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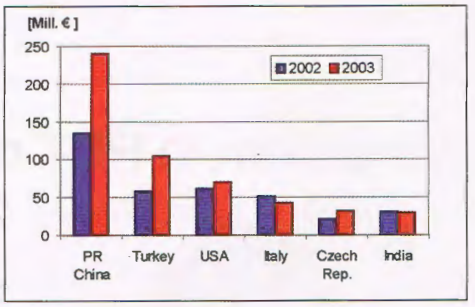

In the first quarter of 2003 German textile machinery exports increased by 19 % with main markets in China, Turkey, USA, and Italy (see page 182 of this issue).

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3D-products for fashion and technical textile applications from flat knitting machines

M. Legner, H. Stoll GmbH & Co., Reutlingen/Germany

Against the trend, most of the other textile machinery sectors have experienced, the demand for modern flat knitting machines has grown steadily over the past years and kept an astonishing, relatively high level of machines being sold per year. There are both economic and technical factors to be found in order to explain this phenomenon:

Economic reasons:

- high demand for knit goods supported by knit-friendly fashion trends
- immense demand for modern machines in Far East to replace large numbers of hand knitting machines
- concentration of knitwear production, primarily in Far East, such as China, Korea and India as well as in Turkey and some Eastern European and Arabian countries with the effect to build up new and modern production units
- global supply of the world markets out of the aforementioned regions, however, also increasing domestic demands in the delivery countries due to a growing prosperity of the home population
- fast response of the traditional, trend setting knit wear production countries towards the use of new techniques to incorporate new design ideas and production concepts.

Technical factors:

- increased versatility of modern machines regarding the diversity of patterning designs
- enhanced flexibility of the machine technology towards gauge conversion and multi- or flexible gauge applications
- facilitated programming and styling of knitted articles by means of modern CAD/CAM systems, supported by mostly automated programming tools
- steadily improved technology to produce integral knit garments to revolutionize the way of garment manufacturing and to strip down the production process.

However, even if the success of the flat knitting technology has been proven as steady, there are more and more indications, that it might just be a question of time, that the era of this technology will be terminated not only due to a market saturation, which will occur somewhere along the way, but also due to new knitting technologies, which do not base on the flat knitting principle.

Lecture held at the World Congress Knitting for the 21st Century in Manchester/UK, October 7/8, 2002

Some people say that there is a growing demand among the manufacturers of knit wear products following the pressure of the powerful purchasing organizations to produce knitted textiles, respectively garments in a faster and finally cheaper way. This demand goes hand in hand with an expectation that there will be a technology available, which produces at a generally good quality level and which requires less experienced personnel to program and handle the machines.

The arguments to be found in favor for this thesis are the continued demand for cotton machines, as well as the enlarged and specifically explored use of circular knitting machines for the production of seamless knit garments, where first attempts to produce coarser gauge outerwear articles have been started as well.

In addition, there are tendencies to produce exceptionally designed fully fashion and seamless garments on tricot warp knitting machines.

These new technologies might represent possible alternatives for the manufacturing for coarser knitted articles in the future in order to achieve the aforementioned expectations, particularly as far as mass production is concerned.

Producers of flat knitting machines follow these development trends closely and are able to respond to it by showing new sides of the flat knitting technology. The way the vast patterning and design possibilities, in conjunction with the capabilities of producing 3D products, are applied to generate new designs and concepts for the general fashion industry as well as for alternative application areas is looked at more closely here.

Scope and versatility of 3D applications for knitted fabrics

In comparison to other builders of textile machinery producing fabrics, the flat knitting machine manufacturer is caught in something of a conflict situation. On the one hand, knitting metered goods using flat knitting machines is a relatively slow process. On the other hand these machines offer a scope for design options which cannot be matched in terms of implementation simplicity as regards their styling and design versatility. Thereby fabric characteristics can easily be influenced as well.

A flat knitting machine comprises two or more needle beds, which are run over by a carriage bearing knitting systems. With every stroke of the carriage, stitches are generated or other knitting functions performed. Each stitch is created by a needle, which is selected by electronic means following a program laying down the knitting sequence of a pattern.

To knit, for example, a spherical shell the needle on the left begins with only a few stitches, increasing the number of stitches towards the center needles and then decreasing their number again by the time needles, positioned further to the right, are reached. When this process is continued regularly with once activating the needle operation and once disabling its function, a spherical shell is produced, presuming, that every needle knits precisely the number of stitches corresponding to its section of the periphery, considering the fact, that every stitch theoretically represents an object of a constant parametrical size.

