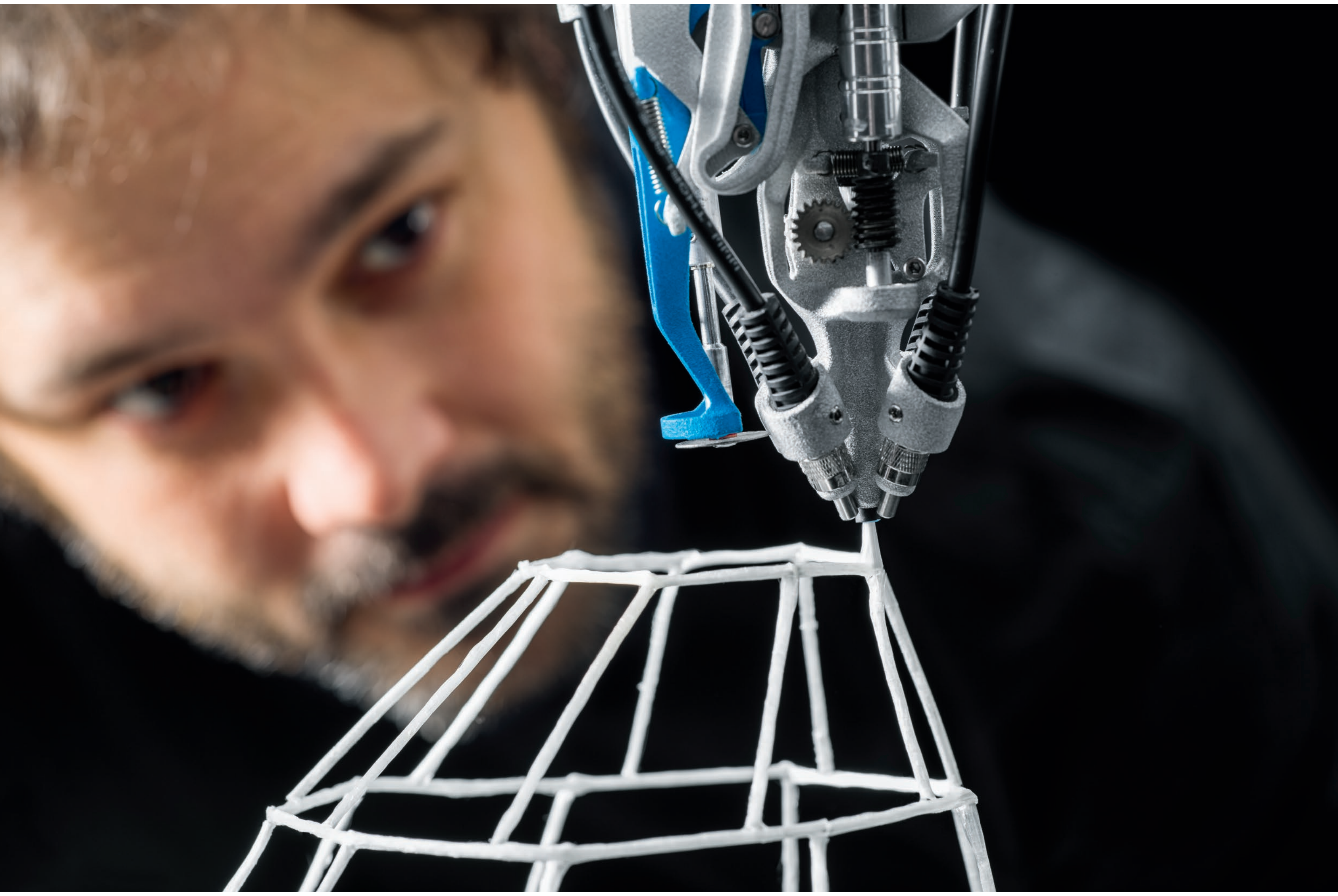
3D Cocooner

Bionic lattice structures from the robotic spinneret



3D Cocooner
Stable lightweight construction method in three-dimensional space


01

The art of construction and architecture is associated first and foremost with mankind. Yet impressive constructions also emerge in wildlife. African weaver birds, for example, weave artistic nests out of leaves and stalks, where hundreds of animals live over several generations. And while bees, wasps and termites construct their homes layer by layer, spiders and butterfly caterpillars create impressive shapes with the help of spinning threads. To do so, they produce a fluid that polymerises into a solid thread outside the body and can thus be shaped into sturdy webs or cocoons.

