ZSK STICKMASCHINEN

White Paper
A GUIDE TO TECHNICAL EMBROIDERY

How to find the right additive textile manufacturing equipment for your business needs

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A Guide to Technical Embroidery

How to find the right additive textile manufacturing equipment for your business needs

Technical embroidery is an emerging field in additive textile manufacturing where flexible materials and functionalized fabrics are created for a wide variety of uses and purposes.

Existing products and structures that have been developed with other additive manufacturing techniques are quickly being converted into technical embroidery for high throughput production runs. These embroidered parts are produced with highly automated equipment reducing labor costs and increasing overall cost efficiency while adding new functionality to fabrics and substrates that has never been seen before.

As the technology is fresh, emerging markets and applications are continuously being discovered. Strong new market cases have been found in composites, heating wire placement, fiber optics, and flexible electronics industries. The high level of automation and low-cost of manufacturing with technical embroidery equipment has completely revolutionized the field and methods of functionalized textiles.

The ZSK Research and Training Center in Seattle welcomes you to explore the possibilities of technical embroidery with us!

In this guide, you'll learn about:

- Business advantages and approaches of using technical embroidery with ZSK.
- Key parts of a Technical Embroidery Machines.
- Types of materials used in technical embroidery.
- Types of Technical Embroidery Technique and their applications.
- The advantages of ZSK and machine' automated options.
- How to reach out and get started with exploring your product, line, or idea.

BENEFITS OF TECHNICAL EMBROIDERY WITH ZSK STICKMASCHINEN

Technical embroidery has significant advantages in manufacturing if utilized correctly.

The low-cost scalability associated with textile production is unparalleled and can be harnessed by other industries to solve technical challenges in mass production. Like other additive manufacturing equipment, technical embroidery machines can be quickly and easily reconfigured with no change in tooling to run a wide variety of parts. This versatility allows businesses to quickly change design iterations or concepts on prototyping machines.

PROTOTYPING MACHINES

Prototyping machines allow for small development firms to explore the field and the design possibility range of technical embroidery. The prototyping and sampling machines are designed by ZSK STICKMASCHINEN to be easily configurable to run a wide variety of different parts, geometries, and materials. This allows the business to quickly test out new product design iterations for their potential line and evaluate their business case. This data is critical to helping find suppliers and makes the business argument whether the resulting product embroidery should be insourced for control or outsourced for speed.

AUTOMATED AND SCALABLE TECHNOLOGY

Technical embroidery excels as a production technique due to its level of high automation. This automation allows for embroidered parts to be quickly scaled from initial concept to full production line, operating ZSK production machines. Production can occur within the same company that has a sampling and prototyping machine or alternatively can be outsourced to technical embroidery specific mills in the ZSK ecosystem. Please see chapter on the various Automation options offered by ZSK.

FLEXIBLE EQUIPMENT

ZSK Technical embroidery machines are versatile in the speed at which they can be reconfigured to produce new designs. These machines are usually reconfigurable within 5 to 10 minutes of the previous design regardless of material selection or technique. The change is quick, seamless, and requires almost no additional tooling or parts. This allows for the user to complete rapid design iteration in house greatly speeding the development time of a product line. The same machine can be running composites in the morning and car seat heating wire in the afternoon, and flexible electronics in the evening. As such the equipment can be reconfigured by the business to run a wide variety of different business models, parts, or samplings on the same machine. This provides further utility and flexibility within the business model.

MATERIAL OPTIMIZATIONS

As an additive textile manufacturing technique, technical embroidery produces very little waste. Materials are optimized to be placed only where they are needed allowing for significant material savings. The cost associated with material savings can quickly generate quick dividends for the business. If properly implemented, these material savings can cover the machine cost within a year of purchase.

HEAD

The embroidery heads are individual embroidery stations. The embroidery head is part of the machine that contains all the needles and/or all the required technical attachments. Each head is a station where a design can be embroidered at a time.

A multi -head is a machine with more than one head. So, a 2-head embroidery machine is a machine with two embroidery stations, which will embroider two identical designs at the same time. For technical embroidery, three different heads type could be used; either singularly, either in combination.

Each head corresponds to a different embroidery technique, commonly refer to as:

- **W-Head embroidery**,
- **K-Head embroidery**, and
- **F-Head embroidery**.

The three different techniques are well explained in the following chapter.

Figure 1 – Triple Combination Machine with F, ,K and W-Head.

PANTOGRAPH AND FRAME CONSIDERATIONS

PANTOGRAPH

The pantograph is the part of the embroidery machine that allows the frame to move left, right, forward, and backward on the XY table plane.

The pantograph is the most import part of the embroidery machine and is common throughout all three technical embroidery techniques. The movement of the pantograph by the controlled CNC motion, or robotic control, is required to create different designs. It is important to note that during the embroidery process the needles themselves do not move across the table, instead the frame pulls the backing material to the desired position.

FRAME

A frame is the part of the embroidery machine that is moved by the pantograph to create the design, at which the backing material is clamped.

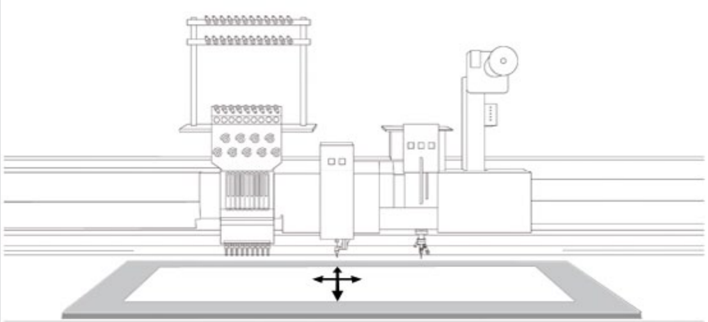


Figure 2 – The Pantograph moves in x and y directions.

FRAME CONSIDERATIONS

One of the most important questions when selecting an embroidery machine is how large the frame size has to be for your application. Frames can be as small as a few centimeters for shoe frames and larger than a meter by a meter.

However it is important to consider that the frame takes up a small amount of the backing material during the clamping process. This means that there is an edge around the outside of the backing material where the clamps hold that embroidery cannot take place. The size and location of this region is defined by the type of clamp that is being used and the embroidery technique applied.

Techniques like K-Head embroidery and F-Head embroidery can proceed close to the clamps. However, techniques like W-Head embroidery require more space between the frame and the embroidered location slightly reducing the embroiderable area.

The backing material could be placed on the frame by:

- **Manual clamps**: this is quick way to get different fabric materials tested of different thicknesses, different substrates, or friction coefficients. The clamping force, or other properties of these clamps, can be customized for the specific fabric or technical application of the machine.
- **Pneumatic clamps**: this allows for a high degree of automation and corresponding cost reduction. Pneumatic clamps have good ability to control tension finely which makes them suitable for a production method; generally not used for prototyping.
- **Magnetic clamps**: allow you to lie the fabric between two high friction clamp surfaces while the clamps compress and tension the fabric accordingly for the embroidery process and are quickly opened and reused increasing efficiency.

T8 CONTROL UNIT

In the embroidery process, a design is loaded onto the controller called 'T8' through the included network card or by USB. This design is examined on the view screen by the operator before embroidery.

Once embroidery is started, the pantograph communicates directly back to the controller of the machine for instructions on stitch locations. It then moves as the controller requires.

The circuit boards adapt the motors to compensate for different moments of inertia from different frame weights increasing speed for simple areas of high efficiency running stitches and decreasing speed for areas with high accuracy or complex geometry requirements.

