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Non-destructive inline sensors for digital material twin in the carbon fiber tape laying process

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Summary:
The use of inline sensors during production enables the detection of quality-relevant material fluctuations. Thus, machine parameters can be quickly adjusted in case of occurring flaws to minimize waste. In addition, semantic integration of sensors and their data into a data ecosystem enables the analysis of complex correlations. As an example, the implementation of a multimodal thermography and laser thickness inspection system with DICONDE standard in the manufacturing of unidirectional reinforced carbon fiber tapes is presented.

Keywords: carbon fibre reinforced tapes, inline inspection, thermography, laser thickness inspection, DICONDE

Introduction

Continuous fibre-reinforced thermoplastic composites exhibit high stiffness at low weight. Using unidirectional fiber reinforced (UD) tapes in the process chain of cutting, laying, consolidation and hot-forming can lead to complex shaped components. The result is a good compromise in terms of mechanical properties and economical production. The consolidation of the fabrics into 3D components in closed molds and the functionalization, e.g. stiffeners or mounting brackets, in the injection molding process enable the efficient production of lightweight structures in large series [1].

However, safety requirements demand high stiffness and breaking strength, high reproducibility while asking for low weight and efficiency. At the same time, we are experiencing a time with growing demands for resource-conserving production. To meet these requests, the application of sensors, mainly in the context of digitization, is still growing [2,3]. When it comes to quality assurance, defects must be avoided and variations of the material properties must be documented. For this purpose, optical sensors and thermographic methods are already in use in the so-called Automated Fibre-Placement (AFP) process for thermoplastic composite production [4]. A project at Fraunhofer [5, 6] goes beyond defect detection. The digital twin is created from simulated data and by recording and localizing individual material properties of the real component and merging them into a data ecosystem representing the complete process chain. The focus of the presented paper relates to one process step of the digital twin, the manufacturing of UD carbon tapes.

Inline Sensor System

A pilot test system with thermographic and a laser thickness inspection systems was integrated into the production of the UD tapes (fig. 1). The test data is automatically related to the spatial coordinates on the tape and stored in DICONDE-standard [7] on a data server. Since the latter is integrated into a data ecosystem (MySQL) the ndt-data can be correlated with simulated, machine or production data as well.

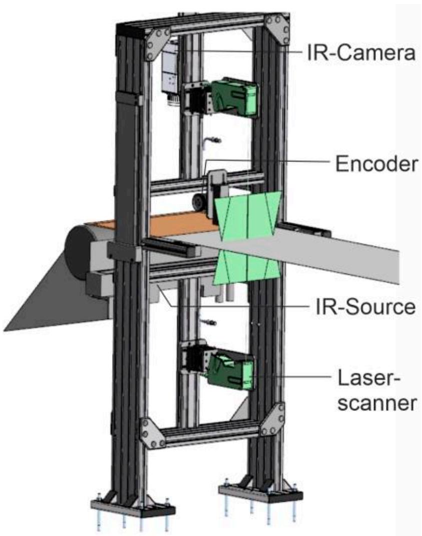

Fig. 1. 3D CAD model of the system assembly with tape moving from left to right side

The inline inspection system is placed just before the rewind station. Due to an encoder with a friction wheel, the acquired data are related to the spatial coordinates on the tape.

The thermography system consists of a line IR-source (IRD S750SM by Optron) and a bolometer camera (VarioCam® HD Head 800 by InfraTec). The thickness inspection system incorporates two laser profilometers with CMOS sensors facing each other. The most relevant defects to detect are the tape thickness, homogeneity, impregnation as well as the C-fibre volume content.

Results

Exemplary results from the inline inspection are given for thermography and thickness inspection in figs. 2. a and b, respectively.

The displayed section of the tape has a length of 4 m. The thermographic image displays the full width of 500 mm of the tape, the thickness inspection system covers a width of 320 mm.

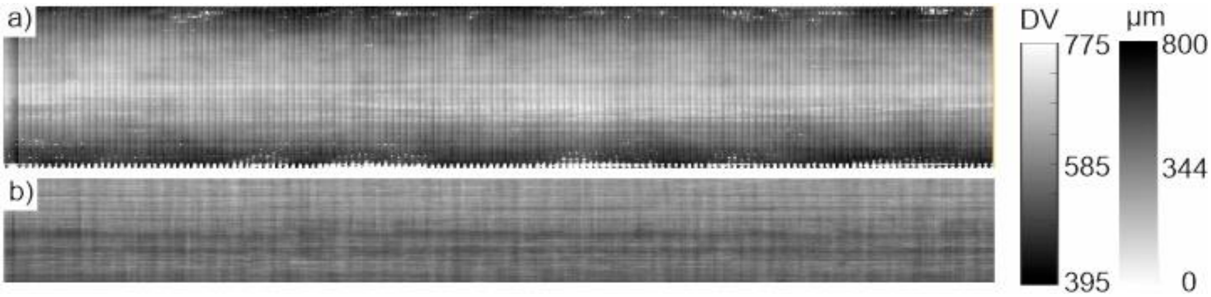

fig. 2. a) digital value of thermography intensity (DV) of the inspected tape, b) corresponding thickness values in µm

The images show the slightly asymmetrical thickness profile of the tape. Typically, greater thickness occurs in the center as the tool deforms due to high pressure. The IR intensity indicates the grade of transparency of the tape to the IR radiation emitted by the line source. The intensity contrasts and their spatial distribution is useful to infer defects. In particular, bright lines indicate gaps and small cracks.

The combination of the two modalities offers additional value, for example to investigate questions, such as whether the occurrence of defects is correlated with the tape thickness or where defects tend to occur. In order to allow the examination of cross-correlations by machine learning and other algorithms, the images are saved in DICONDE format at the end of each imaging cycle and automatically uploaded to the DICONDE server. The information provided by the DICONDE server is connected to a data ecosystem ruled by an ontology specifically adapted to the process which was developed with partners during the project. Hence, the inspection data can be analyzed and compared for example with the machine data to investigate the effect of influencing factors like tool temperature, on the defect frequency, and the data are available for further, more comprehensive process analyses.

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