DEUTSCHE INSTITUTE FÜR
TEXTIL+FASERFORSCHUNG

ANNUAL REPORT 2023

TEXTILE FUTURE

DITF.de

OPEN THE WINDOW
INTO THE WORLD OF TEXTILE

TAKE A LOOK INTO THE DETAILS OF OUR RESEARCH, IN IDEAS AND INNOVATIONS FROM THE GERMAN INSTITUTES OF TEXTILE AND FIBER RESEARCH DENKENDORF

DEUTSCHE INSTITUTE FÜR TEXTIL+FASERFORSCHUNG

ANNUAL REPORT 2023

FOREWORD

Dear Reader,

We are delighted to present you with our 2023 annual report, which reflects the diversity of fiber-based R&D projects in the country's future fields. From the molecule to the finished product, we report on forward-looking developments and show the wide range of applications and the enormous potential offered by fiber-based materials and textile technologies.

Textile products and processes that we develop at the DITF Denkendorf are drivers of innovation for many industries. They provide impetus in lightweight construction, in medicine and environmental technology, in the fields of renewable energies, resource efficiency and mobility or in the classic areas of clothing and home textiles. As a companion in these fields of application, we are shaping the future with practical solutions and ideas.

Research that gets through

The most important task of the DITF is and remains the development of market-ready products, processes and services for industry and thus the orientation of our work towards the needs for the industry. Small and medium-sized enterprises in particular value the DITF as an important research partner and supplier of innovative expertise. The proportion of SMEs in industrial projects was around 80 % in 2023. At the same time, numerous ZIM projects and projects from the Invest BW programme help to strengthen the innovative power of SMEs. In politically and economically challenging times and against the backdrop of the current transformation requirements, this support for SMEs is of existential importance.

Transforming the World of Textiles

This was the motto of ITMA 2023 and could not have been better chosen for the DITF's research. To the key themes of Advanced Materials, Innovative Technologies, Automation & Digital Future, Sustainability & Circularity, we were able to present a wide range of developments across all textile production stages to the international audience. The traditional ITMA wrap-up at the DITF, which summarises the most important trends of the trade fair for the industry in cooperation with the Forschungskuratorium Textil e.V., was a must.

Shaping digital change

Currently, there is hardly a project that does not address this task. Digital future technologies such as AI processes, machine learning and neural networks now play a central role in almost all of our research projects – be it to optimise development and production processes through digital engineering and to develop solutions for digital transformation, or to advance the functionalisation of textile products by integrating electronic components.

The DITF are making an important contribution on the path to Industry 4.0 with the Digital Textile Microfactory and the Mittelstand-Digital Zentrum Smarte Kreisläufe, among others. In addition, three projects in the field of digitalisation and artificial intelligence were launched in 2023 as part of Invest BW, the largest single-company funding programme in the history of Baden-Württemberg.

Peter Steiger Prof. Dr. rer. nat. habil. Michael R. Buchmeiser Prof. Dr.-Ing. Götz T. Gresser

Focus on sustainability

The "European Green Deal" addresses a broad spectrum of research topics. There is a wide range of tasks that need to be solved on the path to climate neutrality and sustainability in Europe. Textile products and processes that we develop at the DITF offer a variety of forward-looking solutions. The 2023 annual report presents current research projects with a different application focus on the sustainability topics of energy and resource efficiency, recycling and renewable raw materials as well as the circular economy.

The current situation also requires a critical analysis of our own energy consumption and CO_2 footprint. The DITF want to make their contribution to the country's climate targets and become climate-neutral by 2030.

In association with strong partners

In order to strengthen the performance of research funding in Germany, the DITF consider cooperation with the research communities focussing on industrial research at state and federal level is of particular importance. We have valuable partnerships with the institutes of the Innovationsallianz Baden-Württemberg (innBW) and the ZUSE community and are heavily involved in committee work. In 2023, Peter Steiger, Director of Administration and Finance, was elected as a member of the Zuse Community Executive Committee.

We would like to thank all our partners, sponsors, supporters and, above all, our employees for their passionate and valuable commitment. This annual report will give you an insight into the details of our research, ideas and innovations from the German Institutes of Textile and Fiber Research Denkendorf.

We wish all readers of our annual report an inspiring read!

Sincerely

Your DITF Executive Board

Prof. Dr.-Ing.
Götz T. Gresser

Prof. Dr. rer. nat. habil.
Michael R. Buchmeiser

Peter Steiger

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> Publicly funded research projects

> Published final reports, publications, lectures, press releases

> Dissertations, awards

> Events, trade shows, exhibitions

> Patents

> Bodies, scientific advisory councils

Orders: info@ditf.de

DITF

DEUTSCHE INSTITUTE FÜR
TEXTIL+FASERFORSCHUNG

GERMAN INSTITUTES OF TEXTILE AND FIBER RESEARCH DENKENDORF

FUTURE TEXTILES

The areas of textile chemistry and man-made fibers, textile and process engineering, and management research are united under the umbrella of the DITF. With their main research areas, they together cover the entire production and value chain of fiber-based materials – from the molecule to the product. Their potential lies in their close connection. Together, they are paving the way for the textile future.

GERMAN INSTITUTES OF TEXTILE AND FIBER RESEARCH DENKENDORF

We think in textile systems. They are the key to innovation in many important industries and high-tech sectors.

The DITF form the largest textile research center in Europe

With more than 250 scientists and technical employees, the German Institutes of Textile and Fiber Research Denkendorf cover the entire production and value creation chain in textiles as the only textile research institution in the world. The DITF have been covering all the important textile topic fields since 1921. In their fields of activity the DITF belong to the world-leading research institutions.

Application-oriented research from molecules to products

The DITF carry out application-specific research over the entire textile production chain. With product- and technology-oriented innovations as well as modern management concepts, the Denkendorf researchers contribute to the competitiveness and safeguarding of both the German and European economy.

R&D services

The DITF are an important R&D partner for industrial and service companies in fields ranging from ideas to material research, the development of prototypes and industrial processes, from pilot production to testing. The DITF are an important supplier of innovative expertise, especially for small and medium enterprises that do not have their own R&D departments.

Industry partners

The DITF are partners with numerous local and international enterprises. They take part in public research processes or issue direct research assignments to the DITF. The DITF support and advise companies in the most important industrialized nations worldwide.

Technology and knowledge transfer in practice

The DITF quickly transfer sustainable research results into economic utilization and application. Our most important goal is the conversion of scientific knowledge into market-ready processes, products and services.

Teaching and practical further training

As one of the leading European research institutions in the field of textile technology, the DITF have a special responsibility to encourage young scientists. Therefore, training and further education are among the DITF's central tasks.

Numerous lecturing and research collaborations have been formed with regional universities. A collaborative research and lecturing association with Reutlingen University exists through the Center for Interactive Materials (CIM). The DITF also have a close connection with the University of Stuttgart in the form of three professorships as well as courses in other study subjects.

Professorships at the University of Stuttgart

Professorship in Macromolecular Substances and Fiber Chemistry – Institute of Polymer Chemistry
Prof. Michael R. Buchmeiser

Professorship in Textile Technology, Fiber-Based Materials and Textile Machinery – Institute of Textile and Fiber Technologies
Prof. Götz T. Gresser

Professorship for Diversity Studies in Engineering – Institute for Diversity Studies in Engineering
Prof. Dr. rer. pol. Dipl.-Ing. Meike Tilebein

FROM MOLECULE TO MARKET – WHAT WE OFFER

Molecule | Fiber | Tissue | Technology | Process | Prototype | Product | Market

The DITF support you – starting from brainstorming through material research, development of prototypes and production processes, pilot manufacture and testing to advice on new business models. We orient ourselves to the needs of the industry and create market-ready products, processes and services for it.

Denkendorf Future Workshop

Innovations are rarely created by coincidence or simply by intuition. A structured innovation process is essential for creating new, market-ready and implementable ideas. The Denkendorf Future Workshop can help with this. It offers companies targeted and systematic support for brainstorming.

Applied research and development

We invest in preliminary research, make the latest results from fundamental and application-oriented research available to the textile sector, operate joint research, contract research and development on commission. From the molecule to the finished product and its entry onto the market we research and develop along the entire textile value creation chain and in the process, also develop business processes and models.

Testing services

Since their foundation the DITF have had test laboratories and offer a comprehensive service catalog for testing fibers, yarns, surfaces and textiles. Hardly any other institution offers such comprehensive technology for the research and testing of fiber-based materials and textiles. State-of-the-art analysis and testing techniques are available for examining textile-technical, chemical, biological and sensory testing processes.

Pilot factory

The DITF operate a pilot factory in which all the important technologies along the process chain are implemented. With this pilot factory we offer the industry a unique opportunity in the textile market for zero and small series manufacturing. Experienced staff, combined with the existing machinery park and well-equipped technical facilities guarantee optimal framework conditions for contract manufacturing.

Prototype construction

We have in-house development and construction facilities for prototype construction. Well-trained personnel use the modern equipped workshop and the electronics laboratory to develop new ideas for testing and production processes for the textile industry. In this way we offer the textile industry the opportunity to test and optimize at specially built test stands.

Please ask us!


20 mL
Metrohm
On
Status
888 Titrando
OMNIS ready
Metrohm

DITF RESEARCH FIELDS

The DITF research fields underwent a complete update in 2022 as part of the strategy development process. The new definition focuses on the markets and needs of tomorrow. It addresses the megatrends of global development and the associated challenges.

The previous six research fields, which focused on the entire production and value chain, have been reduced to five. They now form the thematic focal points in the DITF research portfolio, which the centers fill with life with their projects in line with demand.

NEW MATERIALS

- Processing of natural fibers
- Biopolymers
- Biobased, biodegradable polymers and coatings
- Biocompatible biomaterials
- Oxide ceramic fibers
- Thermoset and thermoplastic matrices
- Low-cost, low-energy biobased carbon fibers
- Functional fibers (conductive, self-healing, sensory)
- Sound-absorbing and light-technical materials
- Flame retardants

LIGHTWEIGHT CONSTRUCTION

- Tailor-made textile fiber composites: braids, woven fabrics, nonwovens
- Multifunctional thermoset and thermoplastic matrix systems
- Nonwovens for thermoplastic composite
- (Continuous) fiber reinforced 3D printing, (braid) pultrusion, tape laying,
- 3D textiles for near-net-shape, adaptive and functionally integrated structures
- Fiber-based prestressed concrete
- Urban Textiles
- Component monitoring with integrated sensor technology

SUSTAINABILITY

- Single-variety composites
- Productivity increase and optimal raw material utilization
- Resource-efficient processes and procedures
- Energy generation through textiles
- Textile materials for biotechnology and environmental protection
- Holistic view of sustainability
- Circular economy
- Mechanical, thermal, chemical recycling

The revision of the research fields is based on research and takes a large number of studies into account that are relevant to the DITF. These include the BMBF's High-Tech Strategy 2025, the FKT Perspectives 2035, the innovation strategy and the State's coalition agreement, and many more.

At the same time, an analysis of the centers within the strategy process supported the classification into the new research fields. The current research topics can be precisely assigned to the newly selected research fields.

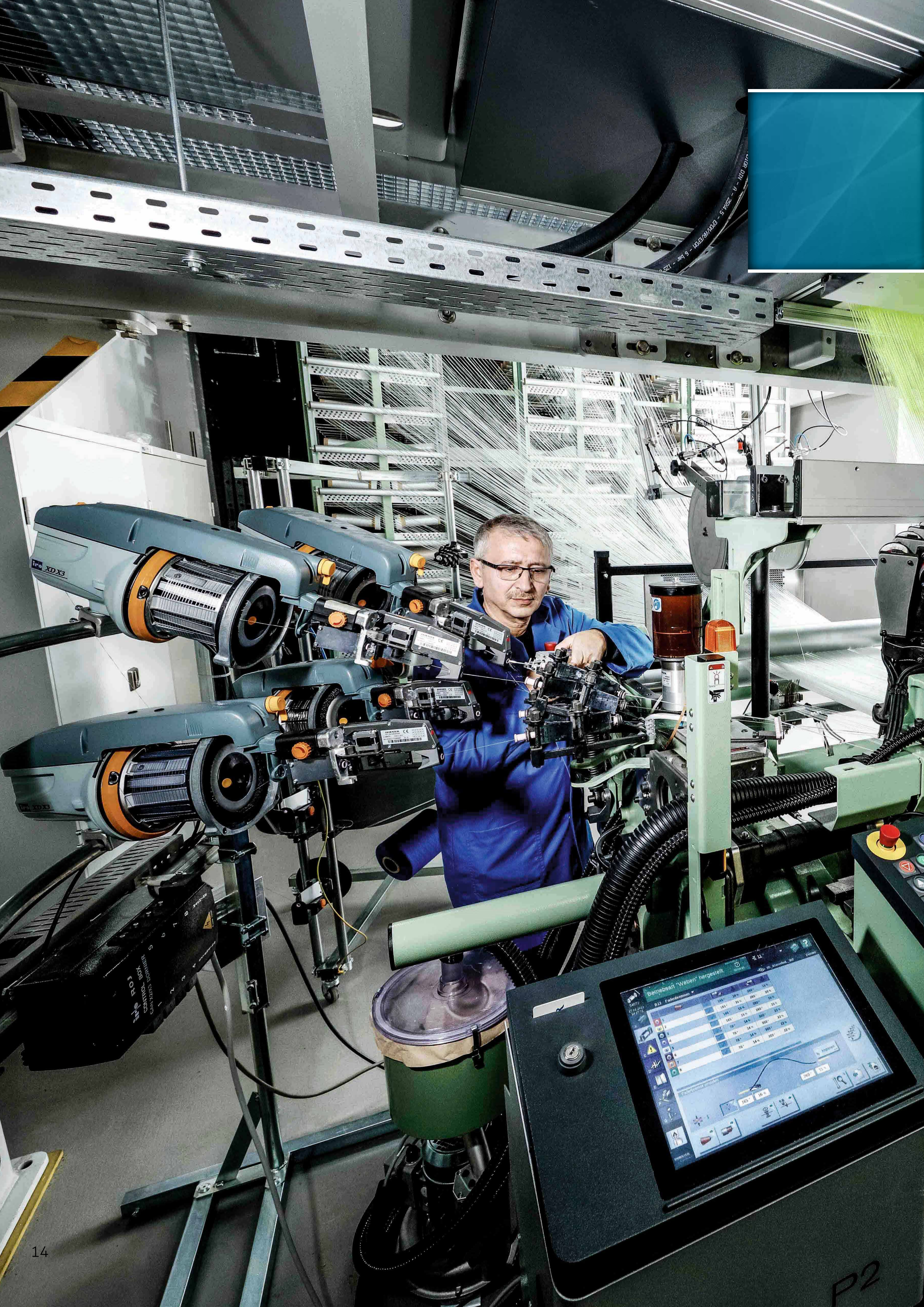
DIGITALIZATION

> Digital textile engineering
> Virtual testing
> Cross-scale modeling and simulation
> Digital material twins and process twins
> AI-assisted processes,
> Smart Home & Neighborhood
> Lot size 1
> Digitally networked production
> Sustainable and digital business models
> Socio-technical systems and value creation structures

HEALTH

> Medical fibers and nonwovens
> Antibacterial and antiviral finishes
> Therapeutic textile products
> Drug delivery systems
> Theranostic systems
> Additive processes for individualized medicine
> Textile-based sensors and actuators, coupled with artificial intelligence (AI)
> Clinical and ambulatory health monitoring
> Personal protective equipment

THE **FUTURE** IS TEXILE!


