Journal of Textile and Apparel, Technology and Management

Special Issue 2: ITMA, 2023

Automated Cutting and Sewing for Industry 4.0 at ITMA 2023

Minyoung Suh, Associate Professor,
Textile and Apparel, Technology and Management,
Wilson College of Textiles, NC State University,
Raleigh, NC, USA

Introduction

Unlike other industries where diverse products have been manufactured not much relying on human labor in the past decades, automation has made little progress in apparel manufacturing. Compared to other rigid materials, such as plastic and metal, fabrics are notorious to have much higher degrees of freedom when being transported. They deform themselves significantly even under a very small load, such as dead weight or air resistance. It has led to extreme challenges to have flexible textile materials handled by machinery. Despite continued advances of the latest technologies, fully automated apparel manufacturing still seems illusive.

Amazon initiated the service on on-demand apparel manufacturing in 2015 and patented their automated apparel factory in 2017. The facilities include printing customer-provided designs on textile surfaces, cutting the fabric into a custom size and fit, and assembling the garments without relying on human labor. Their service is geared toward the production of made-to-order T-shirts, which is relatively simple in its design and structure. It is known to take a few weeks from an order to delivery. Considering that it traditionally takes 12-18 months to have a clothing line ready for market, it is revolutionary to shorten the lead time remarkably.

On-demand or just-in-time production is not a new concept in the fashion market. Every garment was made-to-order in history. Due to the lack of skilled labor and accessible resources, it required a long time and high cost to produce a single garment before industrialization. Turning into ready-to-wear market in 19-20 centuries, textile products became more abundant and affordable as the industry was mechanized and grew rapidly through the industrial era. More recently, as a major breakthrough in the ready-to-wear market, the modern concept of on-demand manufacturing focused on making garments only when someone needs them within a fair amount of time at a reasonable price. Technological advances are key drivers to lead and support this transition.

In ITMA 2023, Kornit Digital hosted a showcase with great visibility under the slogan "Digital Production Goes Mainstream". Their end-to-end production facilities were highlighted for on-demand manufacturing, where the latest manufacturing technologies have been integrated into a T-shirt production line. It starts with user-friendly design software. The 3D simulation of a virtual garment enables customers to evaluate and finalize their design decisions. Uniquely customized designs get digitally printed by a direct-to-garment printer, where curing is also administered seamlessly. The finished products are automatically packaged and shipped out for delivery. During the entire process, every tangible and intangible resource is managed by barcodes, such as print designs, decisions on fabric substrate, information on size and fit, etc. Although Kornit did not spotlight cut-and-sew processes of the T-shirts in detail, automatic cutting and assembly might have been involved at some levels.

Automated manufacturing of sewn products is a prerequisite condition to enable on-demand production. Thanks to computer-aided-design tools and network systems, product development processes continue being digitized and remotely managed, but cut-and-sew operations still heavily rely on skilled human labor for hands-on assembly (Suh, 2019). Electrically powered sewing machines have assisted the fashion industry for over 100 years, but the dependence on human dexterity and experience has not yet been lowered as radically as expected. Meaningful advances are semi-automated sewing systems that began to be introduced to the market, where a human operator loads and aligns workpieces to the machine (Suh, 2019). Sewing automation is considered the last piece of the puzzle that finalizes the transition to a new revolutionary age in the future of fashion.

Since the worldwide clothing market is worth about $1.52 trillion (Aeppel, 2022), on-demand manufacturing has arisen as the game changer boosting the global economy as well as innovating the quality of life. The benefit will not be limited to fashion consumers taking advantage of satisfactory products at an affordable price right on time. It allows a more ethical work environment for product developers by releasing the pressure from seasonal deadlines and inventory management. Less waste is generated because every production guarantees actual sales (Davies, 2021). Personalization could have customers emotionally attached to what they create and buy, and therefore the product lifespan becomes extended, turning the fashion market over for sustainable developments.