Inspired by this, Festo has developed the 3D Cocooner as part of its Bionic Learning Network. Just like a caterpillar, it spins delicate shapes and creates custom-made lightweight structures out of a glass-fibre thread. With the help of a handling system, the spinneret can be precisely manoeuvred and the glass fibres, which are simultaneously laminated with UV-curing resin, are glued together to form complex structures. In contrast with other 3D printing methods, however, these structures are not built up on a surface one layer at a time, but are actually constructed freely in space.

A vertically arranged type EXPT-45 tripod acts as a specialised handling system for the 3D Cocooner. The three-armed parallel kinematics system can be controlled quickly and precisely in the space and its manoeuvrability makes it ideal for such a task. Furthermore, instead of a gripper, the tripod is equipped with a specially developed spinneret, into which a 2400-tex glass-fibre roving is continuously threaded.

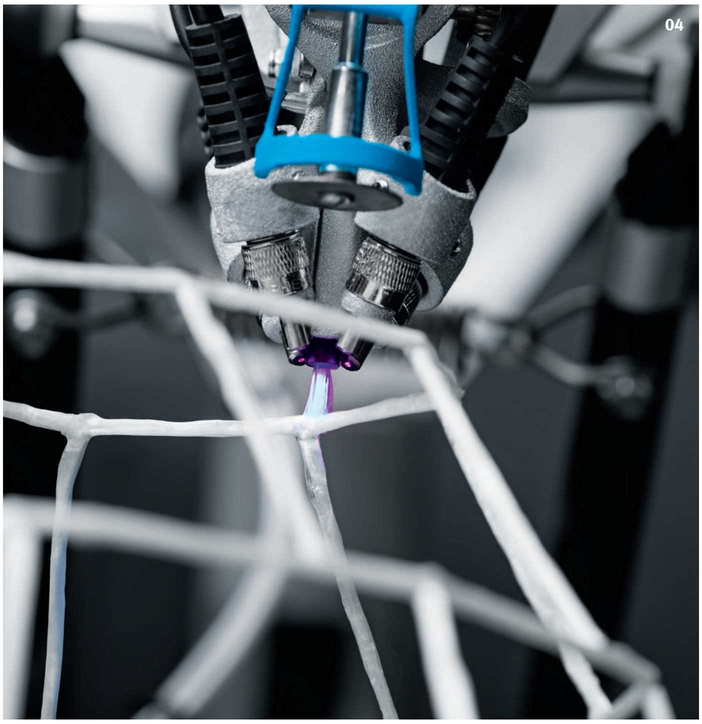
Real-time construction with light-curing plastic
In order to convert the soft thread into a solid lattice structure, it is moved forward over a pair of rollers in the spinneret and simultaneously covered with a viscous resin. As soon as it comes out, a UV light cures the fibre soaked with resin with pinpoint accuracy and hardens it into a sturdy little rod. The thread is cut off with a small cutting disc and the spinneret can start again in a different place. By exactly regulating the amount of UV light, the resin can also be temporarily kept in a liquid state in order to glue a new section together with structures already in place. In this way, it is possible to construct complex shapes in three-dimensional space without any supports.

01: **Precise travel paths:** the extremely manoeuvrable tripod kinematics allow the spinneret to move freely in space

02: **Virtual depiction:** both the shape model and handling system are visually stored in the animation software

03: **Natural role model:** the thumb-sized cocoon of this small butterfly can be found in the Ecuadorian rainforest

04: **Light-curing plastic:** using four UV lights, glass fibres and resin are merged to form a solid lattice network



The tripod receives the necessary positional data and control signals directly from an animation software program that is normally used to create virtual 3D models, computer graphics and simulations.

Digital set of rules for individual configuration

The three-dimensional shape model of the desired structure is developed in the software and turned into a physical form by the spinneret. With this process, the body is not built up by traditional 3D modelling, but generated instead according to parametric construction principles. For this purpose, a set of geometric rules is stored in a specially developed program, providing the basic shape of the structure and the design parameters – such as height, width and rotation of the body as well as the shape and number of the individual meshes.

The user only has to specify the parameters, while the program calculates the details automatically. With the software's graphical user interface, even a layperson can adjust the design attributes however they want using a slide control and thus configure their individual structure from the basic shape stored in the program.

