# Optimisation de couplage Procédé/Propriétés/Fiabilité des Structures en Matériaux Composites Fonctionnels


**Doctorant·e**

MTIBAA Mohamed

**Direction de thèse**

SAOUAB ABDELGHANI (Directeur·trice de thèse)
BOUAZIZ SLIM (Co-directeur·trice de thèse)
EL HAMI ABDELKHALAK (Co-directeur·trice de thèse)



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**Rapporteurs de la thèse**

KANIT TOUFIK PROFESSEUR DES UNIVERSITES UNIVERSITE DE LILLE
SOULA MOHAMED PROFESSOR ECOLE NATIONALE D'INGENIEURS DE TUNIS

**Membres du jurys**

BOUAZIZ SLIM, PROFESSOR, ECOLE NATIONALE INGENIEURS DE SFAX
EL HAMI ABDELKHALAK, PROFESSEUR DES UNIVERSITES, INSA de Rouen Normandie
EL MAHI ABDERRAHIM, PROFESSEUR DES UNIVERSITES, UNIVERSITE LE MANS
EL MOUMEN AHMED, MAÎTRE DE CONFERENCES (HDR), LUXEMBOURG INSTITUTE OF SCIENCE AND TECH
HADDAR MOHAMED, PROFESSOR, ECOLE NATIONALE INGENIEURS DE SFAX
KANIT TOUFIK, PROFESSEUR DES UNIVERSITES, UNIVERSITE DE LILLE
SAOUAB ABDELGHANI, PROFESSEUR DES UNIVERSITES, Université Le Havre Normandie
SOULA MOHAMED, PROFESSOR, ECOLE NATIONALE D'INGENIEURS DE TUNIS


**Abstract**


This research focuses on the challenges and interactions between the manufacturing processes (Resin Transfer Molding ‘RTM’ and Compression Resin Transfer Molding ‘CRTM’), the mechanical properties, and the reliability of composite material structures; more specifically the functional composites. A number of numerical models have been developed for simulating the suspension (resin + particles) impregnation through the fibrous medium (fibers) in the RTM and CRTM processes. These models are validated by comparing their results with experimental, semi-analytical, and analytical ones from the literature. A parametric study is carried out to demonstrate the impact of various process parameters on particles’ distribution in the final composite. Moreover, a comparison between the injection and compression modes is done. The results of this part show that the distribution of particles in the final part depends on the initial concentration, the distance travelled, and the initial fibers’ volume fraction. However, it is independent of the parameters values of injection and compression. It is also observed that the CRTM process with imposed pressure injection and imposed force compression represents the most favorable scenario for producing composite parts. For the purpose of controlling the final particles’ distribution in the composite material, manufactured by the RTM process, two key steps have been identified. The first step consists in a sensitivity analysis that examines three parameters: the temporal evolution of the initial injected particles’ concentration, the injection pressure field and the initial fibers’ porosity. The conclusions indicate a minimal impact of the initial porosity and the injection pressure field; while the evolution of the initial concentration of the injected particles has a dominant effect. In a second step, an optimization algorithm is implemented in the numerical model of the RTM process. It is used to determine the optimal configuration of the initial injected particles’ concentration’s evolution; in order to approximate the particles’ distribution in the final composite to the desired profiles. The obtained results from the genetic algorithm provide a very satisfactory control of this distribution. To complete this section, a model, estimating the mechanical properties of the manufactured part, is developed. It is found that there is a positive correlation between the particles’ fraction and certain mechanical properties, namely the elastic modulus E11 and E22, and the shear modulus G12 and G23. Nevertheless, the Poisson’s ratio (Nu12) is inversely proportional to the particles’ fraction. Also, the shear module G12 is the most significantly influenced by this fraction. Following this, the control of the mechanical properties of the composite parts, manufactured by the CRTM process, is targeted, and compared to the results of the RTM process. The conclusions reveal that the RTM process offers a better control of these properties. Whereas, the CRTM process improves considerably the mechanical properties of the parts due to its compression phase, which increases the fibers’ volume fraction and consequently enhances these properties. Finally, a static analysis is conducted based on the developed numerical model that uses the finite element method (Ansys APDL). This model is combined with those of the CRTM process and the mechanical properties calculation. An optimization algorithm is integrated in our global model to adapt the mechanical properties of the composite part according to the configuration (cantilever or simply supported) and the load distribution. Moreover, it minimizes the

composite part’s weight and ensures the respect of the predetermined mechanical constraints such as the maximum deformation limit. The obtained results correspond perfectly to these objectives.