Based on the observations and discussions with machinery producers during ITMA 2023, this article introduces recent technical advances in automated apparel manufacturing. ITMA is the largest international textile and garment technology exhibition that takes place every 4 years. It had 18 sectors for different manufacturing divisions, such as spinning, weaving, knitting, printing, etc., and two sections were explored and investigated in depth under the garment making division: automatic cutting systems and automated sewing units. By illustrating several examples of automated equipment, novel features and key trends are highlighted for apparel cutting and sewing technologies. Along with the development of new machinery, it also addresses the progress toward Textile Industry 4.0 and what awaits us beyond that. Reviewing the report on the same topic out of ITMA 2019 (Suh, 2019), readers could gain more insights into where textile and apparel technologies were, are, and will be.

Automation in cutting

Cutting rooms in apparel manufacturing facilities have been consistently mechanized and digitalized in the past 60 years since Gerber technology introduced the first automated cutting system in the 1960s. Nowadays, computer numerically controlled (CNC) cutters are widely spread and adopted by many apparel manufacturers dealing with large quantity production. Various cutting technologies have been offered for diverse applications, such as blade, laser, water jet, plasma, or ultrasound. As automated cutting technology reaches maturity, cutter manufacturers focus on the development of auxiliary systems maximizing cutting efficiency.

Multiple major CNC cutter manufacturers participated in ITMA this year. Morgan Tecnica seemed to be a visible leader in cutting innovations. Zund and Kuris were steady key players, and Serkon Makina continued to thrive. Based on thorough observations on the automated cutting systems during ITMA 2023, key technical features could be characterized into 3 points: seamless integrations of equipment before and after cutting, popularity of optical pattern matching system, and enhanced heavy-duty cutting capability.

One of the noticeable features in the latest cutting equipment was the system integration that was more aligned with each other than before. Multiple manufacturers presented their cutters together with other equipment in a row mimicking an actual production line, such as fabric inspectors, spreaders, and pattern labelers. For example, IMA showcased "Syncro Cutting Room" where equipment can be mixed and matched from a fabric roll loader, a spreader, an automatic cutter to a labeler. Spreaders and labelers are not brand-new technology, but the seamless integration in between equipment was spotlighted in machine demonstrations.

Kuris showcased a spreader with air blowers (Figure 1) in connection with their cutter. Air blowing facilitates precise and accurate control of elastic fabrics. Compressed air supply up to 6 bar flattens and prevents the cut edges from curling. It also assists to blow fabric folds out from each layer, which minimizes human intervention during spreading. Vibrating plates are equipped to help release unnecessary tension on the fabric. Orox Group also introduced a spreader with compressed air of 100 L/min (7 bar). Their spreading stick was equipped with the buttons for remote control (Figure 1) to maximize productivity of the operator.

Figure 1. Air blower on Kuris A23 spreader (left) and Orox VRun spreader (right)

Although cutting had fairly been automated since the late 1900s, it has remained heavily dependent on human labor to sort and bundle the cut pieces. Labelers started to be incorporated into the cutter and assisted manual unloading processes. The features of labeler seem to be diversified into multiple approaches. Morgan Tecnica continued sticking thermally printed labels directly to the cut pieces by locating an additional crossbar for labeling purposes (Figure 2). Another approach was demonstrated by Serkon Makina who placed a projector screening pattern layouts and the associated information over the cutting table (Figure 2). Laser projection has been priorly implemented for leather cutting, where non-rectangular substances with intricate geometries must be detected and located on the table before cutting. This technology is now widespread and assists sorting and unloading cut pieces. A Chinese company, TPET, showcased a stamping machine that inks the information directly on each cut piece after unloading (Figure 2).