Consequently such a spherical shell is not made by a particular 3D forming device, but is generated by a 3D knitting program.

Spherical shaped objects are not the only 3D realizations possible with flat knitting machines. Within the framework of three-dimensional styling options, the following possibilities can be implemented by using all techniques of fabric forming of flat knitting machines. All these possibilities can normally be produced and even jointly applied on the same machine:

- *Voluminous knit structures*

The double bed set up is used to create two-faced knit structures which have a higher volume compared to single-face fabrics. This can lead to a considerable fabric thickness of approx. 1 cm, when applied on a machine of gauge E 3. Depending on the knitted construction, the fabric thickness can be further increased and strengthened by tuck stitch insertions.

By means of needle selection, voluminous stitch allocations can be optionally positioned in a regular knit fabric for optical design affects or cushioning purposes.

- *Spacer structures*

With this type of knitted fabric, two or more single-faced fabric sides positioned opposite to each other are joined together by stitch or tuck links. The generated volume as well as the fabric characteristics depend on the construction and the selection of the pile material by causing stuffing or springing effects.

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- *Web or Interface structures*

Here, the three-dimensional formation of the fabric is created by a knitted bridge or crosslink connection of two or more fabric layers positioned opposite each other.

By knitting the fabric layers with every second needle (1x1 needle selection), the remaining empty needles can be used for formation of the connecting webs. In this process, the length of the webs and thus also the height of the overall fabric can be optionally selected and also varied in terms of the appearance of the surface evenness. The orientation of the connecting webs can also be modified by influencing the rhythm of the stitch formation of the individual layers. The cavities created by this process could be subsequently filled, for example, by inserting reinforcing materials, pipes, cables or others.

- *Tubular structures*

With the aid of the double needle beds, tubular structures of optional diameters can be produced on flat knitting machines. Besides the production of tubes as such, tubular extensions and attachments can be implemented in a knit fabric in various manners. Knitted tubes can be placed along the selvedge or in any location of the fabric face.

- *Spherical 3D structures*

In contrast to volumetrically engineered 3D fabric forms as described, the so-called wedge technique permits the shaping of a knitted fabric in a three-dimensional, spatial way. The technique of implementing spherical curved fabrics as described before can also be applied in segments of other, more complex knit applications, such as in the heel area of stockings or contoured seat covers. During the knitting process, individual needles or groups of needles are allotted fewer stitches than others. The stitch allocation per needle can be performed along geometric fabric lines or homogeneously distributed over the surface of the knit object. This knitting method, known as the wedging technique, forms less fabric in certain sectors and more in others. This causes the fabric to take on a three-dimensional shape. This technique can be additionally supported by different stitch sizes in individual sections. Different materials and narrowing or widening processes can also be applied. Warp and weft threads can be integrated, as can floats and tuck stitches. Equally, functions such as stitch splitting and transfer can additionally extend the repertoire.

The variable use of the wedge technique opens up new possibilities for fabric styling and product customization. The immense potential of 2D and 3D shaping, which is inherent to the styling techniques of modern flat knitting machines however needs to be seen in the option to freely combine all the above mentioned techniques in - if required - one knitted product. This permits an enormous degree of design variability, which can be utilized in the development of new ways of producing and designing knit garments as well as in generating new fields of application for knit products.

Use of 3D knitting applications in fashion

- *From yarded goods - cut to size - to fully fashioned fabrics*

In former years, the standard method of production was to knit a length of fabric, cut out the required panels and make them up into a finished article.

Using modern electronic control systems, it is now possible to simply program a flat knitting machine in a way, that the individual needles perform precise operations to conduct intended functions. This capability has led to the success of "fully fashion" manufacturing of knitted articles. By widening and narrowing the fabric, parts are fashioned on the machine. Panels, fashioned in this way for the body and sleeve components are sewn together to create the end product. The benefits - besides enhanced optical appearance - are material savings and exact, reproducible garment sizes.

In the fashion sector, when producing conventional outerwear garments, 3D applications have been restricted largely to structural design features. These refer to familiar relief-type effects produced by interchanging plain and purl stitches, missed stitch applications and pattern formations such as cable and Aran designs.

Knit-in pockets can also be viewed at as 3D applications. Additionally, varied accumulation of stitches in the form of "wave motifs" can be termed as 3D fabric appearance.

