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Automated Cutting and Sewing for Industry 4.0 at ITMA 2019

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Introduction

An apparel product is one of the consumer goods that have a large number of fragmented supply chains. It starts from fiber selection, proceeds to yarn and fabric production, and ends up with apparel manufacturing. In many cases, there are several additional industries involved in the processes to finish the final product that produce trimming, finding, embroidery, leather and many other fashion accessories.

Apparel manufacturing is labor-intensive and has been accomplished by highly-skilled manual operations using traditional materials and equipment. The major operations are categorized into three groups; pre-production, production and post-production (Nayak & Padhye, 2018). Pre-production processes focus on the preparation of necessary materials and services, and include line planning, sample development and approvals, sourcing, and production scheduling. During the production, fabrics are spread, cut, bundled, and sewn. Several post-production tasks are followed to get sewn products ready for consumers such as pressing, inspection, folding, packaging, etc. Apparel production still relies on manual practices much as it was a few hundred years ago (Burns, Mullet, & Bryant, 2011).

Cutting and sewing are unique iconic tasks in apparel manufacturing, which are highly labor dependent and therefore expensive. According to Burns, Mullet, and Bryant (2011), fabric purchase and cut-and-sew labor are the two largest expenses when an apparel product is manufactured. Raw material takes 50-70% of the total product cost (Vilumsone-Nemes, 2018b), but a compromise in quality and quantity of fabrics is not under consideration since it directly influences the quality of a final product. Instead, the viable solution to reduce the fabric cost is to realize the most efficient marker through accurate and precise cutting. On the other hand, sewing is known to take 35-40% of the total cost (Gries & Lutz, 2018). Sewn product manufacturers have lowered the labor cost down through global supply chain management over the past decades by locating their production facilities in developing countries. However, this business strategy became difficult to maintain due to recent changes in global labor market. There are urgent needs to find alternative solutions to overcome this. Hence, to provide a high-quality product at an affordable price, it is necessary that the cutting and sewing processes are automated by the advanced machinery.

Automation improves productivity as well as the quality of fashion products by minimizing human intervention and preventing potential human mistakes during manufacturing. Automated systems can be achieved by embedding a new system or technique between or within the existing electronic devices (Nayak & Padhye, 2018). The examples of the new system or technique include mechanized fabric handling, computerized techniques, automatic sewing machine and robots. They assist smooth automatic transitions of workpieces between processes or during a process. Several stages of apparel manufacturing can benefit from the application of automated systems.

Focusing on the technological innovations presented in the recent textile machinery tradeshow ITMA 2019, this article demonstrates the advanced state of automation in apparel manufacturing. There were six sub-sections established under the garment making system. Those were product development equipment; shrinking, fusing, and cutting; sewing; sewing supplies and consumable; product finishing. Cutting and sewing are the major areas of observations, and multiple examples of automated equipment are reported to highlight key features of technical innovations in cutting and sewing automation.

Automation in cutting

With an increasing demand of mass production, the cutting room in an apparel manufacturing facility has been constantly automated by several inventions of new machinery. Spreading machine carried a roll of fabric over the table and drastically reduced the human workforce. Introduced in the early 1900s, die cutters increased cutting efficiency and quality dramatically as well. With the appearance of numerically controlled (NC) machine in 1940s and 1950s, continuous cutting became possible. This led to a greater flexibility in production as well as more economic use of material. Later on, digital technology created computer numerically controlled (CNC) machine and other supporting tools such as CAD/CAM programs. This steady and persistent effort made the cutting room evolved into the most advanced department in the apparel manufacturing industry (Vilumsone-Nemes, 2018b).

Most systems in automated cutting have a similar configuration, where a cutting device is housed in a carriage that is attached to a crossbar over the cutting table. The carriage moves along the crossbar across the width of the cutting table, while the crossbar moves along the length of the table. These movements let the cutting device travel over the cutting area, and are managed precisely by a control unit. In modern cutting devices, cutting tables are equipped with a vacuum system to hold the material down and enhance cutting accuracy during the cutting process. Porous materials, such as most of textiles, have to be cut with an impermeable plastic cover because of this. According to Vilumsone-Nemes (2018a), suction blowers are the component that consumes the most power in cutter operations.

Various cutting technologies are available for a cutting device, such as computer-controlled knife, laser, water jet, plasma, or ultrasound. Knife cutters are suitable for multi-ply cutting of heavy textile materials and have been most widely adopted by textile product manufacturers (Vilumsone-Nemes, 2018a). The knife cutting head is equipped with multiple cutting tools: knives, notch tools, drill punches, and markers to meet diverse cutting and marking demands. Laser cutters are the second most methods in textile cutting and frequently adopted for single-ply cutting. It can create anti-fray edges on thermoplastic materials which are most of synthetic fibers including polyester and nylon. Diverse treatment effects are attainable, such as cutting, kiss cutting, and marking, through controlled laser intensity. The choice of cutting method depends on the properties of materials as well as the complexity of required contours to be cut.

The most important consideration in the configuration of automated cutting system is whether a single ply or multiple plies of fabrics would be cut. Single-ply cutting enables continuous processes and eliminates the presence of spreader since the fabric can be fed to the cutting area directly from a roll. A conveyorized cutting table is used for increased productivity, where the cutting continues with the advance of the cutting surface. With the moving surface, an extra-large component exceeding the length of cutting table is possible to be cut in this configuration.