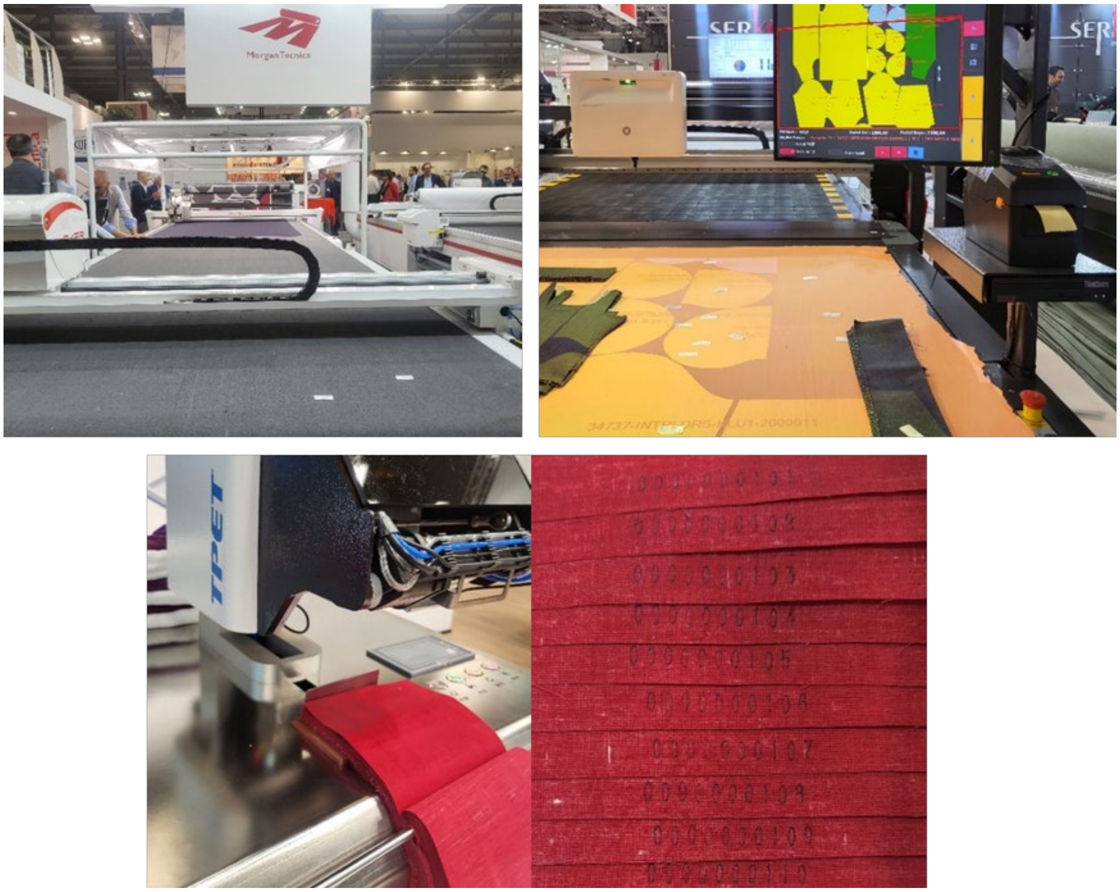

Figure 2. Various types of labeling device: printed sticker by Morgan Tecnica (top left), laser projection by Serkon Makina (top right), stamping machine and stamped fabric samples by TPET (bottom)

Vision technology for pattern alignment has become more popularized than before. Machine vision technology collects information from visual resources, detects optical characteristics of the surface, positions and manages them interactively (Li, Zhao, & Yang, 2023). Pattern matching assistance using optical devices was initiated in the early 2010s, and the technology continued growing in the past decades. As a result, most cutters at ITMA 2023 were equipped with a high-mounted camera (Figure 3) capturing the surface characteristics of cutting beds in real time. Recognizing design patterns over the fabric surface, this camera synchronizes the fabric surface information between the cutting table and marker screen. This allows visual administration of pattern alignment for garments made from stripes or plaids and engineered prints. Possible technical shortcomings are known to be associated with poor image quality, low precision, low efficiency, and high labor intensity of manual operation (Li, Zhao, & Yang, 2023).