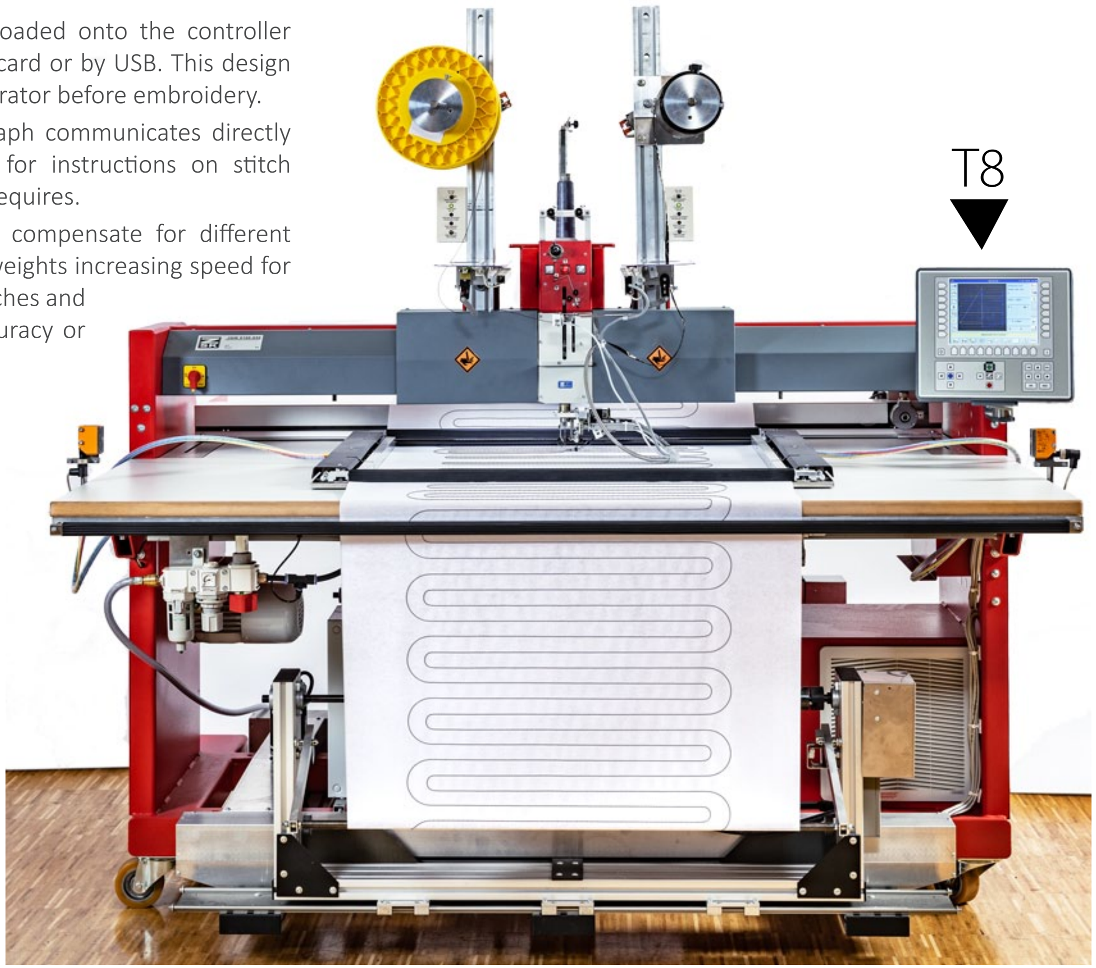


Figure 3 – T8 Control Unit at a JGW 0100

ZSK TECHNICAL EMBROIDERY MATERIALS

In Technical Embroidery we are always dealing with the realization of functionalized fabrics (or commonly called 'PREFORM' for W-Head Technique) that are made by the combination of a:

- top and/ bottom stitching threads,
- backing material
- technical material

BACKING MATERIAL

The backing material is the material that is loaded and clamped to the pantograph frame; therefore the material that is embroidered into to.

Depending on the structural properties of the base material, an additional stabilizer material might be required to reinforce the fabric on the back. This backing or stabilizer holds stitches as they lock preventing damage and tear-out in delicate materials.

Examples of backing materials used in Technical Embroidery

- Standard Thermoplastic woven / nonwoven fabrics
- Glass/Carbon woven /nonwoven fabrics
- Plastic Film
- Tarping materials
- Biomedical materials
- Leather and Natural materials
- Metal Wire meshes
- Laces
- Soft / Semi-Rigid Foams

STITCHING THREADS

There are a wide variety of different threads that work throughout the embroidery process as both upper and lower threads. These variations open many different material possibilities and technical capability.

Thread quality including technical parameters such as twist per inch, denier, stock material, and lubrication factors are all important in the embroidery process and required to achieve optimal speeds and results. Threads that are not designed specifically for embroidery can cause numerous thread breaks and other machine problems as they have not been designed for high tensile, high speed, machine usage. Therefore, it is recommended to only use high quality embroidery grade thread. A standard embroidery grade thread is a weight 40 thread however, for finer applications, embroidery threads 60wt, 75wt, or even 120wt can be used.

Examples of technical embroidery threads:

- **Polyester**- Standard thread in a wide variety of different colors and lusters
- **Nomex** - High temperature thread with self-extinguishing characteristics
- **Kevlar** – Strong thread that resists cutting, flames, and heat
- PTFE- Resistant to many chemicals and processes, very high heat tolerance
- **PEEK**- High melting point and resistance to extreme chemical environments
- **Nylon**- Low glass transition temperature, melts, used often in composites
- **Dyneema**- Extremely strong high tenacity thread with very low weight
- **Cotton** – Biodegradable, gets stronger when wet, can have sustainability benefits

TECHNICAL MATERIAL

In technical embroidery a technical material comes in place. This material differs in its definition and shape depending from the type of Embroidery Technique we are considering: W, H, or F-Head.

The table 1 reports a quick overview with the most common examples (but not limited to) of technical materials. The following chapter instead will explain in details the three different embroidery techniques and relative usage of technical material.

Technique	Technical Material
F-HEAD	• RFID Chips automatically placed • LEDs automatically placed • Conductive Threads - Silver coated polymer threads that can withstand laundering
K-HEAD	• Conductive Threads - Silver coated polymer threads that can withstand laundering • Some wire
W-HEAD	• Wires - uncoated covered, single or multicore 53µm to 1cm of diameter • Carbon, Glass, Aramid Fiber – 2k Tex to 48k Tex, with or without sizing • Basalt Fiber, Natural Fibre, Biomaterials • Commingled Tow – Carbon or Glass Fibre mixed with Thermoplastic Fibre • Fiber optics - Single or multimode fiber optics from plastic or glass filament • Tubes- Flexible tubes with silicon, latex, or other soft elastomer composition • CNT Threads - Carbon nanotube threads both spun and twisted • 3D Printer Filaments - Consumer level PLA, TPU, or ABS filament

Table 1 – Chart comparing Technical Material for W, K, and F-Head embroidery

TECHNICAL EMBROIDERY TECHNIQUES

Each Technical Embroidery Technique has recommended materials, usage, and applications. By selecting the right embroidery technique for your prototype, a higher quality and speed can be achieved.

Additionally, as represented previously in Figure 1, heads can be combined so to form combination machines, allowing for even more sophisticated prototyping and products.

Technique	Speed	Standard Part Size	Main Industries of Application
F-HEAD	1.000-1.200 RPM	1 cm – 50 cm	• Automotive • Wearable • Biomedical • IT
K-HEAD	700-750 RPM	2 cm – 50 cm	• Biomedical • Sport and Leisure
W-HEAD	800-850 RPM	5 cm– 120 cm	• Composite • Automotive • Sport and Leisure • Industrial • Aerospace • (Flexible) Robotic

Table 2 – Chart comparing W, K, and F-Head embroidery

APPLICATIONS

A few select examples of applications of technical embroidery to solve technical problems are below.

If your idea does not fall within one of these categories, reach out to ZSK to determine how to best move forward with adaptions in technical embroidery.

Technique	I.e. of Applications
F-HEAD	• Flexible textile circuits • Smart Textiles • Car Seat Leather interiors • RFID Chips
K-HEAD	• Reinforcement of engineered scaffold • Textile Electrodes with various shapes, conductivity and material combinations for 1. Body signal measurements: • Heart Rate • ECG Electrocardiography (i.e. T-Shirt) • EEG Electroencephalography • EMG Electromyography 2. Electrostimulation: • Rehabilitation • Sports and Fitness
W-HEAD	• Car Seat Heating Systems • Carbon Fiber Wheels, Suspension Links, Hood Reinforcements • Fiber optic paths for strain sensors in composite parts • Floor Heating/Cooling • Reinforcements for Carbon Fiber Wind Turbine • Wire routing for heating clothes • Antenna for signal • Flexible Pneumatic Actuator • Embroidered electromagnetic shields

Table 3 – Sample applications for W, K and F-Head embroidery

W-HEAD TECHNIQUE

OVERVIEW AND PRINCIPLE

W-Head embroidery is arguably the most material-versatile embroidery technique allowing for the widest range of materials combination and applications.

