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Combining Laser and Textile Technology for Just-in-Time Production of Composites

Kompozitlerin Tam Zamanında Üretimi için Lazer ve Tekstil Teknolojilerinin Birleştirilmesi

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Araştırma Makalesi / Research Article

COMBINING LASER AND TEXTILE TECHNOLOGY FOR JUST-IN-TIME PRODUCTION OF COMPOSITES

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ABSTRACT: The demand for composite components is rapidly increasing by a simultaneous demand for increasing component performance. Compared to established construction materials, production technologies in the composite field often have a lower technological maturity. Current production technologies for fiber reinforced plastics (FRP) are using 3D multi-layer textile preforms. The preform production is often characterized by high manual workload. High level of automation, including automated quality assurance, is often cost-effective only at high volumes. In the highly innovative EU and OP.EFRE funded “CarboLase”-project ITA RWTH Aachen University and Fraunhofer ILT are developing in corporation with industry partners the future fully automated preforming process chain. Sensors as well as flexible software and hardware interfaces are integrated in the process chain, enabling the transfer of product and process data along the process chain. One core innovation is the combination of productive 2D CNC cutting, high-precision laser material processing of the textile preforms by ultra-short pulsed laser radiation and a fully automated application of metallic fasteners into the preforms. The technologies are integrated in a single robot cell.

Keywords: Composites, Laser, Automation

KOMPOZİTLERİN TAM ZAMANINDA ÜRETİMİ İÇİN LAZER VE TEKSTİL TEKNOLOJİLERİNİN BİRLEŞTİRİLMESİ

ÖZET: Kompozit bileşenlere olan talep, artan bileşen performansıyla simultane biçimde hızla yükselmektedir. Mevcut yapı malzemeleriyle kıyaslandığında, kompozit alanında daha az teknolojik olgunlaşma görülmektedir. Güncel üretim teknolojileri lif takviyeli plastiklerin (FRP) üretiminde üç boyutlu çok katmanlı tekstil kalıpları (preform) kullanılmaktadır. Kalıp üretimi çoğunlukla elle yapılan iş yükü olarak nitelendirilmektedir. Otomatik kalite güvencesi içeren yüksek seviye otomasyon çoğunlukla yüksek hacimli üretimlerde daha uygun maliyetli olmaktadır. Son derece yenilikçi, AB ve OP. EFRE tarafından desteklenen “CarboLase” projesinde, ITA RWTH Aachen Üniversitesi ve Fraunhofer ILT endüstrideki işbirlikçileri ile birlikte geleceğin tamamen otomatikleşmiş süreç zincirini geliştirmektedir. Esnek yazılımlar olarak sensörlerin ve donanım arayüzlerinin süreç zincirine entegrasyonu, ürün ve süreç bilgisinin süreç zinciri boyunca iletimini sağlamaktadır. Diğer esas yenilik ise yüksek verimli 2D CNC kesimin, Ultra kısa atımlı lazer ışıması ile tekstil kalıplarının yüksek hassasiyetli lazer malzeme işlenmesinin ve kalıplara metalik hızlandırıcıların tamamen otomatik olarak uygulanmasının birleştirilmesidir. Teknolojilerin tamamı tek bir robot hücresinde entegredir.

Anahtar kelimeler: Kompozitler, Lazer, Otomasyon.

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1. INTRODUCTION

The demand for components made of fibre-reinforced plastics (FRP) is constantly increasing due to the growing importance of energy and resource efficiency with a simultaneous demand for increasing component performance [1-3]. For manufacturing technology, this means that process chains in particular must be simplified and costs must be reduced despite the wide variety of geometries.

Due to the high lightweight construction potential, the demand for FRP components for "multi-material design" applications is growing simultaneously. The concept of multi-material design plays a central role in the development of future generations of vehicles. The concept is based on the best combination of material, design and production technology to increase the total performance of a part. [4] In order to take advantage of this mixed material construction method, challenges in the field of joining technologies have to be overcome [5-7]. The realization of detachable, flexible and standardized connections is a prerequisite for the substitution of existing components by FRP components. These connections are realized by metallic fasteners (e.g. inserts with internal or external threads) [4, 8, 9]

The production of textilie, near net-shape preforms, together with material costs, is the main cost driver for the production of FRP components (together up to 70% of component costs) [10]. Currently, the production of FRP components, especially in small and medium-sized companies, is characterized by a high proportion of manual work. This can lead to a high susceptibility to errors in the entire production process and to fluctuations in production quality. This results in a high number of scrap in the form of textile waste (up to 50%) and defective, already cured components.

