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PCCL-K1

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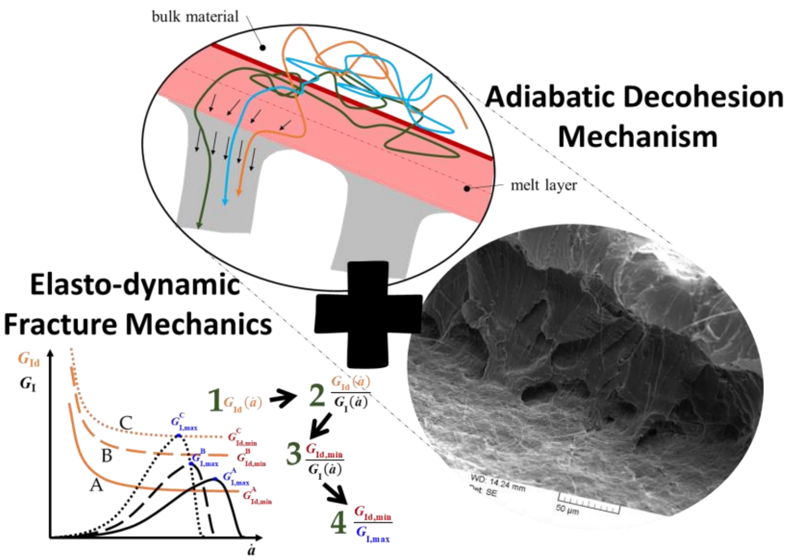
Programme line: COMET-Centre

Type of Project: Rapid Crack Propagation in PA12 grades, 2020-2021, single-firm



FRACTURE MECHANICS AND POLYMER PHYSICS AS A TOOL TO ECONOMICAL MATERIAL DESIGN

WHY CONDUCT COSTLY EXPERIMENTS TO CHARACTERIZE RAPID FRACTURE RESISTANCES WHEN A COMBINATION OF STRUCTURE-PROPERTY RELATIONSHIPS BASED ON UNDERLYING FAILURE MECHANISMS LEADS TO THE SAME RESULT MORE EFFICIENTLY AND ECONOMICALLY?

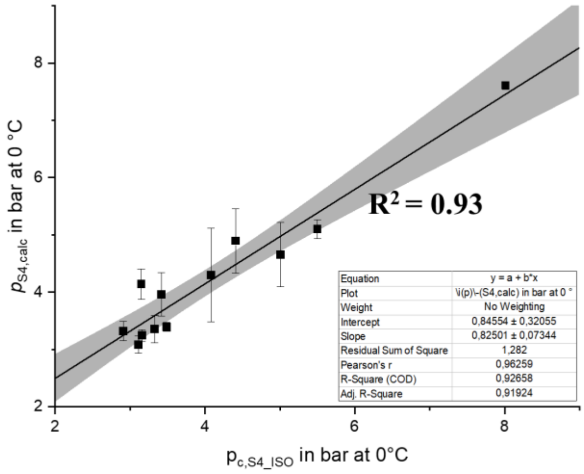
The high-quality standard of living in the 21st century is unimaginable without the presence of suitable piping systems for infrastructural gas and water supply, as well as wastewater transport. It is true that plastic pressure pipelines have proven themselves suitable for long-term service. However, under certain circumstances, such as abrupt loads caused by excavation works, unexpected premature failure can occur due to Rapid Crack Propagation (RCP). That is, a crack propagating at speeds of up to several hundreds of meters per second over long distances - a catastrophic failure that can cause significant environmental damage (e.g., release of hazardous and flammable fluids, splinter fragments, etc.). For this reason, piping systems must be designed safely against RCP failure, in particular, when new materials are developed for high-pressure pipe applications.

Impact and effects

To determine the resistance against RCP failures, pipe grade materials have to be tested via the Full-Scale method standardized in ISO 13478. Subsequently, a critical pressure value is established, above which RCP can occur. Thus, a limit for the maximum operating pressure is defined for the selected pipe grades. This approach requires 25-30 m long pipe samples and is therefore not only associated with extremely high experimental costs, but also with significant production and time expenditures.

For this reason, pressure pipe manufacturers appealed to the Small-Scale Steady-State (S4) test (ISO 13477), in which a rapid crack is induced in a 1-2 m long pipe sample. In so doing, a critical S4 pressure ($p_{c,S4}$) is determined below which safe operation of pressure pipes is guaranteed. However, for competitive development of new material formulations and for a quick qualitative characterization of RCP properties, even an S4 test is uneconomical and inefficient. Instead, material developers long for a relatively simple batch test or an accessible and reliable model for virtual RCP testing.

To achieve this goal, the underlying physical processes at a molecular level (e.g. chain disentanglement driven by adiabatic decohesion) were explored during RCP within the COMET project "Rapid Crack Propagation in PA12 grades ". This has led to the possibility of precise predictions of $p_{c,S4}$ of different PA12 pipe grades using elasto-dynamic fracture mechanics and numerical support. This outcome seems promising, as material developers would not necessarily need to conduct S4 tests, instead, measurements of DSC, molecular weight and Young's modulus may lead to similar estimations of critical pressure ranges.



©PCCL: Correlation between predicted and experimentally measured critical RCP pressure.

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