W-Head embroidery allows a technical material to be stitched over a backing material, in the quantity and in the directions desired. This additive technique is commonly called Tailored Placement.

- The technical material could be different types of wires, tapes, tubes, and/ or fibers.
- The backing material, which is clamped to the frame of the Pantograph, could be a fabric, a thermoplastic film, or other substrate material.

To fix the technical material over the backing material, two things need to be happened simultaneously:

- The pantograph must move in the X and/or Y directions. We call this movement 'Pantograph Stroke'.
- The Swing foot swings left and right so to place safely and spread accordingly the technical material, away from the needle. We call this movement 'Swing Stroke'.

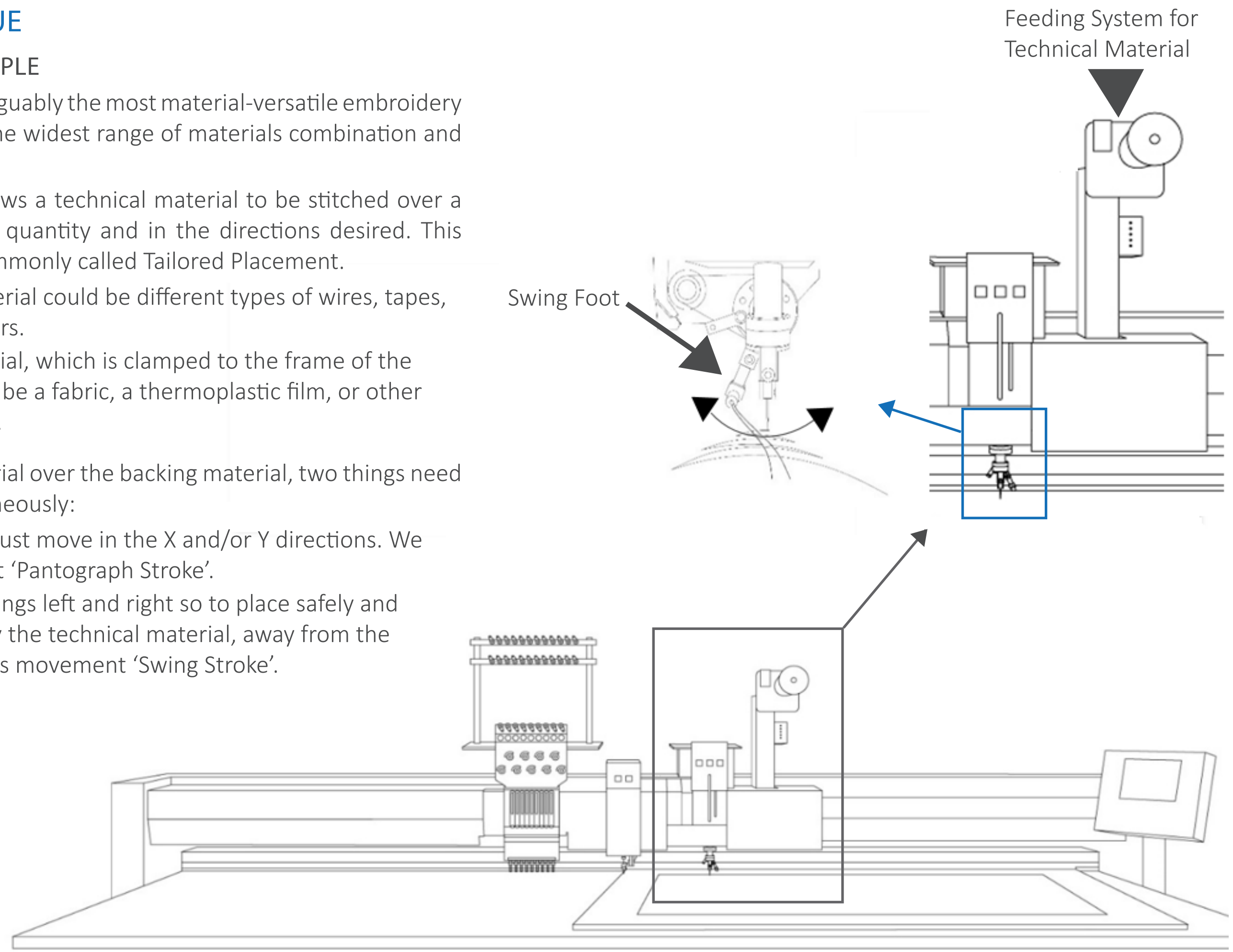


Figure 4 – Overview and Key Parts for the W-Head

TECHNICAL EMBROIDERY TECHNIQUES

The Active and automatic Feeding System for the W-Head continuously feeds fresh technical material to the Swing Foot.

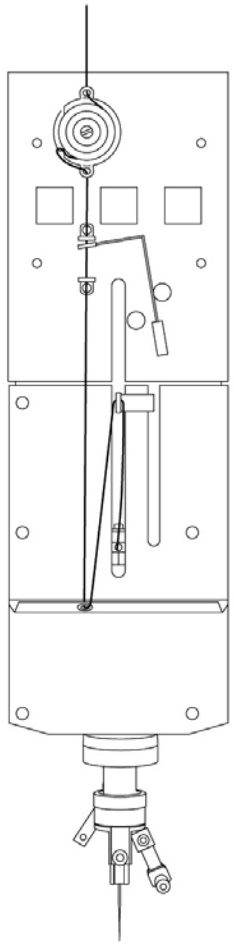
This system consists of a large motorized spool feeder for unwinding of heavy materials and controllably delivering them to the stitch hole. These mechanized spool feeders are monitored and activated by a control loop that checks tension regularly and adjusts the speed of material unspooling. In this way, industrial cones of carbon fiber, or large spools of wire for examples, can be brought to the embroidery head and embroidered without the interruption of changing smaller cones commonly used in Cooling Embroidering. This process can continue and in a nearly endless loop further decreasing machine downtime and increasing the quality of the resulting embroidery.

Pros.:

- Highest amount of material flexibility
- Fastest speed of fixing material to a substrate
- Highly repeatable process
- Highly scalable and automated technology
- High degree of machine customization available
- Tunable Local Thickness
- Can embroider parts up to one centimeter in height
- Increased optimisation of fibre/wire placement
- Cost-effective and green technology
- Reduction in material waste

Cons.:

- The technical material stays on the surface
- Cannot wrap the technical material through a circuit board
- Requires an additional stitching; top thread and bottom thread



PRINCIPLE

Figure below shows the principle of W-Head Technique, where ZigZag stitches are created so to constrain and fix the technical material to the substrate.

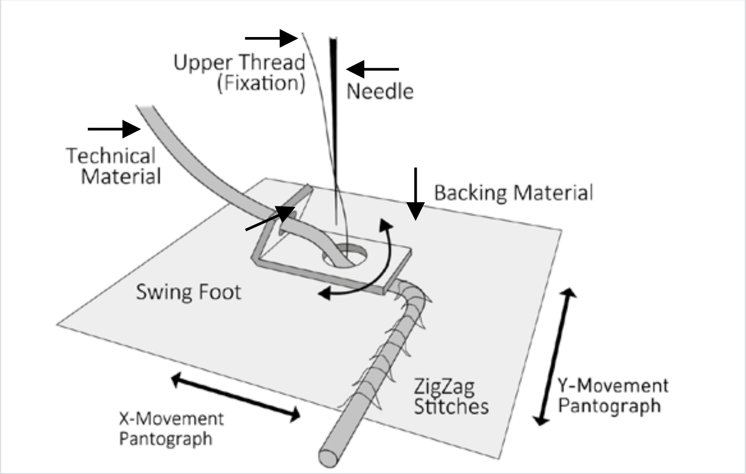


Figure 5 – Principle of W-Head Technique

The figure 6 explain better how the ZigZag are created and what are the parameters that influence the Stitch Length. At the top of the figure, we see six stitches in blue across an imaginary red datum line. These running stitches are each separated by a Stitch Distance of 5 millimeters. This representation with a running line is how we design the file for W-Head Technique in the embroidery software.