- *From fully fashion to ready-to-wear articles*

With the introduction of the knit and wear technology by H. Stoll GmbH & Co., Reutlingen/Germany and the way to produce complete garments on flat knitting machines, an actual 3D manufacturing process is commonly applied on flat knitting machines.

This technology is based on a technique, where - when producing a pullover - three fashioned tubular parts are joined to form a finished, ready-to-wear article through knitting, transfer and linking processes.

The way, ready-to-wear garments can be designed, hardly finds any restrictions any longer, since besides structural effects, simple jacquard and Intarsia patterns, typical knitwear formations for the shoulder, neck and collar area can be applied. Thus shoulder formations such as inserted sleeves, Raglan and Saddle shoulders can be standardly incorporated in new, very fashionable variations.

The same applies to the styling of necklines and collars, which also allow common designs, however open up the creativity for new, ready made solutions as well.

The underlying knitting principle applied in the production of knit and wear articles is that of knitting with halved gauge, in which knitting takes place only on every second needle. As a result of the 1x1 needle selection, free needles remain in both needle beds which can be used for any optional transfer processes required for structural effects or narrowing operations.

Within an increasing acceptance of so-called "seamless garments", today, machines have been majorly asked for in a gauge range from E3 to E12 as concerns the appearance of the finished outerwear garments. As regards the needle bed configuration these machines are capable of producing finer gauges but are fitted with needles with a larger needle hook to allow a coarser textile look, when the knitting process is performed by every second needle.

Depending on the required knit fabric design and by the possible use of machines with additional needle or transfer beds, such as the Stoll CMS 330 TC-4 and TC-R, complete outerwear garments are also produced in finer gauges.

Looking at technical restrictions of seamless circular knitting machines to implement the perfect shape, this complete garment technology of flat knitting machines might open up their use for new or former fashion areas, which have not been of particular interest to most of the flat knitting machine manufacturers in the past.

Alongside the advantages offered by this production technology to integrate knitting and making-up in one process, this knitting technique also allows new approaches in the design and styling of fashion articles and other applications. The restrictions posed by the making-up process, which also apply to regular fully fashion production, are no longer binding when using the knit and wear technique. This manufacturing process permits new paths to be explored in the production of different fits which were not possible or are only possible by using

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highly complex conventional manufacturing methods. Thus contemporary fashion trends like tight fits can ideally be supported accentuating particular body curves and lines.

- *Benefits of the knit and wear manufacturing*

Even if - depending on the actual design - the summarized knitting time for the individual components of a sweater might be less than the manufacturing of a complete sweater, the overall production time, needed to sew and finish the product, generally takes much longer. Compared to the manufacturing period required to produce, for example, a complete woman's fully fashion sweater, time savings of about 35% can be reached. This is not very surprising, considering, that steps like cutting, if still required, checking and pressing of the individual parts become obsolete. Finally linking and sewing operations do not apply either.

Depending on the production organization further stages like a build up of garment components, handling and shipping of the individual parts to the making-up locations and all relevant organizational and control efforts around these stages are not required either.

The production of complete garments is the optimal process regarding yarn consumption, since there virtually is no waste generated due to the missing cutting and sewing operations. All yarn is supposed to run into the sweater. The particular knitting process also allows the continuous use of yarn cones and facilitates and optimizes the actual yarn processing. The volume of the yarn orders can be adapted and does not need to foresee a comprehensive excess charge.

An economic evaluation of the aforementioned points indicates that due to shortened lead time the cash flow is positively activated due to an overall reduction in idle times. The streamlined process resulting in the knitting being the major production part reduces the number of personnel being involved in the manufacturing and the production control.

Further positive cost reductions are achieved by the optimized yarn consumption, minimized storage and logistic costs as well as by less expenditure for waste disposal. The decreased number of production and handling steps reduces the risk of defects and damages. As a consequence of the single piece production method, the product quality can be seen as more constant and homogenous. This helps avoiding the damage and loss caused by defective parts.

Besides its general economic advantages the Stoll - knit and wear manufacturing method makes the whole knitwear production more compact and faster. The knitwear producer controls a more reliable and simpler production process, which will allow him to accept orders more flexibly. Thus he can respond to short termed orders more easily than with any traditional production operation.

