**17th International Conference on**
**Flow Processes in Composites Materials (FPCM17)**
**Sheffield, United Kingdom, 30 June to 02 July 2026.**

**TITLE:** Mitigating heterogeneity effects in rheological characterization of recycled long-fiber thermoplastic composites from low-shear mixing

**AUTHOR(S):** Paul Ivan Ceralde (UT/TPRC), Prof. Dr. Ir. Remko Akkerman (UT/TPRC), Dr. Vahid Rezazadeh (TPRC), Dr. Ir. Laurent Warnet (UT)

**AFFILIATION(S):** University of Twente (UT) / ThermoPlastic Research Center (TPRC)

**ABSTRACT:**

Thermoplastic composites (TPCs) enable direct recycling (shredding, mixing and remoulding) offering a circular route that requires low energy and cost. However, in most cases, such as injection moulding of recycled TPCs (rTPCs), the reinforcement fibres experience significant breakage during the compounding step. Dilution with resin is also required to improve processibility of the input material which results in lower fibre content. Ideally, maximum fibre length and high fibre content should be retained after the recycling process to achieve optimum mechanical properties and performance of the recycled component. Low shear mixing (LSM) is a promising method to homogenize rTPCs with minimum fibre attrition. In LSM (figure 1), the original fibre bundle structure of the feedstock (e.g. woven or unidirectional flakes) is disentangled, transforming the latter into compression moulded compounds with long discontinuous fibres (>10 mm) at high fibre volume fractions (>30%).

Rheological models are essential for the performance predictability of recycled components since performance is strongly influenced by the flow-induced reinforcement structure. To develop such models, reliable characterization data capturing flow behaviour under relevant conditions is required. Unfortunately, rheological studies on low-shear mixed rTPCs are challenging due to the resulting intricate arrangement of their reinforcement fibre network and significant process- and material-induced heterogeneities.

Previously, the flow behaviour of low-shear mixed rTPCs under squeeze flow conditions were characterized using dedicated geometries that respect the separation of scale condition (i.e. specimen dimension = 5-10x fibre length). However, the average compressive stress values were measured with standard deviations >50%. This significant scatter in the experimental data was attributed to the variability in the mesoscale structure of the material as a result of poor mixing quality. A new developed planetary LSM with helical mixing mechanism (refer to Figure 1) was recently fabricated to address the issues from this previous LSM iteration.

The aim of this study is two-pronged. First is to provide for low-shear mixed rTPCs a sampling protocol to achieve representative flow behaviour and interpretable data when performing relevant rheological experiments. Second is to validate via rheological experiments the optimum mixing parameters of the newly developed planetary LSM obtained from quality of mixing measurements.

Similar to specimen preparation methods for rheological experiments involving bulk moulding compounds (BMCs), a preforming step is implemented to reduce the void content of the specimen via consolidation and to reorient the fibres, giving them a planar arrangement with preferential orientation, by allowing flow over longer distances (see Figure 2).

As shown in Figure 3, after the preforming step, the sampling region will be determined by analysing the local thickness of the plate where variations may occur from boundary effects or fibre bundle entanglement resulting in flow jamming. Further qualitative measurement of heterogeneity (e.g. fibre-matrix separation) within the sampling region will be performed using non-destructive testing via ultrasonic scanning. The test specimens are then obtained from the sampling region and subjected to rheological experiments.

To assess how mixing parameters impact variability in rheological response, small amplitude oscillating shear (SAOS) tests and axisymmetric squeeze flow (ASF) experiments will be performed. SAOS provides information about the viscoelastic behaviour of the material under simple shear flow without significant changes in the internal structure. ASF provides the average compression stress-displacement curve of LSM-rTPCs under conditions comparable to industrial processes. For both cases, circular disks are prepared by compression moulding of long-fibre rTPC doughs to form rectangular plates and then machining to obtain desired dimensions.

**Acknowledgements:**

The research leading to these results has been performed within the framework of the FibReLoop project and has received funding from the European Union's Horizon 2024 research and innovation programme under the Marie Sklodowska-Curie grant agreement No. 101169071.

