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Procedia CIRP 62 (2017) 27 – 32

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10th CIRP Conference on Intelligent Computation in Manufacturing Engineering - CIRP ICME '16

Thermal image-based monitoring for the automated fiber placement process

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Abstract

Due to increasing consumption of fiber-reinforced plastics (CFRP) especially in aerospace applications also production processes such as Automated Fiber Placement (AFP) gain in importance. However, manual visual inspection in the AFP quality assurance is time consuming and insufficient, not least through the low contrast of CFRP materials. The presented process monitoring for AFP bases on occurring temperature differences during the lay-up process. Therefore, a newly developed monitoring system containing an infrared camera integrated in the Fiber Placement head is presented. Its algorithm can localize tows as well as certain temperature anomalies. Combined with the process knowledge provided by the path planning defects can be detected online.

Peer-review under responsibility of the scientific committee of the 10th CIRP Conference on Intelligent Computation in Manufacturing Engineering

Keywords: Automated Fiber Placement; Process Monitoring; Thermography;

1. Introduction

The Automated Fiber Placement (AFP) process evolves into one of the most important manufacturing processes in lightweight industries. During the process, the CFRP components are build up additive. Tows* are placed course after course on a tooling through a fiber placement machine. Certainly different kinds of defects can occur during the process and need to be detected. Not detected faults lead to high repair cost of the cured part at a later point of time. Therefore, the process monitoring and quality assurance are of high importance.

The quality control is predominantly carried out as a visual inspection by the operator after the lay-up of each ply. This operation is not only time consuming but also very difficult due to the low visual contrast of the CFRP material and huge toolings whereon the lay-up takes place. The time for inspection and repair during the AFP process sums up to 32 % [1]. At this time there is no commercial online monitoring system available for integration in to Automated Fiber Placement processes. Shadmehri et al. [2] link a laser projector with a vision system to assist the operator by projecting the characteristic properties on the target surface. This approach is able to identify the ply location and fiber orientation as well as it can detect gaps. Another approach is to monitor the system with a laser scanner mounted on the AFP head, to scan the placed surface geometry [1], [3].

The idea for a new developed thermographic monitoring system is to use the thermal contrast between the tows and the tooling surface that occurs during the lay-up process. Ideally, the material is kept cool to prevent fouling and to secure good material properties. However, to ensure a good tack, the tooling will be heated up just in front of the compaction roller. Hence, behind the roller the placed tows have a cooler temperature compared to the surrounding surface and a temperature gradient occurs.

The US patent 7513964 B2 [4] already pictures a thermal AFP monitoring system wherein an infrared (IR) camera is

* Tows are pre-impregnated thermoset carbon-fiber slit tapes storaged on a carrier foil.

Peer-review under responsibility of the scientific committee of the 10th CIRP Conference on Intelligent Computation in Manufacturing Engineering
doi:10.1016/j.procir.2016.06.058

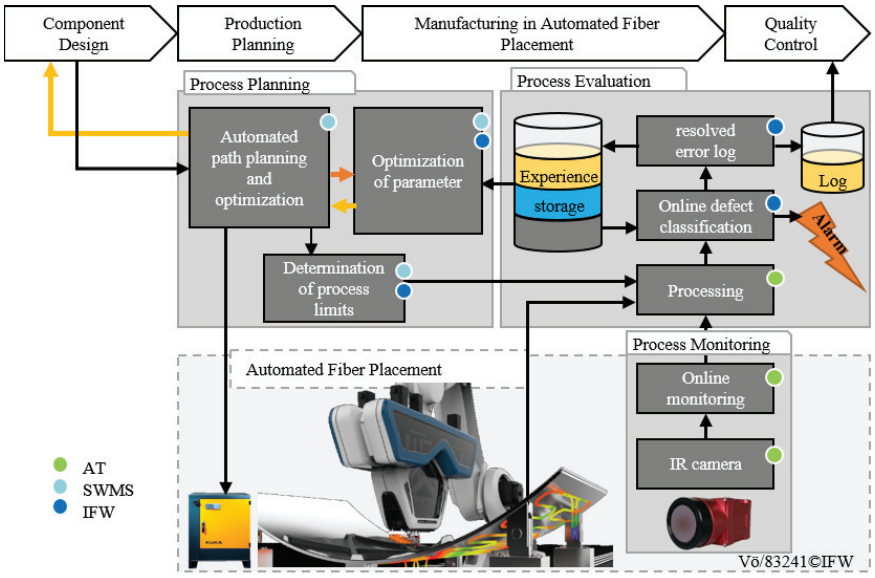

Fig. 1. Therm-O-Plan diagram

integrated. A heat or a cold flow is used to induce a thermal contrast. The composition of all frames shows a whole ply and can be analyzed. However, there is no known implementation of this patent so fare.

2. Thermographic Process Monitoring

The newly online monitoring system is part of the research project Therm-O-Plan that connects path planning, process monitoring and process evaluation as shown in the diagram of the superordinate solution (Fig. 1).

This project is a cooperation of the Institute of Production Engineering and Machine Tools (IFW) at the Leibniz Universität Hannover, Automation Technology GmbH (AT) and SWMS Systemtechnik Ingenieurgesellschaft mbH (SWMS). The aim is to develop an automated optimization module for path planning and process monitoring that is capable to be integrated into standard AFP systems. Therefore, the results of the monitoring module combined with the information of the path planning will be saved in an experience storage to generate process knowledge, that can be used to optimize the path planning and parameter adjustment of the AFP machine.

In the following, the focus will be on the thermographic process monitoring system and the data exchange between the path planning and the process monitoring to classify detected defects within prescribed tolerance ranges. The goal of the online monitoring system is to localize the tows and detect occurring defects during the lay-up process. Therefore, the algorithms are divided into two detection principles, the edge detection to determine the tow position and geometry and the surface inspection to detect defects and foreign bodies.

Looking via a thermal camera at the compaction point there is a temperature contrast between the relative cool tows placed on the heated surface (Fig. 2, 3). The thermal contrast is at its maximum right behind the compaction roller and the temperature profile at this line shows a good contrast between the surrounding surfaces and the cool tows (Fig. 4). If there is a gap of a certain size, the surface radiation is visible through the gap and will result in a local temperature maximum. If an overlap accurse the double amount of material placed results in a local temperature minimum. Using an edge detection algorithm, it is possible to detect the tow edge position. The positions of the tows are saved in the coordinate system of the robotic AFP system. Therefore, the actual position can be compared to the planned position and the algorithm can estimate the tow and gap widths. Planed gaps are not

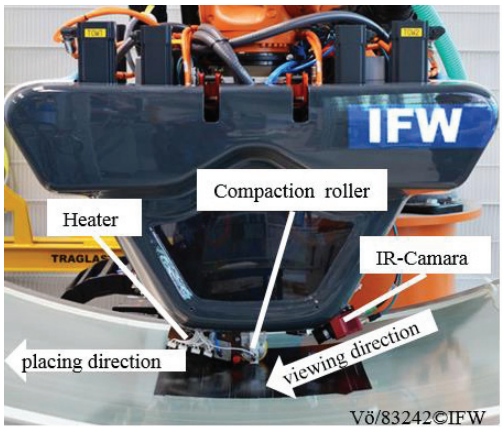

Fig. 2. IFW fiber placement head with thermal camera

avoidable but do not have any negative influence on the target properties, if they are within the planed tolerances. However, small overlaps are size-independent defects and need to be detected.