The Use of Thermal Data for Quality Assurance in the Process of Continuous Ultrasonic Welding of Thermoplastic Composite Materials

Dominik Görick[1], Lars Larsen[1], Isabelle Stingl[2], Dirk Baumbach[2], Alfons Schuster[1]

[1]Center for Lightweight Production Technology, German Aerospace Center (DLR), Germany, [1]Institute of Optical Sensor Systems, German Aerospace Center (DLR), Germany

Continuous ultrasonic welding (CUW) is a manufacturing process used to join thermoplastic composite (TCs) materials using high-frequency ultrasonic vibrations. Under pressure and vibration the welding material heats up, melts and connects to its welding partner. CUW is a welding technique where the welding materials are fused together without the need for additional adhesives, solvents, or fasteners. The development of CUW is getting raised attention over the last decade since the use of TCs in the production industry and especially the aerospace sector demands for economic and fast joining techniques. A major advantage is that no holes have to be drilled for the process and therefore no chips are produced and no tooling is worn down. Therefore, future assembly processes for aircraft structures can be optimized to be much more ergonomic, cost-effective and clean. It is possible that during the welding process some irregularities in the welding seams can appear. These irregularities might come from process fluctuations, changes of the welding parameter during a weld but also can be a result of errors or foreign substances in the welding zone. Thermography provides the opportunity to investigate the result of the welding process immediately after the melting of the material took place and is therefore considered to be a game changer in the quality assurance of the CUW process. In order to optimize the process and to monitor the quality of the produced weld, thermal data can be analyzed and used to make assumptions about the weld quality. For the interpretation of recorded thermal data and to understand the process more in detail, AI algorithms as well as basic exploratory data analysis can be used. In this work three different thermal measuring systems are set up in the CUW process and compared to each other. Namely, thermocouples were used to measure temperatures on different surfaces, one thermography camera was used to record the whole welding plate during the joining process and one thermography camera was set up to record the thermal patterns in a close up of the welding zone immediately after the melting of the material took place. With the help of the global thermography measurement, an overview of the thermal behaviour of the welding plates can be generated as well as information about the cooling process after welding took place. The local thermography measurements enable thermographic panoramas of the welding zone and the investigation of heating patterns. All thermal measuring techniques are evaluated and the most promising system is taken to investigate the possibility of QA for the CUW process. For these investigations the thermal data is preprocessed and fed into a deep learning algorithm. The results of the training process of the algorithm indicates that the developed models learn from the given thermal data and are able to predict the bonding quality of the produced welds. The use of thermal data in the process of quality assurance for CUW might be a game changer when thinking about AI supported quality assurance and the in-line regulation of the welding process itself and might help to establish this joining process further in the industry.