SIMULATION-DRIVEN QUALITY ASSURANCE FOR LASER ASSISTING AUTOMATED FIBER PLACEMENT PROCESSING OF CARBON FIBER THERMOPLASTIC COMPOSITES

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Abstract

Carbon fiber reinforced thermoplastic composites have gained significant attention in various industries due to their exceptional mechanical properties, lightweight nature, and potential for cost-effective manufacturing. The use of automated fiber placement (AFP) techniques for thermoplastic materials has further enhanced their applicability in complex structures. Lasers are often used during this process. However, ensuring consistent laminate quality poses challenges, particularly in terms of temperature measurements and the need for homogeneous heat distribution.

Accurate temperature control is crucial for achieving consistent laminate quality and evaluating potential degradation. A number of multi-physics numerical models are developed [1-3]. The modeling of the laser-assisted fiber placement process involves several steps. Firstly, the physical situation, including the substrate, roller (including roller deformation), and laser beam, needs to be accurately modeled. This step ensures that the simulation captures the real-world conditions of the process, including the deformations of the roller. However, it is worth noting that current models may have weaknesses in this area, as they often simplify the physical situation and sometimes consider it in only two dimensions.

Next, the heat flux is determined, often using ray tracing techniques. This helps in understanding how the laser energy is distributed and absorbed by the material. Once the heat flux is known, the computation of the energy absorbed can be performed in order to determine the amount of energy transferred to the material during the laser-assisted fiber placement process.

To determine the temperature field, thermal finite element modeling is employed. From the temperature field, multi-physics models are utilized to determine various properties of the laminate, such as crystallinity, degree of bonding between plies, and potential degradation of the matrix. These models take into account multiple physical phenomena and provide a comprehensive understanding of the material behavior during the laser-assisted fiber placement process.

However, the lack of accurate knowledge of the AFP head position and velocity as well as the lack of consideration of the orientation of the substrate ply orientation, especially during layup over large and complex 3D geometries, poses a challenge for accurate modeling.

This paper will present the Simureal® Heat solution a new simulation tool developed by Coriolis Composites that intends to address these limitations. This solution offers a fast, efficient and industrial model. It incorporates realistic movements through the Virtual Numerical Controller (VNCK), which considers head positions relative to the surface and known velocities. The solution also requires knowledge of the surface and substrate orientation, allowing for the reconstruction of previously deposited layers and automatic 3D meshing of the substrate.

Using roller deformation computation, ray tracing technics and integrating the real laser beam profile, the Simureal® Heat V1 model focuses on the absorption of surface energy, while Simureal® V2 computes the temperature field. Figure 1 shows a color mapping of the energy absorbed while laying up a panel with ramps computed by Simureal® Heat V1. The ramps create a variation of the energy absorbed while going over the ramps. The paper will show how the energy can be optimized by

changing the programming of the part. Figure 2 shows the validation case of Simureal® Heat V2 using data from Dolo’s Ph.D work [4].

To conclude, carbon fiber reinforced thermoplastic composites offer numerous advantages, and AFP techniques enhance their applicability. The Coriolis Simureal Heat solution provides a fast and efficient model for achieving consistent laminate quality through homogeneous heat distribution. However, there are limitations to be addressed, such as the lack of support for multi-layer winding and the need for further validation.

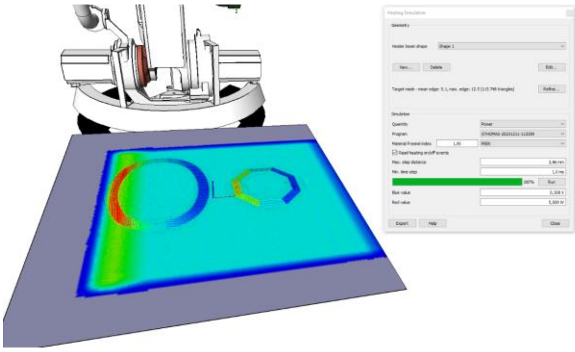

Figure 1 : Colour map of the energy absorbed computed using Simureal® heat V1

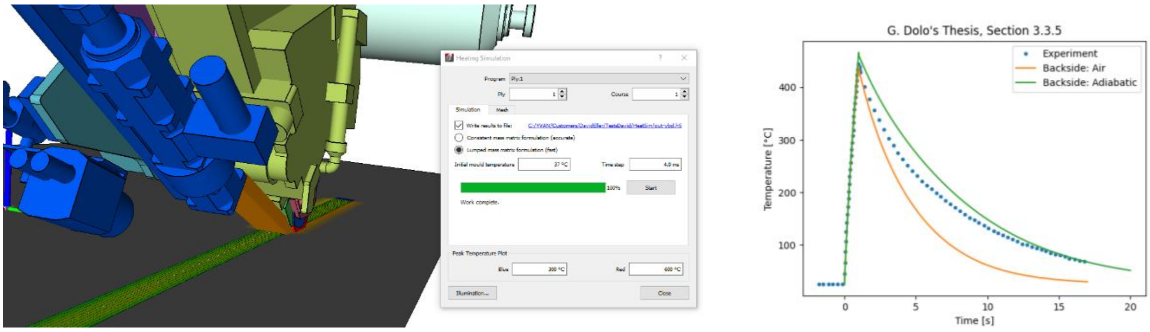

Figure 2 : Simulation of the validation case, left: 3D model of layup of a single tape at constant velocity, right comparison of experimental data from [4] with Simureal Heat V2 results with two boundary conditions (under side cooled by air (orange) and under side adiabatic (green)).

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