LABORATOIRE DE THERMIQUE ET ÉNERGIE DE NANTES UMR 6607

IRT JULES VERNE

Program PERFORM – IRT Jules Verne: proposition of PhD Thesis

Fusion bonding of thermoplastic composites: experimental characterization and modelling of the out-of-equilibrium auto-adhesion kinetics.

Laboratory: LTEN
Team: TTMI (Heat Transfer in Materials and at Interfaces)
Location: LTEN, La Chantrerie, Nantes.

Advisor	**Co-advisors**
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Keywords

Composites, adhesion, inter-diffusion, rheology, wetting, experimental characterization.

Summary of the PhD project

Context and objectives

Thermoplastic composites are expected to take an increasing part of the global market of composite materials. This is mainly due to their tremendous properties in terms of impact resistance, storage, structures lightening and recyclability, that make them particularly interesting candidates for aeronautics and automotive industries. With the additional possibility of melting the polymeric matrix, new promising processes developed such as: tape placement, overmoulding or more simply fusion bonding.

The control of those processes requires a fine understanding of the phenomena of thermos-adhesion in the context of fast industrial processes (some seconds) which arises several scientific problems: the experimental validation at short times is scarce, the quality of the used mechanical tests is often questionable (SLS type tests), and the effect of the fibrous reinforcement is overlooked (woven, UD, presence of an intefacial matrix layer,…). Furthermore, the effect of wetting, though often mentioned in the literature, is never accounted for in adhesion models.

For those reasons, IRT Jules Verne and LTEN propose this PhD Thesis, which results will in the long run feed the technological developments in the field of thermoplastic composites assembly or overmoulding. Findings of this work will contribute in improving simulation tools as well as the design stage for new assembly processes.

The objective of this PhD thesis is the deep understanding of physical phenomena (thermal, mechanical, physico-chemical) that take place at the interface between two composite parts made of the same thermoplastic resin in industrial processes representative conditions. To that purpose, the governing physics will have to be perfectly controlled in order to be able to deduce the main parameters impacting the adhesion quality ad kinetics (interface temperature, contact pressure, wettability of surfaces, …). The goal is to propose a validated experimental protocol starting from the

realization of adhered samples up to the proper mechanical loading of interfaces. This protocol will be used to determine a constitutive equation enabling to predict the quality of adhesion in terms of the processing parameters.

This methodology will be developed in the scope of aeronautical applications, on the typical example of a PEEK semi-crystalline high-performance matrix reinforced with carbon fibers. This material has already been tested and characterized in the LTEN from the thermos-physical point of view. It won't require additional characterization campains. This generic work will be carried out in the perspective of two particular technologies: induction welding of composites and automated fiber placement process of TP tapes. The first one is currently under study in the IRT project called SidEffect, where the LTEN is also implied whereas the second process has been the subject of WP6 in the Competh chair (IRT Jules Verne). In this context, an experimental bench enabling to ttest the adhesion at very short times has been developed. Both processes imply very fast heating times but strongly differ in their cooling times. Cooling is indeed quite slow for the induction welding (~1 min) and very fast for the fiber placement (~1s). This comparative study will enable to highlight the effect of crystallization on adhesion quality.

Provisional program:

1) Bibliographic study on thermoplastic adhesion, its link with rheology, existing models and experimental methods, associated physical theories.
2) Improvement of the existing bench for the time-controlled adhesion kinetics of PEEK
3) Experimental study of the impact of fibers on the adhesion kinetics on the basis of the same device: case of UD and layered structures. Analysis of the role of fibers orientation.
4) Improvement of the Competh device for the out-of-equilibrium characterization (laser heating up to 1000K.s^{-1})
5) Correlation with the rheological approaches of polymers healing, establishment of a link between adhesion time and relaxation times (reptation).
6) Development and identification of one or more adhesion models and implementation in simulation tools for validation on simple cases.

<u>Resources</u>
Existing experimental devices: TA Rheometer, homogeneous adhesion bench and G1c bench, Competh bench for short times analysis.
Funding: 30k€ on IRT-PERFORM contract.

Required skills

Knowledge	Know-how	Soft skills
• Polymers & Rheology • Composite materials • Metrology • Heat transfer and mechanics • Numerical methods	• Modelling • Experiments management • Numerical simulation • Bibliographic searching • Scientific writing	• Curiosity • Determination • Autonomy • Team work

• Englih: fluent • French: expected		
Background :	• Master or Engineering diploma • Speciality: mechanics of materials (and/or) processes (and/or) thermal sciences • Significant research experience (internship or other)	
Contact :	Please send a detailed CV, a letter of motivation and a letter of recommendation (if possible) at: recrutement@irt-jules-verne.fr and steven.lecorre@univ-nantes.fr	