MECHANICAL ENGINEERING

Multifield modeling of curing for virtual manufacturing of composites

Funded By	MINISTERO DELL'UNIVERSITA' E DELLA RICERCA [P.iva/CF:97429780584] Dipartimento DIMEAS
Supervisor	PETROLO MARCO - marco.petrolo@polito.it
Contact	
Context of the research activity	This project combines virtual manufacturing with Artificial Intelligence to mitigate defects in composite structures. A typical, expected result is a total 3D output including thermo-chemical effects of a complex part within minutes instead of days to unleash the potential of virtual manufacturing towards the improvement of the quality of composite parts, minimize the curing time, cure degree inhomogeneity, defects formation, energy consumption, and thus improve resource efficiency.
Objectives	Manufacturing science for composites has gained prominence over the last two decades as successful manufacturing is a prerequisite for a successful design. Composite manufacturing is complex and fragile, and there are increasing research efforts to develop computational simulation. Manufacturing simulation aims to obtain the complete distribution in time and space of relevant parameters, e.g., chemical, physical, and mechanical properties. Afterward, these parameters can be helpful in various ways, e.g., feed models for failure analysis, evaluating the effect of equipment and tooling, and thermal boundary conditions. Simulation has begun to be used to design parts, tools, and autoclaves, as in the Boeing 777x program, and it may have a decisive influence on the finished parts. Virtual manufacturing can contribute to advancing and making manufacturing more efficient, e.g., optimizing process and development time and reducing defects. The development of models to simulate composite processes is an interdisciplinary problem involving physics, chemistry, material science, and engineering. It includes various phenomena, e.g., heat and mass transfer, thermo-chemical phase transitions, and highly nonlinear and time-dependent viscoelastic stress developments. This project aims to exploit the synergy between structural mechanics, material engineering, and AI to unleash the potential of virtual manufacturing. The aim is to deliver optimized, first-time-right composite parts, i.e., satisfying geometric tolerances and performance requirements, without the time-consuming and expensive iterative production of different physical molds and parts. AI, structural mechanics, and material engineering incorporate the thermal mismatch between the fibers and the matrix, the chemical shrinkage,

	and the tool-part interaction with computational times of the order of minutes. The activities include the numerical modeling of curing using advanced finite element formulations; models for process-induced deformations and stresses; development of defect mitigation strategies; surrogate models and artificial intelligence to optimize design and manufacturing; AI algorithms for process simulation; extension of AI algorithms to parameter calibration and optimization.

Skills and competencies for the development of the activity	Finite element modeling; mechanics of composites; structural analysis; Matlab, Fortran, and Python programming languages; basics of artificial intelligence; basics of material science and manufacturing for composites; thermomechanical analysis; numerical methods