Direct control of the tripod kinematics

Alongside the parametrically designable object, the entire handling system is also stored virtually in the software. This allows the complete path planning to be directly calculated here and visually simulated, whereby all the key process parameters such as speeds, thread feed or amount of resin are already taken into account and exactly coordinated with each other.

The actual production process is not only depicted virtually, however. It can also be started up without any further steps. At the press of a button, the program transmits the required geometry to the kinematic travel paths. The shape parameters are translated to the handling system's control system via direct software access.

This direct path from the design to the production tool is very unusual in the current production environment. It is, however, an important prerequisite for customised manufacturing processes in the future. The efficient and flexible production of batch size 1 plays an important role in the ideas relating to Industry 4.0.

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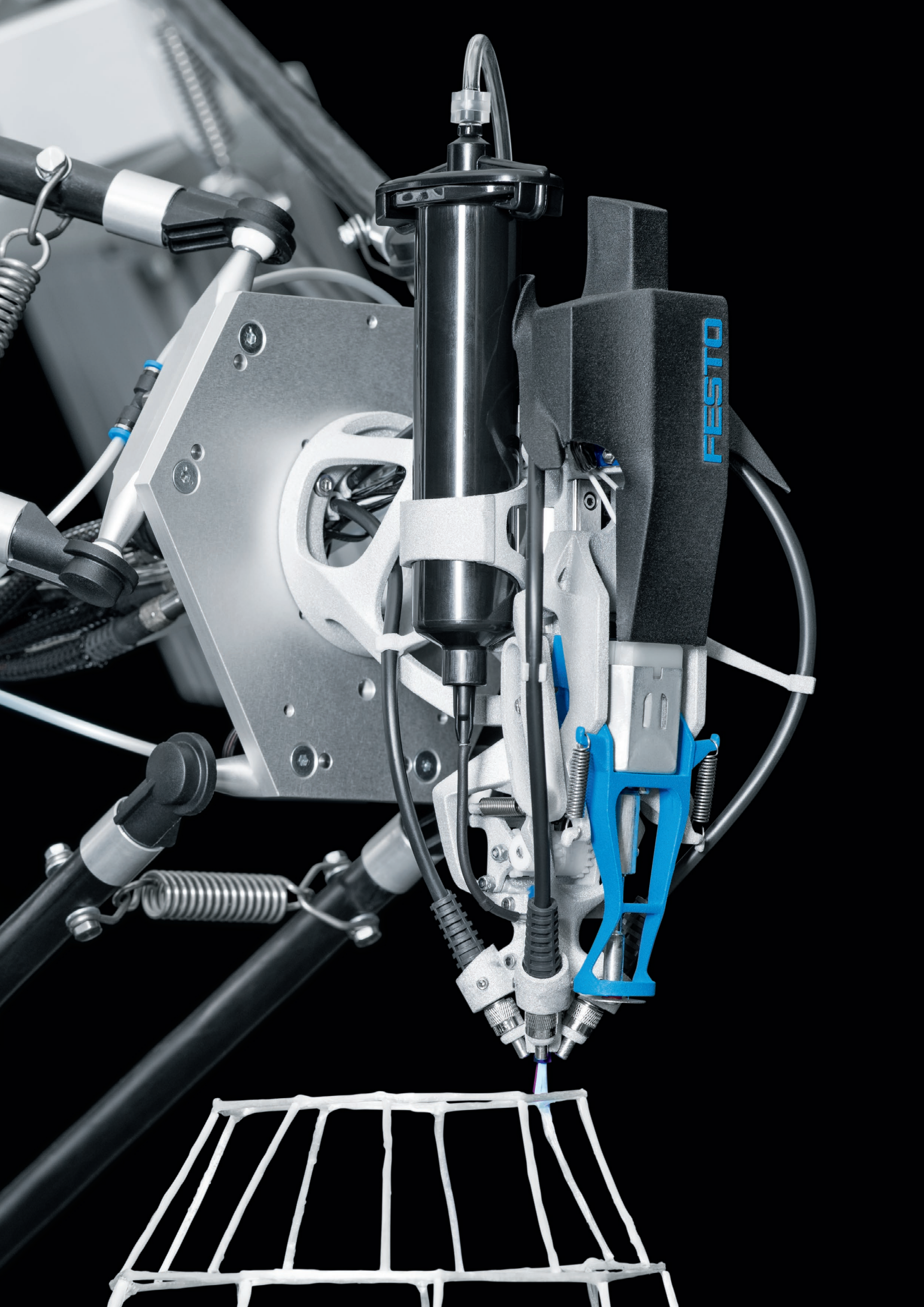
Complex lattice structures from the robotic spinneret

Special features from the natural role model
Whether in the form of a net to catch prey, or a protective cocoon, spiders and caterpillars can create amazing shapes with the help of their spinning threads. To do so, they produce a fluid that hardens into a solid thread when it comes out of the body. In the case of butterflies, the thread is laid around the caterpillar by specific movements of the head and woven into a delicate yet extremely sturdy cocoon.

