fibre, its raw material is wood and responsible for deforestation (Chakraborty, 2016).

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Sustainable raw materials

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Vegetable Cashmere is 100% plant-based fabric primarily composed of soy protein spun from pulp borne from tofu production. It is soft, silky, and loaded with plant proteins that nourish the skin. Keeps warm in cold weather and remain cool and comfortable in hot weather (https://kdnewyork.com/pages/vegetable-cashmere).

Wool blends with recycled polyester originating exclusively from textile waste generates a combination of the performance of synthetics with wool comfort regarding thermo-regulating and moisture-managing attributes as well as a soft hand touch (https://www.texdata.com).

Knitted fleece are produced from used plastic bottles, which traps air to retain heat and reduce fibre loss. They are 100% recyclable and circular, and also 25% lighter than the original product (www.apex.polartec.com).

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Sustainable design of knitted fabrics

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Product design and development play a fundamental role in the design and manufacture of sustainable products. The choices made during the product design and development process influence up to 80% of a product's environmental and social impacts. The selection of materials, forms, colours, and production systems also affects the use and disposal of the product throughout its life cycle.

A sustainable design must consider ecological aspects:

- Limiting resource use through waste-free production, use of renewable resources, emphasis on recycled materials;
- Reducing or eliminating waste by minimizing consumption;
- Reuse when possible and recycle when necessary;
- Prefer non-toxic materials and those that contribute to human health;
- Put quality and durability above price (Taieb, 2014).

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3D Shaping - Sustainable Solution for fashion and Technical textiles

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The potential of 3D shape knitting has long been recognised, even though machine technology was not yet available (Brackenbury, 1992; Spencer 1997). Conventional hand-knit 3D shaping techniques are the basis for creating a structure on automated machines. However, it is only since the mid-1990s, with the development of flat knitting technology and computer-aided design software (CAD), that this potential has been realised.

The latest generation of computerised flat knitting machines, recently introduced, are the most advanced knitting machines ever made. A representative of this new generation are the knitting machines made by Shima Seiki (Japan), Stoll (Germany), Universal (Germany), Protti (Italy) and Steiger (Elvetia), which are equipped to produce the most intricate and elaborate designs desired by the fashion world and industry.

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3D Shaping - Sustainable Solution for fashion and Technical textiles

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Knitting to shape is an important feature of knitting technology. The flexibility of the knitting process is achieved by the possibility of needle selection and the variety of structural designs.

The possibility of customization to specific shapes and sizes, the absence of cutting and waste, the one-step production on the machine, provides a sustainable alternative for the production of interesting fashion and technical items.

With the modern development of electronic V-bed flat knitting machines, the ability to knit in shape has been greatly improved due to some well-known advantages (Araujo et.al, 2004): electronic needle selection; CAD systems that contribute greatly to design capability; fast knitting machine set-up; knitting in shape allows the formation of shaped fabrics in 2D and 3D, contributing to waste reduction and improved garment fit.

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3D Shaping - Sustainable Solution for fashion and Technical textiles

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The main approach for knitting 3D shaped structures consists in transferring the 3D form into a 2D suitable pattern, as the widening and narrowing operations can only be determined according to 2D patterns (Blaga and Ciobanu, 2013).

In this case, the operations to be performed are: increasing and decreasing the number of operating needles (narrowing and widening) identical to the technique used for the formation of heels and toes in hosiery production.

All stitches are held to be reintroduced and knitted at a later stage. This ensures that the segment isolated for knitting is linked to the rest of the fabric.

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3D Shaping - Sustainable Solution for fashion and Technical textiles

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The technique can be described as knitting in which the wales within the fabric contain differing number of stitches (Underwood, 2009). This technique provides a 3D effect on the surface of the fabric. The structure used is a single jersey structure and the fashioned lines are given by the partial knitting of rows. During the knitting sequence, knitting is isolated to selected areas, while the remaining stitches are held and do not knit (Blaga and Ciobanu, 2014).