XD X3
Betriebsart "Weben" hergestellt

FIELDS OF APPLICATION

We encounter the textile world everywhere. Textile development and products are the key to innovation in many important industries and high-tech sectors. Fiber-based materials are among the most important materials of the 21st century. Multi-functional, cost-efficient and sustainable, they are recommended for more and more fields of application. We have carried out diverse research projects for industrial as well as public clients in the following fields of application:

Architecture and construction

Construction materials with textile components, fiber-based materials

Energy, environment and resource efficiency

Energy technology, environmental technology (e.g. water treatment, geo- and landscape protection, recycling of high-performance fibers), intelligent energy management

Health and care

Textile implants and regeneration medicine, wound treatment products, diagnostic and monitoring systems, smart textiles, depot and therapy systems

Production technologies

Process engineering and technology for higher productivity, quality and energy efficiency, automation

Mobility

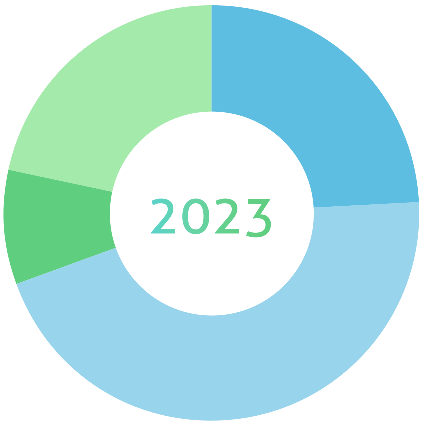
Fibers, structures and products e.g. for the automotive industry and for aviation and space travel technology

Clothing and home textiles

Functional clothing, climate-regulating textiles, light textiles, sound technological textiles, smart textiles

FIGURES – DATA – FACTS

27.811 Total revenue



Revenues Industry:	6.750 TEUR
Revenues from public contracts:	12.584 TEUR
Other revenues:	2.505 TEUR
Institutional funding:	5.971 TEUR

(Income excludes ITV Denkendorf Produktservice GmbH)

In terms of industrial revenues, small and medium-sized enterprises play a particularly important role for the DITF. The share of SMEs in industrial projects in 2023 was approx. 80 %.

132 Public research projects

Subsidies from state, federal and EU programs. 25.0 % of revenue from public contracts in the reporting period came from the ZIM funding program, which is open to all technologies and sectors and aims to sustainably strengthen the innovative strength of small and medium-sized enterprises.

Employees as of 31.12.2023

DITF

223 employees
- 101 scientists* and engineers*
- 122 non-scientific employees

12 doctoral students
28 students (Bachelor and Master students)
43 % share of women

ITV Denkendorf Produktservice GmbH

40 employees

77 publications

54 of these in peer-reviewed journals

9 bachelor theses

9 master theses

6 dissertations

2 patents

Quality Management

Selected DITF laboratories and the testing laboratory of the ITV Denkendorf Produktservice GmbH are accredited according to DIN EN ISO/IEC 17025:2018.

The production areas filament yarns, needle felts, coated PP monofilament and the development areas of the DITF in the regulated area of medical devices as well as the ITV Denkendorf Produktservice GmbH are certified according to EN ISO 13485:2016. Scope: Design, manufacture and distribution of absorbable and non-absorbable polymers, fibers, films and membranes, surgical sutures, implants, wound dressings and anti-microbial meshes.

NETWORKS AND COLLABORATIONS

Networks help us to drive innovation faster and to operate more successfully in the market. For that reason, we actively promote networking and collaborations – across industries, nationally, and internationally.

Combined expertise

In addition to having close links to the business and science community, the DITF are closely involved in the activities of a wide range of associations, organizations and thematic networks of excellence, which serve as a platform for cross-system, interdisciplinary research.

Applied research

One crucial task of the DITF is the support of SMEs through applied research together with the successful transfer of technologies. Networking and collaboration with other business-related research institutes help to reinforce the mid-tier research capacity in Germany. Accordingly, the DITF engage with the most significant research communities concentrating on industrial research at the state and federal level.

innBW INNOVATIONSALLIANZ BADEN-WÜRTTEMBERG

The DITF are part of the Innovation Alliance Baden-Württemberg (innBW), a group of 10 non-academic, business-related research institutions with a total of 1,500 employees. The institutes carry out result-oriented contract research in areas relevant for the future of the state. With around 4,800 industry projects per year, the innBW is an important partner, particularly for SMEs.

ZUSE-GEMEINSCHAFT

The DITF co-founded the German Industrial Research Foundation Konrad Zuse e.V. This association represents the public interests of non-profit industrial research institutions in Germany and is open to all technologies and sectors. Its members include independent research institutions from all over Germany. They promote innovations in all sectors, from agriculture to medicine to mechanical engineering and shipbuilding.

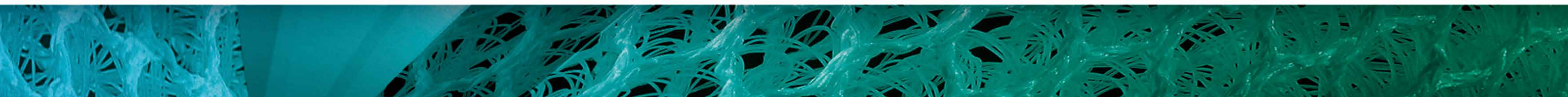
Universität Stuttgart | AiF Mitglied | südwest textil | GESAMTMASCHE | Textranet European Network of Textile Research Organizations

Forschungskuratorium textil | Hochschule Reutlingen Reutlingen University | AFBW Allianz Faserbasierte Werkstoffe Baden-Württemberg e.V. | edana | TLH TECHNIKUM LAUBHOLZ

innBW INNOVATIONSALLIANZ BADEN-WÜRTTEMBERG | techtera | VDMA | ETP Fibres Textiles Clothing EUROPEAN TECHNOLOGY PLATFORM | Industrievereinigung Chemiefaser e. V.

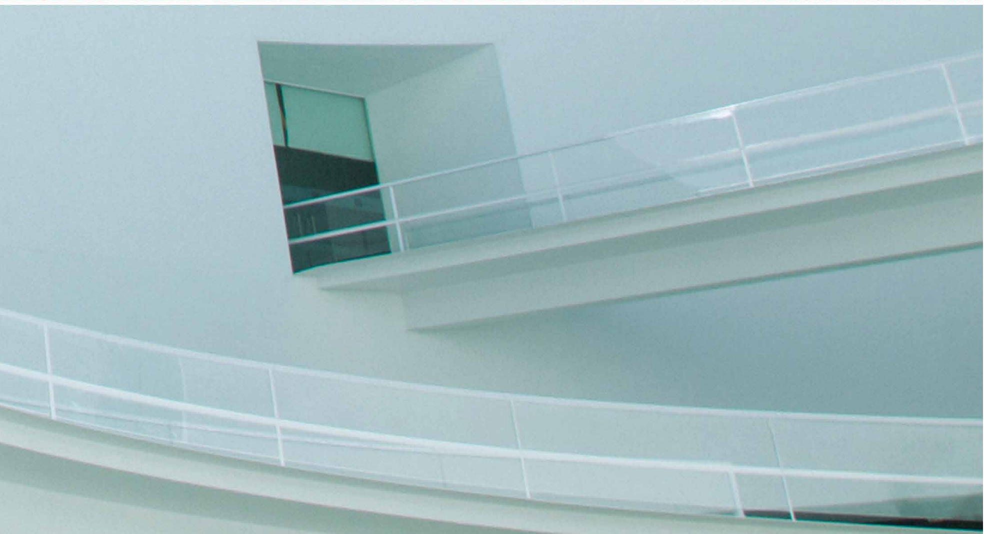
BioRegio STERN | MedicalMountains | ZUSE-GEMEINSCHAFT | microTEC Südwest | ALLIANZ Industrie 4.0 BADEN-WÜRTTEMBERG

ARENA2036 | SWISS TEXTILES | LBZ LEICHTBAUZENTRUM Baden-Württemberg LBZ-BW e.V. | IVGT | CU COMPOSITES UNITED | Kompetenznetz Biomimetik Competence Network Biomimetics


ARCHITECTURE AND CONSTRUCTION

Fiber-based materials and processes for the construction of tomorrow. Innovations for more aesthetics, sustainability and functionality. For temporary and permanent buildings.



> Textile facade elements: intelligent, lightweight building shading
> Light directing textiles
> Acoustic textiles
> Pneumatic and hydraulic textile actuators
> Autonomous Living Wall Systems
> Optically transparent, fiber-reinforced materials
> Textile solutions for smart homes and smart neighborhoods
> AI in the construction industry
> New textile materials for construction

Architecture and construction

Upheavals in the energy supply, a need for affordable living space and changing living situations define the future tasks in construction. Sustainable, affordable and liveable solutions must be found that make the energy transition climate-neutral in both urban and rural areas and take into account the changed living situations in the context of working from home. The DITF are therefore developing textile solutions that are resource-efficient and recyclable to meet the challenges in construction in a qualitative and socially responsible way.

Smart textile “redensification solutions”

The DITF develop new textile materials, structures and systems for the entire field of construction, which can be tested and demonstrated in the Denkendorf ForschungsKUBUS. The focus here is on integrated solutions. For example, the context of redensification often requires new solutions for sound and light. New shading textiles create a lighting situation in the interior which, despite reduced glare, directs so much valuable daylight into the room that artificial lighting can be dispensed with. Integrated textile sensors measure the illuminance and control the shading with the help of AI. Both the intrinsic properties of textiles and textile options for acoustic effects can be used specifically for redensification in order to manage noise problems in a way that conserves resources. The increase of extreme weather conditions such as periods of heat and heavy rainfall are generating new requirements for redensification. Textile Living Wall systems not only improve the quality of air and life in densely built-up inner cities, but can also be used in urban water management thanks to their controllable water retention capacity and, if used intelligently, reduce the heat island problem.

In this way, these solutions can help to implement the currently pending refurbishment of the building stock more economically and at the same time realise energy potential. They thus directly support the endeavour for affordable housing.

Fiber composites in construction

Against the backdrop of global growth and limited raw materials, the decarbonisation and reduction of mineral materials is a key task for the future of construction. This is why fiber composites are also becoming increasingly important for use in construction. They open up new possibilities with industrially relevant property profiles due to their high specific strengths and stiffnesses. The material properties can be optimised by the fiber orientation, the fiber-matrix adhesion and the wide range of possible combinations of fibers and polymer matrices can be tailored to a wide variety of applications.

Fiber composite building materials that permanently store carbon and remove more CO_2 from the atmosphere than is released during their production have great potential for innovation in this area. The DITF are leading the joint project DACCUSS (Direct Air Carbon Capture, Utilisation and Safe Storage), which is investigating the absorption and fixation of carbon dioxide (CO_2) in a new type of lightweight construction material (see highlight on page 23).

Natural fiber high-performance composite profiles for architecture

The DITF have developed a sustainable fiber composite material made from renewable raw materials for architectural applications. Hemp and flax fibers were used as reinforcing components and an epoxy resin with a high organic content based on linseed oil for the new biocomposite material. The material therefore offers numerous advantages compared to petroleum-based glass fiber plastics.

Pavilion LightPRO Shell

The DITF have developed support profiles and connecting nodes for reusable temporary structures from the new material. The first realisations on an industrial scale were the LightPRO Shell Pavilion and the Buckyball, a section of which could be seen at the Biennale exhibition in Venice. The buildings consist of a latticework of tubes joined together. The tube profiles were manufactured using pultrusion (extrusion), while the connecting nodes were made from multi-layered natural fiber fleeces using a hot pressing process. The partners in this project were ITKE- BioMat and the companies CG TEC, BAB, Zenvision and Steinhuder Werkzeugbau.

Practical tests have shown that the biocomposite material developed at the DITF is suitable for a wide range of architectural applications. Compared to glass fiber plastics, biocomposites do not splinter in the event of a crash. They are also a sustainable building material. They consume much less energy during their production and bind a large amount of carbon in the long term. Due to their low density, they weigh little and are therefore suitable for many applications in lightweight construction.

