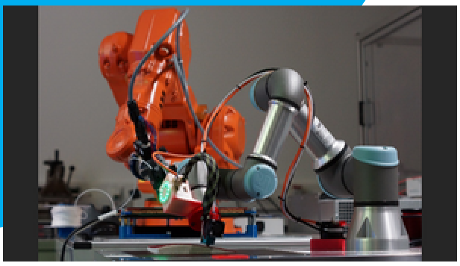
Robot-based additive manufacturing of complex multi-material components

Technologie-Lizenz-Büro der Baden-Württembergischen Hochschulen GmbH

Robot-based additive 6D manufacturing process for the continuous production of complex structural components with integration of fibers or conductor tracks

- Maximum flexibility thanks to mobility in six degrees of freedom
- Printing of significantly more complex components possible, without support structures
- Multi-material components can be easily realized
- Significant increase in strength and stress resistance
- Close-contour printing along the 3D shape of the object
- No step artefacts
- Integration of continuous fibers, electrical or optical conductors running through several layers



Fields of application

Structural and flexurally stressed components, Functional components with electrical, optical properties, Free-form components

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Service

Technologie-Lizenz-Büro GmbH has been entrusted with exploiting this technology and assisting companies in obtaining licenses.

Background

In recent years, additive manufacturing has undergone an impressive transformation and developed into a disruptive technology. With its ability to reduce costs, individualize, accelerate product development and focus on sustainability, 3D printing has become significantly more important. The numerous methods now available allow for a wide range of applications, from simple hobby or model-making applications to the production of prototypes, small series and highly complex components in the mechanical engineering, automotive and aerospace sectors. Continuous technological advances in materials, system control, component properties, precision and speed are constantly opening up new fields of application.

Problem

The quality of additively manufactured objects depends heavily on the manufacturing technology used, the material used and the complexity of the component to be manufactured. For example, the layer-by-layer production of curved components often results in layer line artefacts, which are visually disturbing and often structurally disadvantageous. Another problem is that in known additive manufacturing processes, there is often no component-adapted planning of the print paths, e.g. to increase the local strength in certain areas of the component or to combine different materials (e.g. integration of fibers). Accordingly, additive manufacturing can often not be used for structurally stressed (lightweight) components, where its use would be particularly economically interesting.

Solution

Prof. Börret's Optical Technologies working group at the Center for Optical Technologies (ZOT) at Aalen University has developed a robot-based additive 6D manufacturing process for the production of complex multi-material components. The device consists of an actuator unit that can move in six degrees of freedom. Thanks to the 6D freedom of movement, which comprises three spatial directions and three angular directions, the device can be moved, rotated and tilted in all spatial directions. This high degree of freedom of movement means that the device can be used much more flexibly and is therefore able to break out of the usual layer-by-layer deposition in the xy plane. In this way, the device can follow the three-dimensional contour in space, particularly with curved components, and change the print path accordingly in the z-direction. This results in no staircase effect and an attractive and high surface quality. By using different extruders or print heads, different materials can be used, making multi-material components possible. For example, continuous fibers can be integrated into areas subject to particular stress in order to create resilient structural components. By integrating electrical or optical conductors, new applications and uses can be opened up, or the components can become "intelligent", e.g. defect detection, electrical conductivity or heatable 3D printing materials. By using an intelligent control system, strain properties, mechanical strength (force conduction and tension/compression direction), surface quality, electrical properties or conductivity and optical properties (e.g. refractive index) of the component can be taken into account in the alignment and progression of the layers to be deposited. For example, web distances can be changed to realize specific variations of the properties within the object, and the feed direction of the printing unit can be changed to print slower in critical areas and faster in flat areas.

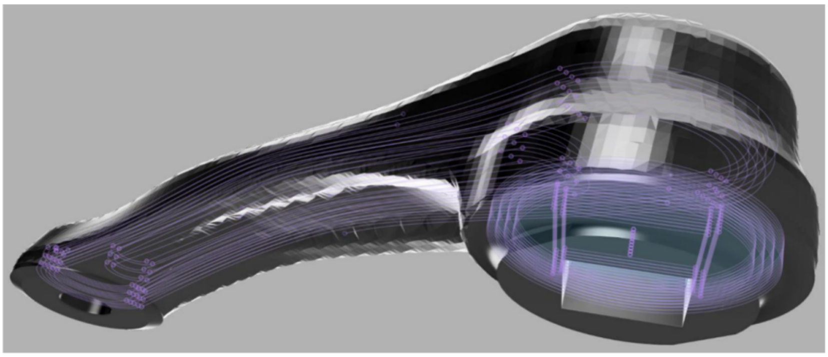

Figure 1: Fiber path planning for the production of a 6D-printed bicycle crank made of PLA with integration of carbon fibers along the load paths (Prof. Börret, ZOT, Aalen University)