When that line of 6 stitches is loaded into the T8 controller, the T8 controller performs a mathematical operation upon those blue dots in order to shift them perpendicularly away from their red datum line.

If a Pantograph Stroke value of 4 millimeters is selected, every other blue stitch point will be perpendicularly moved away by 2 mm from the red datum line, as shown in the middle sketch. At the bottom instead, the resulting ZigZag stitches can be seen as blue stitch points connected by a thinner blue thread which segments represent the Stitch Length.

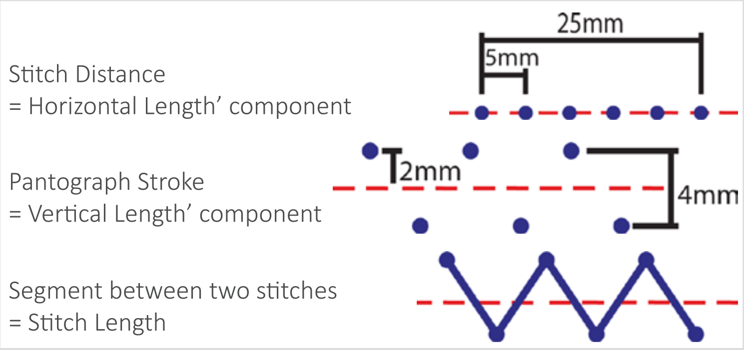


Figure 6 – Parameters to determine the ZigZag Stitches

It is straight forward to understand that larger stitch distances allow for the embroidery machine to stitch a material down faster, while short stitch distances allow for a material to be stitched down with higher quality especially around tight radii. Similarly, a wider pantograph stroke permits to lay down wider technical material, but a narrow pantograph movement allows thin wires application.

However it is extremely important to remember that the stitch length is determined by the combination of stitch distance and pantograph stroke; understanding how these combinations effects the embroidery speed, therefore finding the optimal value is fundamental in technical embroidery.

PROCESSES AND APPLICATIONS

Depending on the technical material that we are considering, the Swing foot and the Feeding System of the W-Head technique can be customized, giving life to different processes:

Tailored Fiber Placement (TFP)

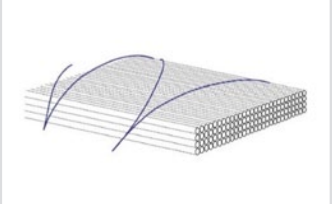


Figure 7

Tailored fiber placement allows for the stitching of highly controlled areas of fibrous roving and/or tow material. These fibers can be natural fibers as well as more modern technical materials including:

Carbon fiber, Basalt fiber, Fiberglass, Aramid fiber and Thermoplastic Commingled fibers.

TFP serves inevitably a critical role in the Composites Industry as it allows for composite preforms to be produced at near net shape, eliminating almost waste of material as there is no laminate cutting process as per standard composite manufacturing products.

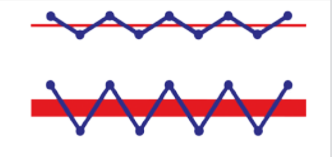


Figure 8

As carbon fiber is a particularly valuable and energy intensive resource to make, these small material savings can represent are significant efficiency on production and cost reduction.

Additional benefits of TFP allow for highly controlled fiber directions and orientations to be placed. These fibers are placed where most mechanically needed reducing the amount of fibers in noncritical loading directions.

Figure 7 represents schematically a fibrous tow (composed of thousands of filaments) material that has been stitched over and fixed to a fabric with a blue top thread. Limitless combinations of threads, fibers, and substrate materials are available.

Very fine fibers as well as very large tow could be placed using TFP; for instance, carbon fiber as fine as 2k Tex has successfully been placed with tailored fiber placement as well as thicker carbon fiber up to 48k Tex. This is possible playing and optimizing the combination of Swing Foot and Pantograph Stroke values, as shown in representative image in figure 8.

The main examples of composite parts that benefit of the advantages of TFP technology are:

- Car wheels, suspension links and hood reinforcements
- Shoe insoles and shoe reinforcements
- Protection equipment for sport applications
- Wind turbines
- Bicycles saddle, rims.

Tailored Wire Placement (TWP)

A wide variety of different wires can be used in W-Head embroidery.

Wires as small as 53 micron stainless steel wire have been successfully utilized to create W-Head designs.

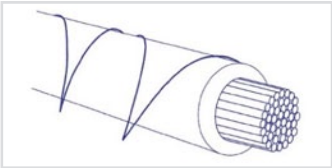


Figure 9

Thicker wires up to CAT5 cable or coated thermal heating wires have also been used to route complex functionality into highly controlled geometries. Single core or multi core wires can easily be adapted to this process.

The wires used in TWP can be uncoated or can additionally be coated with a wide variety of plastics, rubbers, elastomers, or twisted thread coverings.

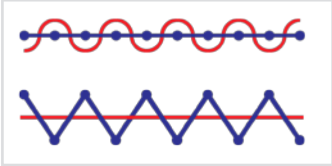


Figure 10

In Figure 10, two ways of embroidering wires are shown.

Above, the blue points indicate the stitch locations; the blue lines connecting them indicate instead the top thread of the running stitch.

In this technique, no stroke is added to the pantograph and a high Swing Foot stroke value is added to compensate and fix the wire to the fabric. This technique allows for a small amount of stretch and elasticity in the wire embroidery for specific technical applications.

At the lower drawing of figure 10, an alternative technique has been shown where no swing value is added. In this case though, a very high stroke value is added to catch and trap the red wire and hold it to the fabric substrate. This technique allows for some movability and play of the wire within the fabric.

TWP is a reliable and well-used technology in the automotive heat seating industry. The placement of resistive heating wire in tailorable locations allows for efficient heating with less wasted energy. However TWP technology is broadly used by our customers also in sectors such as wearable, medicine and industrial. The most common areas of TWP application are:

- Heating system for car seat heating and steering wheel
- Heating systems for clothing garments
- Sensors for wearable or medical applications, such as temperature, stretch, humidity and pressure.
- RFID antennas to increase range and gain of antenna

Tailored Tube Placement (TTP)

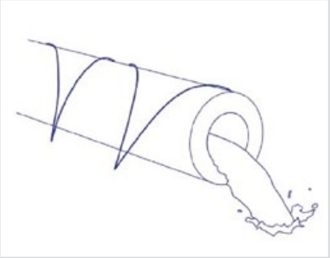


Fig 11

Another interesting and less known technique includes tailored tube placement (TTP).

TTP allows for the controlled placement of a tube to be put into a textile. These placed tubes can have desirable heating and cooling applications as well as applications requiring a channel to route other wires.

By creating channeling tube, wires can be inserted into the material in a post embroidery process opening construction possibilities. Additionally, TTP can be utilized in more esoteric pneumatic applications such as textile robotics.

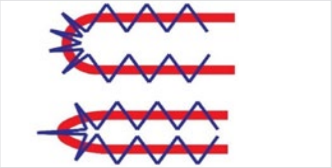


Fig 12

The primary property of tubes that is relied upon to create desirable embroidery is the flexibility and ductility of the tubing material. Softer and more flexible tubes such as silicon tubing or latex tubing have higher degrees of embroiderability then very stiff tubing made with materials such as styrene or PVC

Technical embroidery techniques exist in order to ensure that the tube is evenly embroidered and does not kink. In figure 12, the design geometry has been modified so that the radii of the tube is properly set to the material type to eliminate any chances of kinking.

The most common areas of TTP application are:

- Heating of roof structures for de-icing
- Creating a heat exchanger in the roof structure
- Integration of tubes into automotive interior as preinstalled cable harness into the roof lining
- Pumping cold fluids through garments or accessories to cool down wearer in extreme heat environments

Ribbon / Tape Embroidery

The W-Head can be modified with a ribbon foot in order to place different ribbons down onto a substrate. Ribbons can be functionalized with different electronics in order to have easy construction. These frilled ribbons can serve mechanical purposes for structural stabilization, or can create sensors like stroke sensors or movement sensors. In a similar technique to ribbon embroidery, tape embroidery allows different plastic tapes to be embroidered into a substrate so to provide areas of high thermal resistance, chemical resistance, or increased dielectric strength further increasing the functionalization of the textile at that location.