When multiple stacks of a fabric are spread to cut, stronger cutting power is required, of course, than single-ply cutting. An oscillating knife maximizes the cutting capability by moving up and down as the knife advances. The depth of oscillating stroke ranges from 5mm to 200mm (Vilumsone-Nemes, 2018a) and needs to be engineered according to the cutting conditions. Serkin Tekstil introduced the intelligent knife which oscillates not only up and down, but also from side to side. This additional motion of the knife is helpful to cut pieces accurately across the thick stacks of multiple textile layers. Due to the oscillating motions of the knife, the surface of cutting tables must be loose enough to support the movement. In case of multi-ply cutting with an oscillating knife, the surface of a cutting table is made of bristles, which is typically a static flatbed table. This static cutting configuration ensures higher cutting accuracy than conveyorized surfaces.

Since Gerber Technology introduced the first fully automated cutting system in 1960s, automated cutting market has been matured and become much competitive over the several past decades. The main areas of current innovation are related to elaborated sub-functions or supplementary assistance to the existing cutting technology. The major fields of new developments observed at ITMA 2019 could be summarized into three aspects; productivity, versatility, and pattern matching capability.

To enhance productivity, some automated cutters are equipped with an additional cutting device and crossbar, which performs synchronized and simultaneous cutting. According to Kuris Spezialmaschinen GmbH (2010), dual cutting heads can save up to 40% of cutting time. Another example of increased efficiency is the implementation of an automatic labeler, and this system was presented by Morgan Technica and Serkon Tekstil at ITMA 2019. Labelers are incorporated into cutters to ease human mistakes and confusions during unloading processes followed after cutting. The stickers, of different dimensions according to the needs, are thermally printed and placed in the middle of each cut piece (Figure 1). This makes the necessary information including bar codes immediately visible on the cut pieces.

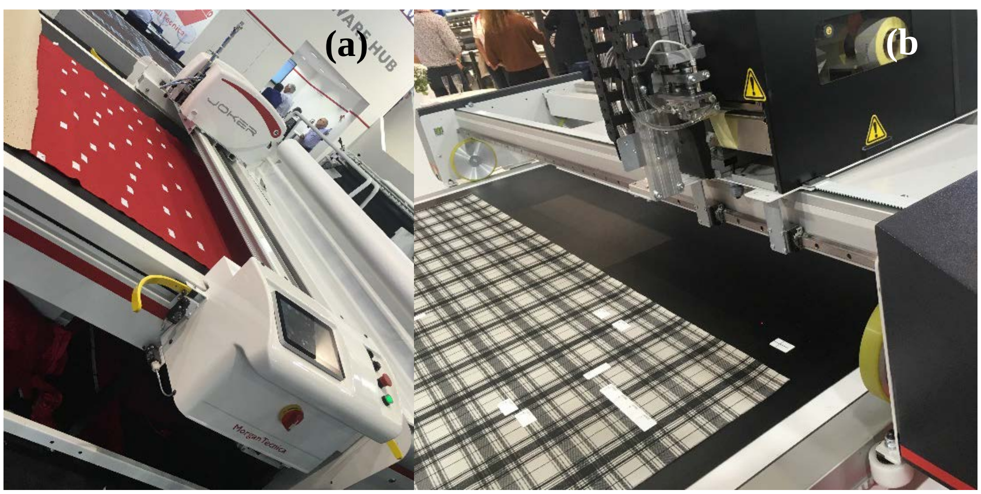


Figure 1. Automatic labelers by Morgan Technica (a) and Serkon Tekstil (b)

Aiming at the versatile use of a single cutter, Zund adopted modular tooling (Figure 2a) in their automated cutters, with which the configurations of cutting device can be changed interactively by the user. Various cutting devices are selected and mounted on the carrier in a few quick easy steps for specific cutting operations. The available options are extremely wide including electric or pneumatic oscillating tools, rotary or knife blades, laser modules, perforating or creasing tools, and marking or plotting modules.

Eurolaser presented an automated textile cutting system specialized for wool fabrics based on laser technology (**Figure 2b**). Called “Cut’n Protect Technology”, their cutter was equipped with a steamer which could stabilize the fabric and create smooth lint-free cut edges. This cutter also incorporated dual cutting devices of laser and a blade for versatile applications to textiles.

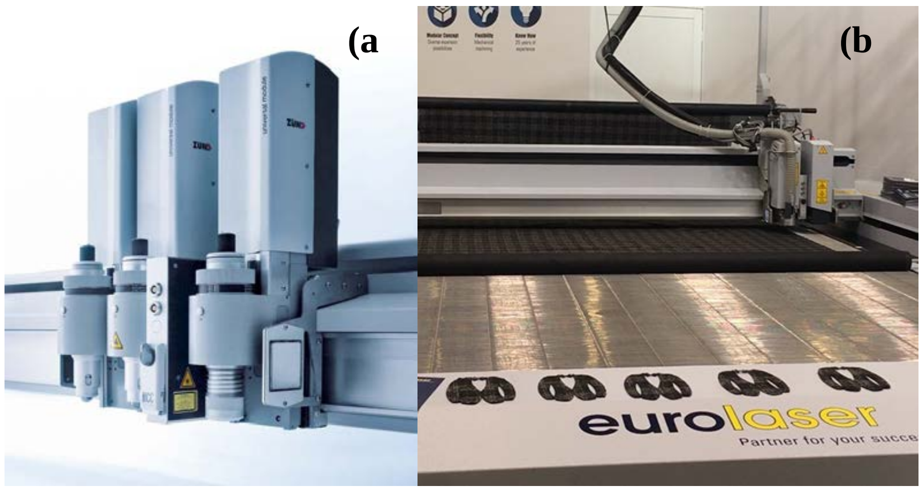


Figure 2. Modular tooling by Zund (a) and laser wool cutting by Eurolaser (b)