Fasteners are currently being integrated via complex mechanical finishing of the hard component. [10, 11] Due to the highly abrasive material properties, contact-based mechanical finishing of cured FRP components (e.g. drilling or milling) is time- and cost-intensive (up to 20% of component costs) [10]. Automated integration of the fasteners before consolidation into three-dimensional textile preforms has failed so far due to deficient procedures for the feasibility to cut highly presions notches into multi-layer textile preforms.

As an alternative to mechanical machining processes, laser processing offers the advantages of tool wear-free operation, high flexibility and the highest precision in the micrometer range. Compared to conventional lasers, ultra-short pulse lasers in particular allow low-damage processing with minimal heat impact and increased precision. [12-15].

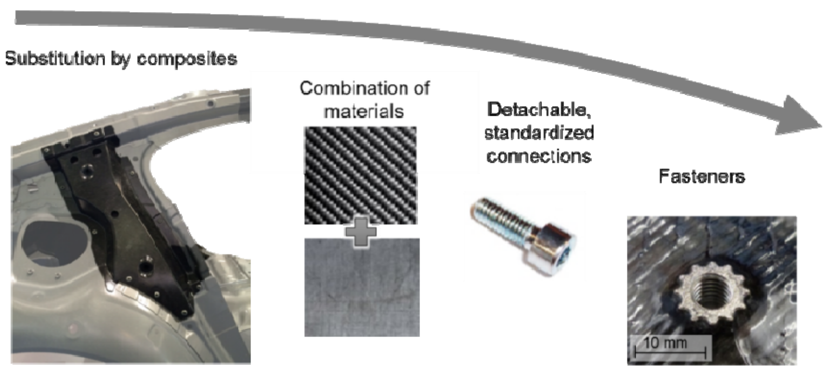

Figure 1. Motivation – Fasteners for multi-material design applications

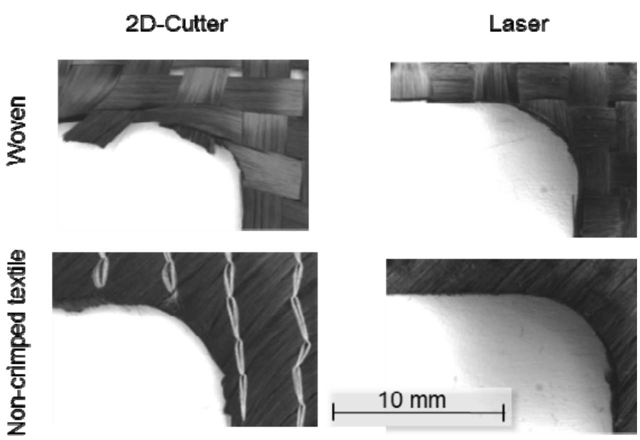

Figure 2. Comparison of the cutting edge for contact (left) and contactless material processing by laser (right)

2. EXPERIMENTAL SET-UP AND PROCEDURE

Since March 2017, the CarboLase project has been adressing the descriptive challenges. The core innovation is the combination of productive 2D CNC cutting, high-precision laser material processing of textile preforms using ultra-short pulsed (UKP) laser radiation and fully automatic handling of individual preforms with integrated metallic inserts. The technologies are integrated into a robot cell. By the integration of flexible software/hardware interfaces and sensors in the production process, a highly flexible, hybrid production system is created. The networking of the sub-steps in preforming (cutting, stacking, joining and forming), laser beam drilling and integration of the fasteners as well as handling processes are carried out automatically with high reproducibility (Fig. 3).

3. RESULTS AND DISCUSSIONS

A core component of the process chain is also the realization of a flexible tool which enables the forming, the thermal activation of polymeric binder powders between the textile layer packages, the laser material processing to drill holes, and the integration of fasteners on one station. One central challenge is the separation of the required air flows for the:

- heating of the preforms to melt the polymeric binders between the individual layers during forming,
- cooling of the preforms after forming has been completed and
- removal of gases and particles generated during laser material processing.

