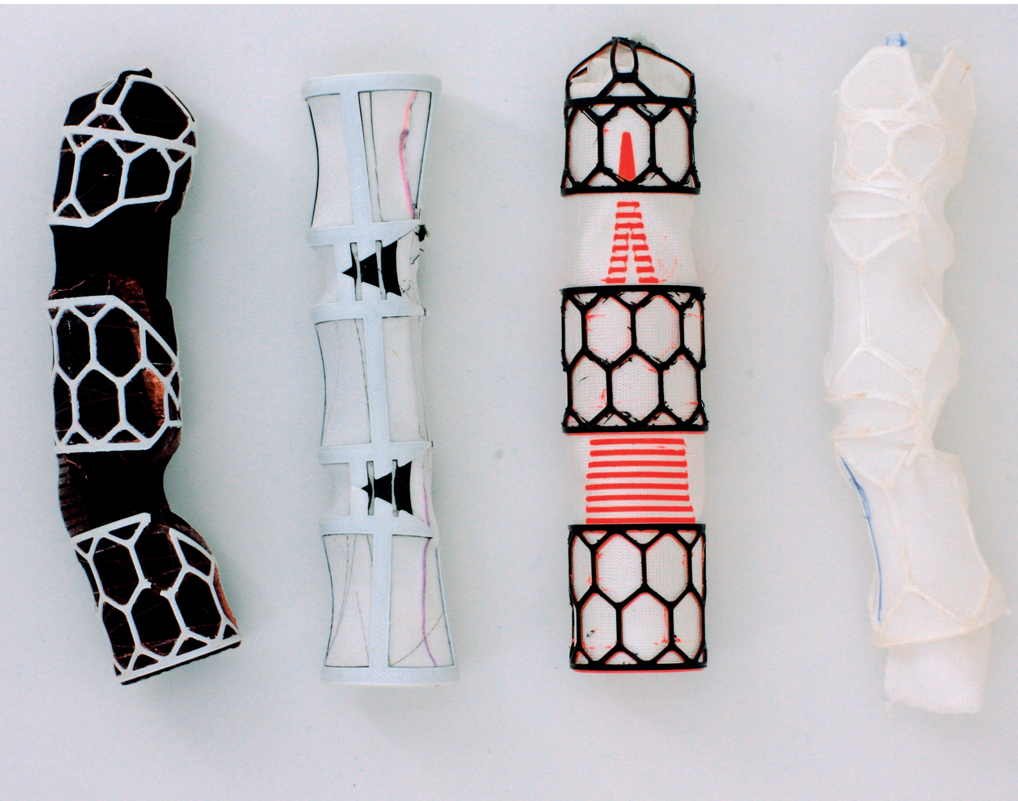
From Static to Adaptive Products with 4D Textiles

Into the Fourth Dimension with 3D Printing

Textile structures can be equipped with shape-changing properties at all stages of their production. So-called 4D textiles are created. They offer great advantages for medical technology and protective clothing. They can be manufactured by printing a pre-stressed textile using FDM printer.



4D materials are ideal for personalized medical technology such as orthoses. © ITA

The demands on products and components are constantly changing. This requires adaptable materials and structures. At the same time, resources should be saved and therefore less material used. Novel materials must be able to withstand these changes and the structures should be programmed to learn from the changes and react accordingly. Textile structures can be programmed at all stages of their production: functionality can be added at the level of fibers, yarns and fabrics and subsequently through additive manufacturing. In addition, there are textiles that change their form or function through an external stimulus. Such textiles are called 4D textiles (**Box**).

One research focus at the Institut für Textiltechnik (ITA) at RWTH Aachen University in recent years has been on multi-material structures consisting of textile membranes with polymer beam structures 3D-printed on top. The textile membrane can store mechanical energy. By releasing the stored energy, a two-dimensional structure becomes a three-dimensional structure with bistable behavior. The stable states are two different three-dimensional forms of the structure. The change between the stable states can be activated by external stimuli such as heat, electricity or moisture. This can lead to a change in function. It is now possible to program such structures. However, the accuracy still needs to be improved.

Production of the 4D Textiles

To produce the structures FDM 3D printers (Fused Deposition Modeling) are used (**Fig. 1**). Recent advances at ITA have been made with silicone 3D printing on pre-stressed textile (**Fig. 2**). Previous research at the ITA has already used various filaments such as polylactide (PLA), acrylonitrile butadiene styrene (ABS) and thermoplastic polyurethane (TPU) to produce 4D textiles.