Traditionally, pattern matching was attained by preparing sectioned markers and having two separate cutting steps, rough cutting and fine cutting (Vilumsone-Nemes, 2018a). Although these processes were time- and labor-consuming, pattern matching accuracy was still elusive, and unnecessary material wastes were generated between rough and fine cutting. Several companies, such as Zund, Morgan Technica, Kuris, and Gemini, have invested efforts to develop pattern matching hardware and software and demonstrated the improved pattern matching capability in ITMA 2019.

In an automated system, pattern matching can be achieved either by generating an on-screen image of the fabric patterns over the marker table or projecting images of markers on the fabric. In the former method, fabric prints are scanned by an optical device on the cutting head and imported to the marker making software. Garment patterns are placed and a marker is prepared over the fabric image (Figure 3a). This allows the operator to optimize cutting parameters for accurate and precise cutting outcomes. Often called “visual nest”, the latter technology helps the operator view and edit markers in a real time, checking a marker image projected on the fabric surface before cutting (Figure 3b). The operator can relocate or reorient pieces to match intricate fabric patterns or manipulate with engineered patterns. Since the operator still performs a significant role during the processes, these systems are considered as semi-automated.

The key technology of Kuris highlighted at ITMA 2019 was the integrated camera system that records and recognizes the material to be cut. Photographed images of fabric surface are processed to calculate cutting coordinates. This technology enables a single-ply cutter to perform even without markers in cases of garment patterns printed by a sublimation method (Figure 3c). Based on the imaging technology, their leather-cutter can also detect the arbitrary contours of a leather piece, determine different qualities of surface conditions, and auto-nest markers directly on the leather matching the quality zone (Figure 3b).

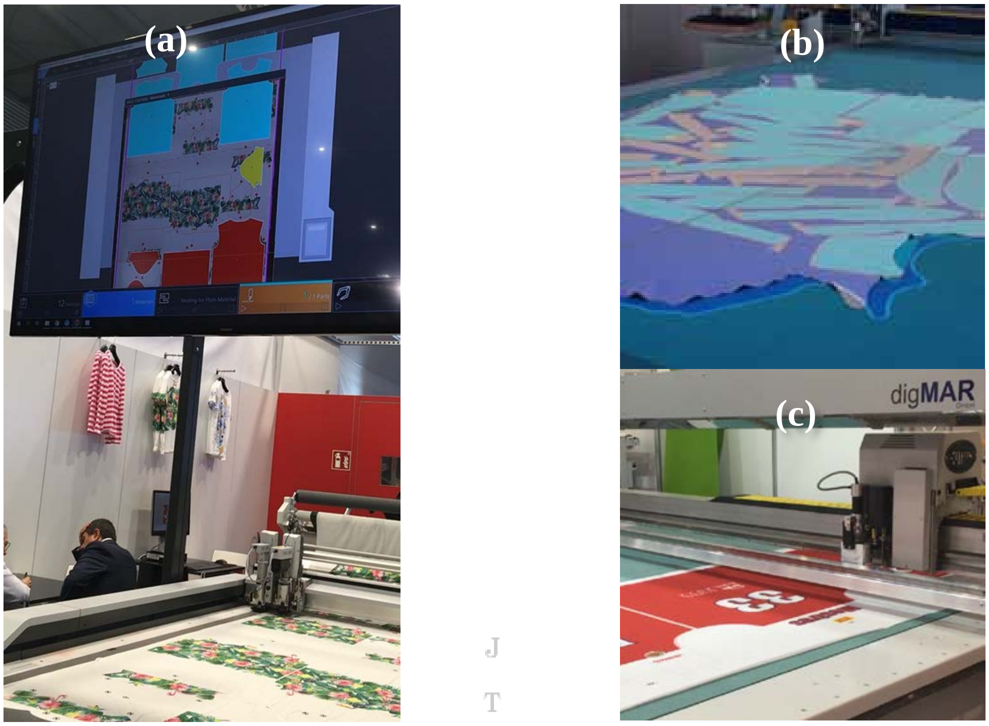


Figure 3. Pattern matching system: CAD software by Zund (a), visual nest in leather cutting by Kuris (b) and sublimation print cutting by Kuris (c)

Automation in sewing

Production processes involved in garment assembly are divided into two sub-functions; handling of material and joining of fabric components. In garment manufacturing, significant time and labor are spent in material handling, such as lifting, moving, mounting, re-positioning, and re-orientating of cut or semi-finished fabric components. Considering quality assurance in seam productions, it is critical to handle those with a precise and gentle treatment in an economic and efficient way (Lutz, Fruh, Gries, & Klingele, 2018). In commercially available workstations, loading is mostly manual, while sewing and unloading processes are somewhat automated (Jana, 2018).