- *Supplements to the Stoll - knit and wear technology*

1. Multi - layer fabric applications
(Stoll - applications)

Both in the traditional and in the seamless production method the use of every second or even higher numbered needle permits the production of multiplied textile structures. This ability can be used either to create certain design effects or to implement specific pattern or functional applications. This way, it is possible to enhance knit fabric designs and to manufacture simple integrated pockets and structural designs on seamless garments. The same technology can be applied at conventionally fabricated knitwear to generate interesting multi - layer fabric appearances and to integrate finished collar oversteps, button tapes and complex pockets with structure effects and flaps by knitting independent fabric layers which are linked along specific lines.

2. Multi - gauge applications
(Stoll - multi gauges)

The possibility to freely apply the needle selection on modern flat knitting machines according to the knitting pattern and operation demand allows to select adjacent needles subsequently or to select needles deliberately following a particular sequence, i.e. every second, third needle etc.

On machines, similarly equipped like the Stoll CMS knit and wear machines, this feature is particularly used to combine fabric structures of different fineness. The larger hook of the fine gauge needles permits to use coarser yarn qualities and follows the idea applied for the complete garment manufacturing by working with every second needle and as such producing fabric structures of coarser appearance.

The yarn feed technique bases on the Intarsia principle, which allows the creation and free combination of various fields of different fabric fineness.

Thus particular pattern and Intarsia designs are possible, enhancing the quality of the knit fabric appearance in a way of imitating elaborately made up knits and enriching the scope of patterning possibilities.

The technique can also be applied during the making of complete garments opening up another field of design options for three dimensionally styled knit products.

Future and alternative 3D-knitting applications

- *Underwear and foundation garments*

In earlier times, stockings, leggings and underwear garments were traditionally produced on flat knitting machines, mostly run by hand. Nowadays by exploiting the experience gained from the Stoll - knit and wear technology and the availability of machines of fine gauges, i.e. E 18 and E 20 or with additional needle beds these garment sectors might gain in importance again for the flat knitting technology due to the new concept of ready-to-wear production combined with the above described patterning options.

In the clothing sector, the fine gauged machine range can open markets for articles worn next to the skin.

Even, if we take the impressive achievements in the development and implementation of seamless garments of the circular knitting technology into account, there is still interest in improving the actual shaping performance and the capability to get complete garments off the machine without further making up works.

If we contemplate, for example, the complex making-up involved in the production of leg wear articles, the elimination of the following work stages by an integral knitted process is possible:

- sewing together the two leg halves and adding an elastic waistband
- cutting out and sewing in the gusset insert
- closing the ends of the toes
- producing a uniform fabric quality, without seams.

There are possibilities to generate various waistband solutions added to a completely finished hose with integrally knitted in gusset section and toes regularly linked on the machine.

Thanks to a tension-controlled yarn feeding and adjustable stitch densities, the processing of elastic yarns represents no problem and permits the manufacture of a homogenous stitch quality.

The field of application ranges from a coarse-knit pantyhose and leggings in staple fiber qualities and - if required - with structured patterning in the customary gauge segment up to fine products in gauge E 18 or E 20 in an elastic multifilament quality.

In a similar way to the above described production optimization the use of the knit and wear technique might also be evaluated for other areas in the sports- and home wear or lingerie sector, partic-

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ularly, when highly labor intense work stages are involved.
Narrowing and widening processes permit the styling of contours and shapes of knitted tops and brassiere types of garments. The wedge technique can support the 3D shaping of cups. Further knit applications and structures might be applied to integrate technical details to enhance the performance and quality of the knit product.

- *Functional and medical garments*

The field of knitted compression textiles with weft or tuck inlaid pressure generating elastic yarns, covers a wide spectrum, starting with the manufacture of various forms of sport and support braces for orthopedic problems, through to custom-made compression garments for treating disorders of vein and lymph vessels as well as of wounds after burns and plastic surgery.
Flat knitted stockings are preferably used wherever high compression values are called for and the strength of the material structure needs to exert a certain supporting effect. The perfect and adaptable fit of the fully-fashioned knitted garments still raises the quality and effectiveness of these articles above most of its competitive products.
The possibility of reliably securing an elastic weft or tuck thread into a tubularly knitted formation allows the flat knitting method to combine the above-described capability of producing articles as ready to wear with the characteristics of a classical compression article. The scope for fashioning is not restricted and even allows producing complex and customized seamless gloves. The products demonstrate a good compressive effect and can be manufactured within an economically viable period on the machine. The aesthetic appearance of the products has improved by elimination of the seams, and this has been very positively received by affected patients.
If this production method is able to assert itself in today's largely automated knitwear manufacture of custom - made compression articles, we may assume that other compression products as aforementioned will be produced in the same way.