PapierEvents – recyclable event and trade fair furniture made of paper

A lot of waste is generated in the event industry. Furniture that can be quickly assembled and stored in a space-saving manner and can be easily recycled at the end of its useful life makes sense. Paper is the ideal raw material here: locally available, renewable and recyclable with an established process. The DITF and their project partners PMV of TU Darmstadt, GarnTec GmbH, quintessence design and Rödig GmbH have therefore jointly developed a recycling-friendly modular system for trade fair furniture in a project funded by the DBU.

As demonstrators, a sensory and luminous counter, a customer stopper and a pyramid-shaped display stand with structure-coiled paper yarns were realised, which show a completely new design language. The furniture is lightweight, modular and can be shipped in individual parts in packages. All parts can be used multiple times, i. e. for campaigns lasting several weeks.

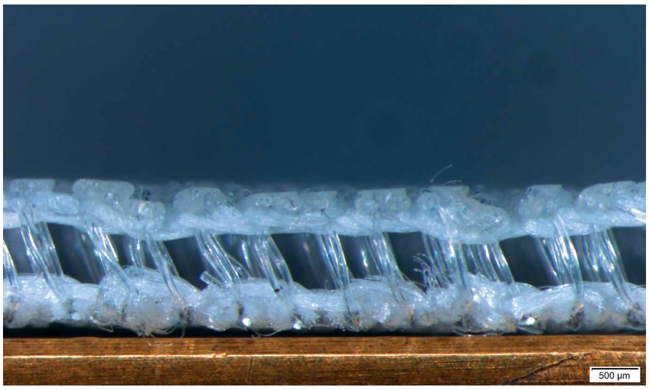
The unusual look is created in the structure winding process. In this technology developed at the DITF, the yarn is precisely deposited on a rotating mandrel. This enables high process speeds and high degrees of automatisation. The yarns are then fixed so that a self-supporting component is created. An adhesive was used in the project for the fixation, which, like the sensor yarns produced with paper, is fully recyclable via the normal waste paper process.

Pyramid-shaped display and sensory and illuminated counter

Vacuum insulation elements rethought!

Adjustable insulating elements allow the reaction to changing thermal loads. Adaptive building envelopes can adjust the heat transfer depending on the thermal power requirement of a room and the outside conditions, thus enabling a reduction in both heating and cooling energy requirements. Furthermore, they can utilise structurally necessary building masses as flexible thermal energy storage for building temperature control.

The ReVaD project is developing controllable insulating elements based on the Knudsen effect: The thermal conductivity of porous structures changes significantly with the gas pressure prevailing inside. In order to use the technology sensibly, the highest possible switching factor is required. To achieve this, the pore system and gas pressure range must be optimally harmonised. The multimodal pore system required in the insulation panel is being developed at the DITF in the Technology Center Knitting Technique in the form of mesoporous spacer textiles. The greatest challenge here is initially the compressive rigidity of the filling core, which must only allow minimal deformation at a surface pressure of 10 N/cm².



Pressure-resistant spacer fabrics are used as textile filling cores for vacuum insulation elements. The pore properties can be flexibly adjusted during the knitting process by selecting the yarn and weave.

In the joint project, the Institute of Institute of Engineering Thermodynamics at the German Aerospace Center (DLR) in Stuttgart is developing a reactor component for the controlled adjustment of the vacuum gas pressure by means of reversible gas-solid reactions. Institute for Building Energetics, Thermotechnology and Energy Storage at the University of Stuttgart is integrating the panels into the wall composite, analysing them using a demonstrator and simulatively determining the energy potential for different building types.

Textile-based, non-combustible materials

The possible applications of fiber composites as concrete reinforcement and generally for the construction of buildings and bridges have so far been limited primarily by the relatively low temperature resistance of the organic matrices (< 200 °C) and their flammability or fire behaviour. In the AiF project NiBreMa, the DITF have taken up this challenge and developed a new phosphate ceramic matrix as a solution. For this development approach, the DITF, together with the German Aerospace Center (DLR), investigated both the matrix and the process development.

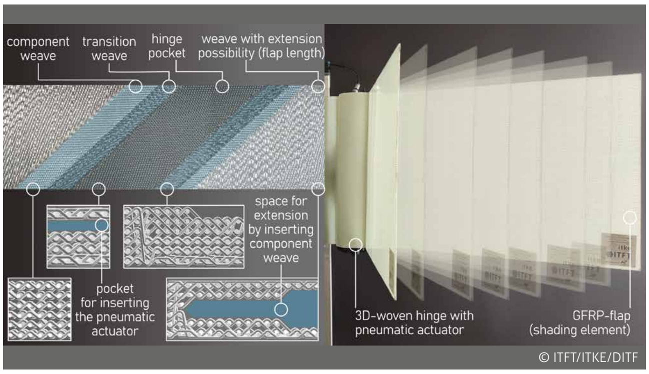
The new fiber composite material consists of a fiber reinforcement made of glass and basalt fibers and the newly developed phosphate ceramic CBPC (Chemically Bonded Phosphate Ceramics). The chemically bonded ceramics can be manufactured at temperatures below 200 °C. The basalt fibers have a temperature resistance of up to 650 °C, the CBPC matrix even up to approx. 1100 °C. The cold-cured basalt fiber-reinforced composites have good mechanical properties and good compatibility with Portland cement concrete.

The new material achieves EU fire protection class A1 and fulfils the current fire protection requirements in the construction industry. The CBPC composite maximises the use of E-glass and basalt fibers for construction applications and at the same time enables economical production with a better CO_2 balance than reinforcing steel. With this performance profile, the new material shows great application potential, for example for reinforcing bars and other components manufactured using pultrusion and fiber wrapping.

Basalt roving, CBPC matrix, pultruded profiles and wrapped sheet

3D woven adaptive fiber-reinforced composites

The integration of compliant hinges in adaptive fiber-reinforced composite components opens up new fields of application for resource-efficient lightweight construction in civil engineering. By substituting rigid body mechanisms, the mechanical complexity of movable structures is significantly reduced. This means, for example, that low-maintenance shading systems for complex building geometries or even short-term, temporary structures such as tents, camps and living containers can be realized. The textile layer structure is a decisive aspect for the efficient production of adaptive FRP components.



Left: 3D woven structure for adaptive FRP, Right: demonstrator of a 3D woven adaptive façade shading component

As part of the "FVK-Gelenke" project, for the first time a hinge based on a 3D weave with a thread orientation of ±45° was developed and manufactured. The 3D weaving technology not only enables gradual material transitions for better load distribution but also allows interlaminar connections. In addition, the semi-finished textile product can be manufactured in a single production step. The development work included a detailed analysis of suitable material combinations in terms of their compatibility, strength and durability in order to be able to combine flexible and rigid properties in one component. The analysis of different fabric weaves in combination with other aspects of the investigation, e. g. fiber volume fraction, elastomeric fraction and fiber-matrix adhesion, led to a textile structure with comparable load distribution and a fatigue strength of over 5,000 cycles. Based on the analyses and calculations carried out, guidelines were derived regarding how FRP hinges can be sensibly configured.

CO_2-negative construction thanks to innovative composite material

The DITF are leading the joint project "DACCUS-Pre"*. The basic idea of the project is to develop a new building material that stores carbon in the long term and removes even more CO_2 from the atmosphere than is released during its production.

In collaboration with the company TechnoCarbon Technologies, the project is now well advanced – a first demonstrator has been realised as a house wall element. This consists of three components: Two slabs of natural stone form the visible walls of the wall element. Carbon fibers in the form of technical fabric reinforce the side walls of the wall elements. The third component of the new building material consists of biochar. This is used as a filling material between the two rock slabs. Each individual component contributes in a different way to the negative CO_2 balance of the material.

From a technical point of view, the already realised demonstrator, a wall element for structural construction, is well developed. Gabbro natural stone from India was used, which has a high-quality appearance and is suitable for high loads. This was verified in load tests. Bio-based carbon fibers serve as the top layers of the stone slabs. The biochar from Convoris GmbH is characterised by particularly good thermal insulation values.

Fully assembled wall element

The CO_2 balance of a house wall made of the new material was calculated and compared with that of established steel concrete.

This results in a difference in the CO_2 balance of 157 CO_2 equivalents per square metre of house wall. A significant saving!

* (Methods for removing atmospheric carbon dioxide (Carbon Dioxide Removal) by Direct Air Carbon Capture, Utilization and Sustainable Storage after Use (DACCUS).

HEALTH AND CARE

Textile materials, products and processes for innovative fields of application related to human medical care.

- Resorbable polymers and bio-materials
- Implants
- Scaffolds for regenerative medicine, biohybrid organs
- Additive manufacturing, micro injection molding
- Sensory textiles
- Personalized orthotics
- Wound dressing materials
- Bioactive coatings, e.g. for wound dressing
- Drug delivery systems: Drug capsules and porous fibers
- Antibacterial and antiviral textiles
- Textile-based surgical instruments
- Hospital and surgical textiles
- Biological testing on medical devices, implants, antimicrobial textiles, barrier textiles and clothing

Health and care

In 2023, textile medical devices and textiles for health in general continued to face various challenges. The authorisation procedures for textile medical devices have increased significantly in their complexity, even the question of whether an existing or new product is a medical device at all is often not easy to answer. Textile research never tires of finding new and innovative solutions. The healthcare industry is and will remain a growth market, and medical textiles play an important role as an innovation driver and trendsetter.

The challenge of sustainability

In addition to biocompatibility, which is taken for granted and ensures the compatibility of textile medical products through suitable biocompatibility tests, sustainability aspects are also playing an increasingly important role in medical products. The industry faces the challenge of developing more sustainable production and disposal processes. The circular economy and environmentally friendly materials are key topics for future developments, always, of course, against the backdrop of difficult authorisation conditions. For the time being, the focus here is less on implants or medical textiles that come into direct contact with non-intact skin or wounds. The products that come into contact with and are thus contaminated are products that could be reused with reasonable effort.

Intelligent and antimicrobial textiles

There are many pioneering developments in the field of medical textiles in the area of intelligent textiles, which are used in telemedicine, for supporting and monitoring patients at home and in rehabilitation. In the field of antimicrobial textiles, new materials and coatings are also preventing the growth of microorganisms on textile surfaces and the transmission of infectious pathogens, there is a high potential for innovation. This is particularly important for medical clothing, bed linen and bandages. Additive manufacturing is being used more and more widely in the functionalisation of textiles, e.g. for protective clothing, but also in the production of complex textile structures that can be individually adapted to the patient. This can create new possibilities for prostheses, orthoses and implants.

DITF Quality Management

The higher classification of medical devices in accordance with the Medical Device Regulation (MDR) influences the authorisation process mentioned at the beginning in several aspects, as more extensive conformity assessments are required for higher-classified products. This includes clinical trials, risk assessments and the involvement of a Notified Body, possibly also for products that have been successfully marketed as Class I products for a long time, but are now being placed in a higher class. The MDR requires detailed clinical data to ensure the safety and performance of already approved products with comprehensive clinical studies. A quality management system is not only required for higher-classified products. The DITF support manufacturers in development and production of textile components and absorbable polymer materials through certification in accordance with ISO 13485 and with accredited testing in accordance with DIN EN ISO/IEC 17025 by the DAkkS.

Biological tests with microorganisms of risk group classification 2

Whether bacteria, viruses or moulds: the biological laboratory at the DITF works with microorganisms of risk group 2. These microorganisms can cause diseases in humans and/or animals. Official authorisations are therefore required for corresponding activities in the laboratory of biosafety level 2. Following the authorisation for work with pathogens up to risk group 2 under the Infection Protection Act, which has been in place for many years, the authorisation for work with animal pathogenic microorganisms under the Regulation on animal diseases (TierSeuchErV) has now been added. This has further expanded the testing options and the selection of relevant microorganisms. Textile-related microbiological issues can be dealt with using application- and practice-oriented microorganisms. Examples include relevant pathogens responsible for hospital-acquired infections, "athlete's foot" or suitable virus surrogates for SARS-CoV-2.

ReBa^2-testing device for determining the bacterial penetration

The **Re**alistic **Ba**cterial **Ba**rrier test method (ReBa^2) for evaluating the bacterial penetration through cleanroom garments is a new addition to the range of tests. How many bacteria from the human skin flora can penetrate through the cleanroom garment to the outside when it is worn? The test method largely reproduces the wearing situation and thus enables a meaningful determination of the barrier function of the cleanroom garment textiles against bacteria.

The ReBa^2 test method can also simulate numerous test scenarios. In addition to the influence of intermediate garments worn under the cleanroom garments, the sweating process or the wetting of the cleanroom garments by process-related liquid splashes or disinfectants is also tested.

Bone replacement from the 3D printer

Additive manufacturing with Arburg Plastic Freeforming (APF) was used to produce biomimetic bone scaffolds to promote osteosynthesis made of polycaprolactone with channel structures for ingrowth of blood vessels. A specific creation of defined channel structures is very important to support ingrowth of blood vessels, which significantly promotes the regeneration of natural tissue.

Development of individual implants with optimized structural design

A tibia model was divided into the cortical bone and the cancellous bone in order to be able to compare the realization of the different requirements of the two natural structures with the printed structures. The filling density of the cortical and cancellous bone scaffolds is within the physiological required range. Vertical and horizontal channels of the cortical scaffolds are well developed with diameters between 200 and 1000 µm. Compression tests showed that the channels in the tibia corticalis lead to a slightly higher stiffness than those without channels. The stiffness of the cancellous bone scaffolds with channels is lower than those without channels. The porosity achieved for both scaffold types is within the required range.

The APF process is fundamentally suitable for the production of biomimetic scaffolds. Future development will increase the compression stiffness of the cortical bone scaffolds by fiber reinforcement.