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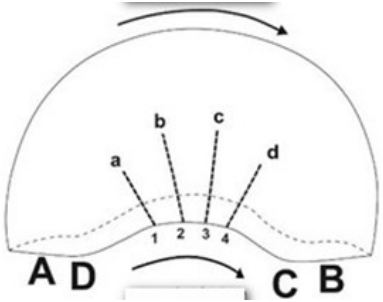
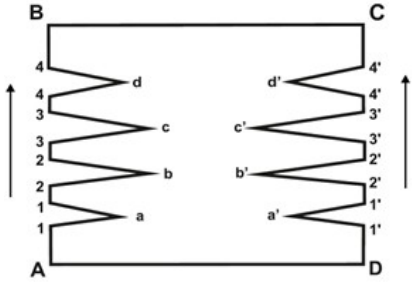
Hemispheric forms

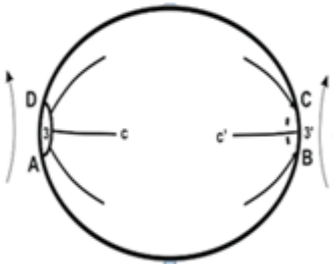


3D theoretical form

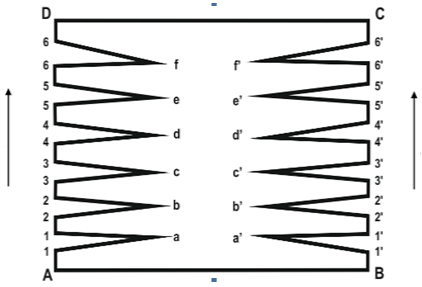


2D pattern

Spherical forms



3D theoretical form



2D pattern

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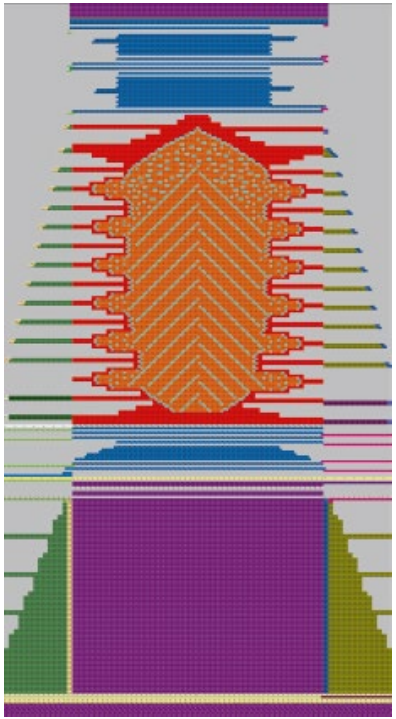
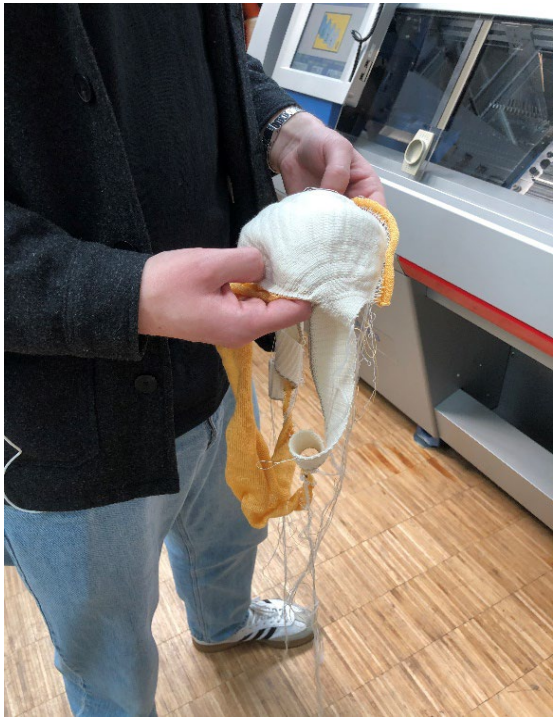
3D knitted mask with knitted in filter section

From the Knitting program (Stoll M1Plus®) to the almost directly wearable mask.





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Sustainable manufacturing methods of knitted fabrics

- Stoll-knit and wear® technology (KW) enables parts to be knitted, shaped and joined in a single operation on just one machine. The result is high-quality, seamless knitted products with high wearing comfort that are almost ready to wear.
- Time-consuming further processing steps are completely eliminated. Coarse and fine knits, all sizes, many pattern possibilities as well as jacquards and intarsia are possible.
- The same knitting and garment machine can also knit full-fashion, multigauge and extra-wide fabrics, which means total flexibility for the user (www.stoll.de).

