DEVELOPMENT OF A CLOSED LOOP CONTROL SYSTEM AND INTEGRATED QUALITY INSPECTION FOR LIQUID COMPOSITE MOULDING

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Composite materials are used increasingly often for different applications, e.g. to manufacture high-performance parts for aerospace and automotive applications. At the same time more economical resin injection processes progressively replace typical aerospace processes such as the well-known autoclave-technique. Today, Liquid Composite Molding (LCM) has become a well-established technology for medium size series and fiber volume contents up to 50%.
Manufacturing of LCM parts mostly relies on experience, i.e. on expensive and time-consuming trial-and-error procedures. On-going developments in process modeling, simulation, and optimization will further improve the possibilities to predict flow front behavior in an early development stage, contributing to reduce development time, risks and costs for tooling and tests. Nevertheless, the LCM-process has shown to be very sensitive to slight changes of the process conditions, resulting in often unacceptable quality fluctuations. This issue is obviously asking for an improvement of process authority and the capability to influence flow front behavior during the injection process.
In this context, the PhD project which is sponsored by Alcan Technology & Management Ltd. aims at the development of intelligent injection strategies. Our approach is using in-house developed monitoring technologies to track relevant process parameters such as resin behavior (filling and curing) in conjunction with the development of appropriate closed-loop control strategies and multigate injections.
The filling process is simulated and optimized using FELyX, the Finite Element Library developed at our chair. For this purpose, FELyX has been extended with a LCM simulation and optimization tool. The optimization is based on evolutionary algorithms, to determine several sets of optimal filling patterns (gate location and gate timing as well as injection pressure), targeting minimal injection time and best part quality by avoiding dry spots and void formation.
Any unpredictable effects, like race tracking and fiber washing, cannot well be included in a deterministic modeling, so that the ideal process mapped by the simulations may deviate from experimental observation.
A complex LCM mold for manufacturing a wingnose has been instrumented with sophisticated monitoring and control transducers for advanced laboratory experiments. The closed-loop control strategy uses observed deviations of the real injection process from the simulated ideal process to adjust the filling parameters for achieving one of the optimal filling patterns and produce high quality parts.