Figure 3. High-mounted cameras for fabric pattern alignment by Zund (left), Lakeview Technology (middle), and Bullmer (right)

Morgan Tecnica configured their vision system differently from other manufacturers. While others adopted a single commercial off-the-shelf camera (Figure 3), Morgan Tecnica developed multiple cameras specific to their system. The cameras were mounted as low as 50-60cm from the cutting table, together with plenty of light sources (Figure 4). To ensure a wider angle of view, 4 cameras were installed processing data in connection. Intense lighting from relatively short distances could provide clearer vision, improving accuracy and completeness of the overall system. It might also be easier to manage the cameras and light sources in case physical adjustments are required. In addition, the optical system that "sees" the fabric surface makes it possible to cut sublimation printed fabrics without creating separate markers since the print contours are detected for a cutting line as shown in Figure 4.

Figure 4. Morgan Tecnica Vision System (left) with multiple low-mounted cameras (right)

Additional emphasis was seen from enhanced heavy-duty capabilities of cutting equipment. FK Group and IMA showcased their cutter models, Iron Heavy and Typhoon, respectively, capable of cutting 60mm-thick stacks of denim fabrics (Figure 5). IMA also presented a sloper cutter, Maxima SP, that can cut 5mm-thick hard boards for the accurate and precise management of flat patterns. A German automated cutter manufacturer, Bullmer, employed modular cutting tools for their cutter, Premiumcut ELC, that can handle various composite materials from fabric, rubber, and metal, for diverse industry applications, where the maximum cutting depth varied depending on the material.

Figure 5. Heavy-duty cutters demonstrated by FK Group (left) and IMA (right)

Automation in sewing

In contrast to the competent progress on cutting technology, automated sewing is still in the middle of developing its core technology. It is known to be notoriously difficult to automate apparel assembly. In most commercial systems currently available, automated sewing capability was limited to simple textile products, such as pillowcases, bed sheets, towels, and mats. Having only straight seams involved in a simple structure, these types of products are the first generation pioneering the sewing automation. Automated production of those products looked more specialized and diversified than before and demonstrated by a number of companies during ITMA 2023.

Multiple technologies were featured for fully automated production of bed sheets, towels, and mats. Having a flat single layered structure, these products can be simply finished by cutting fabrics and finishing the edges but sewing techniques varied quite depending on production needs. The systems for bed sheets and towels, demonstrated by Texpa and Schmale Durate, respectively, were equipped with fold-and-sew stitchers located on the path along which the fabric was transported. With multiple trimming options, decorative effects were available (Figure 6). TPET completed towels by applying overlock stitches covering the edges instead of folding and Rimac chose to stitch a binding around a car mat (Figure 6).

Figure 6. Automated sewing for towels by Schmale Durate (top left) and TPET (bottom left), bed sheets by Texpa (top right), and mats by Rimac (bottom right)

The appearance of diverse handling technologies was noticeable in each system. As captured in Figure 6, TPET used a metal plate pressing a fabric piece against a worktable to rotate the piece while its 4-side edges were being sewn. Another type of handling technique, 4 grippers (Figure 6), was charged to pick up, unload, and stack the finished towels up. Rimac adopted spheric rollers (Figure 6), where roller arrays spined omnidirectionally and transported a workpiece over the sewing table. Schmale Durate and Texpa utilized a few sets of cylinder rolls to feed and drive fabric forward. Though omnidirectional rotations were not achievable in this configuration, it was still possible to turn the workpiece perpendicularly. More than a single layer of fabric needs to be incorporated for pillowcase production. Fully automated pillowcase production started with 2 fabric layers passing through feeders into the system directly from fabric rolls (Figure 7). They were seamed at each side by 2 sewing machines located on their path (Figure 7) and cut to a certain length depending on pillow dimensions. Flowing on a conveyor, the workpiece was turned to 90 degrees and the third seam was finished while a product label was inserted simultaneously (Figure 7). Heat treatment followed on the unseamed side to protect the edge from unraveling.

