Symposium *Lightweight Design in Product Development 2018* (LWD-PD18)
Zurich, Switzerland, 14th–15th June 2018

CONCEPT FOR A TAILOR-MADE VISUAL INLINE INSPECTION SYSTEM FOR FIBRE LAYUP PROCESSES DEPENDING ON MATERIAL AND PROCESS CHARACTERISTICS

Sebastian Meister[1]
[1] German Aerospace Center e.V. (DLR) -
Center for Lightweight-Production-Technology, Stade, Germany. sebastian.meister@dlr.de

1. INTRODUCTION

Fiber layup processes like Automated Fiber Placement (AFP) are state of the art technologies for the production of large scale lightweight components like wing covers or fuselages. Lukaszewicz [1] gives a detailed review of both technologies. These composite components are produced layer by layer using narrow material strips. During this material layup it is possible to generate defects e.g. wrinkles, twists, gaps, overlaps, etc. with probably a huge influence on the mechanical properties of the produced component. [2], [3] Recognizing these defects, inline quality assurance (QA) systems are part of ongoing research and industrial development. These systems are mostly inflexible in the use of different sensors and algorithms. One single system is used for every production case. For different materials and various processes, this system performs differently and possibly non-deterministic. In order to compensate this issue it is necessary to understand the relation between optical material properties and the applied sensors and algorithms.

Optical properties of individual resins and polymers as well as textiles are described in literature. [4], [5] Various composites are not part of this existing knowledge. The approach considered in this paper is based on analyzing optical properties of fiber materials and link them to the characteristics and properties of various feasible sensors and algorithms. Beyond that, the knowledge is usable for design aspects and the manipulation of component behavior. The concept provides the opportunity to characterize materials itself and the current material status based on optical properties. This offers the possibility to determine changes in chemical properties and derive statements on the manufacturing performance of a particular material. [6]

In automated quality inspection, this proposal has the potential to increase the performance of an inline QA system significantly. Using this optical properties data, it will be possible to build a tailor made inline inspection system. This system is specifically designed by knowledge and had a well-known error range. Beyond that, directly to the producibility correlated material parameters can be derived from the optical material properties.

During this work, the following scientific questions have to be answered:

- Which dependencies in optical characteristics had to be analyzed to configure a tailor-made inline QA system for a specific material?
- How do we describe layup defects by its optical characteristics?
- How robust performs an inline QA system for different materials?

2. CONCEPT

This concept paper describes an approach for the measurement and interpretation of optical material properties, with the aim to optimize production and inspection processes.

Effects

For the material analysis using optical characteristics, several influencing variables are of interest. These include electromagnetic radiation influences as well as climate ascendancies. The following effects have to be measured for a material characterization:

- Spatial reflection behavior
- Spatial scattering behavior
- Spatial transmittance behavior
- Emission ratio
- Reflection ratio
- Transmittance ratio
- Angle of polarization
- Surface texture

Material

The presented concept focusses on the analysis of resins and composites with a minimum filament gap of 5.5 µm. Being able to measure the effects mentioned above, it is necessary to consider samples with a minimum size of 20 x 20 mm and a maximum size of 100 x 100 mm. Having regard to the huge thermal influences on the materials behavior, the samples are air condition stored. Simulating a production environment, it is possible to heat the samples up to 400°C during measurement cycle.

Sensors

Achieving a deep understanding of materials behavior, the mentioned effects have to be sensed within a spectral range from 300 nm up to 3500 nm. [4], [5] Recognizing thermal influences, it is also necessary to consider information from thermal infrared region from 7.5 µm to 13 µm.

Meeting these requirements, it is reasonable to use three different types of sensors. At first a monochrome camera with a spectral resonance from 350 nm to 850 nm is applied. Measuring the thermal infrared band, a thermal imaging sensor is used. Acquiring spectral information, a radiation spectrometer with a measuring range from 300nm to 3500nm is sensible.

Lighting

In Order to use the sensors mentioned above in its entirety, a selection of a reasonable lightings is indispensable. The radiation spectrum extends from 300 nm up to 3500 nm. This includes ultra violet, visible light, Near-Infrared and infrared spectrum. Therefore the exposure rate (E) has to be greater than $E > 6000 W/m^2$. It is important to guarantee an illumination of the measurement sample over the entire spectral range. This is feasible in various ways. One possibility is the radiation with various discreet working, superposed radiation sources. Another option is the assignment of a broad band radiation source. Combining these approaches is also possible to induce homogeneous radiation intensity over the entire radiation spectrum. In Order to distinguish polarization effects, the use of polarization filters is also required.

Data evaluation

In Order to evaluate generated data and derive predictions for feasible sensor and algorithm configurations, the use of artificial neuronal networks (ANN) is reasonable. Using this tool, also complex correlations are obtainable and extractable.

Depending on the input parameters and the desired predictions, it is necessary to use a fully connected network with multiple layers. Input parameters are the measured optical properties. Output parameters are one or multiple sensors and algorithm combinations for a particular process and material. Keep the possibility in mind, that various combinations solve the requirements with the same performance.

Training the ANN can be carried out by using the optical material characteristics and evaluate them using defined scoring values. These performance figures are determined for each sensor with single and multiple algorithms in use. Following, the forecast for a sensor and algorithm combination is possible.

Time line

It is planned to implement the general system concept, including multiple sensors and algorithms, until Q4/2019. Optical material characterization and the linking to the corresponding sensor-algorithm behavior will be finished in Q1/2021. The validated system is ready to run in Q4/2021.

REFERENCES

[1] D. H.-J. Lukaszewicz, C. Ward and K. D. Potter, "The engineering aspects of automated prepreg layup: History, present and future," Composites Part B: Engineering, 2012, pp. 997 – 1009.

[2] K. Potter, "Understanding the origins of defects and variability in composites manufacture," in Conference on Composite Materials (ICCM), 2009.

[3] C. Krombholz, D. Delisle and M. Perner, "ADVANCED AUTOMATED FIBRE PLACEMENT," in International Conference on Manufacturing Research, Cranfield, UK, 2013.

[4] Bruker Optik GmbH, "Analysis of Polymers and Plastics - Quality Control & Failure Analysis," Bruker Optik GmbH, Ettlingen, Germany, 2015.

[5] Hitachi High-Technologies Corporation, "Measurement of Optical Characteristic of Plastic by UH4150 Spectrophotometer - An example of High Throughput measurements in the UV, Visible and Near-Infrared Regions -," Hitachi High-Technologies Corporation.

[6] G. A. George, G. A. Cash and L. Rintoul, "Cure Monitoring of Aerospace Epoxy Resins and Prepregs by Fourier Transform Infrared Emission Spectroscopy," in Polymer International, 1996; 41: 169-182,.