Compared to bend-resistant materials, the handling of flexible material is significantly more challenging. Due to the softness of the textiles, the material easily deforms impermissibly even under a very small pressure, such as dead weight or air resistance. According to Szimmat, (2007), material handling during product assembly took place mostly (79%) manually in textile product plants. None of the plants handled material automatically, while only 21% companies employed semi-automatic systems. When a piece of clothing is manufactured, the handling time is about 80% of the overall production time, and approximately 80% of the factory cost is related to the handling cost (Gries & Lutz, 2018).

There are several gripping technologies based on either vacuum, Bernoulli gripper, needles, or rollers (Lutz, Fruh, Gries, & Klingele, 2018). In vacuum grippers (Aminpour, 2017), the gripping elements are connected to a pneumatic pump and in contact with the gripping material. The pressure difference allows the gripping material to adhere to the suction pads. Bernoulli grippers enable contactless gripping by creating Bernoulli effect with the direct use of compressed air. In needle grippers, needles penetrate the materials at an angle and are interlocked with the material to grip. Roller systems often employ freezing and surface grippers, which create temporary adhesion using Peltier elements and electrostatic effects, respectively.

However, these advanced gripping technologies are not yet popularized in assembly systems of textile products. It was reported that 72% of current semi-automatic handling system does not employ grippers, and the remaining 28% use needles or scrap grippers (Szimmat, 2007). The only similar application found in ITMA 2019 was the picking pad (Figure 4) demonstrated from an on-going project in a Barcelona-based company named AB Industries. In their system, workpieces are floating about an inch over a table surface since the surface is structured with bristles. This allows a 360-degree robotic arm to scoop the workpieces up easily with a simple gripping element. According to the personnel on duty in ITMA 2019, this technology is currently under development and not yet matured for commercialization.

Figure 4. Picking pad by AB Industries

Sewing represents the most important textile joining technology, taking 85% of all joining methods (Gries & Lutz, 2018). Not much different from the ancient times, sewing is still dependent on highly-skilled labor for manual operations, and takes 35-40% of the total cost (Gries & Lutz, 2018). Over the past a few decades, sewn product manufacturers lowered the production cost down by relocating their production facilities in developing countries with low wages. However, this business strategy is nearing the end of its lifetime as the market conditions have changed much recently. Labor costs are rapidly increasing in many developing countries. There is a global shortage of skilled labor, and consumer behavior changes faster than ever pushed by fast fashion trends. Therefore, garment manufacturing industry is urged to strive for sewing automation.

The most popular and widely adopted automated sewing configuration observed at ITMA 2019 was the conventional sewing machine mounted on the fabric processing machinery such as a winding or calendaring unit. Several companies including Texma and Comatex used these configurations to finish edges, join fabric rolls, or make a tubular structure from a fabric roll (Figures 5a and 5b). Monti-mac supplies a series of mobile sewing machine for this configuration (Figure 5c). Pneumatic-power supply is adopted in some sewing units in case that wet processes are involved simultaneously during sewing operations. The common stitch types used for these applications are either chain (100 or 400 class) or overlock (500 class) stitches since sewing machine for those stitch types is equipped with continuous supply of bottom threads that does not require to stop the machine to load the threads.

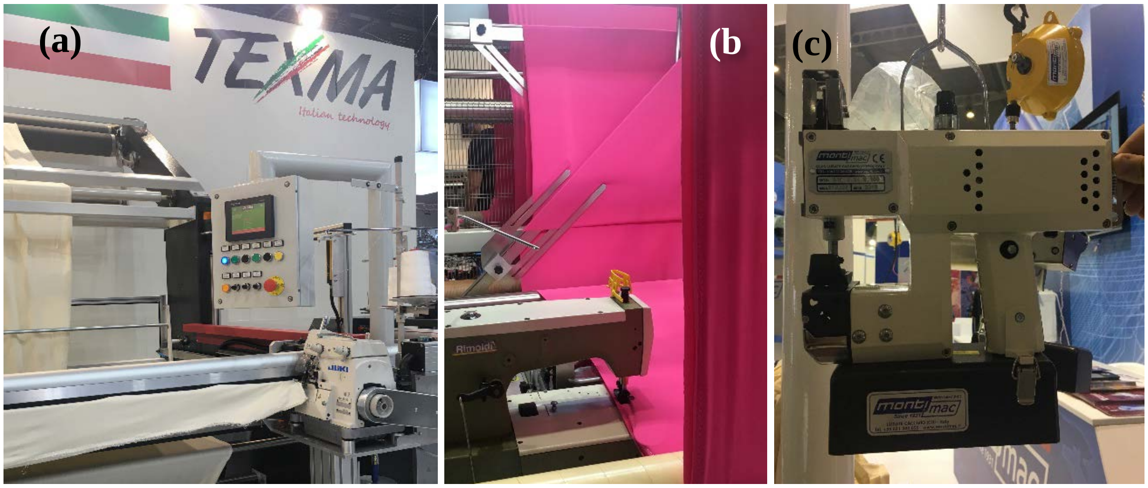


Figure 5. Roll-joining configuration by Texma (a), tube-making configuration by Comatex (b), and movable sewing device by Monti-mac (c)

Automatic bobbin changing system is an innovative solution for increased efficiency in sewing. In lock stitch machine (301 stitch type), a fully-loaded bobbin lasts for less than 20 minutes in continuous sewing (Jana, 2018) and frequent changes of bobbins have been a notorious bottleneck in sewing. The automatic system runs based on two principles; checking the remaining amount of bobbin threads and replacing with a filled one once the predetermined amount of remaining thread is reached.