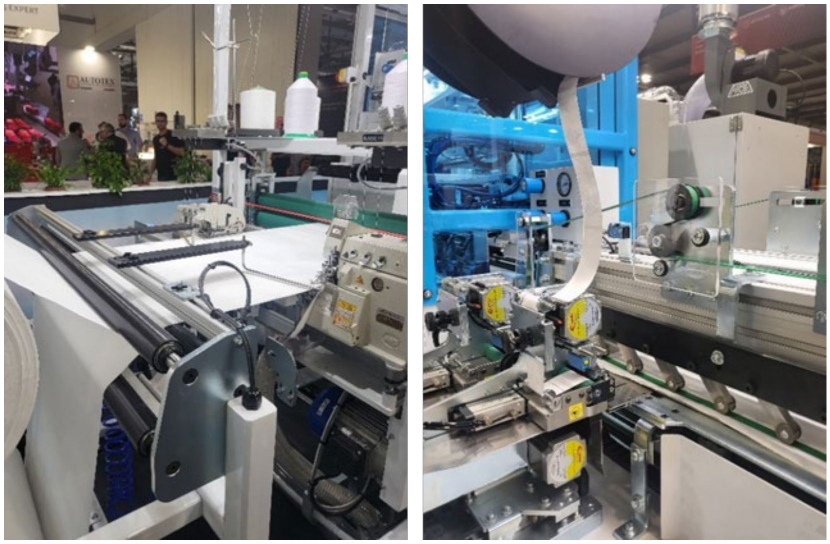

Figure 7. Fully automated pillowcase maker by Automatex: feeding and seaming (left) and labeling (right)

A pillow maker, which is a separate system from pillowcase maker, was demonstrated by a Swedish company, ACG Kinna Automatic (Figure 8). It required a pre-sewn pillowcase to start with, which could be acquired from the system described above. The pre-sewn pillowcase was loaded to the system by a human operator and filled with filler materials (Figure 8). It flowed along a conveyor and the open seam was closed (Figure 8). The pillow maker included two simple operations of filling and closing, but it was remarkable to see that 3-dimensional products were handled and processed through automatic systems. It is expected sooner or later to mechanize the initial loading, having the system fully automated.

Figure 8. Automated pillow maker by ACG Kinna Automatic: filling (left) and closing (right)

One of the new inventions was seen in the T-shirt sewing machine presented by Texpa. They showcase automated sewing capability to stitch seams in a streamlined shape, while all others stay making straight seams. The machine was configured with 2 overlock stitchers located in variable distances (Figure 9). Once 2 layers of T-shirt fabric, front and back piled with each other, were loaded by a human operator, the sewing machines started creating side seams on each side simultaneously. While stitches were made moving the fabric forward, the machines traveled right and left for the predetermined distance and speed. This movement resulted in curved side seams shaping a T-shirt.