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Knit and Wear ®Stoll - Germany

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Whole Garment® (WG) Shima Seiki, Japan

Whole Garment® (WG) by Shima Seiki, produces knitted items in their entirety on the machine and allows 3D preforms and tubing to be produced without sewing.

Elimination of sewing allows for faster turn around and high potential for on-demand knitting. 3D knitting provides fit, comfort, lightness and mobility, key factors that make seam-free Wholegarment knitwear ideal as wearable technology platforms.

Whole Garment® flat knitting machine realizes digitalization, mass customization, on-demand production and just-in-time delivery. It is a genuine sustainable system that provides consumers with what they really want when they really want it.

Whole Garment® is a completely new category of knitwear, based on a rethink of all stages of the knit supply chain from planning and design, production, distribution, marketing and retail sales (www.shimaseiki.jp).

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Whole Garment® (WG) Shima Seiki, Japan

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Seamlesswear®(SM) Santony, Italy

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Circular knitting manufacturer has developed seamless knitting machines, to produce underwear, sportswear, beachwear, sanitary wear (Knitting Industry, Santoni, 2020).
Seamless knitting offers a unique combination of properties including comfort, smooth fit, support, breathability, light weight, pleasant appearance and easy care.

Technology lies in the possibility of developing and creating innovative uppers efficiently and quickly, drastically reducing the overall time of the shoe production cycle and minimizing production waste.

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Technical developments for energy and environment protection

To save preparation and production time, work phases and technological processes were skipped or merged to reduce production costs, machine space, energy, and labour.

Examples of such a technological approach are the hybrid spinning-knitting machine of Maier&Cie, Terrot ans Pai Lung, the warp-weft machines of Shima Seiki or the weaving-in technology of the Stoll company (Cuden, 2022).

Other solutions were envisaging the shortening manufacturing processes, such as merged sock knitting and assembly, or reducing machines dimensions.

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Solutions for reducing the carbon footprint

Reducing the carbon footprint in the knitting industry has become a priority!

One initiative is to phase out old and conventional machine types and install new, technology-driven machines to reduce energy consumption and emissions to the environment from CO.
Few industries are implementing energy labels and ratings to minimise carbon footprints.
There are two approaches recognised by manufacturers to reduce the carbon footprint in the knitting industry.

- reducing idle time to improve machine efficiency
- innovating energy-efficient technology (Maity, 2022).

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Solutions for reducing the carbon footprint

Groz-Beckert has developed a new needle litespeed in which the weight and size of the needle components have been reduced. The needles thus reduce friction during the knitting process, resulting in a reduction of up to 20% in the energy consumption of circular knitting machines and significantly reducing CO, emission by 1,500 kg per machine (needle life based on 208 days or 5,000 hours. In addition, needle life is shortened and less lubricant is required (Maity, 2012).

Fukuhara - the manufacturer of the circular knitting machine - invented E-needle technology, which is said to reduce energy consumption.

Environmentally friendly synthetic knitting oil (Ecoknit, Synol, Kluber, etc.) has been developed to lubricate high-speed knitting machines to achieve very low friction and long life.

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Digitalisation of knitting industry

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Digitalisation of knitting industry

The most important concept in all knitting technologies is the move towards a circular economy and Industry 4.0. Digitization of the production and business environment enables more flexible methods of getting the right information to the right person at the right time.

Both, machine builders and knitted products manufacturers follow this approach and adapted the materials, equipment and production to sustainable concepts, along with smart manufacturing, cloud computing, cyber production control and robotisation of knitting (Cuden 2022).

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Digitalisation of knitting industry

Industry 4.0 offers numerous benefits, such as:

- increased productivity through higher levels of automation that reduce production time and enable better asset utilisation and inventory management;
- higher manufacturing flexibility through machines and robots that can perform production steps for a variety of products;
- increased speed from initial product or factory idea to finished product through consistent data and new simulation capabilities;
- higher product quality through sensors and actuators that monitor ongoing production in real time and intervene as needed to correct a mistake (Cuden 2022).

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Digitalisation of knitting industry

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With the "Knitelligence" concept, Stoll by Karl Mayer GmbH is launching a new generation of knitting machines in 2019 that is adapted to the specific requirements of Industry 4.0. It enables process automation, higher transparency, shorter response times, shorter production cycles and higher productivity.