Technical benefits for Festo
For the 3D Cocooner, the developers equipped a tripod from the standard Festo range with a special nozzle. With the help of UV-curing resin, it spins a soft glass-fibre thread into complex and equally stable shapes that are very similar to the natural structures. The kinematics receive the necessary control commands directly from the design program in which the three-dimensional shape model is generated.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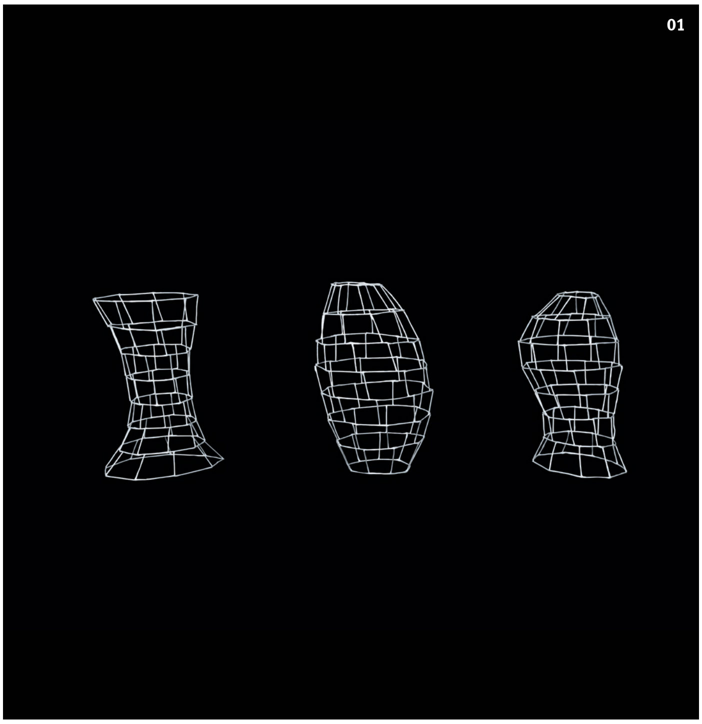
3D Cocooner

New production technology with enormous potential



Even if conventional injection moulding is still superior with regard to tolerance and dimensional precision, additive manufacturing methods already belong to standard industrial production processes. Especially in model construction, 3D printing has become indispensable for making prototypes and end products in small quantities.

As a rule, the required shape is built up layer by layer according to the specifications from a CAD program. Depending on the process, this involves powders, granulates or thermoplastic filaments being melted together line by line to make a solid body. However, materials that can be freely printed in space – such as the UV-cured glass fibres used in the 3D Cocooner – are still largely undergoing basic research and are not yet available on the market.

New dimensions of product design

With the 3D Cocooner, Festo has developed a bionic technology platform that combines the individual benefits of additive manufacturing with the precision controls and agility of an industrial high-speed handling system.

A new tool of this kind enables shapes and structures that cannot be made via conventional production means. The delicate bodies made of frameworks of rods open up new dimensions for individual product design.