Note: for this process the Active Feeding System is not required.

Coiling

The coiling technique allows for the W head to make a full rotation around the wire with a tertiary covering material. As the W head spins and rotates, this covering material wraps around the wire protecting it from damage or giving it added technical features. Two wires can also be twisted together in this fashion creating a pair.

Note: for this process the Active Feeding System is not required.

K-HEAD TECHNIQUE

OVERVIEW AND PRINCIPLE

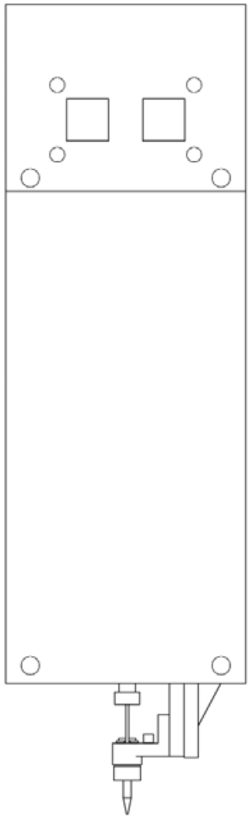
K-Head embroidery is primarily used in technical applications to add different types of electrodes or softened mechanical regions to the textile. Due to its soft hand and flexible compliances, K-Head embroidery has interesting mechanical properties especially when directly interfacing with skin. When K-Head technique is functionalized with conductive materials, this can create interesting types of textile electrodes that don't require gels or metal electrode discs. This can increase comfort to the user and allow for niche technical applications that have high movement demands such as potentially monitoring heart rate in moving subjects.

Pros:

- Thick thread allows for areas to be filled in quickly
- No rotary hook allows for the machine to have continuous operation
- Multi-materials can be fed together to create new structures/properties
- Very soft regions of fabric can be created that conform to skin

Cons:

- Cannot be used with materials like carbon fiber
- Cannot be used with tubes or thick wires
- Cannot be applied onto tubular fabrics such as round hats



PRINCIPLE

K-Head embroidery is an adaptation of chenille embroidery or moss embroidery. In this type of embroidery, a single thread is looped through the fabric by a hooked needle and brought to the surface of the fabric. Unlike traditional sewing machines, there is no rotary hook used to form a knot, the thread is head in place by frictional entanglement resulting in a soft, fluffy, and voluminous region. This technique can be thought of almost as a crochet technique where loops of thread or yarn are pulled to the top of the fabric by the hooked needle.

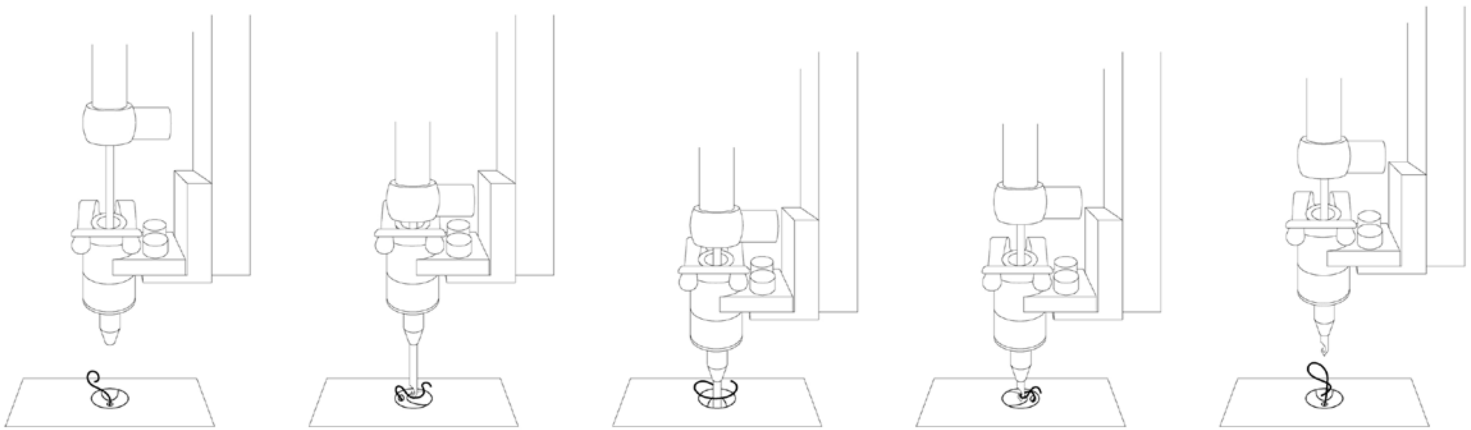


Figure 13 – shows the process of making a Chenille Stitch. This stitching process rapidly proceeds over 12 times/sec.

PROCESSES AND APPLICATIONS

K-Head embroidery allows for two main different processes: Moss and Chain Stitching.

Moss or Chenille Stitching

A hooked needle penetrates the fabric from top to bottom, grabs the thread from the bottom under the stitch plate, and pulls that thread up through the top of the fabric forming a small loop.

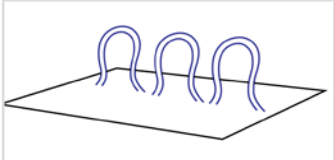


Fig 14 – Schema of moss stitching

The presser foot releases this loop at its peak allowing for a small forest of controlled mossy embroidery to form, as represented in Figure 14.

These looped threads are continuous and unbroken allowing for interesting mechanical and electrical properties. Changing settings such as timings, pressure foot heights, thread types, when the pantograph moves, and stitch density allow for a robust and highly tunable technical fabric area to be formed. Higher loops can create softer areas. Lower loops can create velvet-like areas. Many possibilities exist within this process.

Chain Stitching

Chain stitching is a similar technique to moss embroidery. However, differently than moss embroidery, small chains are made as each loop is pulled through the fabric.

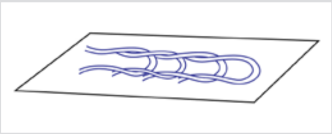


Fig 15 – Schema of chain stitching

After each loop is pulled and created, it is immediately pressed back down against the fabric by the presser foot while the pantograph is moved.This allows the loop to fall and slide open on the face of the fabric.

Another loop is then pulled from within the circle of the previous loop. This allows a concentric and continuous thread structure to form a continuous chain, as represented in Figure 15.

At the end of these chainstitch lines, we create a lockstitch to fix the last chain with a knot and prevent unraveling. These continuous single material chains can have interesting technical properties.

F-HEAD TECHNIQUE

OVERVIEW AND PRINCIPLE

F-Head embroidery has been traditionally used to embroider embellishment on finished goods such as hats, shirts, and jackets.

However, this technique has been modernized in order to incorporate new developments within machine design, technical textiles, and material science. These new techniques allow for the embroidered goods to be functionalized with the F-Head, which has the highest degree of accuracy and speed allowing increased design complexity.

This complexity and accuracy in an embroidered piece can lead to techniques such as circuit board stitching, fiducial finding, and interesting electrical connections.

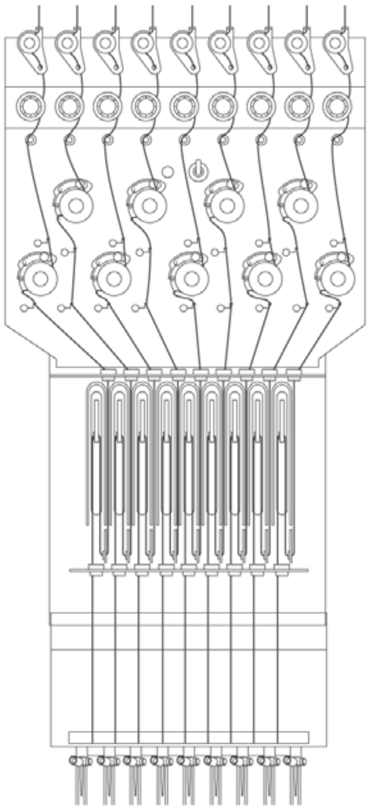
Additionally, the accuracy of the F-Head allows for electronic sequins to be easily and rapidly placed turning the embroidery machine into a textile pick and place for electronics incorporation.