Microtome section through channels of a cortical scaffold

Vibrations show the way

How can visually impaired people be helped to orientate themselves in road traffic and indoors? The company feelSpace GmbH answers this question with its naviBelt®. This is a waist belt that incorporates sixteen vibration elements all round. The belt is thus able to show a direction through vibration. It can be used like a compass or connected to a navigation app. As part of a ZIM project, the DITF have developed a contacting process that can be used to produce this orientation aid – and e-textiles in general – more economically and conveniently.

Contacting of textile-integrated conductors through wire bonding

Together with the DITF and the company AMOHR GmbH, the navigation belt was further developed and innovative production processes were developed. The vibration elements were bonded to a textile, stretchable tape with integrated conductor tracks. The DITF utilise wire bonding, an ultrasonic welding process, for this purpose. Compared to a soldering process, the contact points can be significantly minimised with wire bonding. The contacts are fixed with pinpoint accuracy. The energy input is limited to the contact point, which minimises the heat load on the surrounding textile. The ultrasonic welding process also enables the conductor to be contacted without prior stripping.

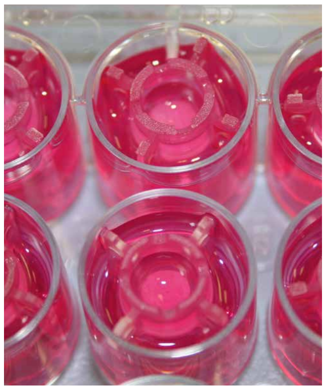
Ultrasonic welding also has health and environmental advantages over soldering. Solder is mixed with flux, which produces harmful vapours that need to be extracted and filtered.

naviGürtel® – Orientation support for visually impaired people

New strategies in the treatment of meniscus injuries

The self-healing potential of the meniscus after a tear is low. Regeneration, as with other body tissue, practically does not take place in the meniscus, which is fibrocartilaginous and poorly perfused. In a DFG-funded project on meniscus regeneration, the DITF, in collaboration with the Trauma Research working group at the University of Ulm, have now laid the foundations for the future mathematically supported development of regenerative meniscus replacement materials.

Biocompatible support for cell colonisation



Holder with colonised PET needle fleece in culture

To this end, the DITF biology laboratory has established the cultivation of human stem cells (MSC) and used growth factors to stimulate them to differentiate into cartilage and thus form a cartilage matrix. PET needle fleeces are used as cell culture scaffolds, for the colonisation of which the DITF have developed a special holding device using a 3D printing process. By positioning the scaffold in the culture dish without contact, it ensures an optimal nutrient supply and good cell distribution in the sedimentation phase (180° rotation). At the same time, the holder can be sterilised using standard methods and is non-cytotoxic.

The scaffolds were seeded at the DITF using an optimised process and analysed after 7 to 21 days of incubation using scanning electron microscopy or light microscopy. At the same time, the working group in Ulm examined the samples immunohistologically, mechanically and by means of gene expression analysis. To improve the differentiation of the MSCs into chondrocytes, the colonised fleeces are to be mechanically stimulated during incubation. For this purpose, a percussion chamber is being constructed at the DITF and manufactured using a 3D printing process.

An elasticated fabric band for respiratory monitoring

Correct breathing is important for human health. However, many people breathe incorrectly. Various techniques, such as biofeedback, can be used to counteract this. Biofeedback involves visualising the body's own processes, such as breathing, using electronic aids. The aim is to use the visualised data to teach people to regulate and control their functions, such as breathing. Smart textile sensor technology plays an important role here, as it combines function with the comfort of a textile.

A stretchable sensory fabric band is currently being developed at the DITF in collaboration with project partners as part of an ongoing ZIM project. The band incorporates sensory silicone yarns integrated into the elasticated fabric, which record the movement of the chest and abdomen in real time and send the recorded signal via Bluetooth to an evaluating electronic system. The electronic system, which may take the form of a mobile phone application, then displays the detected signal in a comprehensible manner, enabling the user to react accordingly and to receive instruction on correct breathing technique. The sensory fabric band is designed and customised in such a way that it can be used universally in terms of size and gender, as it is capable of covering a wide range of body circumferences and shapes. The range of applications is therefore versatile and extends from home use to sports and therapy.

Learn to breathe correctly thanks to the breathing monitoring tape

Smart textiles for protection against cuts

The topic of occupational safety is becoming increasingly important in many professional fields. Intelligent textiles have the potential to reduce the risk in the workplace caused by interaction between humans and machines.

There is a high risk of injury when working with power saws. Frequent injuries are cuts to the hand and arm. In order to prevent serious accidents during tree care in the future, the DITF have developed an intelligent arm protection system. The system protects the arborist from the chainsaw using a series of sensors that are integrated into the textile arm guard and the chainsaw and communicate with each other. The distances between the tool sensor and the sensors on the arm determine whether a protective measure is initiated. If the arm and saw come too close to each other, the machine switches off automatically.

© iStock – sturti

Cut injuries often occur when the tree surgeon takes one hand off the chainsaw to hold a branch and operates the saw with the other hand. Currently available cut protection gloves do not offer complete protection due to their limited multi-layered textile structure, especially not at full chain speed. In addition, the existing textile protection options are limited by their thickness and lack of comfort, as gloves that are too thick are a hindrance to tree care. Smart textiles can overcome this limitation by developing thin and intelligent protective solutions that significantly increase protection.

MOBILITY

Textile innovations from the DITF in the field of lightweight construction/fiber composites are helping to shape the mobility of the future and offer solutions for reducing emissions, conserving resources, comfort and functionality.

> Increasing use of natural fibers, bio-based fibers, bio-matrices and aggregates. Implementation of the NATURALfiberEXTRACTION congress

> Cooperation with V-Carbon for the production of high-quality semi-finished products from recycled carbon fibers for loadbearing components

> Co-Organizing the 5th Carbon Recycling Congress in Stuttgart

> Reduction of the carbon footprint through carbon fibers made from cellulose, lignin and chitin in combination with energy-saving kiln technology

> LCA knowledge of the entire textile processing chain

> Simulation of Manufacturing process and component behavior to reduce costs and extend service life

> Micro-computed tomography for the detection and elimination of component defects

> 3D winding, braiding, pultrusion and tape laying for lightweight FRP construction

> Complex woven ceramic fiber preforms for Ceramic Matrix Composites (CMC) with high stiffness and thermal cycling.

> Cellulose-based filter materials and economical and ecological materials for fuel cells

> Smart, resource-saving, textile solutions for interior lighting, heating, operation, safety and security

> Energy-saving production technologies, e.g. use of UV technology

Mobility

The automotive and aviation industries are key industries in Germany that face considerable challenges due to international competition and new forms of propulsion. Continuous innovation is essential in order to remain competitive. The use of biogenic raw materials, the development of advanced materials and technologies and the recycling of valuable resources make a decisive contribution to the innovative strength and sustainability of these industries. By developing textile solutions that support new technologies and promote sustainability, the DITF contribute in many ways to progress in this area. Collaboration between research institutions and industry will be decisive in successfully shaping the technological and ecological transformation.

Biogenic raw materials

To reduce the CO_2 footprint and achieve climate-neutral products, companies are replacing fossil-based raw materials with sustainable alternatives. The DITF use natural fibers such as hemp in composite materials for various applications. Cellulose and lignin serve as biogenic raw materials for the production of bio-based carbon fibers, which are used in fuel cells for emission-free drives. Pure cellulose composites are being researched to sustainably replace glass fiber composites and are used in filter media. The DITF are also developing bio-based resin systems to replace fossil-based resins such as epoxy and polyester resins.

Recycling

The recycling of high-quality fibers such as carbon fibers is essential to ensure their sustainable use. The DITF have developed methods for the industrial recycling of carbon fibers and underlined their expertise by organising the 5th Carbon Recycling Congress in Stuttgart, among other things.

State of the art in the automotive industry

In the automotive industry, innovations for efficiency and environmental friendliness are essential. Lightweight construction, electric drives and alternative fuels characterise this industry. Textile materials such as hemp and flax fibers in composite materials reduce vehicle weight and therefore fuel consumption and CO_2 emissions. Bio-based carbon fibers, obtained from renewable raw materials such as cellulose, offer similar mechanical properties to conventional carbon fibers, but are more environmentally friendly to produce and dispose of. The DITF are working on the development and integration of such materials in industrial applications.

State of the art in the aviation industry

Fiber-reinforced composites are standard in the aviation industry. Textile-based solutions reduce aircraft weight and lower fuel consumption and emissions. Ceramic composite materials in turbines enable operation at higher temperatures and reduce weight, which increases efficiency. Developing our own ceramic fibers can increase security of supply and reduce dependence on imports. Bio-based carbon fibers play a key role in the production of fuel cells for fully electric drives based on hydrogen. The DITF are leaders in the development of such materials and technologies.

Sustainability and life cycle analysis

A central challenge in the development of new materials is the assessment of their sustainability over their entire life cycle. The DITF carry out extensive life cycle analyses to quantify the ecological and economic benefits of their innovations. These analyses are crucial for the industry to make informed decisions about the implementation of new materials and technologies. Only by taking a holistic view of life cycle effects can sustainable solutions be developed and successfully brought to market.

VOLARE² – Landing gear for air taxi

In all areas of mobility, the endeavour to reduce resource consumption and the ecological footprint has established itself as an important driver of renewal and innovation. In aviation in particular, low weight is synonymous with advantages in terms of fuel consumption, emissions, range and payload. Lightweight construction is the key factor for eco-efficiency, profitability and competitiveness. This is why weight reduction using carbon fiber reinforced plastics (CFRP) is of central importance in aerospace developments.

eVTOL air taxi

The VOLARE² project uses the example of the electrically powered VoloRegion flying taxi from the Volocopter company to demonstrate the advantageous use of 3D fabrics for lightweight and efficient fiber composite construction. With the help of 3D weaving technology, a CFRP structural component of the chassis is created using a completely new lightweight construction concept. 3D weaving technology enables the production of spatially woven fiber structures as a fabric preform, whereby complex component geometries, load-optimised force transmission and joint functions can be realised thanks to the high design flexibility. The risk of the CFRP component failing under load due to delamination of the layer structure is lower with the use of 3D fabric than with the established production from several textile layers. With 3D fabric as a preform, the inherent lightweight construction potential for complex and load-bearing structures can be utilised much better. The design, optimisation, production and testing are carried out with the joint partners DLR, Volocopter and Keim.

NaMiKoSmart

As a cross-sector, cross-material and cross-national technology, lightweight construction represents significant innovation and value creation potential for local industrial structures, trade, service companies and non-profit organisations. As an "innovation driver" for the German economy, systemic lightweight construction offers many diversification opportunities for targeted further development in the automotive and electrical industries, aerospace, mechanical and plant engineering, sporting goods and construction, as well as in neighbouring sectors and market segments.

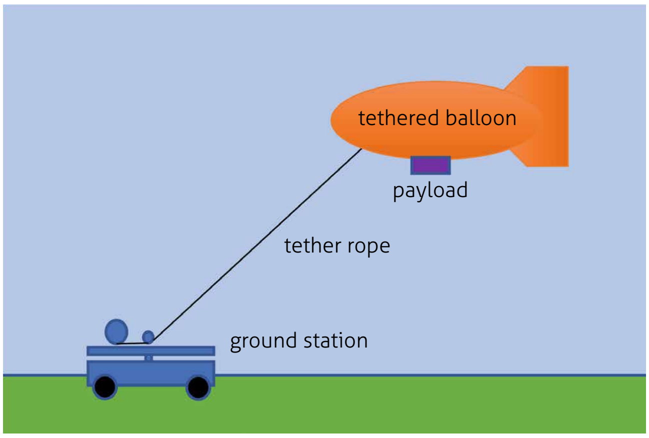
In the "NaMiKoSmart" project, the digital process chain for the three-dimensional fiber composite winding process is being developed using the example of a center console in order to ensure a consistent data structure. By defining the installation space and the subsequent topology optimisation based on the specifications, an initial rough structure is generated from which the necessary winding points are derived. The following process steps, such as beam model, CAD, winding path and robot path, are used to develop the component step by step via the digital process chain.

First demonstrator in the "NaMiKoSmart" project

The aim is to produce a lightweight yet high-strength, rigid truss structure using sustainable fiber and matrix materials that exploit the maximum strength potential of the material used. Furthermore, the lightweight construction concept is to be covered with textiles for a pleasant feel and functions such as lighting, heating and operating options are to be integrated.

ComBalloon – into the air with the textile data balloon

Although tethered balloons are known, they have so far been too inefficient in the lower payload segment and the payloads of earlier tethered balloons are heavy and have a high energy consumption, so that no tethered balloons are used in telecommunications applications in Germany. Currently, only advertising balloons are in use in good weather, but these are secured on the ground at night and have to be refilled daily.



Tethered balloon system principle

Based on this market need, the project consortium consisting of the DITF and Trans-Atmospheric Operations GmbH (TAO) is developing a special tethered balloon as part of the Invest BW project ComBalloon to perform tasks in the areas of monitoring and telecommunications, especially in all areas for a smart society. The balloon system assumes the function of a "flying" antenna mast, is quicker to set up and can be used more flexibly. It can be operated mobile on a vehicle or stationary from a platform. It can be used at variable heights, which influences the transmission and data transfer radius and therefore allows a wider range of applications to be selected.

In its sub-project, the DITF are responsible for the development, construction and testing of the textile materials such as the outer balloon cover, the internal helium-filled gas cell and the aerodynamic cladding of the tether rope. The project partner TAO Trans is responsible for the development of the aerodynamic design and the dynamics of the connection to the tether rope.