RSG Automation Technics demonstrated a fully-automatic bobbin exchanger in ITMA 2019. Their patented bobbin checker uses a unique bobbin coded with a specific combination of RGB colors (Figure 6a). As the bobbin spins during machine operations, a light sensor monitors the color sequence and detects usual bobbin movement or errors when the bobbin runs out of threads. In the bobbin changing unit shown at ITMA 2019 (Figure 6b), a magazine-type bobbin station sits nearby with 15 filled bobbin cases ready, and one space out of 16 slots remains empty for changeover to take place. This leads to minimal production stops, in which the sewing machine stops only for 6-8 seconds each time for bobbin exchange.

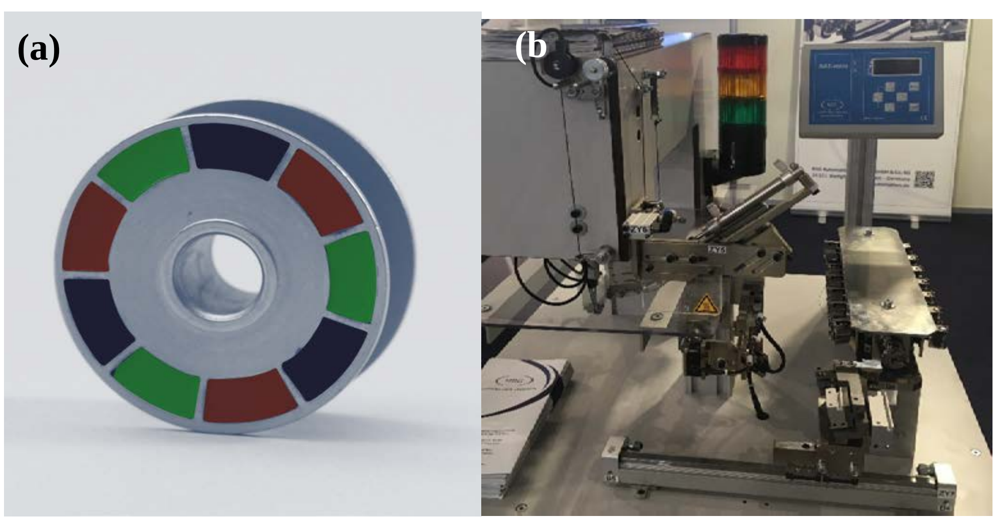


Figure 6. Automatic bobbin exchanger by RSG Automation Technics: color-coded bobbin (a) and magazine-type station (b)

The principles of automated sewing vary depending on the geometry of sewing paths. 2-dimensional seams can be easily created by computer numerical control (CNC) sewing technology, where a single or double mobile sewing heads advance over textiles along the previously programmed seam path. For more complicated cases to convert 2-dimensional fabrics into 3-dimensional seams, the sewing head is guided by a robot in 3-dimensional space along the sewing paths while the fabrics are positioned in a 3-dimensional shape. However, in many of these cases, two fabric pieces have different contours or curvatures along the seam to be joined. This type of seams need to be handled by positioning the fabrics 3-dimensionally and applying different tension to the fabrics in every stitch.

In a 2D-sewing configuration, one or more layers of textiles are stitched within fixed sewing frames. The handling of flexible material is avoided by clamping the fabric pieces into the holders. The holder guides the sewing head into X- and Y-directions following a programmed seam contours. This sewing configuration is mostly used for ornamental and design seams. The size of sewing field is basically limited by the physical dimensions of the linear axes in the machine. Large machine may handle a sewing area up to 3m by 3m, while small machine can cover the space less than 10cm by 10cm (Gries & Lutz, 2018). Large CNC sewing machine is for quilting a blanket or a mattress (Figure 7a). A typical example of small-sized machine is applied when care or brand labels are automatically stitched into clothing (Figure 7b).

Current advances in automated sewing system are limited to certain operations during the sewing process. Various semi-automated sewing automats and units are commercially available from many suppliers, such as Juki, Rimac, and Durkopp Adler. At ITMA 2019, Juki demonstrated a series of automatic sewing machine to stitch buttons, buttonholes, and bartacks, while Rimac showcased automatic binding machine to finish round corners of bedding and automobile floor mats (Figure 8). The workpiece is rotated at corners through a motorized arm to create a constant curvatures with the textile tape automatically inserted through a feeding unit.