Pros:

- Extremely fast stitching with very high degrees of accuracy capable of stitching through fine details like holes in circuit boards or perforated leather
- A wide variety of different attachments to augment function including LED sequin attachments, cording devices, hot air cutters, and more
- Embroiders on both unfinished flat goods and fabrics in flatbed embroidery and also finished goods with tubular embroidery

Cons:

- Being optimized to run quickly the F-Head is more limited in the amounts and types of threads that can be processed
- Requires a top thread and a bobbin thread
- Materials like fiber optics, carbon fiber, and thick wires are not possible to run in F-Head embroidery and bettered suited for other techniques



PRINCIPLE

F-Head embroidery is an extremely versatile way of creating new technical materials that rely on accuracy. F head embroidery is derived from traditional sewing and stitching techniques where a needle pierces the fabric from the top, a rotary hook catches the top thread and creates a locking knot with the bobbin thread on the bottom of the fabric. This process is mechanically controlled and as such has very high obtainable speeds. F head embroidery techniques can complete 20 stitches or more stitches per second allowing for extremely rapid stitching throughput without sacrificing quality.

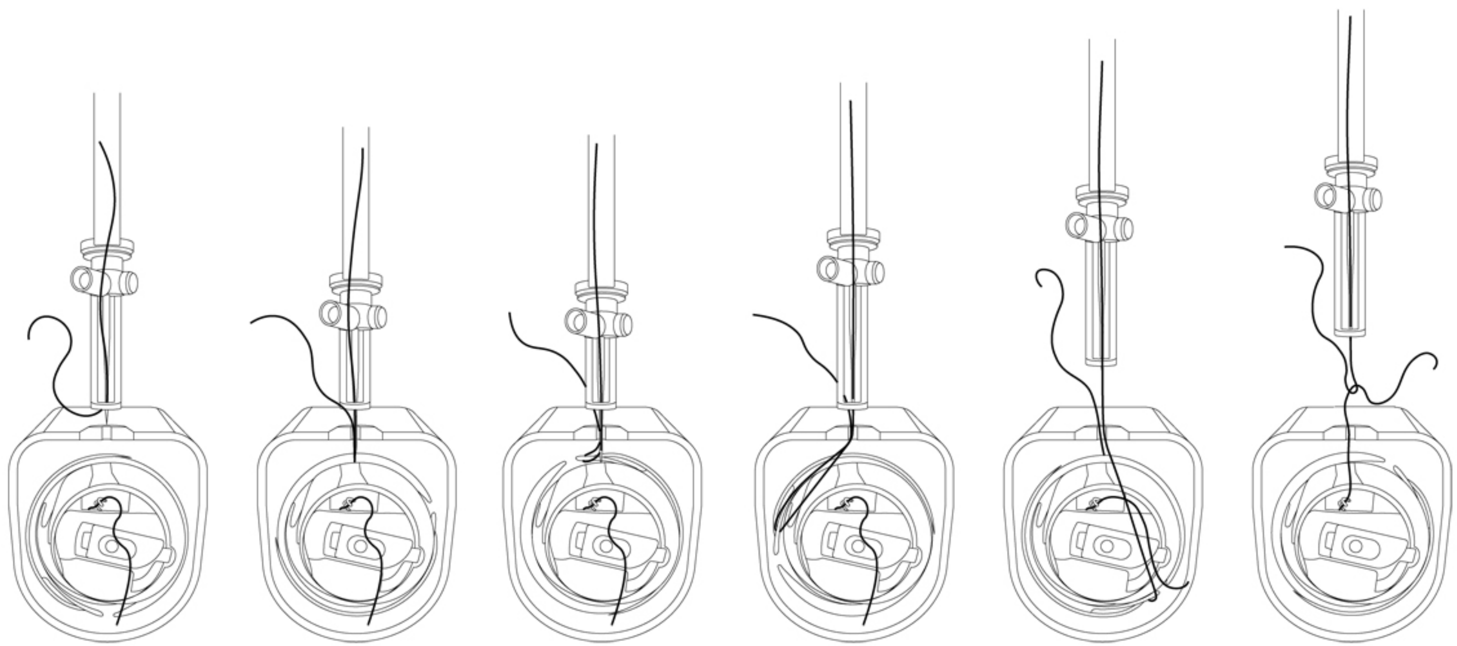


Figure 15 – from left to right, shows the process to make a stitch with F-Head technology.

PROCESSES AND APPLICATIONS

F-Head embroidery has a variety of different processes (see Table 4) that can be applied to solve technical problems for different areas of applications. However, in technical embroidery we usually refer to the combination of these processes so to create innovative Functional Fabrics; therefore referring to F-Head embroidery most commonly as E-Textile.

E-textiles, or the ability to embed electronics and their electrical properties into fabrics, allow for a new class of self-aware materials. They offer you the opportunity to confer functions upon traditional fabrics. These materials can have internal sensing capabilities as well as the ability to adapt themselves to various changing environments. In this way, they open doors to data collection that was not previously economic or even possible before. Technical embroidery offers a host of methods to create new E-textiles and to push the entire field forward. Due to embroidery's high manoeuvrability, quick adaptability to new designs, and established scalability, embroidered systems are increasingly being sought after.

The different processes and their technical use, combined into E-Textile, are reported and explained here below.

Process Type and Technical Use	Technical Material
Comfort Fill Areas	Conductive Thread, Wires
Running Stitches	
Satin Stitches	
F-Head ATTACHMENTS	LEDs, RFID

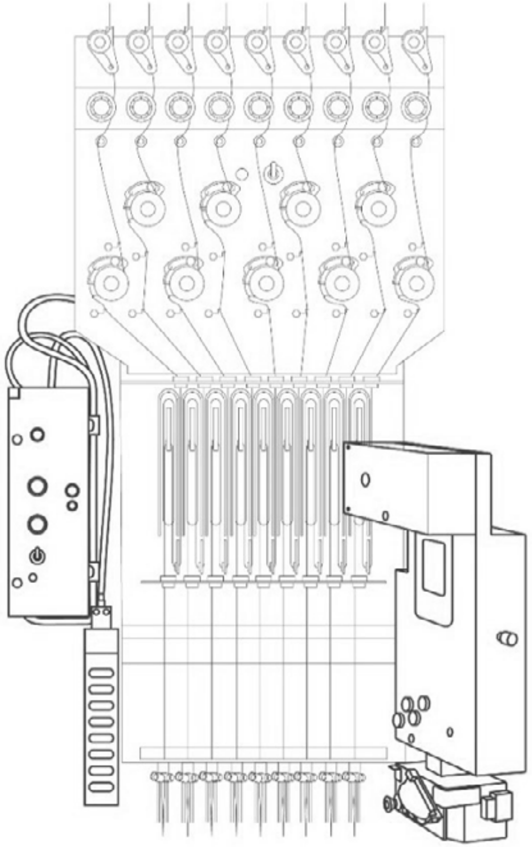
Table 4 – Chart comparing different processes for F-Head

Attachments
- Embroidering Led, RFID and Full Boards Mechanically

Attachments are another method of increasing technical applications with F-Head embroidery and are unique to F-Head embroidery. Attachments allow for different mechanical and technological advancements to be plugged into the head.

These advancements can be devices such as:

- **Cording Device**- Allows for textile cords, thermoplastic cords, and some wires to be stitched
- **Beading Device**- Allows for small glass and plastic beads to be stitched into the fabric
- **Hot Air Cutter (HAC)** - Allows for fabric to be cut in controlled locations or melted selectively
- **Sequin Device** - Allows for small plastic sequins to be placed onto the surface of the fabric , for example RFID-chips
- **LED Sequin Device**- Allows for small electronic circuit boards to be placed on carrier sequins



Embroidering LED and RFID Sequins into a garment during its creation – via FSD - has significant advantages over other e-textile processes as it does not require post-process soldering or additional conductive epoxies. In this way, the embroidery machine serves as a hybrid between traditional pick and place machines to select a component sequin off of a reel and a sequin machine as it stitches the component into the fabric's structure.