Maximum variety using minimal materials

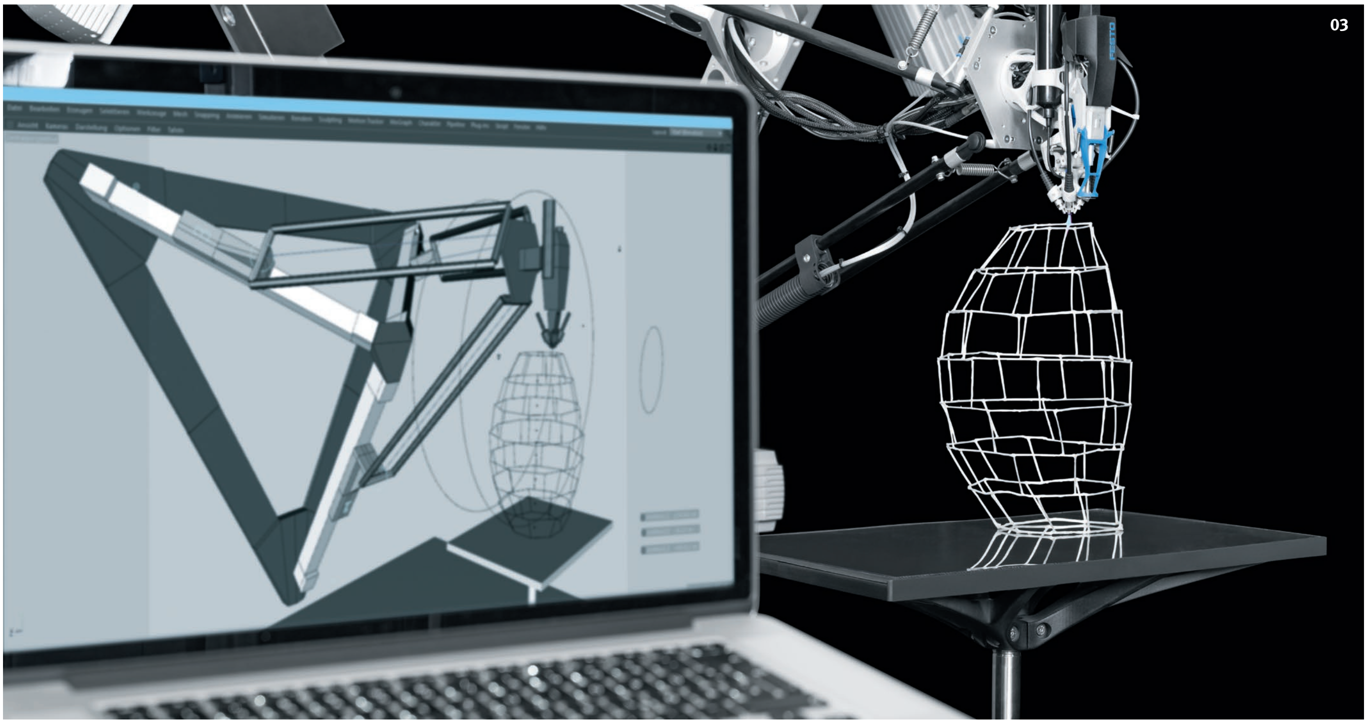
Complex bodies, which up until now have only been able to be depicted as a virtual model in a computer simulation, are now taking a physical and tangible form. Geometric corrections can already be made at an early stage, which makes the design process significantly easier. The thread can be reset at any point on the lattice structure, where it continues to build. This ultimately results in an almost endless variety of design options using minimal amounts of material.

The UV-cured glass fibre itself has astonishing tensile and bending strength. If you were to connect several 3D Cocooners together via a network, extensive structures could be constructed within a very short time, which, thanks to their stability, would have tremendous potential in the most diverse areas.

01: Parametric design: a wide range of variants are generated from one and the same basic shape

02: New concepts: the unique construction method opens up unlimited design options

03: Digital fabrication: the software transfers the geometry of the structure directly to the tripod's travel paths



Particularly in sectors like the packaging industry or medical technology, a host of new possibilities are opened up by this technology. By integrating the spinneret into the tripod, the developers are also testing how existing standard components can be enhanced for digital fabrication, and hence the production tasks of the future.