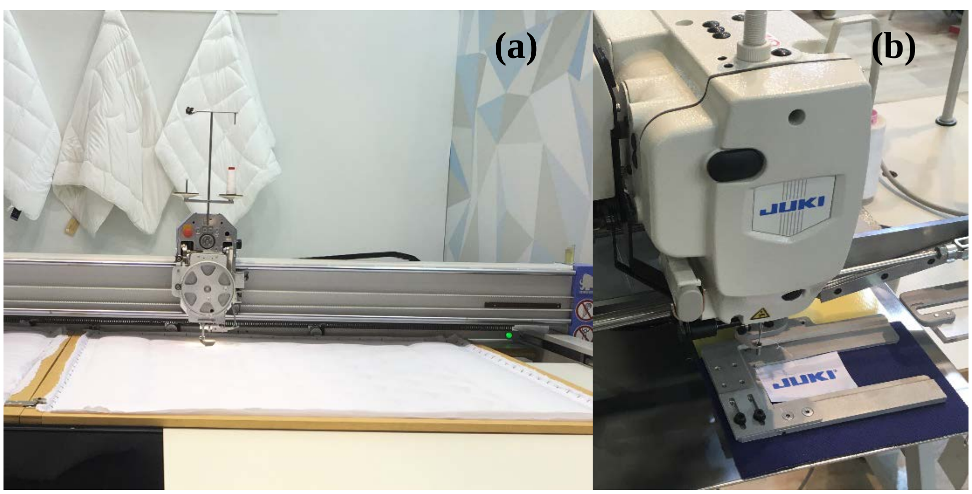


Figure 7. Quilting machine by Mammut (a) and label attaching machine by Juki (b)

Figure 8. Automatic binding machine by Rimac

Durkopp Adler group introduced a modular production system at ITMA 2019 by demonstrating a double welt pocket automat shown in Figure 9. A welt pocket is produced by a two-needle lock stitch head with a center knife cutter and needle feed mechanism (Jana, 2018). Sewing frames with a fixed seam path are hired for template sewing and they clamp workpieces during the operations. Being a semi-automatic configuration, it still remains to the operator to align and feed the pieces to the system. For fully-automated solutions, it is state of the art that sewing machine has its own feeding system which transports and positions the workpiece to a clamping position.

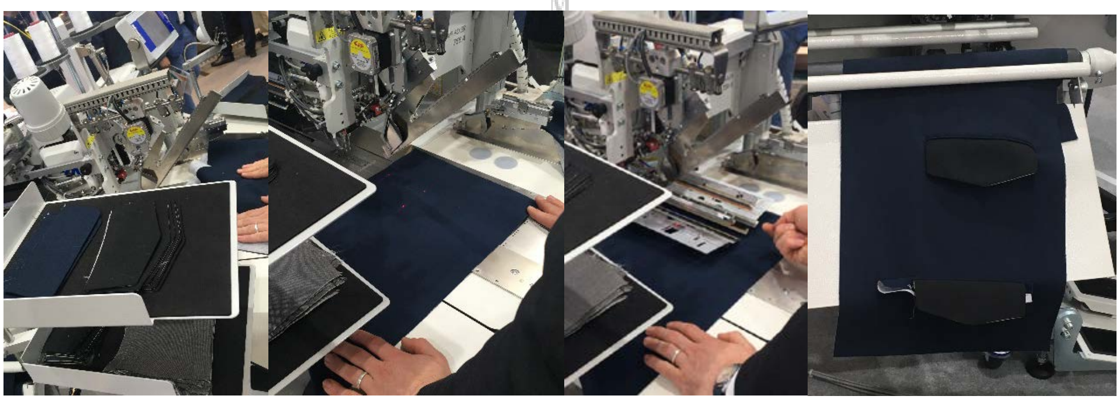


Figure 9. Semi-automatic modular production system by Durkopp Adler

Not participating in ITMA 2019, Softwear Automation Inc. recently introduced a fully-automated sewing system, called “Sewbot”. The major technological innovation is the integration of advanced computer vision systems, which tracks individual threads at the needle and coordinates the precise movement of the fabric (Jana, 2018). Sewbot handles a fabric by a robotic arm and a 360-degree conveyor system (Figure 10a). A four-axis robotic arm can lift and place a piece of fabric using a vacuum gripper (Figure 10b), while a conveyor table can feed the fabric into a sewing unit. The table is equipped with the spherical rollers, called “Budger Ball” (Figure 10c) embedded to the surface. Thanks to these, each fabric piece can go on smoothly in any direction over the table as needed.