Nevertheless, stitching traditional circuit boards immediately into the structure of the textile reduces mechanical strains on the connectors while allowing the control and processing electronics to be physically closer to their supporting electronics. This can have a range of benefits such as increased signal to noise ratio, decreased mechanical fatigue based failure, and reduced need for additional connectors.

For electronics packaging, fabrics offer a new host of materials that not only house the electronics, but also provide functional advantages over traditional materials and processes.

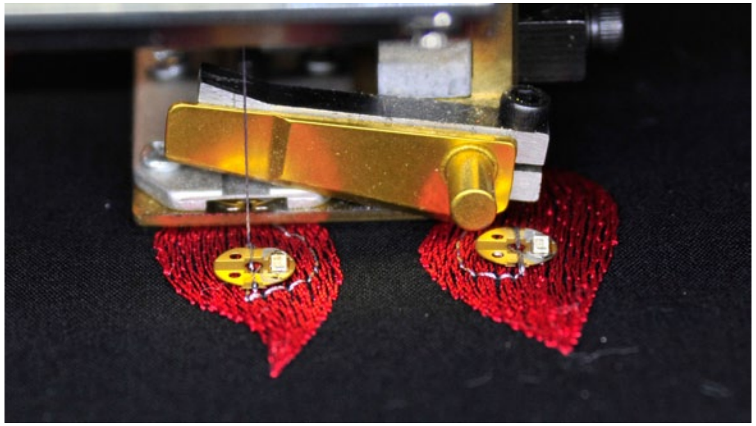


Fig 16 - Functional Sequin for automated Placement of LEDs

Fig 17- Functional Sequin for automated Placement of RFIDs

TECHNICAL EMBROIDERY TECHNIQUES

Comfort Fills - Embroidering Touch Sensors

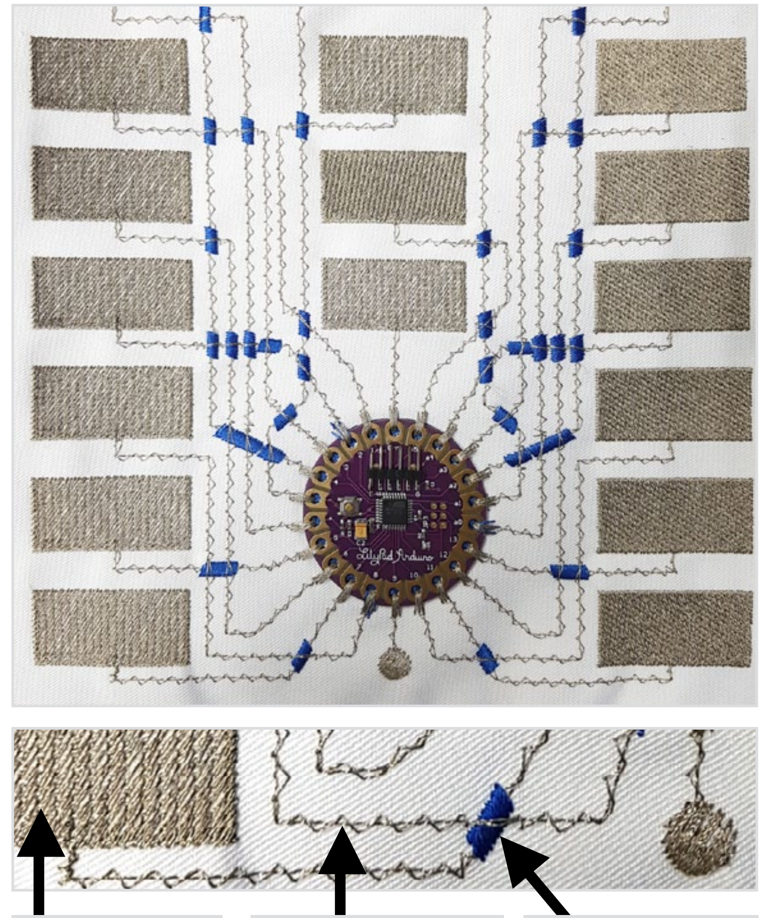
Creates regions on the fabric with large amounts of flat, embroidered thread. The large and flat areas provided by comfort fill can create interesting technical outputs such as conductive touch buttons and sliders. In these buttons large comfort fill areas can be created in order to create different types of tap swipe and touch sensors. This technique can allow for any fabric to be turned into a touch sensitive system opening the doors a wide range of interactive fabrics.

Satin Stitches - Covering Electrical Connections

Satin stitches are like covering stitches in embroidery. For technical applications, a satin cover over an insulated wire can create interesting electromagnetic shielding properties further increasing the signal transmission through the wire. Satin stitches can also be used on the F-Head to embroider thicker cables such as USB cables. Stiff wires such, as s coat hanger, can be bent and placed on the surface of the fabric and embroidered down with satin stitches. Satin stitches allow for a wide variety of different coverings and textile integrations.

Running Stitches - Embroidering Connections to Boards

Another advantage of technical embroidery in E-textiles manufacturing is the ability to embroider electrical connects automatically to the host board using various conductive threads. These connection paths are created via single line running stitches. This process allows for the quick connection of potentially hundreds of electrical connections from a board to their fabric-hosted sensors. By registering the board during its embroidery to the host fabric, electrical connection points on the board are also registered for stitching. This can allow for a single stitched board to merge data from many sensor types into a single output. Furthermore, by changing properties such as stitch distance, swing, and thread tension, the different electrical conductivities can be achieved.



Comfort Fill Areas – Embroidering Touch Sensors

Running Stitches – Embroidering Connections to Boards

Satin Stitches – Covering Electrical Connections

ZSK AUTOMATION OPTIONS

ZSK prides itself on having a wide range of highly automated and customizable equipment.

The high level of automation allows customers to quickly, and cheaply, fulfill their production needs within tight labor markets. Different automation modules and options can be selectively added by the customer in order to create a more seamless and easier manufacturing experience that is customized to the desired product line. Some of the most popular options are:

ROLL2ROLL SYSTEMS

Fig 18 – Multihead ROLL2ROLL

ROLL2ROLL systems are some of the most direct paths towards automation, widely used in Tailored Wired Placement applications.

In ROLL2ROLL manufacturing, a roll of fabric is loaded onto the back of the embroidery machine. This fabric is then pulled forward through to the front of the machine onto a motorized roller.

In this way, the embroidery machine can embroider the design, finish the design, cut the threads and wires and then automatically pull fresh material into the frame.

This process allows for the machine to repeatedly produce the same design continuously. Once the role of fabric has been embroidered with the pattern, wires, carbon, or other material, the finished roll of material can be removed from the machine, sliced, cut, or otherwise processed. ROLL2ROLL systems can be used for small batch manufacturing, where only a few samples are required per day, to full production lines where many thousands of samples are needed. The ROLL2ROLL systems can be movable, following the movement of the pantograph, or fix.

PNEUMATIC CLAMPING FRAME

Fig 19 – Pneumatic Clamping Fr.

The pneumatic clamping frames are utilized often with the ROLL2ROLL system. These frames automatically open allowing for fresh fabric to be inserted, and then clamp on the fabric applying an even tension across its face.

This pneumatic and automated clamping reduces the need to have an operator manually clamping and changing fabric. It also allows for a high degree of repeatability every time the ROLL2ROLL system is initiated.

POSITIONING ENCODERS

Positioning encoders can be attached to each of the stepper motors allowing for a finer degree of motion control. This motion control has wide technical applications, especially when stitching into fine details or fiducials like mounting holes in circuit boards.

Encoders also have importance in the automation of embroidery as the embroidery machine can store and save its previous position.

If the machine is shut down and the frame is accidentally moved, the encoders can track this movement and can adjust the frame's position immediately when the machine is turned back on.

Fig 20 – OPS Camera System

This allows the embroidery to continue at the exact location of the last stitch further reducing any potential chance that a complicated design might be impacted.

Encoders also allow for a high level of positioning required to use the Optical Positioning System (OPS).

