PHD DOCTORAL THESIS POSITION

Multi-scale understanding and characterization of thermal aging phenomena of rotating machine electrical insulation systems

The Saint Exupéry Institute of Technological Research (IRT), Toulouse (France), is an accelerator of science, technological research and transfer to the aeronautics and space industries for the development of innovative solutions that are safe, robust, certifiable and sustainable. At our sites in Toulouse, Bordeaux, Montpellier, Sophia Antipolis and Montreal, we offer an integrated collaborative environment made up of engineers, researchers, experts and doctoral students from industry and academia for research projects and R&T services supported by technology platforms in four areas:

- advanced manufacturing technologies
- greener technologies
- methods and tools for the development of complex systems
- intelligent technologies.

Our developed technologies meet the needs of industry by integrating the results of academic research.

This mission is part of the activities of the Greener Technologies axis and more precisely in the High Voltage Energy (EHT) competence center, which aims to work on the phenomenology associated with the electrical transition in aircraft. This transition corresponds to the replacement of propulsive and non-propulsive aircraft systems by electrical systems, and is associated with an increase in voltage, power and energy density levels. The EHT Competence Center focuses on studying the phenomena impacted by these changes (space charges, partial discharges, surface discharges, dielectric breakdown, electric arcs, etc.) as well as their implications on all elements of the electromechanical chain (generator, cables, power converters, transformers, connectors, protections, actuators, etc.).

The LAPLACE Institute, in the University of Toulouse – Paul Sabatier, seeks weave an “activity continuum” encompassing the production, the transportation, the management, the conversion and the use of the electricity while covering all the aspects right from the study of fundamental processes in solid and gas to the development of processes and systems. Within this widespread field, the major themes concern the plasma discharges as well as plasma applications, the study of the dielectric materials (polymers, in particular) and their integration into the systems, the study and the design of the electrical systems, the optimization of the control and the power converters.

The research topics by their multidisciplinary nature lean on a physical science base willing to study the basic phenomena and introduce new concepts emanating from the fundamental sciences but, evidently, strongly motivated by the constraints and the technological or the environmental locks; they are therefore linked to the industrial activities through various collaborations and participate in the transfer of technologies, especially in the aeronautic domain.

Industrial context:

Manufacturers of rotating machines are facing 2 major technological challenges: efficiency and power density. Improving the efficiency of a machine often consists in reducing the losses linked to the motor control with power converters controlled by pulse width modulation. These new generation components impose a more severe electrical stress that must be taken into account in the design of the machines in relation to their own mission profile, especially regarding temperature.

Improving the power density of rotating machines requires the development of higher voltage machines which can lead to a profound change in the electrical insulation technologies used in its design. The new materials and combinations of materials imagined then raise the question of performance and durability over time.

The existing tools to tackle these 2 issues are limited: the standardized qualification tests that are imposed on the systems do not take into account the non-Arrhenius behaviors of the materials and can sometimes generate too severe and non-representative stresses on the tested samples. The characterization of materials alone cannot fully reproduce the real environment to which they are exposed in the conversion system (associated mechanical stresses, different oxidative environment, etc.), nor the impact of the elaboration process and geometry.

Thesis Objective:

The objective is to make the link between the evolution of physicochemical properties on simple polymer samples under thermal aging, and their occurrence within an assembly through the drift of macroscopic electrical markers.

Tasks:

1) Literature review

Context of electrical rotating machines, degradation phenomena of insulation, aging tests, existing characterization and modeling methods, adapted material laws.

This task is crucial to define the roadmap of the PhD adequately with the objectives of the project and the state-of-the-art.

2) Specification of samples adapted to the change of scale (markers at system level vs. physico-chemical properties at material level).

The objective of this task is to define the type of samples that will allow to study the potential interactions between the different components of the complete electrical insulation system (e.g. twisted pairs, impregnated twisted pairs, insulating papers, etc.).

3) Aging tests on material samples and intermediate specimens.

This task will consist in carrying out isothermal aging tests with regular characterizations (FTIR, DSC, TGA, SIMS, EDX, dielectric spectroscopy, etc.) on the different samples in order to study the evolution of the material properties at various scales.

4) Comparison with data from isothermal aging on motorettes.

Within the framework of the previous project, test campaigns were carried out on motorettes with measurements of macroscopic markers (capacitance, PDIV, leakage current). This task, which is the heart of the subject, will consist in the analysis and the identification of correlation between the changing of the properties characterized in the task 3 and the drift of the macroscopic probed markers. The use of numerical models could be a mean to make the link between these two scales.

PhD thesis duration and starting date:
3 years starting from October 1st, 2022.

Location:
Both at IRT and LAPLACE-Paul Sabatier University, Toulouse, France.

Expected PhD student profile:

- Master's degree (or equivalent engineering school's degree) in Electrical Engineering or Materials Sciences (polymers with knowledge in dielectrics).
- Basics in electrical characterizations, properties of dielectrics, thermal and structural characterizations, physico-chemical characterizations, knowledge of aging
- Curiosity, rigor, team spirit, application, practical work

Expected wages:
31 k€ gross/year before income tax.

Contacts:

Assoc.-Prof. Sombel Diaham (LAPLACE), *Thesis director,* sombel.diaham@laplace.univ-tlse.fr

Assoc.-Profs. Nadine Lahoud-Dignat (LAPLACE), *Thesis co-director,* lahoud@laplace.univ-tlse.fr

Dr. Guillaume Belijar (IRT), *Thesis supervisor*, guillaume.belijar@irt-saintexupery.com