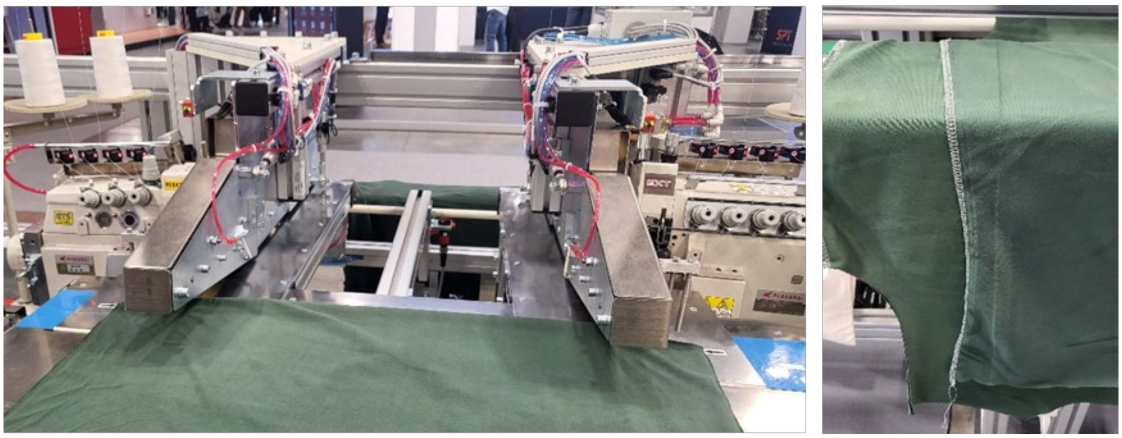

Figure 9. Texpa T-shirts machine with curvature sewing capability (left) and the resulting seam (right)

The approach of the T-shirt sewing machine is somewhat comparable to what Mammut has implemented for mattress production in terms of the fact that both a workpiece and a sewing machine are moving. In their automatic quilter, a big frame holds multiple layers of rectangular workpieces tight along which a sewing head travels omnidirectionally and leaves needle stitches in patterns. Making a synchronized movement to the top sewing head, a counterpart sewing head with a bobbin exists underneath the workpiece. In this way, Mammut could create double lock stitches in diverse quilting patterns. A hollow frame made it possible for needle and bobbin threads to get interlaced at any spot. The overall configuration of an automated quilting machine is similar to the structure of automatic cutters where a cutting head is attached to a crossbar moving over the workpiece. The use of a hollow frame, however, would not always be available when stitching fabric pieces of great variety in their shape and size, such as in apparel production. A Danish proprietary company, Fast Sewn, has proposed an innovative method, called "mobile cavity technology" (Figure 10), for automated garment assembly. A sewing table is made of multiple conveyor belts that transport the workpiece, but the belt successfully detours the sewing spot by creating a mobile cavity around a bobbin, as depicted in Figure 10. In this configuration, the flexible workpiece still gets supported and driven along the process, while the interlacing between needle and bobbin yarns takes place anywhere on the workpiece. This relatively new company is expected to launch commercial machinery onto the market sooner or later.

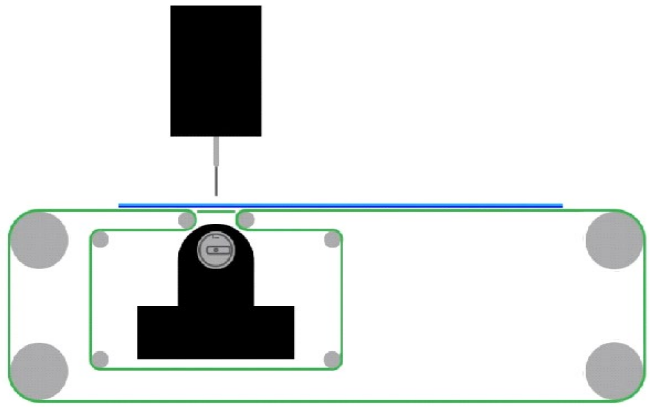

Figure 10. Mobile Cavity Technology by Fast Sewn

One of the leading companies in automated sewing, Softwear Automation Inc., was absent from ITMA 2023. Their introduction of Sewbot® revolutionized apparel manufacturing, proposing the vision to produce clothing without traditional garment workers back in 2012. The system utilizes a combination of patented high-speed vision technology and lightweight robotics, which monitor fabric pieces and steer the workpiece through conventional sewing machines. Specialized in T-shirt production, Sewbot® was launched as a service contract priced for a monthly fee starting at $5,000 per unit (Francis, 2019). An automated T-shirt workline was reported to produce a collared shirt in 162 seconds (Textile World, 2019).