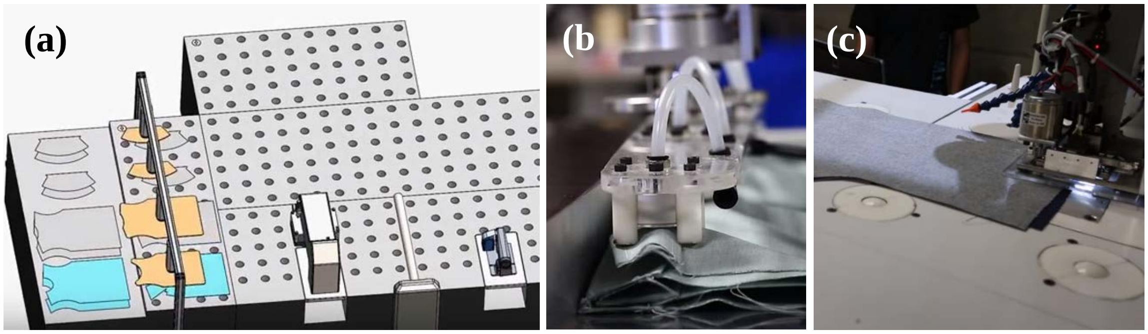
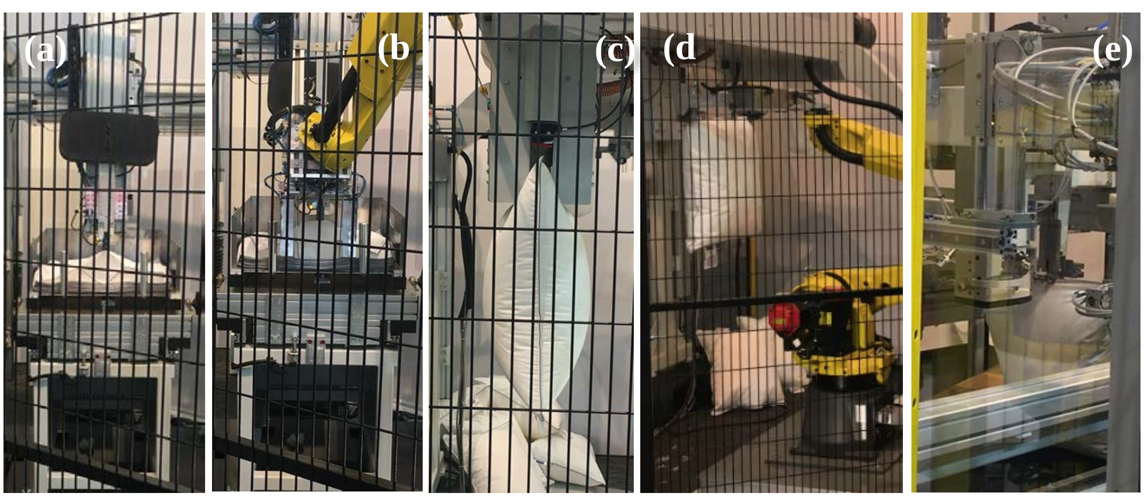


Figure 10. Fully-automated production system by Softwear Automation Inc. (DevicePlus, 2018): sewing machine arrangement (a), vacuum gripper (b), and “Budger Ball” (c)

A Canada-based company, Automatex, demonstrated a full-automated pillowcase production unit at ITMA 2019, where sequential production tasks of trimming, folding, stitching, labelling, and packaging are completed within a single unit. Similar systems are present by Magetron, Texpa, and Schmale for towel production. So far, commercially available production systems with full-automated production capability are limited to planar textile products, such as towel, bedding sheets, and carpets.

Sewing heads need to be mounted on and controlled by robots for 3D-sewing operations. Since many processes and steps of semi-automatic machine have to be incorporated, it is difficult to maintain economical and flexible production. Due to a large scale of investment, robotic systems are not yet adopted in garment production lines. Having considered that, the production demonstration carried out by an Italian company, ACG Kinna Automatic, provided the most futuristic and impressive scenes for automated production. A fully-automated system named “Borsoi” was handling 3-dimensional products, a pillow, using robots. Specifically, it completed picking up a pillowcase (Figure 11a), securing the opening of a seam (Figure 11b), stuffing the pillowcase (Figure 11c), transporting the pillow (Figure 11d), closing the opening (Figure 11e), and packing a finished product in a plastic bag (Figure 11f) in a single continuous production line (Figure 11g). All workpieces are handled and advanced forward between each task by robotic arms with clamps.



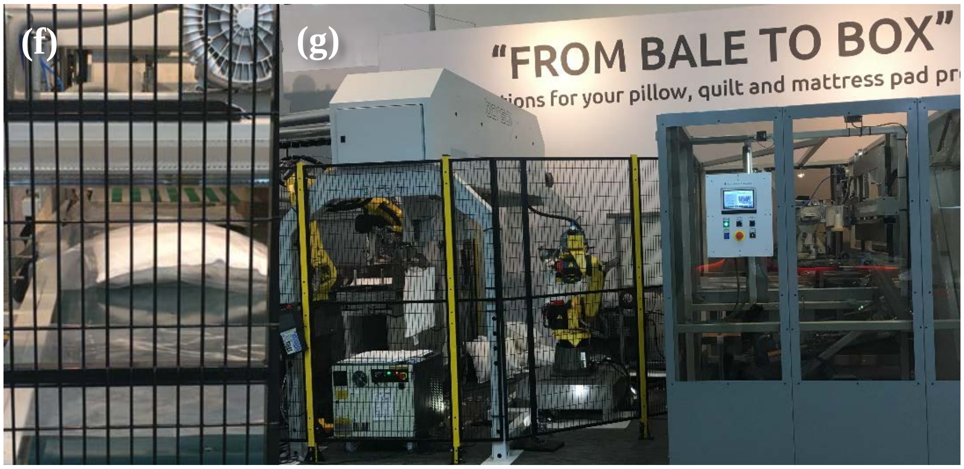


Figure 11. Fully-automated pillow production system by ACG Kinna Automatic

Concurrent completion of more than one production task is a key consideration for current development and advances in automated sewing system. For this, sewing machine has to be implemented within the existing flow of other operations involved in the middle of assembly processes, such as stuffing feeders or seam pressers, as shown in multiple cases at ITMA 2019. Therefore, the configuration of automated sewing system relies on a product design and its production plans. Each production system may have to be customized for different apparel products. Efforts in product standardization would be helpful to lessen this burden, and there are companies like RSG Automation Technics who offers a system customization service for textile product plants.

