GEPEA
UMR CNRS 6144
LABORATOIRE DE GENIE DES PROCEDES
ENVIRONNEMENT AGROALIMENTAIRE

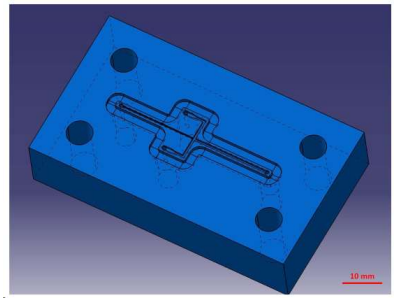
LTEN UMR 6607
LABORATOIRE DE THERMIQUE
ET ÉNERGIE DE NANTES

PhD subject from Nantes Université:

Tuning energetic efficiency of continuous emulsification with biopolymers.

Key words: *Emulsification, energy efficiency, biopolymers, drag reduction, microfluidics.*

Context:



Example of emusifying device studied by LTeN and GEPEA.

The emulsions are liquid/liquid dispersions with many industrial applications and of particular relevance to many engineering settings: food industry, cosmetics, paints, pharmacy, etc.
Among the emulsification methods, it is well established that the generation of inertial turbulent flow efficiently promotes the dispersion of liquids at high flow rates. However, the energy efficiency of devices operating in a regime of inertial turbulence remains problematic. Turbulent flows are generally characterized by a significant energy consumption related to the turbulent dissipation. In order to design innovative, energetically efficient and industrially viable emulsification processes, it is therefore essential to design methods to inhibit the turbulent energy losses without compromising the throughput or the overall quality of the emulsion. It is established that the addition of a small amount of high molar mass linear and flexible polymers in a turbulent flow induces an elasto-inertial turbulence phenomenon and a significant reduction in turbulent drag which results in energy savings that may reach 60% of the nominal operating power.
The GEPEA and LTeN laboratories at Nantes University have been collaborating for more than a decade on the development of a compact emulsification process which operates continuously and is based on the use of fluidic systems comprising submillimeter-sized channels. One of the particular aspects of this process relates to the use of high flow speeds, thus making it possible to process flow rates orders of magnitude higher than what is usually practiced in the field of microfluidics.
This collaboration also focuses on the effect of the formulation on the hydrodynamics and performance of the device.

Thesis objectives:

This work aims to continue the PhD of Elia MISSI (2023, https://www.theses.fr/2023NANU4034) and to study energetically efficient emulsification processes relevant to food related applications. Thus, the biocompatibility of the final emulsion is of paramount importance. In order to respond to the challenges described above, the main objective will be to characterize the behavior of various biopolymers under the effect of confined flow at high speed, in order to propose rational criteria making it possible to guide the choice of molecules and their concentration with the purpose of achieving better energy efficiency.

Progress of the thesis: *Initially, a screening of bio-polymers will be considered based on rheological tests. The molecules tested will be selected among candidates recognized for their drag reducing capabilities but also for promoting dispersion operations such as emulsification (guar, xanthan, carrageenans, alginates,*

animal or vegetable proteins, etc.). The molecule(s) most compatible with the process and judged to be the most promising will then be subject to more in-depth rheological tests in order to map the viscosities and relaxation times in a wide range of concentrations of the polymer(s). Then, the emulsions obtained in turbulent flows in microsystems and in the presence of biopolymer will be characterized ex-situ using optical by optical granulometry measurements. This crucial step will allow one to map the hydrodynamic regimes favorable to the production of fine emulsions. Thirdly, the hydrodynamic regimes will be fully characterized by pressure drop measurements and locally by turbulent velocity field measurements using microscopic Particle Image Velocimetry. Finally, a complete map of the emulsification dynamics will be produced.

The project is essentially experimental and will be carried out jointly at GEPEA and LTeN under the supervision of Agnès MONTILLET (PR, GEPEA), Teodor BURGHELEA (CR CNRS, LTeN) and Jérôme BELLETTRE (PR, LTeN) who developed an instrumented bench equipped with a fast camera adapted to the study of very fast flows and which makes it possible to finely characterize the flows within microfluidic and millifluidic systems.

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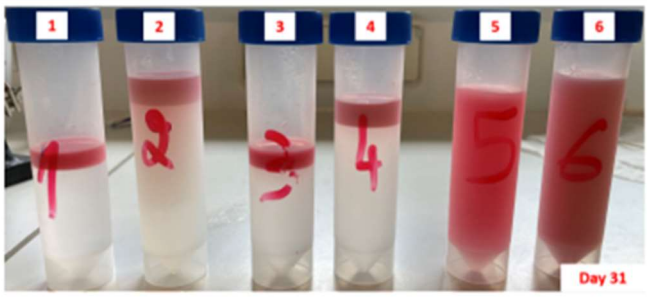
<td> 
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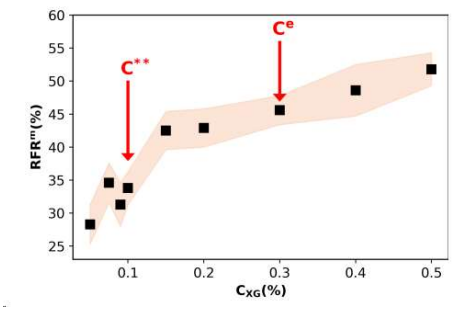
<td> 
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<td>Example of study of the emulsion stability after 31 days, versus the xanthan concentration and hydrodynamic conditions (PhD thesis of Elia Missi (2023))</td>
<td>Evolution of the reduction of flow resistance as a function of xanthan concentration (PhD thesis of Elia Missi (2023))</td>
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Desired profile of the candidate: M2 or Engineer

The desired candidate should ideally have a good background in energy and/or processes (master's degree, engineering school) and must have a good aptitude for carrying out experimental work: rigor in execution, analysis of results and writing reports, as well as knowledge of data processing techniques (knowledge of matlab, python, etc. is a plus). A good level of French and/or English is desirable.

Supervision team and contacts:

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How to receive more information and apply? Send your questions and/or a CV, the latest M2/5A transcripts, and a cover letter to the email addresses of the management team. Application until April 16, 2024: https://theses.doctorat-bretagneloire.fr/sis/campagne-2024