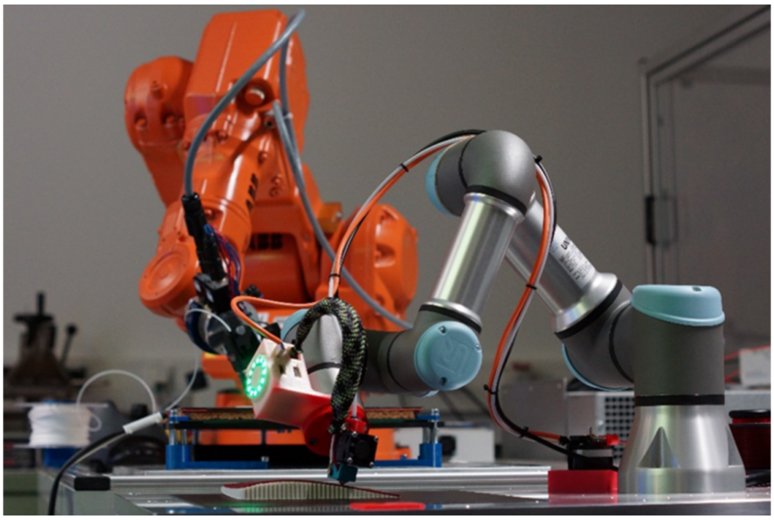

Figure 2: Robot-based 6D printing is possible with different types of robots. (Image source: Prof. Börret, ZOT, Aalen University)

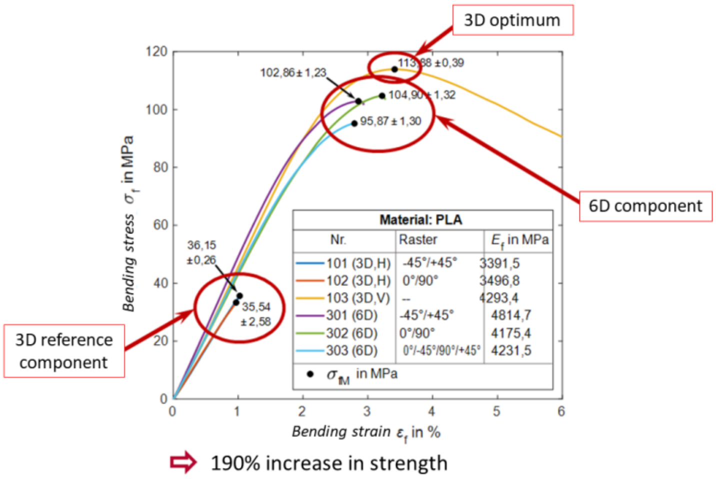

Figure 3: Strength increase (flexural strength) of 6D printed parts by 190% compared to 3D printed parts (Image source: Prof. Börret, ZOT, Aalen University)

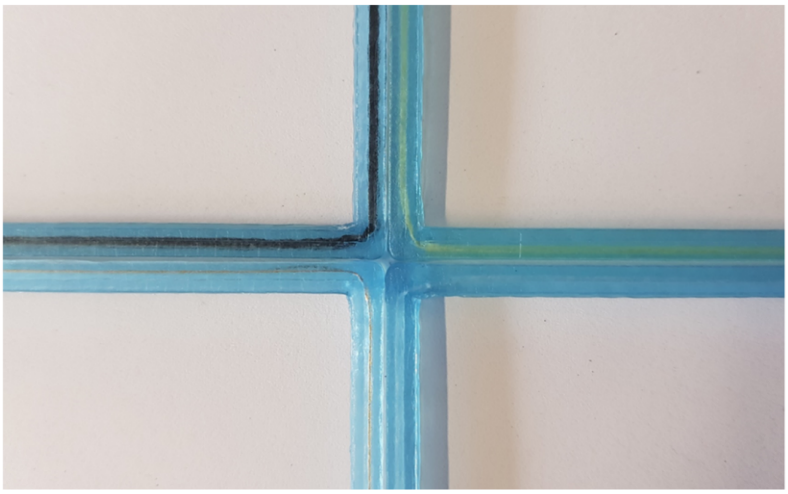

Figure 4: 6D printing of a carbon fiber, a Kevlar fiber, a fiberglass fiber and an enamelled copper wire in an example component (Image source: Prof. Börret, ZOT, Aalen University)

Advantages

- Maximum flexibility thanks to mobility in six degrees of freedom
- Printing of significantly more complex components possible
- Multi-material components can be easily realized
- Significant increase in strength compared to conventional 3D-printed components
- Significant increase in stress resistance compared to conventional 3D-printed components
- Close-contour printing along the three-dimensional shape of the object
- No step artefacts
- Integration of continuous fibers, running through several layers, enabling the production of resilient components
- Integration of electrical or optical conductors

- No support structures required during printing