Textile Industry 4.0

Textile industry had led the first industrial revolution in 1800s, which brought the transition from handcraft production systems to manufacturing systems based on mechanical power generation. The second industrial revolution was carried by modern electrified devices that made industrialization and mass production possible. The third revolution was based on advanced technologies in digitalization and automation. Production lines became equipped with programmable machines. The current era is going through the transition toward the fourth industrial revolution.

Industry 4.0 is a strategic initiative introduced by the German government in 2011 (Rojko, 2017). Industry 4.0 is triggered by the fact that the previous attempts to lower the manufacturing cost are almost exhausted and new strategies are needed. According to Bauernhansl, Krüger, Reinhart, and Schuh (2016), Industry 4.0 factory can save the costs by 10-30% in production, 10-30% in logistic, and 10-20% in quality management. Other expected outcomes are a shorter lead time, an improved customer responsiveness, affordable mass customization, worker-friendly environment, and more efficient use of natural resources and energy (Rojko, 2017). Especially, Industry 4.0 solutions provide key technologies to produce smart textiles, where the largest growth is expected in textile industry. The global market for smart textiles is forecasted to become three billion USD by 2026 (Hayward, 2015).

Aiming to innovate the current industrial production system through digitalization and exploitation of new technologies, the main idea of Industry 4.0 is smart automation based on interoperability and connectivity. The important element is the application of generic concepts of Cyber-Physical Systems (CPS) and Internet of Things (IoT) to industrial production systems. Production facilities are cyber-physical systems, which are physical equipment integrated with information and communication technology (ICT) components. Autonomous systems are able to make their own decisions for self-organization and self-optimization based on machine learning algorithms and real-time data (Kusters, Prab, & Gloy, 2017).

Networked systems integrated into apparel manufacturing machinery were introduced in ITMA 2019. Juke Advanced Network System (JaNets) is software in combination with supporting hardware, where sewing machine in a production line is interlinked to provide data on production activities. Digital sewing machine (Figure 12a) is an essential component to gather detailed sewing data including error codes. Terminals positioned at each workstation provide the detailed analytics of a production progress in real time and reduce time to react to problems. Transparent Electronic Tech (TPET) also proposes smart factory platform for home textile manufacturing. Their system consists of a series of digital machinery interconnected with each other to manufacture products, monitor facilities, carry out analytics, and transport equipment as well as materials (Figure 12b). This enables predictive maintenance of manufacturing facilities based on big data acquisition and analysis.

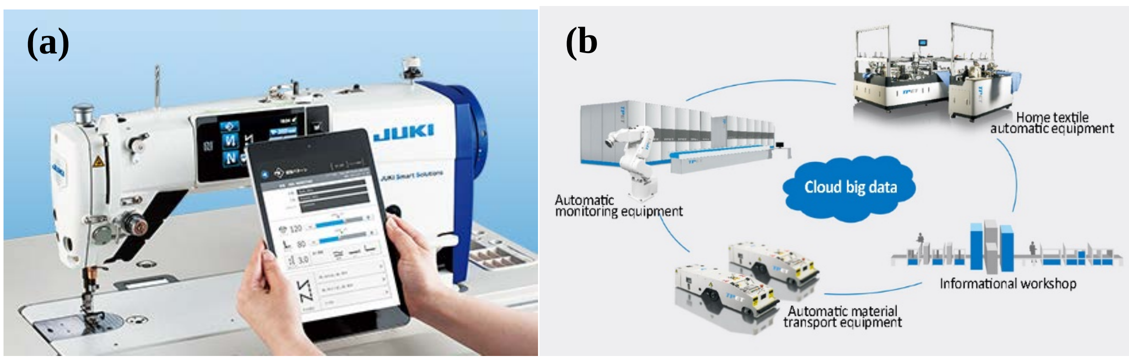


Figure 12. JaNets by Juki (a) and smart factory platform by TPET (b)

Based on the technical advances in digital technology and manufacturing automation, the concept of on-demand garment design and production has been proposed by many researchers (Aminpour et al., 2017; Suh & Lee, 2012), where an apparel product is manufactured after the customized order is received. The system would consist of apparel design database and a series of manufacturing machinery for textile printing, cutting, and assembly. Smart automation is essential to reduce the cost and shorten the lead time. This must be a ground-shaking innovation in textile and apparel business once the whole system becomes commercialized and technically stabilized. It is obvious from ITMA 2019 that textile and apparel industry is making a steady progress every day towards the 4th industry revolution and Industry 4.0.

Conclusion

The technological innovations presented in ITMA 2019 were summarized to highlight the advanced state of automation in apparel manufacturing. The most trend in cutting is the use of optical imaging technologies, and the cutters are becoming more productive, versatile, and precise. Compared to cutting, the development of sewing automation is still in a primitive stage, where only a limited sewing capability is feasible in automated configurations. The most consideration in automated sewing is the seamless integration of customized features into the existing production lines.

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