Doctoral thesis 36 months, starting October 2025.

Mines Paris, Centre de Mise en Forme des Matériaux (CEMEF) Sophia *Antipolis, France*

"Optimizing the performance of recycled plastics: understanding and anticipating changes in their mechanical properties"

Context: Plastics, present in nearly every aspect of our daily lives due to their durability, light weight, and low cost, represent a significant environmental challenge. It is estimated that around 8 million tons of plastic are dumped into the oceans each year, causing irreversible damage to marine life and natural habitats. To combat plastic pollution, plastic recycling has become a global priority. The European Union (EU) and France have set ambitious goals to reduce, reuse, and recycle plastics. European directives on plastics and the circular economy set high targets for plastic recycling by 2030, with a particular emphasis on integrating recycled plastics into industrial value chains. These directives are incorporated into national laws in member states, setting mandatory requirements for the use of recycled plastics under Extended Producer Responsibility. Among the notable initiatives, the **Circular Plastics Alliance (CPA)** has set a goal of recycling **10 million tons** of plastics by the **end of 2025**. To achieve this ambition, the plastics industry must rethink its production model to incorporate more **recycled raw materials (RRM)** into its products while ensuring their **quality, traceability, and safety** for citizens.

Today, significant scientific and technical challenges must be addressed. Recycled materials often exhibit degraded mechanical properties compared to virgin plastics, while their rheological characteristics tend to fluctuate more during processing. These variations stem from multiple interconnected factors influencing each stage of the transformation cycle, from raw material sourcing to the production of the final product. It is within this context that this research program takes place.

The project will be carried out as part of the "Lionel Fourment" Chair program proposed by CEMEF Mines Paris, in close collaboration with IPC (Industrial Technical Center for Plastics and Composites). This chair program, titled "CYCLADES" (reCYcling Composites and poLymers: Advanced processes, Durability, and numErical Simulation/artificial intelligence), primarily aims to understand the impact of incorporating recycled raw materials on the behavior of polymer or composite materials. The project described here focuses on the relationship between the material process, the development of microstructures, and the final properties expected.

Keywords : Polymer Recycling, Rheological and mechanical properties, Artificial Intelligence (AI)

Topic description: The issue addressed by this work is the ability to estimate and predict the final mechanical properties of the product at the compounding stage or during the manufacturing of the master batch (recycled polymer and additives). Two complementary approaches will be used:

- Determining one or more measurable indicators at the compound level for further mechanical properties,

- Using a data-driven model to predict the final mechanical properties based on measurements taken from the compound. This model will help optimize the process to improve the quality of the produced compound.

The thesis is based on a detailed understanding of the origins of variations in the mechanical properties of recycled polymer materials. Experimental tests will be conducted to analyze the physical and mechanical properties of the recycled material, focusing on its composition and developed microstructure. Thermomechanical tests on injected specimens will assess their resistance under various loading and temperature conditions.

The focus will be on post-consumer polypropylene plastic sources, potentially derived from various applications such as packaging and automotive industries. After the compounding process, injection molding will be used for the fabrication of the final specimens.

The proposed scientific approach will rely on an extensive experimental platform, incorporating analytical tools such as scanning electron microscopy (SEM), infrared spectroscopy (FTIR), calorimetry (DSC), dynamic mechanical analysis (DMA), and X-ray diffraction (WAXS and SAXS). Melt processing techniques, including compounding and injection molding, will also be used, ideally with in-situ measurements (IR spectroscopy). The material's behavior in the fluid state will be examined through rheological tests, while in the solid state, thermomechanical tests will be coupled with local deformation and temperature field measurements. Finally, artificial intelligence tools will be used to develop a predictive model for the final properties of the recycled material.

Profile and skills: The selected candidate must hold an engineering degree or a Master's (M2) in polymer materials science. He/she should have strong expertise in polymer materials science, particularly in the physico-chemistry and mechanics of polymers in both fluid and solid states. Given the application-oriented nature of the research, the candidate should have a strong inclination toward experimental approaches. An interest in using AI tools is also expected. Experimental rigor, along with strong analytical and communication skills, will be essential.

Duration: 36 months, starting in october 2025.

Approximate gross monthly salary: ~2300€ brut/month

Location: CEMEF, Mines Paris, Sophia-Antipolis (06), France (https://www.cemef.minesparis.psl.eu).

Research team: Surfaces and Polymers (https://www.cemef.minesparis.psl.eu/presentation/equipe-sp/)

Applications: Applications should be sent to the supervisors listed below and must include: a CV, a cover letter, and the contact details of two referees to recommend the candidate.

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