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Researcher / Associate Engineer (M/F)

Study of Thermomechanical Fatigue Behavior of a Power Module Encapsulated in Epoxy Resin

12-month fixed-term contract, reference HMTFT044

Context and Description

Nowadays, power modules are key components used in electrical energy conversion systems across various fields such as transportation (railways, electric vehicles, etc.), renewable energy (photovoltaics, wind turbines), and industrial plants (motion control, drives, etc.). These modules are increasingly used and face harsh environmental and operating conditions (high temperatures, mechanical vibrations, humidity). Long-term exposure to significant temperature variations and complex mission profiles makes these components prone to fatigue and wear-out, leading to failures. Poor reliability design of a power module can result in unexpected downtime, unscheduled maintenance, revenue loss, electronic waste, and non-compliance with safety regulations.

To meet high reliability requirements, improved power module structures have been developed, such as modules encapsulated in epoxy resin offering longer lifetime. However, these new technologies are also subjected to aging during usage and reveal new degradation mechanisms. Therefore, understanding these mechanisms through numerical simulation tools allows for predicting their operational lifetime and improving future designs.

The proposed position aims to develop a multiphysics model to reproduce the electro-thermo-mechanical behavior of a power module, integrating IGBT (Insulated-Gate Bipolar Transistor) semiconductor chips encapsulated in epoxy resin. The model will quantify aging indicators (stress fields, strain, cracks, etc.) to estimate lifetime. In parallel with the theoretical part, accelerated cycling tests will be studied and simulated to validate the established lifetime model.

Your task/ Mission:

The work will focus on the following areas:

- Literature review on various aspects: industrial and scientific issues, degradation mechanisms of power electronic components, fatigue regimes (shakedown and ratcheting), and Bree diagram.
- Construction of a 3D geometric model based on a real module.
- Finite element simulations (COMSOL Multiphysics) of the electro-thermo-mechanical behavior to predict degradation zones and estimate a module lifetime.
- Study of fatigue behavior (Bree diagram regimes) under different loads, compared to analytical solutions.
- Study of accelerated aging tests and evaluation of lifetime.
- Analysis of failure mechanisms on components from aging tests using various methods: acoustic scanning, optical microscopy, scanning electron microscopy, etc.
- Thermomechanical characterization of materials constituting the test components.

Requirements:

- PhD (or engineer with a minimum of 3 years of experience)
- Experience in finite element simulation
- Skills in multiphysics modeling: electrical / thermal / mechanical
- Autonomy
- Motivation to work in a multicultural environment, with good interaction and adaptability skills
- Strong analytical and communication skills, team spirit, and initiative
- Fluent in English

Duration: 12 months starting from September 2025

Contact: Magali BRANCHEREAU (jobs@fr.merce.mee.com)

Please send your application (CV and cover letter in PDF format) specifying the reference of the job offer.