Digital enhancement for a flexible production process

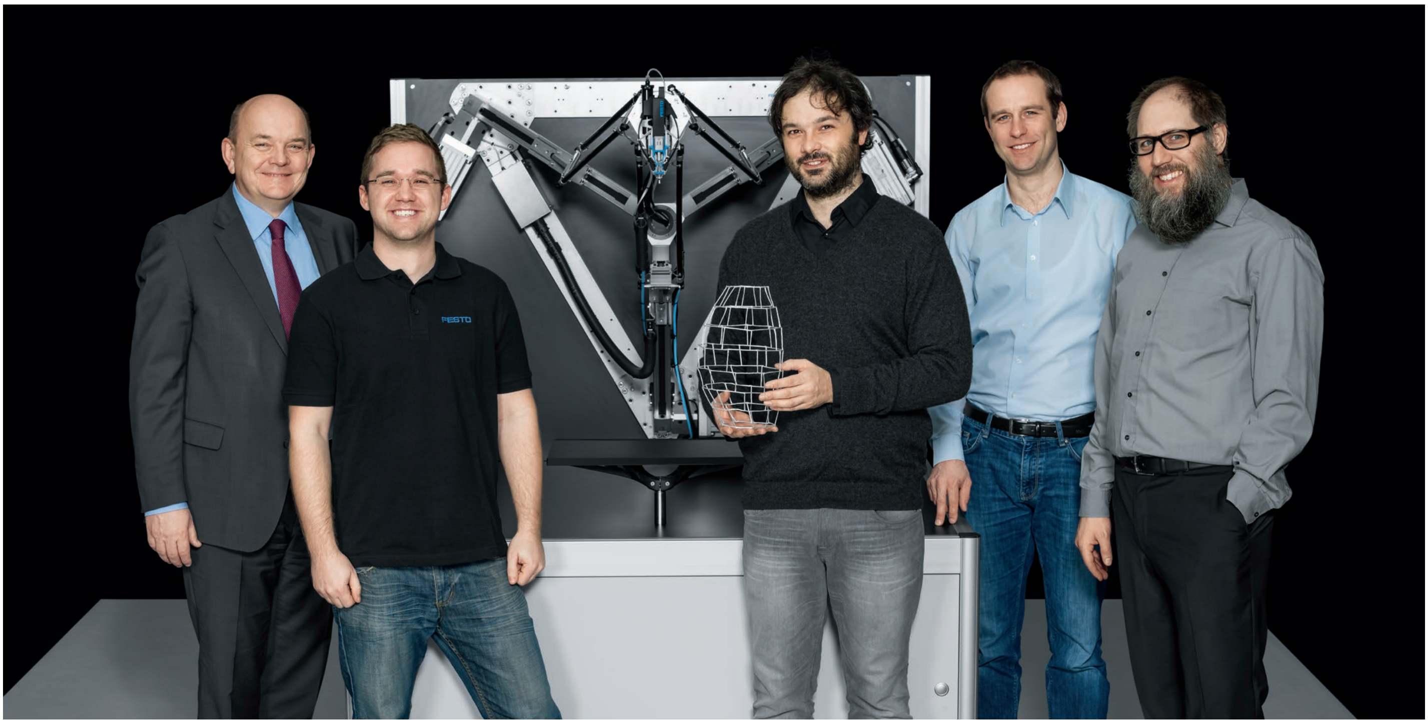
A fundamental change is taking place in industry. The trend is towards customised products. That is why, alongside established mass production, increasingly flexible production facilities are emerging, which can adjust themselves to small batch numbers and a high level of variety – among them also agile design methods, with which individual and tailored goods can be produced in real time using additive manufacturing. In order to manage this complexity, facilities and components have to be able to coordinate with one another. As part of Industry 4.0, a digitisation process is therefore emerging, which allows traditional industrial processes to be merged with modern information and communications technologies.

The components used are given the necessary capabilities by being equipped with wireless and storage-enabled labels with their own computing capacity. In this way, subsystems, tools, transport units and materials will be able to organise themselves in the future to form a production unit at machine level.

From the virtual model to the finished product

On a system like the 3D Cocooner, the virtual design program supplies the assembly instructions directly at tool level. This makes it possible to go digitally from the design to the finished product – without detours via the otherwise usual sales, production and logistics channels.

The declared objective – being able to supply batch size 1 at reasonable costs using automated large-scale facilities in industry – comes one step closer with such solutions. The warehousing costs for finished workpieces are also omitted in the case of such on-demand production. The raw materials must simply be available in a sufficient quantity, while the finished goods can be delivered to the customers immediately.



Technical data

- Design software: .... Cinema 4D
- Multi-axis kinematics: .... Festo Tripod EXPT-45
- Construction space: .... approx. 450 × 300 × 600 mm
- Construction speed: ....10 mm/s
- UV light: .... fibre-coupled LED; 365 nm; 9.3 mW

- Material: .... glass-fibre roving with 2400 tex for producing
  .... glass-fibre rods with 2 mm diameter
  .... and 60% fibre–volume ratio
- Weight of glass-fibre rod: .... 5–7 g/m
- UV plastic: 1-Vinylhexahydro-2H-azepin-2-on,
  .... acrylate mixture

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Picture 03: © Morley Read/Alamy Stock Foto

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