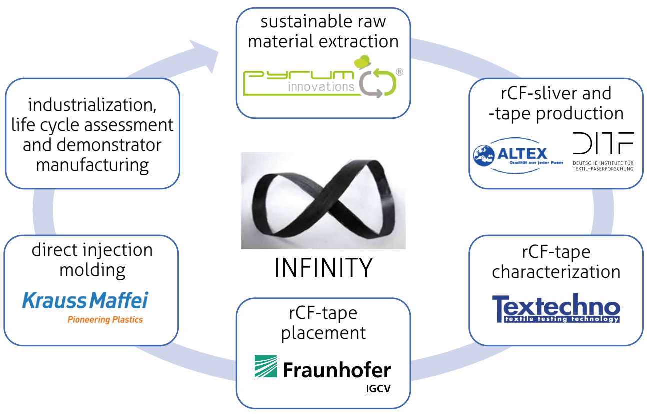
The new balloon system is intended to become a complementary data transfer platform with low capital investment and low operating costs and numerous applications.

Projekt „Infinity" – rCF Tapes for Automated Tape Laying

The aim of the project "Infinity" was to develop and establish a sustainable, efficient and fiber-friendly process cycle for carbon fiber reinforced plastics (CFRP).

The process started with an innovative pyrolysis, which, in addition to the use of high-quality recycled carbon fibers (rCF), also enabled material recycling of the pyrolysis oil produced. The fibers were reprocessed in a modified textile carding process and further processed into highly-oriented rCF tapes. By using automated tape laying technologies, these "Infinity" tapes could be laid according to the load path for use in demanding applications. In the following direct injection moulding process, the rCF intermediates were additionally functionalized by using rCF as reinforcing phase. In addition, a test system for semi-finished tape products was developed and used to continuously determine and improve the quality of the "Infinity" tapes. The study was rounded off by the production of an automotive demonstrator component and a life cycle assessment.

The rCF tape-based composite material developed achieved 88 % of the tensile strength and 89 % of the tensile modulus of a comparable virgin fiber product. In addition, the life cycle analysis showed a reduction in global warming potential of 49.3 % when using pyrolysis fibers and 65.9 % for rCF from production waste. The results thus illustrate the way to true substitution of virgin fiber CFRP instead of downcycling to low-orientated materials and the associated loss of mechanical properties.



Process chain and project partners of the "INFINITY" project

Plant-Tire: New adhesion promoter compounds made from bio-based raw materials as RF replacements

Technical elastomer products are an integral part of everyday life and plant engineering. Applications range from tires, conveyor belts and V-belts to bellows. They are made of high-strength fibers that are embedded in an elastic matrix (e.g. rubber). However, without the use of adhesion promoters to absorb the forces acting on them, the products will not perform adequately. The basic bonding agent system used in technology is condensates of resorcinol-formaldehyde (RF). These are applied to the yarns or textiles and fixed using a hot process. The problem is that formaldehyde is categorised as a CMR substance. Resorcinol is very odour-intensive and is repeatedly being discussed for listing as an SVHC substance.

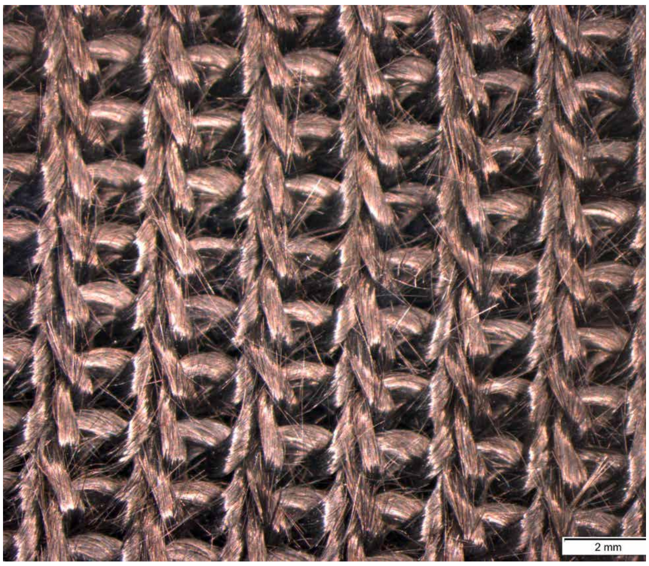
In the search for RF alternatives, work at the DITF is focussing on bio-based systems that have similar chemical and structural properties. The prerequisite is that these are able to build up the required covalently linked network structures of the adhesion promoter layer and that they can ideally be applied under comparable process conditions to conventional RF standards. As the results show, it is possible to use hydroxymethylfurfural (HMF), which is available from natural raw materials, instead of formaldehyde. This is harmless from a health point of view and has the potential to become a platform chemical for future developments in the field of adhesion promoters. Specially processed lignins from annual plants such as straw or miscanthus serve as an alternative to resorcinol. A major advantage in terms of sustainability is that the separation of the lignin-containing fractions requires less energy and time compared to wood pulping.

New carbon filament yarns – effective in processing and highly resistant

When processing carbon fibers and yarns made from them, their low elongation (< 2.0 %) is problematic. This considerably restricts their mechanical processing on textile machines, so that in principle only processing methods with low bending and shear stress can be considered. As soon as the aforementioned types of stress come to the fore, such as in sewing or stitch-forming processes, considerable damage to the carbon fibers is to be expected.

In the carbon filament yarn project, the DITF therefore developed continuous carbon fibers with increased elongation at break and a protective coating. Using irradiation methods and targeted stabilisation methods, the carbon fibers were conditioned in such a way that higher elongation was achieved. The fibers were better protected against external stresses by special coatings and yarn formation processes. After optimising these methods, the carbon fiber yarns were successfully demonstrated in a knitting and tufting process.

The new carbon fiber yarns could be used in the manufacture of wind turbines, but also in other demanding applications such as aviation. Carbon fibers made from biomass, based on the project results of yarn formation with their high elongation of > 3 %, are a forward-looking product that will have a unique selling point on the market for a long time due to the high level of expertise in Europe in the field of biomass.



RR knitted fabric made from chitosan-coated carbon filament yarns

ENERGY, ENVIRON-MENT AND RESOURCE EFFICIENCY

The DITF develop processes and systems for greater energy, environmental and resource efficiency with and for their industrial partners. This results in sustainable products and services for a wide range of applications.

- High-performance fibers from bio-polymers
- Carbon fibers from cellulose and lignin precursors
- Sustainable polymer syntheses to replace petro-based monomers
- Coatings and finishes made from renewable raw materials
- Environmentally friendly pulping processes for natural fibers
- Cellulose-based nonwovens for CO_2 absorption from the air
- Pure, sustainable single-component composites
- Solvent-free, energy-saving processes for coatings and textile finishes
- Minimal application technologies (foam, plasma, 100 % systems)
- Use of AI for parameter setting of coating and finishing machines
- Textile-based thermal solar collectors
- Energy generation through the use of technical textiles
- Economic and ecological materials for the fuel cell
- Textile materials for drinking water from mist and industrial aerosol separation
- Irrigation systems based on particularly high capillary forces and suction stresses
- Filter materials for gas/solid/liquid separation
- Recycling technologies for highper-formance fibers and coated textiles
- Analysis of biodegradation in water and soils

Energy, environment and resource efficiency

The capacities of the research field of energy, environment and resource efficiency are bundled by the DITF in two competence centers, the Competence Center for Biopolymer Materials and the Competence Center for Textile Chemistry, Environment & Energy. The DITF develop new sustainable materials, processes and systems with and for their industrial partners.

Current research work is primarily focussed on the substitution of petroleum-based materials, resource efficiency, the use of artificial intelligence and biodegradation and recycling. These are used in sustainable high-performance fibers, new biopolymer materials, filters and membrane materials for air and water purification, lightweight construction developments, insulating, sealing and insulating materials for buildings and textile-based solar cells.

Renewable energies, energy systems

To generate energy, the DITF are conducting intensive research into solar thermal energy and the storage of thermal energy – even sheep's wool shows good potential here. There are further developments in materials for hydrogen technology, in the storage of electrical energy, in systems for seawater desalination and in fiber composite materials for wind turbine rotor blades.

Textiles for environmental protection

Our environmental protection work includes filter systems for the separation of fine dust/pollen as well as aerosols from the air or exhaust gas streams and microplastics from waste water. We develop textile carrier materials for biological organisms in vertical greening, sewage treatment plants and algae production as well as innovative irrigation and water storage systems. The further development of sound absorption in the home and mobile sector continues to be a research topic. The direct absorption and desorption of carbon dioxide from the ambient air is made possible by newly developed filter materials based on nonwovens made from functionalized cellulose fibers.

Sustainable fibers and composites

In view of the debate surrounding microplastics, our research into natural fibers and polymers made from renewable raw materials that are also readily biodegradable and/or recyclable is of great importance for the future. This includes the processing of natural fibers from wood, hemp, hops, nettles and lavender, among others. Lignin, previously a waste product in paper production, shows great potential as a coating for yarns and textiles. The production of cellulose composites has a positive overall CO_2 balance. The development of reinforcing fibers, new filter materials and composite materials made from cellulose and chitin is based on HighPerCell® technology. The production of bio-based carbon fibers is on the verge of industrial implementation.

These developments are often accompanied and quantified by a life cycle analysis to assess the consumption of our natural resources and the impact on the environment.

Energy consumption in textile production

Textile finishing and coating is the most energy-intensive process in textile production. To save energy, we are working on cross-linking solid systems without solvents and reactive hot melts, on the use of minimal application technologies such as foam application processes and on innovative pre-treatment methods based on ultrasound and plasma.

The use of AI methods in textile finishing makes it possible to create expert systems that save the user resources.

Flexwood – a sustainable leather alternative made from cellulose and lignin

Materials made from domestic, renewable raw materials are becoming increasingly attractive as they reduce CO_2 emissions, prevent microplastics from entering the environment and close the material cycle. Building on this market demand, the project consortium, consisting of Schorn & Groh GmbH, Ribler GmbH and DITF Denkendorf, is developing a new decorative material made from various natural components.

The highly flexible composite material NUO from project partner Schorn & Groh GmbH

This composite material "FlexWood" consists of a decorative layer of wood from sustainable forestry in the form of a thin veneer layer and a textile based on cellulose-based natural fiber materials, which is laminated to the back of the wood veneer for stabilization. Until now, polyurethane films or polyurethane dispersions have been used to bond the textile to the wood veneer. In this project, a sustainable new solution based on lignin is being developed as an adhesive system for the required lamination. Lignin is a waste product of the paper industry.

After lamination, only the thin veneer layer is cut into small segments with a laser beam, leaving the underlying textile intact. The fine engraving gives the wood surface its flexibility and pleasant feel. Due to the resulting extreme bending and draping properties, this composite material can be used as a decorative surface in automotive interiors, interior design, furniture construction, clothing and many other industries and sectors.

BiPoTex: Biopolymers from bacteria protect technical textiles

Textiles for technical applications obtain their special functions through coatings. However, these do not usually fulfil sustainability criteria as they are of fossil origin, non-biodegradable and difficult to recycle.

Coatings made from biotechnologically producible polyhydroxyalkanoates (PHA) can provide a remedy. They are produced from renewable raw materials and are completely biodegradable when released into the environment. Polyhydroxyalkanoates have the advantage that their properties can be customised by varying the molecular structure of the repeating unit during biosynthesis. This means that water-repellent and at the same time mechanically resilient coatings can be produced. As a result, they offer a good basis for use in the automotive sector and also for outdoor clothing. In addition, PHA products are increasingly available on the market, making PHA coatings attractive for technical applications in the future.

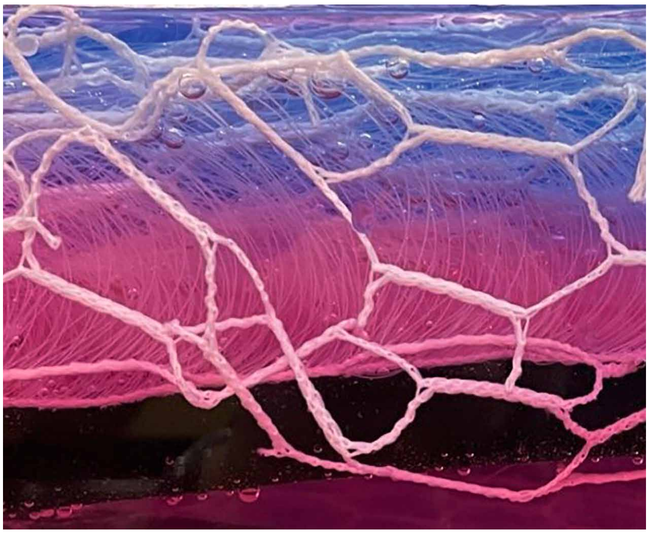
The DITF have already carried out successful research work in this area. Coatings on cotton yarns and fabrics as well as polyamide and polyester showed smooth and well-adhering coatings. Depending on the variation of the side chain, the coated textiles differ in important parameters such as handle, stiffness and wash resistance.

Close-up of a cotton yarn coated with PHA

Sustainable, flexible, space-saving: greywater treatment with 3D textiles

The demand for water in Germany is increasing and used water is not being utilised sufficiently. Greywater in particular, i.e. wastewater from showers, bathtubs and hand basins, offers great potential for further use. It can be treated on site to service water quality and reused for flushing toilets or watering gardens, for example.

Around 50 to 80 percent of all domestic wastewater is grey water. In order to treat it and return it to the cycle, large containers and tanks are required, which take up a lot of space in the building.



3D spacer textile

Together with their project partner ARIS, the DITF have developed a new biological, textile-based system. It is based on a 3D spacer fabric made of highly durable polypropylene. Its advantage is that it can be installed flat and is therefore extremely space-saving. Thanks to its special system geometry, it can be installed in places that would otherwise remain unused - for example under the floor of a new underground car park, on a flat roof or in the garden. It can be modularly adapted to the water requirements and structural conditions in the respective buildings. Even vertical solutions on façades can be realised.