The most used thermoplastic filament is PLA. The polymer, which is made up of lactic acid molecules, is characterized by its biocompatible and biodegradable properties. It is also easily recyclable due to its molecular structure. The decomposition of pure PLA, unlike many other polymers such as ABS, is not hazardous to health as no harmful vapors are produced. This is particularly important for the medical of great importance. Furthermore, printing with PLA on a textile substrate has been proven to have the highest adhesion. However, compared to other types of filament, PLA is brittle and can break easily when printed.

Printing with TPE

Thermoplastic elastomers (TPE) such as TPU are an alternative to thermoplastics. Compared to thermoplastics, they are much more flexible and durable. Since

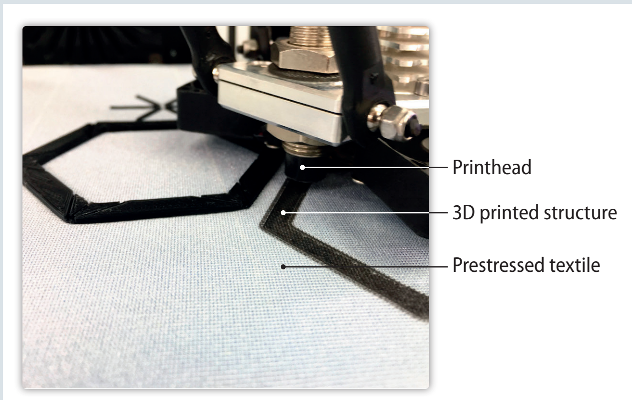


Fig. 1. 4D textiles can be produced by means of using an FDM printer. © Philip Lodd

textiles are characterized by their flexible qualities, the use of TPE is interesting to produce 4D textiles. Due to the elasticity, the structure can better adapt to human movements, for example when used for orthoses. This increases the wearing comfort.

Hybrid material structures such as 4D textiles should find application wherever a change in the shape of the component or product is necessary. Due to their great adaptability, freedom of design and customizability they have a potential for applications. Possible areas of application include consumer goods, vehicle interiors and textile facades. Another focus of research at the ITA in recent years has been the use of 4D textiles in medicine especially for orthoses. »

4D Textiles

4D textiles are textiles or textile products that can change their function or shape over time. This change is stimulated by an external stimulus. They can be used, for example, in rehabilitation medicine. Support structures that are worn close to the body and react adaptively to changing requirements can be individually adapted to the wearer by means of 3D printing. Textiles additionally increase the wearing comfort. 4D textiles are manufactured on the surface by printing a pre-tensioned textile using FDM printing. By relieving the tension on the textile after production, a three-dimensional form with bistability is created from a two-dimensional one.

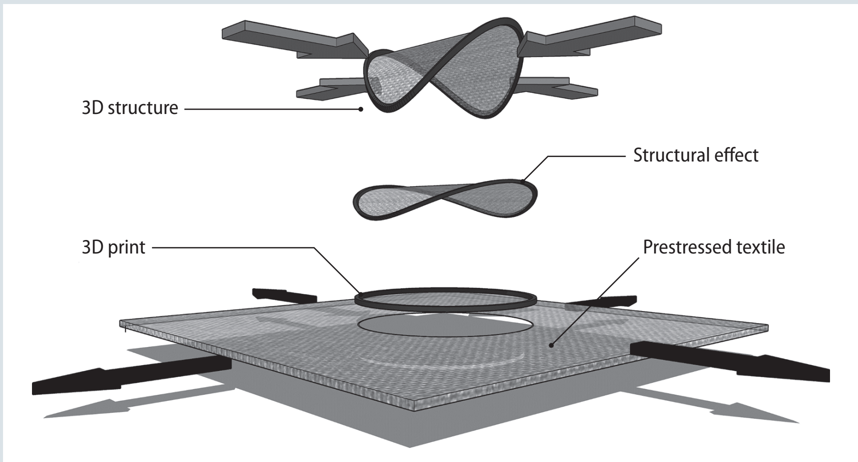


Fig. 2. In the production of 4D textiles at ITA, a structure is printed onto a pre-stretched textile. The shape of the piece is then created by relieving the prestress on the textile. © David Schmelzeisen

The Right Material for Orthoses

Due to the demographic change of the population, especially in the western industrial nations, the demand for orthoses is constantly increasing. In contrast to a prosthesis, an artificial limb, an orthosis is an aid in medicine. Like bandages, orthoses are used for illnesses and injuries of limbs or the trunk. Their functions range from stabilization and relief to correction and fixation. Compared to ready-made orthoses, which are mass-produced by machine, the production of individualized orthoses takes several weeks of manual labor. However, they also allow for a precisely fitting wearing period of several months.

