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An Approach for the Sensory Integration into the Automated Production of Carbon Fiber Reinforced Plastics

Johannes Graf[a,]*, Kristina Gruber[a], Yi Shen[b], Gunther Reinhart[a,b],

[a]*Project Group Resource-efficient Mechatronic Processing Machines of Fraunhofer IWU, Beim Glaspalast 6, 86153 Augsburg, Germany*
[b]*Institute for Machine Tools and Industrial Management, Technical University Munich, Beim Glaspalast 6, 86153 Augsburg, Germany*

* Johannes Graf. Tel.: +49-821-56883-37; fax: +49-821-56883-50. *E-mail address:* Johannes.Graf@iwu.fraunhofer.de

Abstract

The advantages of Carbon fiber reinforced composites (CFRC) lead to an increasing demand of Carbon fiber products. This class of materials is gaining widespread acceptance in various fields like aviation, wind energy or automotive and is gradually replacing traditional lightweight construction materials such as high-strength steel or aluminum. Currently, particular process steps of the production of fiber composite structures are performed manually or semi-automatically. Especially the automated handling of semi-finished products consisting unstable textile poses a challenge for an economical manufacturing. The reasons for the missing automation are beside the lacking technical feasibility most of all, reliability issues during process execution, representing key aspects for potential large-scale production. As a consequence, the integration of sensor systems constitutes a promising approach for process optimization and quality assurance. In order to catch the intricate nature of possible defects and their interdependences during the single steps of the handling process, an approach for selecting, assembling and integrating the ideal sensors at the respective processing station to monitor dominant defects is presented. For this purpose, possible defects and flaws are derived from a comprehensive process analysis and accordingly suitable sensor principles are selected. The application of this approach is exemplarily demonstrated on an automotive case study focusing the separating and draping steps of flat carbon fiber textiles in a mold for a resin transfer molding (RTM) process.

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1. Introduction and Motivation

Current discussions on energy and resource efficiency have significantly influenced the importance of fiber reinforced plastics (FRP). In addition, present social trends such as sustainability and environmental awareness place FRP in the focus. The rising desire for low-emission mobility in the future, emerge in novel challenges in the areas of electrification and lightweight. Thereby, FRP components possess a high potential for the implementation of lightweight structures [1]. Especially its construction and the anisotropic structure provide technical advantages over existing materials in production technology.

Novel approaches in the design and the operation of technical systems can be realized in various industries, such as the aerospace industry and the automotive industry [2,3]. Nevertheless, the structural and mechanical advantages are facing high material and manufacturing costs inhibiting further dissemination and full market penetration. The detailed cost structure of a CFRP (carbon fiber reinforced plastic) component which is manufactured by a conventional RTM process is depicted in Fig. 1.

The total manufacturing costs along the value chain cause a proportion of 64 %. This suggests that especially the reduction of this cost share represent an important lever for mitigating the major industrialization burden.

In order to enable a sustainable and economic production; the following requirements have to be considered:

- Increasing the level of automation in manufacturing by reducing manual operations

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- Enhancing process reliability by stable operations to reduce downtimes
- Reduction of throughput time by lowering cycle times for individual processing steps
- Lowering rejection rates by appropriate quality assurance approaches

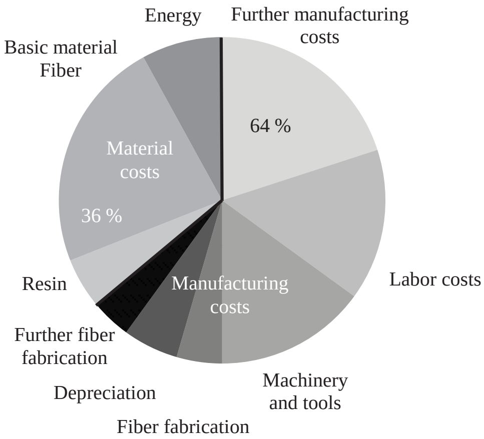

Fig. 1. Composition of the costs of a CFRP component [4][1]

Due to the high cost reduction potential, this paper is focused on the handling steps, which are required to connect the decoupled process steps. Exemplary for the preforming, the handling of instable form and contour variant CF-textiles are considered. These textiles have to be deposited in the mold layer by layer according to the required fiber orientation. Resulting from the anisotropic structure of the textiles a slight difference of the fiber orientation causes a debilitation and significant decrease of the stability characteristic (e.g. 35 % diminution of strength resulting from fiber deviation of 5 °). For example, conventional components in the aviation industry consists of up to 15 layers which have to be placed independently with high attention to their positions in order to enable further processing of the preform.

To ensure high availability for the entire preform process, high robustness must be ascertained for the individual handling steps. Based on the objectives, the automated and reliable handling using appropriate quality assurance measures can be derived as a target. The technical feasibility of the implementation of an automated process has been successfully demonstrated [5,6]. In manufacturing processes, there exist various options to ensure the quality, such as the subsequent listed [7]:

- Away from production – sampling inspection apart from production
- Related to Production – sampling inspection right next to the production
- Integrated in machinery – plant-integrated system for measuring during off-peak hours
- Inline – integrated inspection as a separate additional step in the process chain
- Parallel to manufacturing (online) – integrated inspection during the value-added step with a potential control system in the process

With reference to the described demands the focus is subsequently placed on the online quality assurance as the most appropriate solution. Especially for a handling operation the required partial steps, wherein errors occur during the operation, are identified and provided with suitable sensors following a comprehensive process analysis. The objective is to develop a process-synchronous quality monitoring and control technology of given error sources. Further potential weaknesses have to be identified in order to detect rework at an early process stage. An additional objective is placed on the development of process knowledge for the complex handling operations, wherewith the potential for cost reduction can be reached for further process steps.

2. State of the Art

In literature numerous approaches to quality assurance, as are illustrated in Fig. 2, can be found along the production chain. The classification is orientated towards an industrial process chain for the production of CFRP structures using the example of the RTM process.

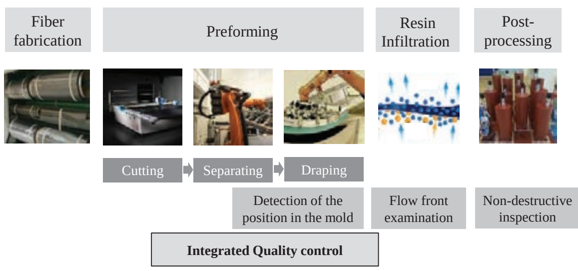

Fig. 2. State of the art of the CFRP production

Generally, the inspections of the finished components are executed with destructive and non-destructive methods as a final step. The most common non-destructive approaches use ultrasonic or thermographic testing methods. Two further methods such as radiography and eddy current testing are also widespread, whereas other possibilities result by using magnetic sensors [8]. Using non-destructive approaches errors such as delamination's, cracking, disbonds, voids, porosity, inclusions and fiber defects can be detected [9]. A decision support for selecting an appropriate testing method is given by [10]. Additional non-destructive tests with finished components are investigated by [11,12,13,14,15]. The inspection is also realized for special applications such as, complex structures [16], joints [17,18] or metallic hybrid constructions [19].

The aforementioned process step deals with the resin infiltration into the current dry textile construction. The flow fronts of the resin as well as the distribution of the matrix

[1] Dimensions 0,8 m x 0,8 m, weight 1,8 kg, complete component costs 50 €-60 €