The system developed by the project partners requires little maintenance and is therefore particularly cost-effective. Compared to previous solutions, it is characterised by a long service life. ARIS plans to commission the new textile-based greywater treatment system in 2024.

Product carbon footprint for textile products and processes

As part of the Green Deal, the EU is planning to require companies to determine and publish the product carbon footprint (PCF) of their products in future. There is a standardized process for this in accordance with ISO 14067:2018. The values vary greatly depending on the material used, the specific process and the energy sources used and must be calculated individually.

The multi-stage nature of textile manufacturing processes increases complexity. The DITF work here with the MFCA method (Material Flow Cost Accounting) and have developed extensive model libraries for common textile production processes, including circular economy approaches (eco-design, recycling).

Three in one: material efficiency, economy and ecology

The special feature of this MFCA method is the possibility of combining different issues in one model: material efficiency, ecology and economy. The focus here is on the use, consumption or loss of resources such as materials, energy, time and costs. Furthermore, new materials, recyclates and recycling processes can be seamlessly integrated into the models. In this way, different scenarios can be developed, simulated and evaluated in order to support well-founded decisions in production and product development.

Determination of the product carbon footprint (PCF) planned

The Center for Management Research at the DITF offers a range of workshops, from initial familiarisation with the methodology to its productive use for calculating complete product ranges or comparing alternative product variants and process technologies.

Bio-based and biodegradable nonwovens made from the biopolymer polyhydroxybutyrate (PHB)

The use of bioplastics opens the potential for a fundamental contribution to a future conservation of resources and to avoid further environmental pollution. Polyhydroxybutyrate (PHB) can act as substitute for olefin-based polymers, is biobased, biodegradable and can be produced via biosynthesis by bacteria strains. The degradability can create closed product loops (C2C). Despite these advantages, PHB is not very suitable for a number of industrial processes and applications. The main reasons for this are slow, but then very strong crystallization, which entails long cycle times in processing as well as embrittlement and also a high melt adhesion ("stickiness"). This is where the research project biobased polymer for product development "PHB2Pro" comes in.

Meltblown, biobased and biodegradable plant pots, made of PHB

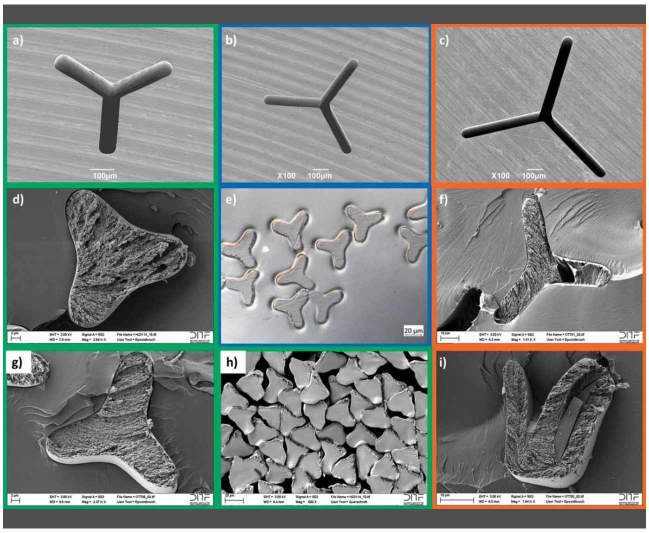
The successful production of meltblown nonwovens without the use of additives was successfully demonstrated by the DITF. Furthermore, the mentioned negative properties for other processes could be used to develop a single-stage process step for the production of meltblown 3D parts, currently still semi-automated. It delivers temperature- and dimensionally stable products (e.g. plant pots). Property constellations, such as a high air permeability combined with minimal water permeability, open up interesting aspects.

Aim of the project partners (DITF, NOVIS and IKT Stuttgart) is to make the PHB production CO_2-neutral, more cost-effective by use of genetically modified, CO_2-consuming microalgae, and to tailor the PHB for the application.

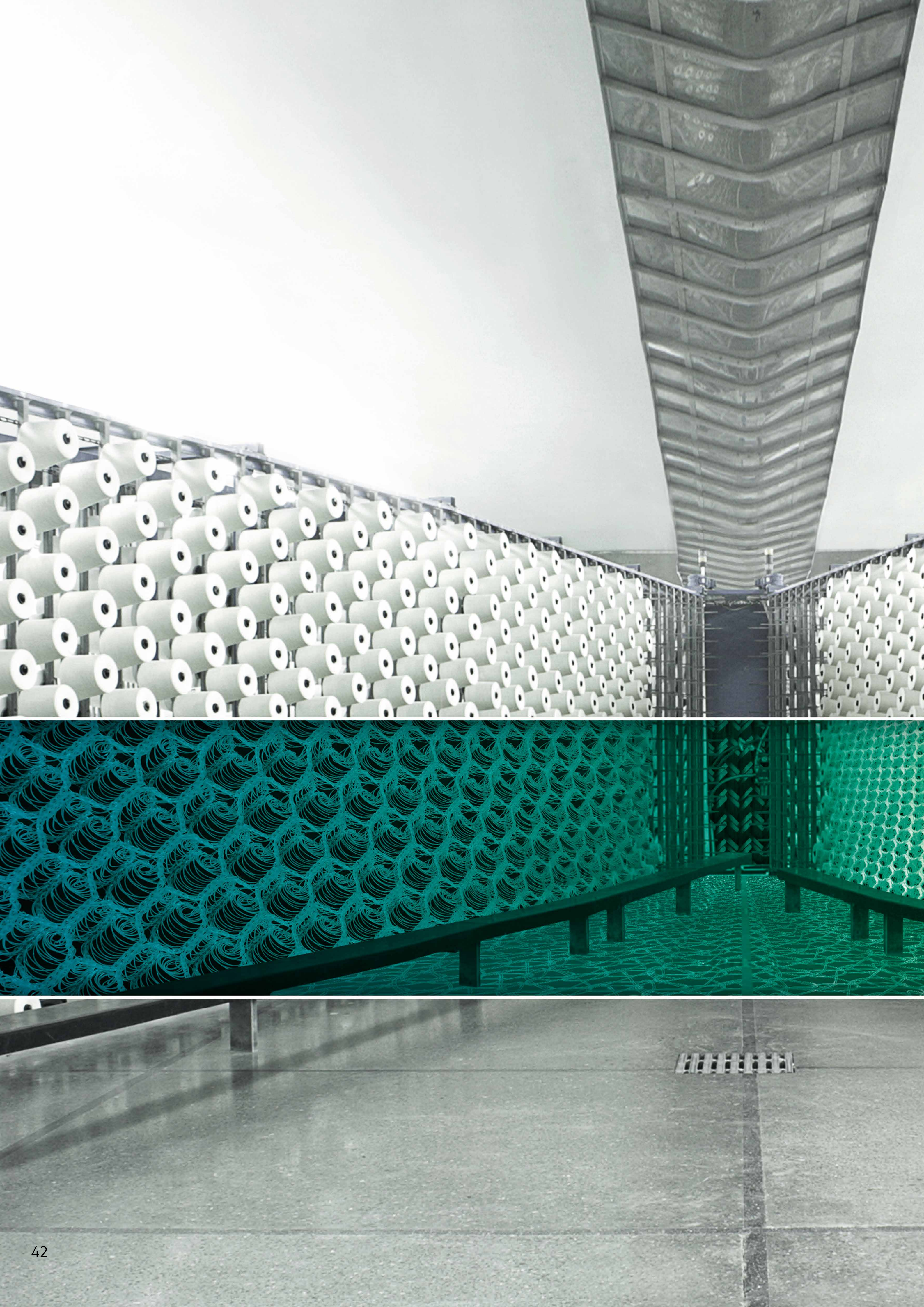
NextSpin: Cellulose filaments with variable cross-sectional shapes

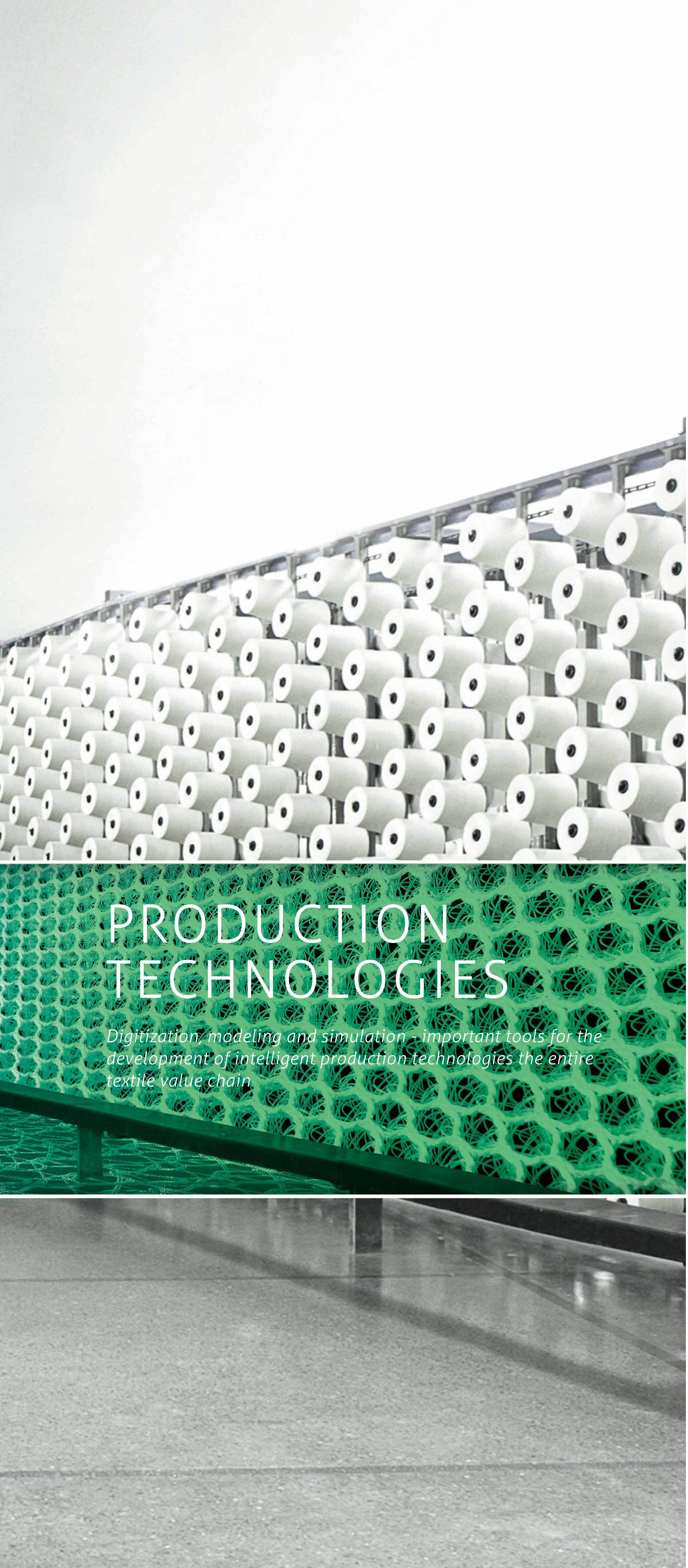
Around 3.2 million tonnes of microplastics are released into the environment every year, around 1.5 million tonnes of which end up in the oceans. Synthetic textiles account for 35 % of this. As an alternative to synthetic plastic fibers, only limited technical fibers based on cellulose have been used today. These are 100 % biodegradable and can be broken down in sewage treatment plants within two months. Synthetic fibers practically do not degrade within the same time.

The aim of the SMU project "NextSpin" was to produce technical-grade filament cellulose fibers with variable cross-sections. Two new technological processes were combined here. An ultrashort pulse laser (USP laser) was used to produce spinnerets with smaller holes and greater freedom of geometry. At the same time, ionic liquids (IL) were used as direct solvents for the biopolymers (cellulose) in the HighPerCell® spinning process. For the first time, profiled, environmentally friendly, technical cellulose fibers could be produced as a substitute for plastic fibers for both textile and technical applications, for example as filtration media.



Trilobal geometries with different leg lengths and -widths. The width of the geometry varies from a) 70 µm, b) 35 µm to c) 50 µm





PRODUCTION TECHNOLOGIES

Digitization, modeling and simulation - important tools for the development of intelligent production technologies the entire textile value chain

- Intelligent process control systems
- Digital technologies for the Industry 4.0
- Microfactories for the digitally networked production
- Textile functionalization with modern technologies
- Systems for human-machine interaction
- Modeling and simulation of processes as a basis for effective process optimization
- New processes for the manufacture printed sensors and actuators on textile

Production technologies

The DITF are the leading partner for industry in the fields of textile process engineering and textile and fiber chemistry. But we are also the preferred development partner for non-textile companies that see the advantages of fiber-based materials in new fields of application. Production technologies are the largest area of research in the DITF's fields of application. Current research focuses result from the technological change brought about by digitalisation and artificial intelligence as well as the global challenges in the areas of climate protection, energy and resource efficiency.

Technologies and processes for the circular economy

In the light of the bioeconomy and the energy crisis, increasingly sustainable, environmentally friendly and resource-saving production technologies are being developed. Terms and practices such as recycling or cradle-to-grave are being replaced by the demand for textile products to be recyclable.

In addition, the globally disrupted supply chains are forcing the sourcing of (recycled) raw materials to be as regional as possible, accompanied by a reduction in transport routes. The raw and recyclable materials should remain in the country and also be processed there. This requires the development of processing and recycling technologies as well as new materials. New process technologies are needed to complete the final step from end-of-life product to spinnable fiber in the circular economy chain

Carbon fibers have a high CO_2 footprint, which raises questions about their environmental compatibility. In order to be able to continue to use these outstanding properties to a limited extent, developments in the area of bio-based carbon fibers and energy-reduced production as well as corresponding recycling technologies and processes must be developed.

