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ROBOTIC 3D DEPOSITION OF IMPREGNATED CARBON ROVINGS WITH GRADIENT PROPERTIES FOR PRIMARY STRUCTURES

Abstract

Fiber-reinforced materials offer a large improvement in structural performance if specific load cases can be determined. In aerospace, lightweight structures are crucial because of launcher limitations. For academic purpose CubeSats are a powerful concept to participate in space research on a low-cost-level.

Reducing the structural mass, while keeping the mechanical performance, provides a bigger payload mass budget. Additionally, there are several types of payloads that do not fit in common structural components. Inasmuch as CubeSats are mainly used in research, such systems change substantially, so that an easily adaptive method would be beneficial to be no longer restricted by prefabricated structural components.

The developed rapid prototyping technology tackles these issues by having an automated 3D deposition method which can produce extremely lightweight as well as geometrical- and load-adaptive primary structures with minimum space requirements. A fiber deposition head for a six-axis robot has been developed to impregnate and wind a single carbon roving on a frame to produce 3D integral components. The geometry of the frame can be adjusted to the required application by introducing holes or attachment points at nearly any position. Its modular layout varies, so that it only can be fabricated economically by fused deposition modeling and removed after resin curing easily. Furthermore, by blending additives into the resin it is possible to create material gradient components. Hence adaptiveness can be generated e.g. in terms of solar energy absorption.

Compared with 1U aluminum wall structures available on market a carbon fiber-reinforced plastics (CFRP) winded structure results in a mass saving of 45% for a solid and 76% for a skeletonized wall segment, premised on calculations for two layers of CFRP made of 24K rovings with a fineness of 1600 tex at a fiber-volume-fraction of only 50%.

This concludes that maximum potential can only arise with optimized fiber path generation. Costs can be saved in terms of material (no fiber blend), molding (3D printed frame), design of fiber path (systematic guidelines), assembly (integral design) and manufacture (robotic production). The advantages will be demonstrated with a generic non-in-situ-sensory 1U CubeSat because it is easy to compare it to other systems due to the strict design specifications.

The paper will include detailed information on the design of the robotic fiber deposition head, the modular and adjustable frame, the winding pattern generation and the mechanical testing.