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Study of the impregnation process of electric engines' rotors with a reactive thermosetting resin: modeling and characterization of multi-physical coupling

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As part of its development in the electric mobility market, the Renault Group assembles its own electric engines. The rotor is the mobile part of the electric rotating machine.
A rotor is mainly composed of a steel core wound by insulated copper wires. During the rotor production, the winding is impregnated with an acrylate-based thermosetting resin in order to:
• maintain the copper wires packed and avoid the relative movements due to electromagnetic, vibrational and centrifugal forces (rotation speed can rise up to 12000 rpm).
• improve the quality of the insulation,
• resist to chemical attacks and moisture,
• improve the thermal conductivity of the winding.
The impregnation process is complex, including an immersion of the winding into a liquid resin bath and controlled temperature settings to facilitate the flow and the polymerization. As opposite to many and well-known composite processes, the processing of the rotor does not involve a pressurization to facilitate the resin flow between the fibers (of few millimeters of diameter) and to avoid bubbles and unfilled areas in the winding. This suggests that capillary and gravity forces play a significant role into the rotor impregnation. The objective of the study is then to evaluate the impregnation quality of the windings within such processing conditions. It will require to characterize and to simulate a multi-materials and multi-physics process in which phenomena such as heat transfer, polymerization kinetics and resin flow are strongly coupled.
The defined research plan considers 2 submodels: heat transfer and flow. The first one includes the heat transfer taking into account the exothermy of the reaction and the second the mass conservation and resin flow, taking into account the chemo-rheology and the capillary effect [1].
Regarding the flow sub-model, the choice of a Darcy-type approach [2] or not is not obvious as the separation of scale is not that well defined (the number of wires is below 200).
In parallel, the material properties have to be characterized: polymerization kinetics, rheology evolution according to time and transformation [4] and capillary forces according to the geometry variations [5].
The developed simulation and characterization approaches will be presented, especially
for the capillary impregnation aspect. Indeed, a capillary rise set-up has been developed to evaluate the impact of various parameters such as wire size, surface preparation or wires drying on the impregnation. Then material properties associated to capillary phenomena (contact angles and surface tension) has been evaluated to link experiments to analytical models [3].

Time Block Preference

Time Block B (14:00-17:00 CET)

References

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