Digital transformation across the entire production chain

Digitalization – together with automation – is becoming a game changer in the industry to meet the challenges of performance, productivity, flexibility and sustainability. The aim is to seamlessly integrate the value chain from design to production, service and recycling. The digital twin is a key concept for Industry 4.0 and an effective tool for rapid product launch, flexible production and data-driven performance optimization. Optimizations in sensor technology will enable further increases in process reliability and energy savings.

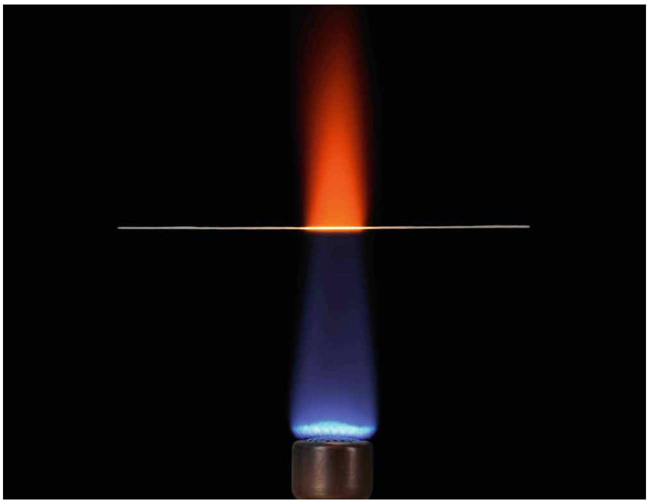
Human-machine interaction and collaboration will continue to increase in production. Machine learning and AI support process optimisation, production analysis and monitoring. AI can predict machine and equipment downtime by continuously analysing data from sensors and other sources and making predictions. This enables AI to monitor important processes in real time and automatically execute appropriate control actions.

Application-orientated research on 25,000 m^2 area

Industrial production technologies are available at the DITF on an area of 25,000 m^2, which are utilized, modified or further developed for customer requirements. Production processes for the manufacture of fiber-based composites, 3D textile structures, digitally printed textile structures, high-performance fibers, etc. are all available under one roof. The machinery enables pilot and small series production close to industrial reality. System prototypes are developed, constructed and put into operation in a wide variety of projects.

DITF pilot line: Further development of ceramic fiber technology

In collaboration with the French company Saint-Gobain (Advanced Ceramic Composites business unit), the pilot line for the production of oxide ceramic fibers at the DITF is being further optimized. The aim is to create ideal conditions for the industrial production of aluminum oxide and mullite fibers. The complex, multi-stage manufacturing process for ceramic fibers, which is divided into the production of a suitable spinning dope, a dry spinning process and calcination and sintering, must be designed in such a way that high-quality fibers can be reproducibly produced at high productivity with minimal energy requirements.



Thermostable ceramic fibers

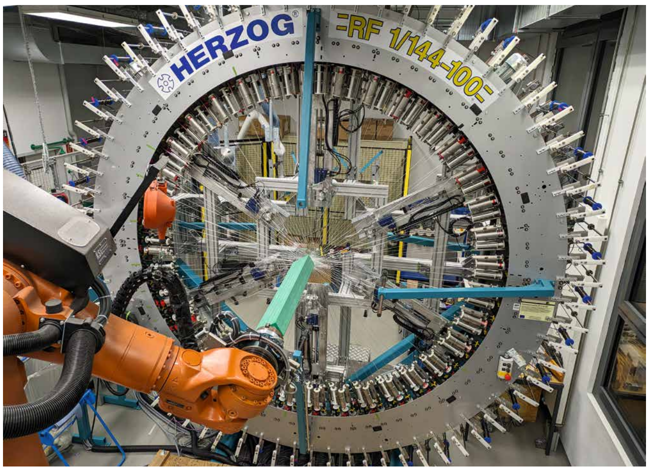
The influence of individual process parameters on the structure formation and final properties of the fibers is currently being investigated in great detail. In addition to our own work at the DITF, we are also cooperating with a research team from the Université PSL, Mines Paris, Center des Matériaux (MAT) via Saint-Gobain. In order to further improve the mechanical properties of the fibers, for example, possible fracture-causing defects are detected and fracture mechanisms are analyzed.

In addition to carrying out fundamental investigations during the process, investments were also made in technical equipment. A newly procured horizontal tube furnace, which can be operated at temperatures of up to 1,600 °C, now complements the existing sintering furnace. This makes it possible to study the sintering process even better with regard to the influence of dwell time and temperature on the final strength of the fibers.

FlexiRing

Through the targeted use of fibers and matrix in a composite component, fiber composite technology enables high strength and rigidity at a low weight. FRPs have long been used in the aerospace industry, and are also increasingly being used in the automotive, mechanical engineering, construction and sports equipment industries - with continuing excellent economic prospects. Braiding technology is an increasingly widespread process for the production of fiber-reinforced composites. On the one hand, endless braided tubes are cut to length, pulled over each other several times and consolidated. On the other hand, braiding is a direct process in which a robot guides a mould core through the braiding ring of a braiding machine.

By braiding the core several times, the preform is produced directly on the core in the final mould. This robot-assisted direct braiding of a core is a widespread and efficient process for producing complex preforms. For the best possible component properties, the fibers in this process must lie directly against the core and thus ideally reproduce the shape of the core. Precise guidance of the core through the braiding ring and the smallest possible and regular distance between the braiding ring and the core are crucial for optimally adapting the braiding to the geometry of the braided core. Changing and complex core geometries, as well as branched components, can be braided with the braiding ring developed in the project, which consists of six segments and adapts to the contour, the flex ring. This means that the braiding process can be made even more cost-effective and further established in lightweight construction.



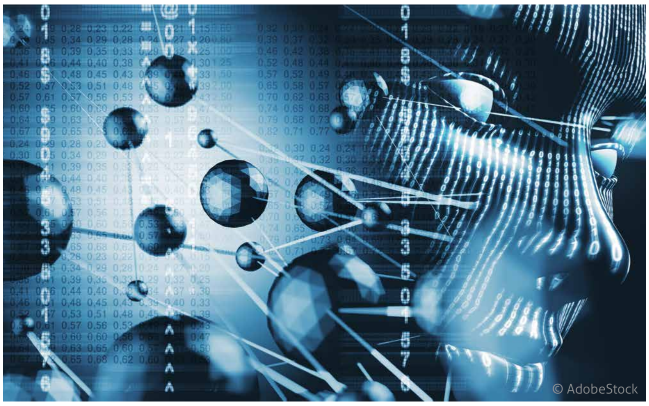
Radial braiding machine with FlexiRing installed

Digital twins and AI at the interface between development and production

The development of textile products is associated with high material, time, personnel and cost expenditure. The development process is characterized by an empirical approach based on the expertise of long-standing specialists. Due to demographic structure of employees in the textile industry and the general shortage of skilled workers, the long-term transfer of knowledge is at risk. Expert knowledge is hardly documented and therefore cannot be retrieved and reproduced at any time. This applies in particular to the development and manufacture of textile products with long product life cycles, complex manufacturing processes or cost-intensive raw materials or semi-finished products. The challenge is to ensure consistent product quality across many production batches with varying raw material qualities. At the same time, all stakeholders are expected to operate in a way that conserves resources.

Digital twins aggregate knowledge within the company

In several national (e.g. IGF no. 22002 N) and regional (e.g. BAW WM33-42-47/149/6) joint projects, the Center for Management Research is developing digital material and process twins, which are used to aggregate information about processes, materials and products. On the one hand, the creation of models provides a platform for discussions and a common understanding in the companies and thus contributes to the transfer of knowledge to the next generation of specialists. On the other hand, the digital twins with their consistently recorded information form the ideal basis for gaining insights for development and production with the help of AI. These are the rapid stabilization of processes, the optimization of settings in complex multi-stage processes or the use of recycled materials with fluctuating qualities.



Commissioning of the new spinning technology center

With support from the state of Baden-Württemberg, the DITF have modernised their melt spinning technology center and significantly expanded it with a bicomponent spinning system from Oerlikon Neumag. The new facility enables research into new spinning processes, sustainable fibers made from biodegradable and bio-based polymers and fiber functionalization. In order to protect the environment and resources, more bio-based fibers will be used in the future and the fibers will be easier to recycle after use. The modernised spinning technology center now offers ideal conditions for these future tasks.

Bi-component BCF spinning system from Oerlikon Neumag

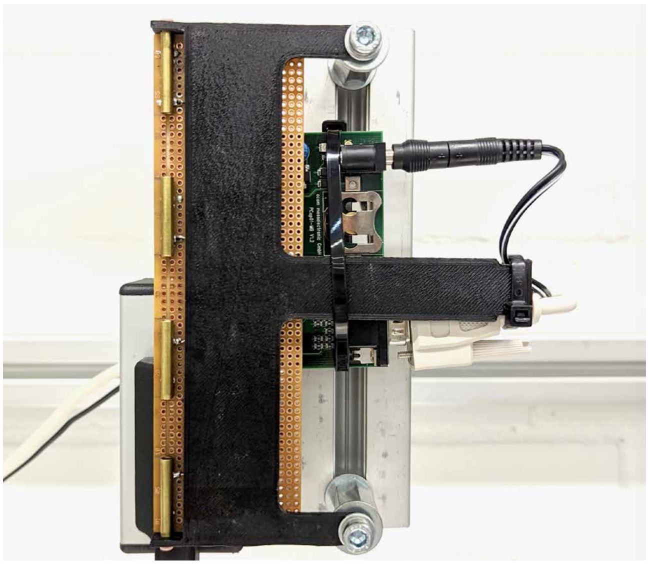
The new bicomponent spinning system was built and commissioned on an industrial scale. The BCF process (bulk continuous filaments) allows special bundling, bulking and processing of the (multifilament) fibers. This process enables the large-scale synthesis of carpet yarns as well as staple fiber production, a unique selling point in a public research institute. The system is supplemented by a so-called spinline rheometer. This allows a range of measurement-specific chemical and physical data to be recorded online and inline, which will contribute to a better understanding of fiber formation. In addition, a new compounder will be used for the development of functionalized polymers and for the energy-saving thermomechanical recycling of textile waste.

The new melt spinning technology center at the DITF offers a highly modern and well-equipped environment for the development and application of new materials and man-made fibers.

Contactless yarn sensor for quality control of sensor yarns

The CRC sensor is a new non-contact, cost-effective sensor principle that can detect defects in the conductive properties of running yarns during production. The potential user group ranges from yarn manufacturers to manufacturers of textile fabrics and manufacturers of smart textiles.

Reliable detection of defects in the conductive properties enables the use of flexible production processes and therefore also the manufacture of individualized products. For many smart products, this is a basic prerequisite for successful market access and cost-effective production, which requires very high process efficiency with low error rates. This is particularly important for e-textiles, as process errors relating to the electronic properties could previously only be detected through complex checks after the individual production steps. The increased and inflexible inspection effort is a major price driver. Errors relating to the intelligent additional functions are typically only detected at the end of the value chain.



CRC sensor for error detection during production

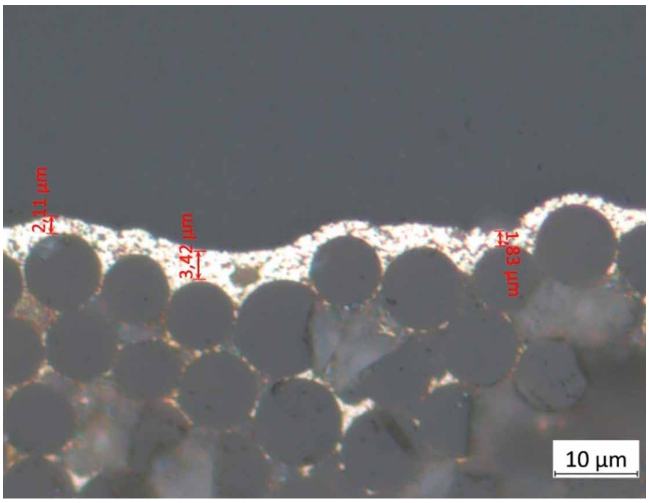
With the new CRC sensor principle, it will be possible for SMEs to immediately detect faulty parts in terms of their electrical properties and sort them out early on in the process chain without additional effort. This will significantly improve quality and reduce the manufacturing costs of smart textiles. The measuring principle received the Show Stopper Award in the "Devices and Tools" category at the Advanced Textile EXPO in Orlando.

Highly conductive inks and laser processes for sintering them

Textiles with integrated electronics represent a rapidly growing market. In most cases, their production is still very complex and cost-intensive. Printing-based production methods could fundamentally simplify processes and reduce costs. Low-resistance conductor tracks and contacts are required, which also have high bending resistance.

Laser sintering of printed structures

As part of the "DruLas" project, electrically conductive inks based on copper and silver were investigated and corresponding formulations developed that can be applied to textile materials using digital printing processes (inkjet, chromojet and dispenser) and conduct electricity. A special pre-treatment was used to achieve a surface pressure that is crucial for the formation of a metallic and conductive layer during sintering. The pre-treatment can be applied using padding or digital printing. By sintering with laser beams, particularly low-resistance prints could be obtained (R<<1 Ohm/sqr). The electrically conductive layers produced can withstand more than 10,000 bending stresses. Contrary to the originally planned combination device consisting of a digital printer and laser device, it has proven to be more practical not to combine the printing application and laser treatment in one device due to synchronisation problems. Sintering downstream of the printing process using a CNC-controlled laser is more advantageous. Suitable parameters for the printing application and laser treatment have been developed.