Combining innovative software solutions under one platform, Knitelligence® covers the entire value chain of the flat knit production. From design to production, knitelligence® can be easily integrated into existing customer processes. The new multi-touch control panel is even easier to use thanks to its improved readability and bright surface. The new remote access facilitates work in production by providing direct access to the M1plus patterning and control station.

From a quick image to the knitting program, via individualized sorting and patterning, to optimized production control - knitelligence® increases the efficiency of the entire value chain (https://www.stoll.com/knitelligence/#knitelligence).

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Stoll knitelligence® system features

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ART - knitting support in Adobe® Photoshop® enables better communication between designers and technicians, resulting in a streamlined pattern development process;

M1plus - the patterning software for efficient knitting program creation;

ACT - Stoll-autocreate® individualized knitting patterns are created fully automatically and without interactive intervention according to a defined list of instructions;

GKS - highly efficient shaping and grading tool that allows knitting programs to be fully parameterized and then edited in M1plus®;

SIN - with Sintral Crypto Infrastructure, knitting programs can be encrypted, protecting the company's intellectual property;

PPS - a central platform for production data and production processes and powerful machine-optimized scheduling enables efficient machine utilization;

APM - Automatic Production Mode (APM) can reduce manpower requirements to a minimum;

EKC - the Extended Knit Control is the operating calendar that enables realistic planning and evaluation of production capacity;

Quick response in problem solving due to the high integration of knitting machines and terminals (cell phone, tablets).

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Total Fashion System by Shima Seiki

SHIMA SEIKI's manufacturing concept realizes digitalization, mass customization and sustainability. With the SDS-ONE APEX series design system and software at its core, TOTAL FASHION SYSTEM realizes effective communication between the design, production and sales phases through smooth workflow and feedback of key information.

Smart, fast and sustainable manufacturing enables industrial transformation that helps customers succeed (www.shimaseiki.com/tfs).

The new SDS-ONE APEX4 has an increased programming and simulation speed compared to its predecessor SDS-ONE APEX3. As part of its full support for planning and design requirements, SDS-ONE APEX4 also offers the latest artificial intelligence (AI) search capabilities. Shima Seiki also offers several IT solutions to help its customers build an intelligent supply chain.

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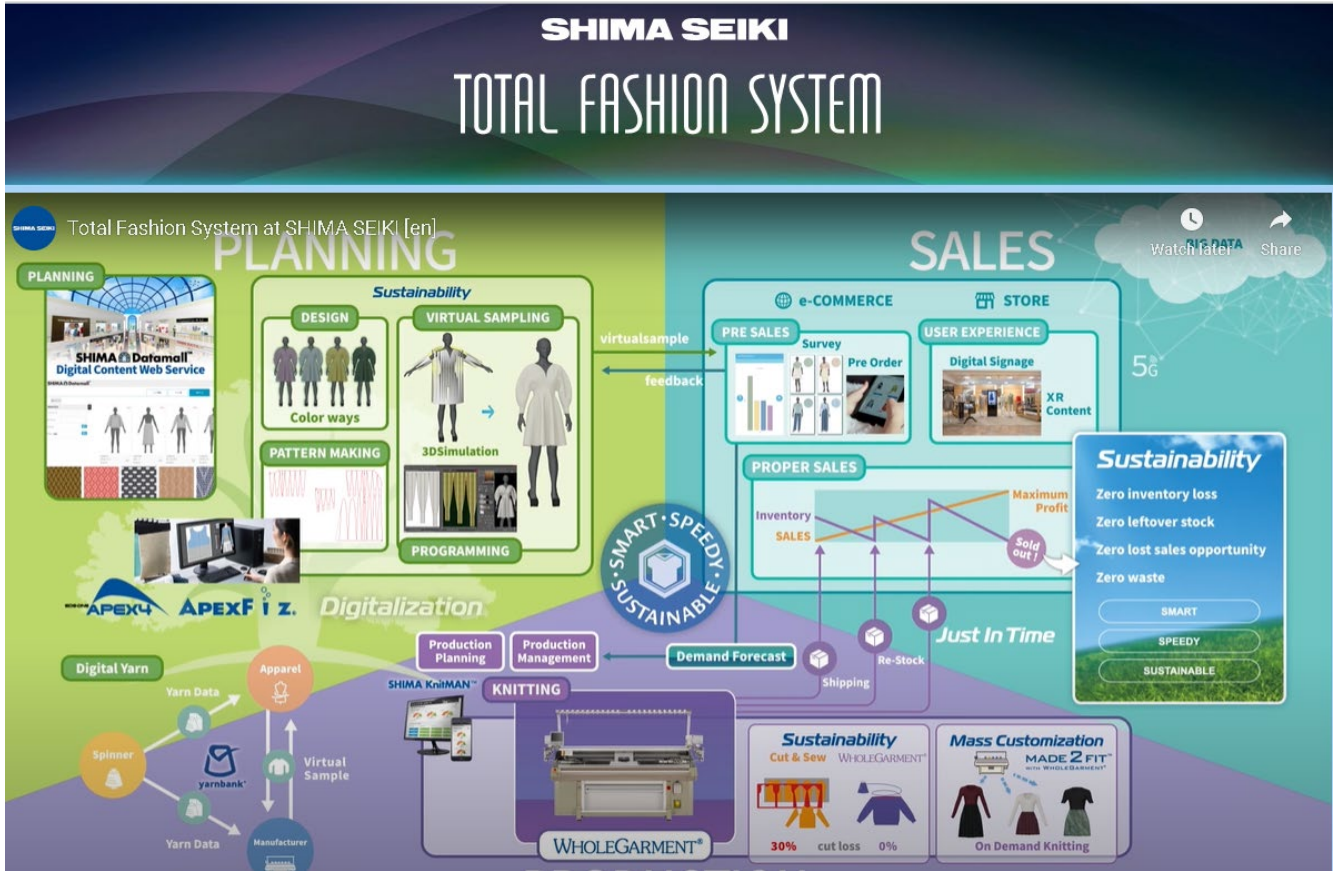
Total Fashion System by Shima Seiki