On the other hand, alternative sewing technologies were more visible than before, which could replace stitch-making operations, such as ultrasonic welding, adhesive bonding, and printed embroidery. Those might be considered easier to be administered without a human operator than conventional sewing. Ultrasonic welding and adhesive bonding are not new technology, but the extended applications of those were featured in ITMA 2023. Optron presented calender rolls that can create welded lines of quilting stitches over a blanket or a mattress (Figure 11). Major sewing machine makers, Juki and Brother also displayed several welding machines that can join thermoplastic fabrics. According to Hayes and McLoughlin (2015), welded seams are less durable, but create softer and smoother joints than sewn and bonded seams.

Adhesive bonding is similar but different from welding in terms that joining is accomplished by the solidification of an adhesive material placed between the layers of workpieces. Typical adhesive materials are in the form of tape. It gets activated under heat and pressure and joins seams by melting through the fabric structure. Bonding is possible for almost all non-fleece fabrics with some limitations, such as porous materials (Sarkar et al., 2023). Brother attracted good attention in ITMA 2023 presenting a bonding machine equipped with a liquid adhesive feeder (Figure 11). Bonded seams for apparel are claimed to be smoother and less visible than sewn seams (Figure 11).

Figure 11. Alternative sewing technologies: welded quilting by Optron (left), bonded seaming by Brother (middle) and the resulting seams (right)

Another sew-free technology example was demonstrated by Kornit Digital. Printed embroidery technique was spotlighted as a part of their digital production line of T-shirts. Their direct-to-garment printers were improved for quality productions enough to mimic 3-dimensional surface decorations such as embroidery. As shown in Figure 12, it was not easy to distinguish between stitches and prints by seeing even at a close distance. A major advantage of using printed embroidery is to have manufacturing processes digitally controlled. Leaving nothing on the wrong side of the fabric, it also allows to keep lighter and softer properties of the fabric than adding intense embroidery stitches.

Figure 12. Alternative sewing technologies: printed embroidery by Kornit Digital

Textile Industry 4.0

The textile industry had led three prior industrial revolutions and is actively adapting itself to the fourth revolution currently going on. Triggered and driven by IT development, the major innovations for Industry 4.0 are based on digital transformation. It aims to merge the actual and virtual worlds through cyber-physical systems and interconnects humans and machines through the Internet of Things (Muller, 2021). This allows apparel producers to monitor manufacturing issues in real time and control production progress remotely making apparel factories smart. The key elements of technology are the internet of things (IoT) and interoperable networks. The overarching goal is maximizing production efficiency and productivity. As evidenced in ITMA 2023, Industry 4.0 is an active on-going term for many companies with lots of technological innovations forthcoming.

Having Industry 4.0 in mind, multiple cutting and sewing machine producers are actively engaged with software development and try to expand the capability of their hardware. Multiple examples were found during ITMA 2023. Zund has been partnered with a Portugal company, Mind Technology to strengthen their user interface. Juki continues linking their hardware devices to the network system, called "JaNets" (Suh, 2019). Mammut launched its own software product series that read machine operation status, formulate analytic reports on productivity issues, and suggest predictive maintenance. ACG Kinna Automatic is working on software development to reinforce their vision technology, not only to enhance pattern matching accuracy, but also to inspect and manage fabric defects efficiently.

In regard to quality control, advanced technologies are more actively incorporated, such as machine learning and artificial intelligence. For a long time, quality control systems were not autonomous and asked machine operators to stay alerted and detect product defects. Relying on human-oriented labor, some defects often ended up staying unnoticed until finished products reached end users. Thanks to recent advances in vision technology, artificial intelligence now replaces human inspectors and assists production optimization by suggesting data-driven decisions. During ITMA 2023, Serkon Makina demonstrated a new fabric inspection system run by deep vision technology and artificial intelligence. Their system was designed to manage not only surface defects, but also color transitions.