During research at ITA, the production of a ready-made and individualized orthosis was developed using 3D scanning and 3D-printed 4D structure (**Fig. 3**). The limbs are scanned in a few seconds to generate a CAD model for an individual orthosis. The structure is then produced using the FDM process. The special feature here is the printing on a circular knitted fabric. The printer has a circular shaft instead of a printing bed (**Fig. 4**).

Up to now, the developed process can only be produced on a small scale. The aim is therefore to scale up both the production and the scale both the production and the effects. This would make it possible to move beyond the prototype phase and develop industrial applications. But challenges still need to be overcome for this to happen. These include, among other things, the print bed size, the feeding of the textile in processes and dimensions typical for the process, the realization of the pretension over a large area and the use of diverse materials in 3D printing. In addition, sustainability aspects are also to be considered. However, the results so far already show that there are many technical innovation possibilities for 4D textiles. ■

Info

Text

Hannah Carlotta Kelbel, M.Sc., researches on the development of 4D textiles since 2018. Since 2020, she has been a research associate at the Institut für Textiltechnik (ITA); hannah.kelbel@ita.rwth-aachen.de
Dipl.-Des. Helga Ahrens-Wels has been working as a research associate at ITA in the Additive and Joining Technologies department since 2019; helga.ahrens-wels@ita.rwth-aachen.de
Katarina Winands, M.Sc., has been working as a research associate at ITA in the Additive and Joining Technologies department since 2021; katarina.winands@ita.rwth-aachen.de

Acknowledgments

The authors would like to thank Schneider Technologies for the excellent cooperation.

Digital Version

A PDF file of the article can be found at
www.kunststoffe-international.com/archive

German Version

Read the German version of the article in our magazine ***Kunststoffe*** or at
www.kunststoffe.de

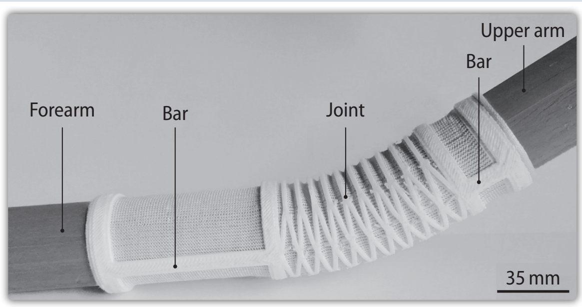


Fig. 3. Prototype of a 4D textile orthosis for the elbow produced at the ITA: it can be individually tailored to patients and is very comfortable to wear due to the use of textiles.

© Miriam Dünzer

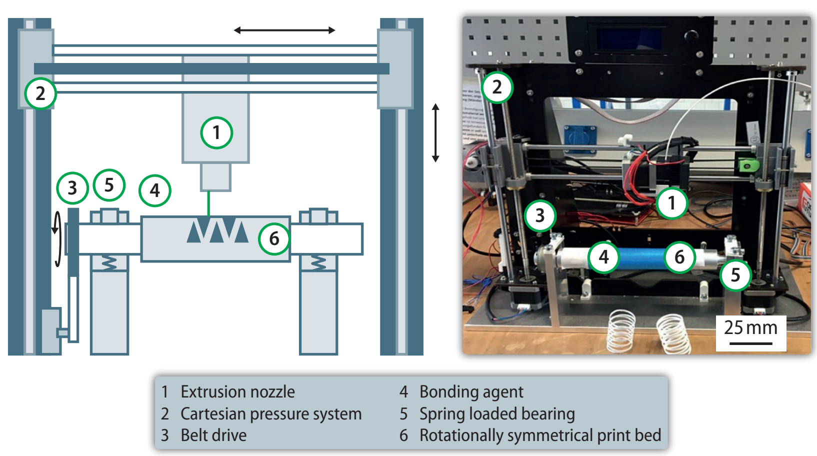


Fig. 4. A 3D printer with a cylindrical print bed is used to produce 4D textiles. © ITA