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Total Fashion System by Shima Seiki

Products are supplied to retail stores in smaller quantities based on a demand forecast adjusted to current market conditions. When stock is depleted, it can be replenished by knitting WHOLEGARMENT as needed. This prevents lost sales opportunities due to insufficient stock. By repeating this process throughout the season, optimized stock levels can be maintained through just-in-time inventory. At the end of the season, all inventory can be sold at retail prices, maximizing profit and leaving nothing unsold.

As a result, the Total Fashion System realizes production with no inventory loss, no leftover stock, no lost sales opportunity, and especially no waste to burn or bury, resulting in Smart, Speedy and Sustainable production.
A completely new fashion distribution revolution that reverses the concept of conventional knit production (www.shimaseiki.com/tfs).

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Virtual Sampling - Shima Seiki

Reduction of materials required for sample making;
Time-savings;
Improvement of presentation quality;
Powerful sales promotion tool;
Utilization for demand forecasting and reservation sales.

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Reflections on the topics presented

Knitting is a special technology that can be adapted and developed to the circular economy and Industry 4.0 environment in terms of sustainability to survive economically in the near future.

The knitwear industry, from the perspective of the increasing demand for knitted goods, should play an important role in saving energy, reducing waste, and minimizing emissions to meet environmental standards in a global scenario. Preference is given to knitting machines with eco-friendly manufacturing processes that have less impact on people and the environment.

Production processes that significantly reduce the time lost or unproductive time between manufacturing steps should be sought (Cuden 2022).

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Reflections on the topics presented

- Achieving sustainability requires the involvement of all knitwear stakeholders. The focus is on reusing, recycling and upcycling raw materials and reducing or even eliminating knitwear waste.
- Manufacturers and users have rethought processes, production and consumption volumes.
- From the manufacturers' point of view, the focus is on the:

  - Selection of sustainable raw materials for knitwear production;
  - Use of energy-efficient technologies;
  - Minimizing or avoiding emissions;
  - Use of environmentally friendly chemicals;
  - Minimizing waste are the concepts to be followed (Maity, 2022).

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Reflections on the topics presented

- Wholesalers and retailers should promote the business of sustainable knitwear produced according to a sustainable approach. Consumers are very aware of sustainable products, but the purchase decision is still driven by price and not by the environmental impact of the product.
- The procurement department of knitting mills must be careful in the selection of raw materials for knitting. The basis for the selection of raw materials should be organically grown or produced in an environmentally friendly or recycled process.
- The knitwear industry should adhere to strict environmental standards, which is not the case in most countries.
- Sustainability testing should be mandatory for all knitted consumer goods to boost the business (Maity, 2022).

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