- *Knitted upholstery fabrics*

Emerging from particular specifications of car and furniture manufacturers knitted upholstery fabric variations have been developed which profit from the fashioning and shaping flexibility offered by the flat knitting technology.
Depending on the actual shape implementation and the required fastening solution, upholstering can actually take place without the need for any particular preparation and making-up process.

Fig. 1 Knnitted spacer structure in coarse gauge, made of glass fiber yarn

Fig. 2 Knitted web or interface structure of a glass fiber/p-aramid blend

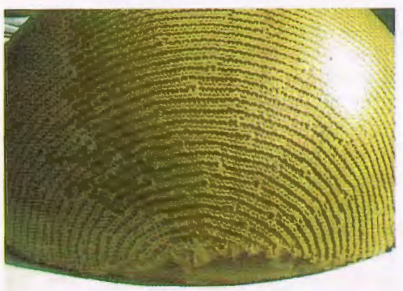

Fig. 3
Spherical shaped, knitted helmet reinforcement inlay, made of glass fiber/p-aramid blend

Particularly for automotive use possible product implementations range from the use of fully fashion knitted inserts and front panels integrated into the complete seat covers by sewing through to three-dimensionally shaped fabrics which follow the progression of the seat contours and thus cover the whole cushion surface.
Following the selected design other upholstered areas of the car interior, i.e. arm- and headrests, side panels or dashboard sections can be covered in the same manner.
A double jersey fabric version permits a wide scope and combination of jacquard and structural pattern variations. Simpler pattern forms such as plain fabrics, decorated by stripes, Intarsia and structured patterns can also be implemented by three dimensionally knitted single jersey fabrics, possibly resulting in knitted to fit slip cover bags. The enhanced elasticity of knitted fabric ensures extremely good draping and covering properties.
Besides the mostly described fashion or fashion related 3D knit applications, the production of knitted-to-use upholstery fabrics opens up a total new scope of possibilities challenging not only the textile world but also the design departments of the relevant seating industries.

- *Knitted spacer fabrics*

The potential offered by three-dimensionally knitted fabrics in form of spacer textiles is still at an early stage of its development. In principle, the possibilities offered here are being met with high interest and compared to other existing production possibilities. Major benefits offered by knitted "spacer" fabrics are beside their perfect symmetrical structure the fully fashioning capability of the fabric, which permits the fabric selvedges to be neatly finished off as well as the arbitrary integration and placement of such structures in any knitted fabric.
The scope of use for these types of knitted textiles ranges:

- as upholstery elements for seats and orthopedic applications
- as dense fabrics used for protective applications
- as open-knit fabrics with large material surfaces for use in the catalytic converters
- as spacers in light-weight constructions.

The materials used can vary and are applied in each case depending on requirements. Both special high-bulk yarns, monofilaments and metal wires can be used as pile material generating either dense and compact or flexible fabric characteristics.

Outlook

The design and application fields presented within the scope of this paper are not complete and can just indicate the potential for uses of this knitting technology. It should not be forgotten, that all the knitting possibilities mentioned here can also be combined with each other using a wide variety of either common or exceptional materials in all known construction variants. Textiles used in automotive engineering and other means of transport, in the technical and industrial field, in medicine technology, in the underwear and clothing industry, in upholstery and also in protective applications can all be three-dimensionally knitted.

knit and wear = registered trademark

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IKME preview

Stoll: flat knitting machines

H. Stoll GmbH & Co. KG, Reutlingen/Germany will present a cross section throughout its entire flat knitting machine program. Visitors will have an opportunity to see for themselves a wide range of machine types from all Stoll machine classes in operation in many different applications. Some interesting new products rounding off the Stoll machine program will also be on show.

One of the focal aspects of the presented machine program and its applications will be concentrating on Stoll-knit and wear. Pattern possibilities and ready-to wear article production with Stoll-knit and wear will be demonstrated with a wide range of ready-to-wear articles, from ultra coarse to extremely fine gauges.

In addition, several pattern workstations M1 will be on show with new interfaces, additional functions and modules. This will feature the latest methods for pattern development, together with applications for the acquisition of operating and machine data, all rounded off by new services for the customer when it comes to Fashion&Technology.

