Executive Summary

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Project "Synthetic fibre with fluid core for damping applications"

The target of this project was to develop fibers that exhibit rate-dependent visco-elastic properties owing to the presence of a fluid core with selectable rheological characteristics. The mechanical coupling between fiber and fluid would be guaranteed by confining the fluid inside a suitably structured fiber core that induces fluid flow upon fiber bending. The major scientific challenges of this project involve the intentional use of non-equilibrium multi-component polymer melt flow behaviour to generate the desired fiber core geometry as well as a fluid filling during melt-spinning with desired rheological properties. The research covered different aspects of the physics of fluids and polymers involved. First an experimental model flow dynamics investigation of a two phase system, co-flowing in a device which mimics the geometry of a melt-spinning spinneret, has been performed. The aim of the experimental work was to look for specific experimental conditions leading to flow instabilities responsible for an interconnected core structure between the two phases. Our results showed that the interfacial morphology can be tuned as a function of flow parameters, material properties, and device geometry to achieve a remarkeable range of core structures. In parallel a computational fluid dynamics (CFD) study was performed for different noozle geometries and for different combinations of melts and fluids. For this purpose, an open source software toolbox OpenFOAM has been used. The C++ source code of OpenFOAM can be modified in order to implement constitutive equations for complex fluids or new solvers for partial differential equations. Experimental cases could be simulated for two-phase systems of Newtonian and viscoelastic fluids. These results from experimental and numerical modelling have been used to adapt a melt extrusion line with customized spinning capability, where Rheocore fibers could be produced using a co-extrusion process combining common polymer melts and a selection of low vapor pressure liquids. Processing could be achieved in a successful way with a specifically designed spinning die, enabling the co-flowing of polymer and liquid, and by adopting appropriate flow viscosities for both polymer and liquid. To our knowledge, such co-spinning of liquid inside polymer has never been described previously. The main strength of this metode is the production of liquid filled fibers in one single and continuous process. This achievement is considered as absolutely novel to the fiber spinning community. Those Rheocore fibers have been characterized morphologically using optical microscopy and using computer tomography (CT) to investigate both superficial and inner morphology. In particular the interface between liquid and polymer has been investigated in a non-destructive way. So far only melt-spun fibers exhibiting two distinct morphologies, namely i) with a continuous uniform core and ii) a series of isolated liquid droplets could be produced. To compensate for the lack of other melt-spun core morphologies, we implemented an alternative post-processing step. Therefore, fibers with initially uniform liquid core are mechanically embossed. The resulting fiber exhibits a modified external and internal structure, which enhances both mechanical fiber-fluid coupling as well as potentially increases the matrix adhesion if used later in a composite material. The latter was not verified within this project. In the last phase of the project, Rheocore fibers have been mechanically characterized to assess their mechanical damping capacity. Different methods have been used to quantify their efficiency to absorb energy upon i) very slow motion using quasi static bending methods, and, at higher frequencies by mechanically induced free vibrations and acoustically induced oscillations. Our results show that Rheocore fibers indeed exhibit a higher damping capacity if compared to suitable reference fibers. Moreover we could show, the rheology of the inner liquid can influence the mechanical damping even in cases where the displaced liquid volumes are rather small. We hypothesize increased energy dissipation into an enhanced polymer volume resulting from energy transmission along the liquid core.