ROLL2BASKET SYSTEMS

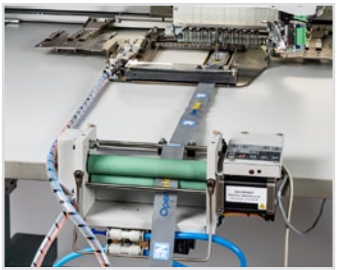


Fig 21 – ROLL2BASKET System

ROLL2BASKET systems are similar to ROLL2ROLL systems, however, are designed for a smaller machine with a different use case.

ROLL2BASKET systems generally are used in the production of embroidered label making. In label making, a strip of labels or ribbon is fed into the back of the machine and embroidered.

As the label is completed the label is pulled through the machine to a storage roller on the front. In this way, a new location for the next label is created. A small basket of finished labels is produced.

Generally, this technique has a limitation of width of from 1-15 centimeters of fabric. In this way, ROLL2BASKET allows for the automation of small designs.

AUTOMATIC BOBBIN CHANGER

Fig 22 – Auto. Bobbin Changer

The automatic bobbin changer is a popular automation upgrade as well.

This upgrade allows for the technical embroidery machine to remove its own bobbins out of the rotary hook with a small robotic arm, and replace them with filled bobbins.

New bobbins are mounted on a carrier magazine in sets of eight. This magazine is designed to run for approximately 8 hours of continuous and automated use before needing to be replaced. In this way, each manufacturing shift puts in a fresh magazine into the machine when the shift starts, and does not have to worry about bobbin changes until the end of their shift.

Additionally, newer versions of the bobbin changer system allow for top threads and bottom threads to be selectively matched. Alternative combinations of upper and lower thread can be additionally and automatically matched allowing for electrical circuitry to flow through both sides of the fabric selectively. This opens the door for a wide variety of different techniques when designing flexible circuit boards.

HOT AIR CUTTER

Fig 23 – Hot Air Cutting Device

The Hot Air Cutter, or HAC, is not notoriously known as being an automation method of embroidery, however it does have some interesting timesaving arguments that could be made.

The HAC allows for the F-Head embroidery machine to cut out selected areas of embroidery during the embroidery process.

Utilizing this in a smaller production piece can allow for parts to be cut out automatically out of the fabric on the table. If used correctly, this decreases the need for a manual cutting process later. As the material is already in the frame, and the location of that frame is already known within the system, no added time is required to setup for this type of cutting.

HOW TO GET STARTED

At the ZSK Research and Training Center in Seattle, or at the ZSK STICKMASCHINEN Headquarters in Germany, our engineers can support you through the development of your product or idea.

ZSK offers extensive trainings in the newest materials, techniques, and attachments that allow for competitive advantage when using ZSK equipment. Our development and application engineers are available for your questions, comments, and training needs.

ZSK regularly works with their customers to support them in their usage of technical embroidery for their individualized business models.

There are many ways to get started exploring the technical possibilities of ZSK equipment in your designs and production. This section highlights the process most commonly used to get started with using ZSK technical embroidery equipment.

INTRODUCTIONS AND CONSULTATION CALL

All new developments must start somewhere; chat with us! Shoot us an email that you are interested in doing some explorations of how technical embroidery can help support your business model. We'll get back to you and setup a time to video chat about the possibilities. We have customized webinars, trainings, and brainstormers to see if technical embroidery is right for your business model. If you'd like to reach out with technical embroidery questions, contact us at the email below.

ZSK Research and Training Center

990 Industry Drive

Seattle, WA 98188, USA

Email: T@zsk.com

PROOF OF FEASIBILITY STUDY

After we chat about your specific manufacturing challenges, the next step in the process is to complete an early proof of feasibility study. If we feel that we can add value to your product line, in this early study, you can ship us materials and we can begin to evaluate if they are possible to embroider using one of our many techniques.

Utilizing our facilities to evaluate materials and find settings allows companies to have a jumpstart with testing out new ideas and concept feasibility.

WHAT WOULD WE NEED FOR YOUR SAMPLES?

Materials:

We do recommend that you send the fabric you'd like to use as well as any technical materials.

We'll keep your materials stored safely on a storage shelf for you until you're ready to begin development. We have all the rest needed embroidery materials in stock such as thread, needles, and more.

However if there is a custom thread that you would like to try, or custom colors, please send that over too.

File Type:

Our software imports Adobe Illustrator files as well as .DXF files natively, easing file transfer.

Sampling Frame Sizes:

We have the full range of technical embroidery sampling machines, attachments, and frames in the ZSK Research and Training Center.

New technologies are regularly added as they are developed in Germany. To get started with your design, select the standard frame that best fits your size from the list currently available.

Frame sizes below are always available as well as larger and smaller frames if requested. Below are some of the recommended sizes of fabric and embroidery. Larger size frames are available for sampling if needed at ZSK STICKMASCHINEN in Germany.

	W-Head	K-Head	F-Head
Large Frame			
Embroidery Field:	1.020 mm x 620 mm / 40,1” x 24,4”	1.050mm X 680 mm / 41,3” x 26,7”	1.000 mm X 680 mm / 39,3” x 26,7”
Recommended Fabric Size:	1.500 mm x 900 mm / 59” x 35,4”	1.500 mm x 900 mm / 59” x 35,4”	1.500 mm x 900 mm / 59” x 35,4”
Medium Frame			
Embroidery Field:	550 mm x 550 mm / 21,7” x 21,7”	500 mm x 500 mm / 19,7” x 19,7”	550 mm x 550 mm / 21,7” x 21,7”
Recommended Fabric Size:	940 mm x 940 mm / 37” x 37”	800 mm x 800 mm / 31,5” x 31,5”	940 mm x 940 mm / 37” x 37”
Small Frame			
Embroidery Field:			250 mm x 250 mm / 9,8” x 9,8”
Recommended Fabric Size:			400 mm x 400 mm / 15,7” x 15,7” *
Very Small Frame			
Embroidery Field:			140 mm x 140 mm / 5,5” x 5,5”
Recommended Fabric Size:			225 mm x 225 mm / 8,9” x 8,9” *

*Magnetic frame

Post Sampling Discussion

Once you have been able to sample your prototypes and tests within the ZSK Research and Training Center, we can arrange to sit together in person or have a web call to discuss the techniques implemented as well as any challenges that were observed in the sampling process.

A full sample write up sheet is available upon request detailing the technical findings of the sampling project. This documentation can help speed future development.

In House Development

The ZSK Research and Training Center can then continue to sample directly with you remotely or in person.

Many customers chose to begin to purchase sampling machines of their own at this point to continue the development quickly in house. This can allow for IP generation, complex optimizations, or other uses of the equipment.

Production

Following the completion of your sample development, we can arrange another call to work directly with you to create the perfect production machine for you to produce in house.

Alternatively, we can find you a manufacturing partner within the ZSK Technical Embroidery Ecosystem.

THE ZSK ADVANTAGE

At ZSK's headquarters in Germany, all embroidery machines are designed, programmed, and assembled. This closed loop manufacturing system allows for high quality control and reliability that our customers have come to rely upon.

ZSK STICKMASCHINEN is an established embroidery company existing for over 50 years. This long history has allowed countless developers to experiment and explore the usage of embroidery for their creative design ideas.

The ZSK ecosystem consists of a wide range of different designers, manufacturers, and material suppliers who worked together in order to solve problems with in technical embroidery.

ZSK STICKMASCHINEN develops and constantly invest significant time in modernizing embroidery equipment. New ideas, concepts, and equipment attachments are developed based on internal sampling and R&D as well as based on customer requests and feedback. This allows for a high degree of customization as well as a quickly developing and evolving embroidery ecosystem that stays far ahead of its competition.

ABOUT

ZSK Technical Embroidery Systems is a division of ZSK Stickmaschinen GmbH, the leading German manufacturer of industrial embroidery machines „Made in Germany“.

ZSK STICKMASCHINEN is the leading brand for industrial embroidery machines and technical embroidery systems MADE IN GERMANY.

The application of unusual material like fibers, wire, tubes or even LED to ZSK STICKMASCHINEN's approved embroidery technology opened a wide scope of products, applications and methodical procedures.

Today companies from diverse branches develop and manufacture functional products, fashion, advanced composites or wearables with the embroidery solutions of ZSK TECHNICAL EMBROIDERY SYSTEMS.

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For Training and Sampling Visit
https://training.zskusa.com/