The last air stream must be removed separately and filtered immediately, as the carbon fibre particles, some of which are harmful to health, endanger employees and short-circuit electronic components due to their electrical conductivity. Due to their highly abrasive nature, carbonfiber particles in the micrometer range can lead to significant wear in axes systems and robot joints. In order to unite the tasks mentioned above into one step, which used to be are carried out in separate stations according to the state of the art, different concepts were developed and evaluated. Figure 4 shows a CAD-model of the identified solution concept. This is currently being implemented at the ITA Preform Center.

4. CONCLUSIONS

Industry and research work closely together in the CarboLase project. Together with AMPHOS GmbH, the Fraunhofer Institute for Laser Technology ILT develops laser technology tasks in a project context. As a system integrator, LUNOVU GmbH supports the networking of individual process steps and implements the integration of sensor technology into the robotic cell at the Institute of Textile Technology at RWTH Aachen University ITA. Kohlhage Fasteners GmbH & Co. KG develops the automated provision and integration of fasteners (inserts). ITA takes over the implementation of the automated process chain for the production of laser-processed preforms in close cooperation with all project partners.

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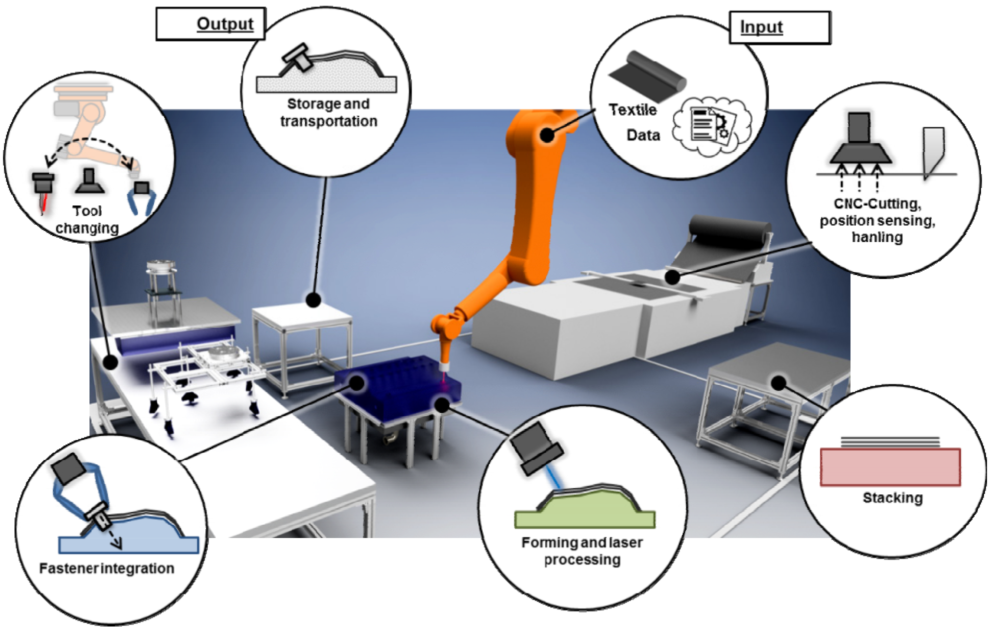

Figure 3. Representation of the CarboLase process chain

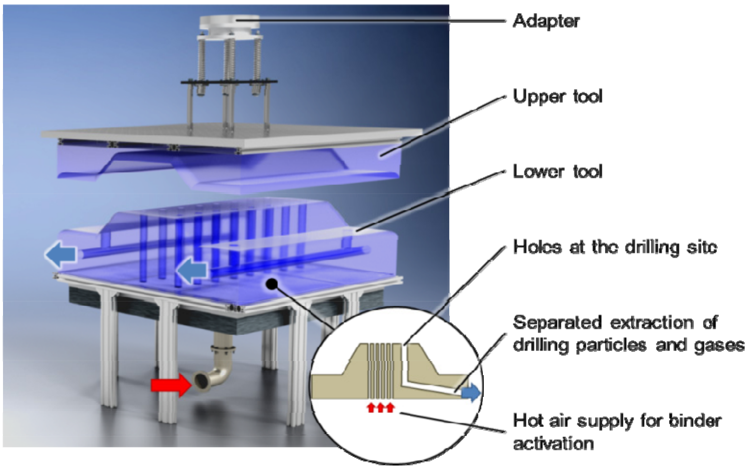

Figure 4. Detailed view of the multifunctional tool.

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