Mécanique des mAtériaux pour l'inGénierie et l'Intégrité des Structures
MAGIS Paris

Année universitaire 2024-2025
Sujet de Projet/Stage

Titre : *Degradation of PE pipes for the conveyance of drinking water and lifetime prediction*

Le projet pourra se poursuivre par un stage dans l'itinéraire :

☒ Itinéraire 1: Endommagement et rupture des matériaux et structures (thilo.morgeneyer@minesparis.psl.eu)
☐ Itinéraire 2: Mise en forme des métaux et fabrication additive (morgan.dal@ensam.eu)
☒ Itinéraire 3: Cycle de vie matériaux polymères et composites (bruno.fayolle@ensam.eu)
☐ Itinéraire 4: Procédé d'usinage avancé et simulation (charly.euzenat@ensam.eu)

Tuteur universitaire :
Nom : Marquez Costa
Prénom : Juan Pablo
E-mail : juan-pablo.marquez_costa@ensam.eu

Tuteur universitaire :
Nom : Colin
Prénom : Xavier
Téléphone : 01 44 24 61 47
E-mail : xavier.colin@ensam.eu

Tuteur industriel :
Nom : Ravereau
Prénom : Jennifer
Téléphone :
E-mail : jennifer.ravereau@suez.com

Descriptif du projet/stage

Context:
Microscopic examinations made on PE pipes aged on the pilot at SUEZ have revealed the formation of an important deformation in the internal surface followed by its micro-cracking when the pipes are subjected to a standardized punching combined with a chemical degradation initiated by the chlorinated disinfectants of the drinking water. SUEZ asked the PIMM laboratory to develop a model coupling the effects of the mechanical loading and chemical degradation in order to predict this damage for two different generations of PE pipes (PE80 and PE100). The PIMM laboratory decided to develop this model based on a methodology composed of three main stages. The two first stages will consist of studying the decoupled problem, i.e.:

1) The programming under Abaqus of a Finite Element (FE) model describing the mechanical response of the pipes in the absence of chemical degradation and before any damage. The reliability of this model was successfully checked from results available in the literature during a first master's internship last year.

2) The determination of the law describing the alteration kinetics of the mechanical properties caused by the chemical degradation by performing an aging campaign on pipe samples in chlorinated water at SUEZ, followed by their characterization with a multiscale approach at PIMM. This multiscale approach will involve several complementary techniques:

- Measurement of the Oxidation Induction Time by DSC (OIT-DSC) to monitor the chemical consumption kinetics of antioxidants,
- FTIR spectroscopy in transmission mode to monitor the oxidation kinetics of the polymer,
- And tensile tests on dumbbell specimens to determine the consequences of oxidation on several key mechanical properties: Young's modulus, yield strength, yield and ultimate elongations, etc.

The last stage of the methodology will consist in studying the coupled problem:

3) By introducing the law of alteration of the mechanical properties into the FE model and by comparing numerical calculations with experimental data. In particular, it will be tried to reproduce under Abaqus the damage observed when the pipes are subjected to a standardized punching in chlorinated water at SUEZ. A particular attention will be paid to the deformation of the internal surface of the pipes, the initiation of cracks and their propagation through the wall thickness and along the length of the pipes (i.e. the shape of the crack network). Pipe samples will be carefully cut around and far from the damaged areas by the punch. The corresponding polished cross sections will be examined by optical microscopy and mapped using some physico-chemical techniques (OIT-DSC, FTIR spectroscopy, etc.) in order to determine the concentration profiles of antioxidants and oxidation products in the pipe wall, respectively in the immediate vicinity and far from the cracks. The comparison of these profiles will also allow evaluating the effect of mechanical deformation on the chemical consumption kinetics of antioxidants and on the oxidation kinetics of the polymer.

Internships program:

- Bibliographic study on the chemical and mechanical degradation of polymer pipes by chlorinated disinfectants,
- Post-treatment of ongoing experimental results,
- Realization of complementary (both physico-chemical and mechanical) experiments,
- Development of the FE code under Abaqus for pipe punching,
- Identification of the law of alteration of the mechanical properties,
- Introduction of this law into the FE model and solving of the multi-physical problem,
- Comparison of numerical calculations with experimental characterization,
- Proposal of practical solutions to reduce/avoid damage,
- Lifetime prediction of pipes subjected to the combined action of standardized punching and chemical degradation.