In addition, a new Stoll-pattern collection is being developed with current knitting trends. The very latest trend yarns will be used to present new knitting techniques and applications in all customary gauges. ❐

Groz-Beckert: needles

In Milan, Groz-Beckert KG, Albstadt/Germany presents the product group knitting machine needles. The company informs about its new developments.

Universal Stricksysteme: flat knitting machines

Universal Stricksysteme Vertriebs GmbH, Westhausen/Germany will show the following new and developed flat knitting machines:

- Flat knitting machine for the production of trendy "ready-to-wear" articles, type MC-844 RTW E10, with four identical systems (2x2), 80 inches, two compact carriages.
- Flat knitting machine at a reasonable price, type MC-328 E14, covering large part of the production nowadays required, with two identical systems (2 x 1, 2 x 43 inches, as well as 1 x 2, 1 x 90 inches), two compact carriages.
- High performance flat knitting machine with high productivity, type MC-868 E7. With six (2 x 3).
- Traditional compact flat knitting machine, type MC-825 E10, for Fully-Fashion fabrics, with two identical systems and one compact carriage.
- High performance flat knitting machine for Fully-Fashion, type MC-835XL E8, in particular suitable for large sizes, with three identical systems and one compact carriage
- Flat knitting machine type MC-825CXL E3 for all kinds of precious coarse gauge fabrics, with two identical systems and one compact carriage.
- Flat knitting machine for highest productivity, type MC-844 XL E5, to knit shaped fabrics, very flexible and suitable for outsize articles, with four identical systems and two compact carriages, design work station MA-8000.

Memminger-IRO: yarn feeders

Already market-proven products, a range of product modifications as well as product improvements and innovations will be shown by Memminger-IRO GmbH, Dornstetten/Germany.

- SFE: Storage feeder for all knitted structures requiring irregular yarn demand. The following improvements can be attained. Production increase thanks to a considerable reduction of yarn breakage and a simultaneous acceleration of the machine speed. Yarn of poor quality can be made processable by installing the paraffin wax device (e.g. dry yarn, which has been stored over a longer period of time). Less knitting pieces of second quality and less wastage. Improved length consistency of the fabrics.
- EFS-620: Yarn tension controlling feeder for the infeed of bare and covered elastanes in flat knitting machines. The production of knitted garments with bare elastanes on flat knitting machines offers the following advantages: Very good shape recovery effect; less garment wear , e.g. at the sleeves. More aesthetic garment due to improved fitting. Lower stock keeping costs as bare elastanes can be processed into any color, whereas covered elastanes must be stored in all colors.
- MSF-AI: With the MSF-AI combination feeder, air-interlaced yarns can be directly produced on the machine and fed to the machine in a targeted manner.
- Rojtricot: Storage feeder with yarn separation and fixed winder body.
- MLT-Wesco: Electronic measuring device for the measurement of yarn tension, yarn length and yarn speed.

With this product program the Memminger-IRO GmbH company once more proves its corporate objective of enabling its customers the realization of reliable production solutions on an extremely high level of economical and quality-relevant aspects.

Saxonia International: guide needles and sinkers

Under the headline of Saxonia International the worldwide operating companies Saxonia Umformtechnik GmbH, Göppingen, Saxonia Hitmetal Asia Ltd., Arrow/SI Inc., and the Bayerische Nadelleistenfabrik Leistner GmbH, Schwabach, present themselves at a common.

As worldwide leading suppliers of guide needles, sinkers and subassemblies for warp knitting machinery, flat knitting machinery, circular knitting machinery with large diameter, sock and hosiery machinery, Jacquard machinery and the general textile machine engineering Saxonia International will present the latest developments and products in the well-known OEM quality. The company Leistner produces a great variety of pin plates for stenter frames and comb bars. Among other things further improvements of wear-resistant surfaces will be on show, which have been designed for most different applications in the textile machine engineering with regard to the warp knitting and knitting field. Moreover, a further development in the rounding and hardening of looping elements as well as the production of complete subassemblies out of fine blanked elements will be presented.

On the basis of Saxonia's experience as a long-standing development supplier and the utilization of know-how resources from Saxonia International quick and uncomplicated customer-orientated and innovative solutions are offered, which fully match the requirements of our customers. For the After Sales market Saxonia offers a great range of spare parts, which mostly can be delivered ex stock.

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