Another visible area pioneered by artificial intelligence is creative design. By merging artificial intelligence into CAD tools, the intelligent CAD system creates digital designs automatically based on the database from various resources and provides professional suggestions for new designs. This enables people with limited expertise in design to customize the products for themselves, which supports the very first stage of on-demand manufacturing. A start-up company, Myth, presented an AI-based pattern design tool during ITMA 2023 that visualized unique unlimited options of new designs out of multiple clicks.

In the meantime, the next revolution, Industry 5.0, is already on its way, while many industries are still in the middle of Industry 4.0. According to the European Union (Muller, 2021), Industry 5.0 discusses the values beyond manufacturing efficiency and productivity. Shifting the focus from economic to societal values, it adds sustainable development and human-centric solutions to Industry 4.0. The concept is not new, however. Environmental, social, and governance (ESG) or triple bottom line approaches have been emphasized during the past decades by different levels of entities across the world. Industry 5.0 reminds human, environmental, and social aspects as corporate social responsibility for textile and apparel industry. Supporting Industry 5.0, specific examples of machinery in tangible and intangible formats are foreseen to dominate future ITMAs.

Conclusion

The technological innovations presented in ITMA 2023 were summarized to highlight the advanced state of automation in apparel cut-and-sew processes. The advances were obviously seen both in quality and quantity. More diverse applications of automated cutting and sewing technology were visible compared to ITMA 2019 (Suh, 2019). The key trends in cutting were seamless integrations of equipment before and after cutting, popularity of optical pattern matching systems, and enhanced heavy-duty cutting capability. Compared to cutting, sewing automation was still under active development of core technologies, which allowed only limited types of products in automated configurations. The direction of this developmental journey is undoubtful that the textile and apparel industry is making steady progress every day towards the fourth industry revolution and Industry 4.0.

References

Aeppel, T. (2022). Robots set their sights on a new job: sewing blue jeans, *Reuters*, Retrieved on July 2023 from https://www.reuters.com/technology/robots-set-their-sights-new-job-sewing-blue-jeans-2022-12-12/

Davies, G. (2021). How does on-demand manufacturing work for fashion brands? *Techpacker*, Retrieved on July 2023 from https://techpacker.com/blog/design/fashion-on-demand-manufacturing/

Francis, S. (2019). SoftWear Automation launches Sewbots as a service, *Robotics and Automation News*, Retrieved on July 2023 from https://roboticsandautomationnews.com/2019/02/05/softwear-automation-launches-sewbots-as-a-service/20847/#:~:text=For%20a%20monthly%20fee%20starting,and%20three%20shifts%20a%20day

Hayes, S. & McLoughlin, J. (2015). The sewing of textiles, In J. Jones and G.K. Stylios (Eds.) *Joining Textiles* (pp. 66-122). Sawston, United Kingdom: Woodhead Publishing.

Li, R., Zhao, S., & Yang, B. (2023). Research on the application status of machine vision technology in furniture manufacturing process. *Applied Sciences*, *13*(4), 1-14.

Muller, J. (2021). Enabling Technologies for Industry 5.0, *European Commission*, Retrieved on July 2023 from https://op.europa.eu/en/publication-detail/-/publication/8e5de100-2a1c-11eb-9d7e-01aa75ed71a1/language-en

Sarkar, J., Rifat, N. M., Sakib-Uz-Zaman, M., Al Faruque, M. A., & Prottoy, Z. H. (2023). Advanced Technology in Apparel Manufacturing. In M. Rahman, M. Mashud, and M. Rahman (Eds.) *Advanced Technology in Textiles: Fibre to Apparel* (pp. 177-231). Singapore: Springer Nature.

Suh, M. (2019). Automated cutting and sewing for industry 4.0 at ITMA 2019. *Journal of Textile and Apparel, Technology and Management*. Special Issue, 1-13.

Textile World (2019). Sewbots® Transforming The Sewn Products Industry, *Textile World*, Retrieved on July 2023 from https://www.textileworld.com/textile-world/2019/07/sewbots-transforming-the-sewn-products-industry/