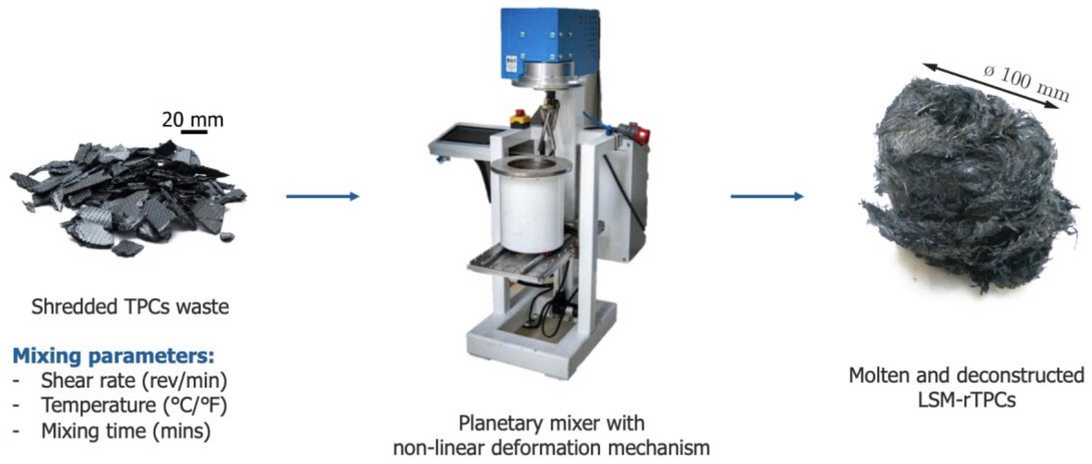


*Figure 1. Recycled thermoplastic composites (rTPCs) from low-shear mixing (LSM) process*

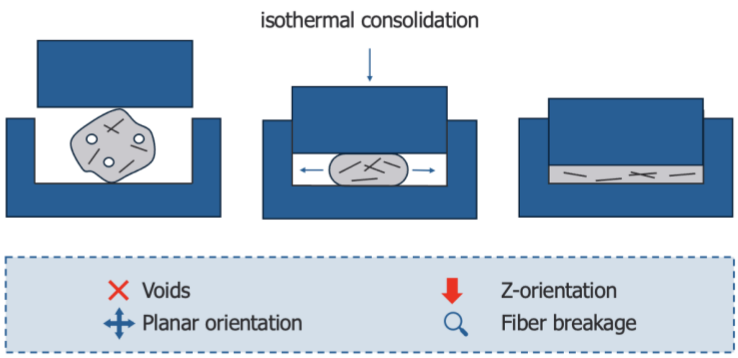


*Figure 2. Preforming of LSM- rTPCs, a prerequisite in the proposed specimen preparation method*

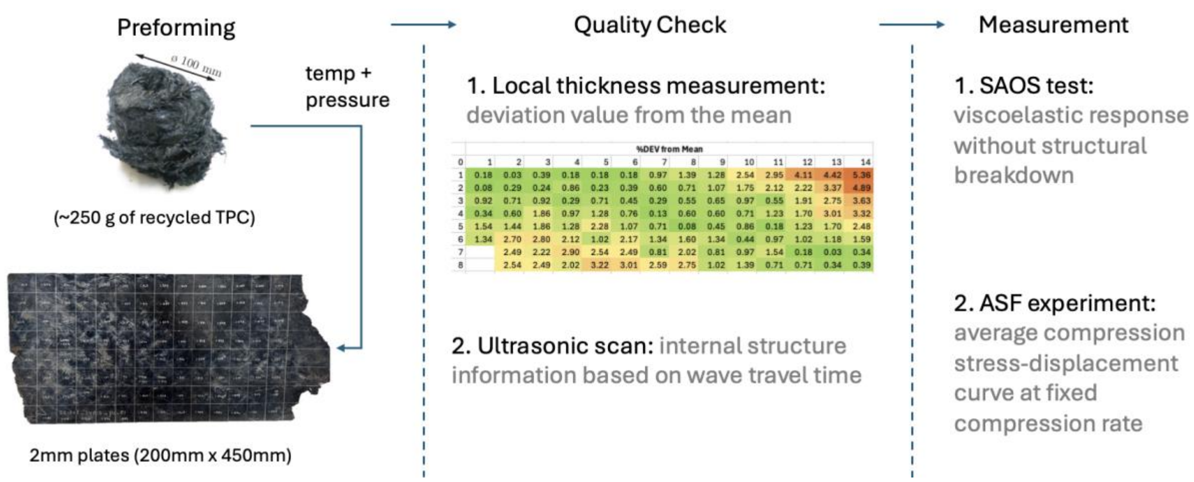


*Figure 3. Sampling protocol to prepare LSM-TPC specimens for rheological experiments*