Cross-section of an electrically conductive print treated with laser

CLOTHING AND HOME TEXTILES

New and further development of textiles and processes. For more comfort, functionality, and sustainability.

- > New fibers and technologies to improve mechanical, haptic, optical, or acoustic properties
- > Antibacterial and antiviral finishes
- > Development of fluorine-free and formaldehyde-free finishing processes
- > Development of highly efficient halogen-free flame retardant finishes and coatings
- > Finishing via physical processes (UV, ESH, plasma)
- > Innovative carrier-free dyeing processes for high-performance fibers
- > New dyeing systems for NIR camouflage
- > Textiles with selective remission or reflection of thermal and IR radiation
- > Compressive sports textiles
- > Coated textiles, membranes, and laminates for comfort and security
- > Textiles for art and light applications
- > Sensor and actuator textiles through integration or printing on the respective circuitry, as well as fluorescent or electroluminescent colors and pigments
- > Digital coloring and functionalization of textile procedures
- > Textile lettering procedures for traceability and prevention of counterfeiting
- > Virtual product development and retailer feedback processes within the clothing industry

Clothing and home textiles

Away from "fast fashion" towards sustainable production

The adoption of the "Green Deal" by the EU Commission in March 2022 and the Ecodesign for Sustainable Products-Regulation have a serious impact on large parts of the textile economy. The EU's goal is to achieve climate neutrality by 2045, which requires a radical rethink from "fast fashion" to sustainable production. Manufacturers of fibers and textiles are being forced to refocus and to reorganise. Key words such as "circular economy", "sustainability" and "life cycle assessment" are now part of everyday language in the textile industry. Textiles with a short life time, poor recyclability, a severe product carbon footprint or the potential for long-term accumulation in the environment must be replaced by sustainable and circular fiber-based materials and products. Textiles and textile composites that are as pure as possible make recycling much easier or even possible in the first place. One focus of research at the DITF is therefore on bio-based polymers for fiber materials and coatings and including recyclabilty.

Textile recycling and circular economy

As ITMA 2023 in Milan showed, the topic of "Textile recycling" is currently the dominant topic in the industry. The associated challenges have been and are currently being addressed in several research projects at the DITF. In the clothing sector, there are three EU projects in particular that are pursuing different approaches. For example, the "Herewear" project is attempting to make cellulose from various raw material sources, such as straw, usable for fiber production (see the following article on the project). The basis for this is the "HighPerCell" technology developed at the DITF. In the project "Solstice" is the DITF's mission to develop a new process for recycling polyamides and aramids in particular. The companies involved form the entire process chain. The "FiberLoop" project focuses on closing the loop in certain manufacturing processes and supply chains. A major challenge will be to develop validated analytical methods for determining the proportion of recycled fibers in textiles and to make these available to the industry.

Digital engineering and transparency in supply chains

Regulatory changes – such as the Supply Chain Due Diligence Act or greenwashing – are challenging the industry. Fundamental changes need to take place, which can be achieved through regional development and supply networks, among other things. This requires a fully networked, integrated chain for an on-demand network that uses digital technologies and enables individualised production based on demand. At the same time, these chains must be transparent and provide information on the carbon footprint and, increasingly, on water consumption. This will become regulative, known as Digital Product Passport (DPP). In a multifunctional laboratory, the DITF demonstrate the possibilities of digitalization and show the way for customised corporate solutions. A central focus here is the modelling and integration of individual value creation stages and steps as well as supply chains with regard to ecological and economical aspects. End-to-end digital engineering from design to product is a milestone in the digital transformation, and not just from a technical perspective. Fully integrated, highly automated digital process chains also make completely new business models possible. As compact microfactories for the regional or urban production of small batches or customised, individualized items, they address current market needs.

Flexidress made from straw-based cellulose filaments

The HEREWAER project aims to create a European circular economy for locally produced textiles and clothing made from bio-based resources.

The Flexidress shows the successful collaboration between the project partners involved: researchers at the TNO (Netherlands Organisation for Applied Scientific Research) provided sustainably produced cellulose. The cellulose filaments were produced using HighPerCell® technology in the DITF's spinning technology centers. At the same time, the designers of the fashion label Vretena created the design for the flexible, two-piece dress, which can be knitted into shape without cutting waste. The dress was knitted and made up by textile engineers and technicians from the DITF in the institutes' technical center.

From straw to sustainable flexidress

In addition, the "Value Chain" and "Digital Twins" for the digital traceability of the production processes were created at the DITF.

The result is sustainable clothing, produced in a local cycle, made from bio-based raw materials, which can be converted back into secondary raw materials without waste and remnants, and digitally traceable.

Circular knitted pressure sensors

The DITF and the producer of knitted fabrics roma-Strickstoff-Fabrik Rolf Mayer GmbH & Co. KG combined the advantages of the circular knitted fabrics, such as bending elasticity, dimensional malleability, a pleasant feel and a wide range of visual design options with the functionality of a force sensor. As part of a ZIM project, we developed, evaluated and implemented reliable sensor designs using computer tomography. The project developed a basis for the simulation and optimization of knitted sensors. The results are circular knitted fabrics with reliable sensor functionality while maintaining a good look and feel. The size, number and distribution of the sensors can be customised according to the requirements of the application.

Practical test: Pressure-sensing chair

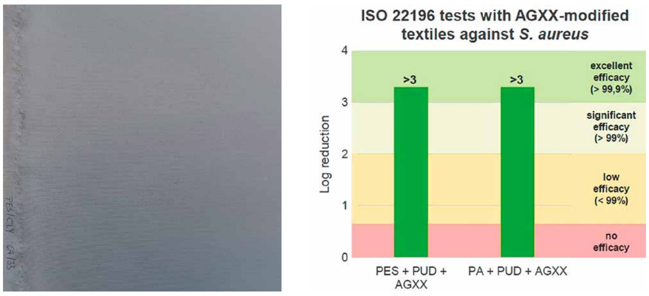
To demonstrate its function, we integrated the knitted sensor fabric into an office chair with four sensor patches each in the backrest and the seat area underneath the upholstery fabric. The textile-based sensors are connected to a microcontroller with a Bluetooth module located underneath of the chair. The developed software enables the determination of seat occupancy and sitting position. A color change from green to red on a tablet via an app with a graphic representation of the chair and the sensors visualises an increasing pressure load. The demonstrator clearly showcases the functionality and potential of the developed circular knitting sensors for industry.

Pressure-sensing chair

Antibacterial fibers and coatings with AGXX particles for textile applications

In Germany alone 400,000 to 600,000 patients annually contract hospital-acquired infections, a portion of which can be prevented or influenced. Against this background, the use of antimicrobial functionalized clothing by hospital or care personnel therefore plays a significant role in minimizing the spread of bacteria and viruses.

The mechanism of action of AGXX is based on a catalytic redox reaction converting humidity and oxygen into reactive oxygen species (ROS) that eventually kill the microorganisms. The effectiveness of AGXX has already been proven against more than 130 different microorganisms, including germs with multiple resistances against antibiotics, e. g. MRSA, or against conventional silver leaching technologies, such as certain E.coli types.



The polyester/lyocell fabric treated with 0.66 % by weight AGXX (left); antimicrobial efficacy of textiles treated with AGXX, using the example of polyester and polyamide fabrics (right)

As the catalytic AGXX technology is neither based on metal ion leaching as conventional silver technologies nor on the release of any environmentally harmful substances, it is not consumed over time and has a long-lasting effect.

In a joint project the DITF and Heraeus are working on the incorporation of AGXX into medical textiles, in the form of fiber additives and surface coatings. The tests show that AGXX has an excellent antimicrobial effect in fibers and textile coatings. Extended laboratory tests are currently being carried out on the effect, resistance and properties of use.

The economic exploitability aims at establishing and expanding the use of AGXX particles in everyday, occupational and medical applications. In addition to the application intended here for the treatment of workwear for sick and nursing staff the potential for adaptation to other applications is considered to be very high.

A pressure-sensing mat for balance training

Balance exercises strengthen the muscles, promote balanced movements, thus preventing the risk of falling. For this reason, the DITF developed a pressure-sensing mat to improve balance sense.

Two sensors out of piezoresistive nonwovens are integrated into the mat to measure the pressure. A blend of sensory and non-sensory fibers was used to detect the weight shift of an adult and allows the material to recover after pressure was applied, ensuring a reproducible signal. The fibrous structure also allows the sensor material to be more resistant to fatigue than film sensors.

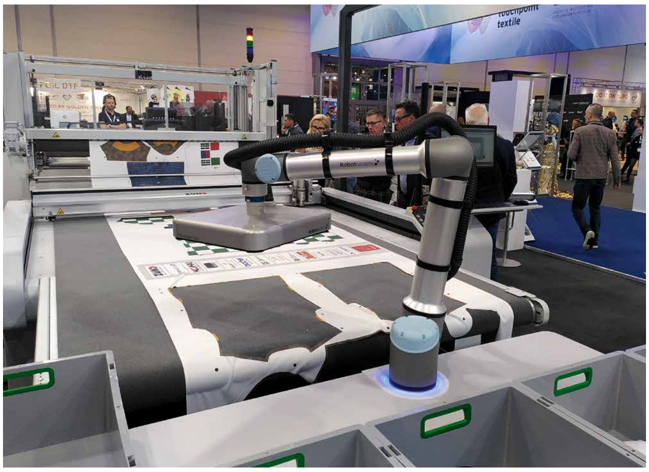
The textile sensors generated this way are used in this mat to control a game. They are connected to two LED strips via a microcontroller. The upper strip indicates the position to be reached by means of a light signal. The light signal on the bottom strip can be moved to the left or right by shifting weight. Once the two signals are aligned, the position must be held for 5 seconds. If successful, a new challenge is set. The game ends after five rounds.

Sensor mat for balance exercises

In today's society, health problems due to lack of exercise, poor posture or incorrect weight bearing are on the increase. E-textiles can analyse strain and movement and motivate us to prevent damage in an intuitive and playful way.

Blueprints for configuring a Digital Textile Microfactory

A digital textile microfactory enables the design, development and production of sustainable textiles in small quantities, tailored to individual needs. The DITF develops concepts, blueprints and business models for this purpose, thus enabling the realization of such microfactories.



Digital Textile Microfactory, exhibited at drupa

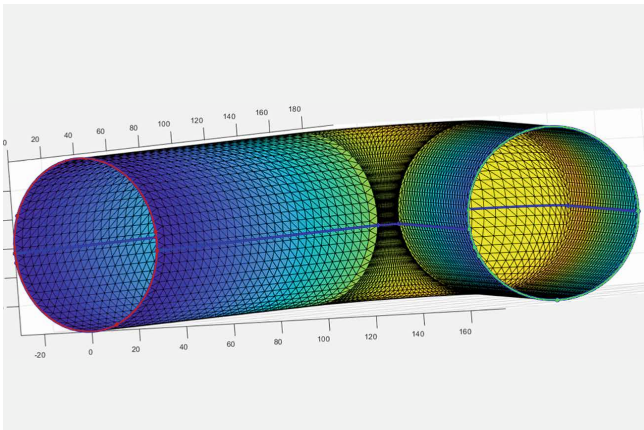
The centerpiece is an integrated production line with design, textile printing, cutting and robot-supported garment preparation. The end-to-end digital design links all process steps from individual textile samples and garment configuration, including 3D simulation and visualisation, to the generation of machine control data, for example for colour-accurate printing.

Such a microfactory can operate independently. However, connecting several (similar) microfactories makes sense and is easy to realise in order to adjust capacity. Further digitally networked process stages such as weaving, knitting and finishing can be integrated by digitising and interoperating the machines. The individual components of a microfactory (machines, systems and software) are offered commercially by leading companies. The DITF provide support with selection and configuration. The DITF's Center of Management Research (MR) has developed a project-oriented approach for this purpose. The core elements are blueprints of the master diagram and the business model. The development and initial validations were carried out as part of the EU project HEREWEAR (https://herewear.eu/). MR is working on the integration of additional processes to further develop the transformation to a circular economy.

Addknit: From 3D scan to knitted fabric

As part of the IGF research project Addknit, the DITF have created a process model for the development of individualised knitted fabrics that covers all steps from the definition of requirements to the knitted product. The requirements profile includes all the properties necessary to characterise the finished product. For realisation, a division is made into physical properties of the surface and properties of the 3D model.

The surface properties are taken into account by selecting the material mix and weave. The stitch size depends on the material and weave and is determined in the process model by material tests. The Matlab algorithm developed by the DITF calculates a knitted jacquard from a 3D model, for which the stitch size is the key parameter. The starting point for the 3D models can be scanned or CAD-generated 3D models, which are first reduced to the surface to be knitted and adapted if necessary.



3D model visualised in the Addknit software

The knitted jacquard created in this way can be converted into knitting programmes using software interpreters from various machine manufacturers. For this purpose, a symbol or colour is defined once for each knitting operation in the knitting algorithm and created accordingly in the interpreter. The knitting programme is loaded onto the flat knitting machine and knitted with the appropriate yarn count.

The knitted product is equipped according to the specifications in the requirements profile and the accuracy of fit of the product to the original 3D model is checked. Optical processes such as comparative 3D scans can be used for this purpose.

DITF BODIES

The DITF – founded in 1921 – are a non-profit research institution in the legal form of a foundation under public law. They fall under the jurisdiction of the Baden-Württemberg Ministry of Economic Affairs, Labor and Tourism.

The supervisory body of the DITF is the Board of Trustees. It advises the Management Board on questions of professional and structural orientation and includes representatives from science and business administration and representatives from the ministries of Economic Affairs, Labor and Tourism as well as Science, Research and Art of the state of Baden-Württemberg. The scientific advisory committees of the research institutes provide topic-specific advice directly to the specific fields.

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