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| **Project title:** | **ThermoformSim - Multi-Scale Modelling of Thermoplastic Fibre Reinforced Composites during Thermoforming** |
| **Partner:** | Institut für Angewandte Mechanik an der RWTH Aachen |
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Mission Statement

Thermoplastic fibre reinforced composites (TPFRCs) most often come in the form of blanks which are produced by stacking several plies of thermoplastic (TP) foil in between carbon fibre or glass textile layers and consolidating them using heat and pressure. These blanks can be handled and transported easily and stored over extended periods of time without cooling. The final part producer only needs to heat up the blank above the melting temperature of the polymer and form it into the final part shape. This can be done with short cycle times (~1 min. or less). Existing metal-forming machinery and methods can be utilised.

Despite the advantages of TPFRCs, the process stability is a major problem. Residual stresses due to thermal gradients and coefficient of thermal expansion (CTE) mismatches between fibre and matrix might lead to shape distortions of the final part – commonly referred to as the “spring-in” effect. To counteract this effect, process parameters such as heating/cooling rates, tool shape, and part positioning must be carefully determined. This is typically done by trial and error, making development time-consuming and cost-intensive. To eliminate trial and error, computational models of the thermoforming process are needed which can predict residual stresses and spring-in for TPFRC parts. To achieve this, several innovations are required. The build-up of residual stresses must be considered at multiple scales, since there is a CTE mismatch between individual fibres and their surrounding matrix (micro-scale) as well as between tows and matrix (meso-scale). Thermal gradients occur at all scales. The entire process temperature range of the polymer must be considered, from room temperature to above the melting temperature and back. Finally, the melting and solidifying of the polymer in the presence of fibres must be fully characterised and considered.

This project will result in a scale-bridging thermoforming simulation of TPFRCs with three major innovations. First, a matrix material model for the entire temperature range of thermoforming will be developed for TPs. It will find application in the project at micro- and meso-scale. Second, a meso-scale tow model based on a micro-scale representative volume element (RVE) and the previously developed matrix material model will be created for both solid and liquid matrix phases. Third, both models, matrix and tow will be fully characterised experimentally over the entire temperature range. The target materials will be a glass fibre weave with a polyamide 6 (PA6) matrix, but the approach will be generalised for application to many related material systems. All of this will be combined in a meso-scale model of the thermoforming process with a new level of fidelity (figure 1).

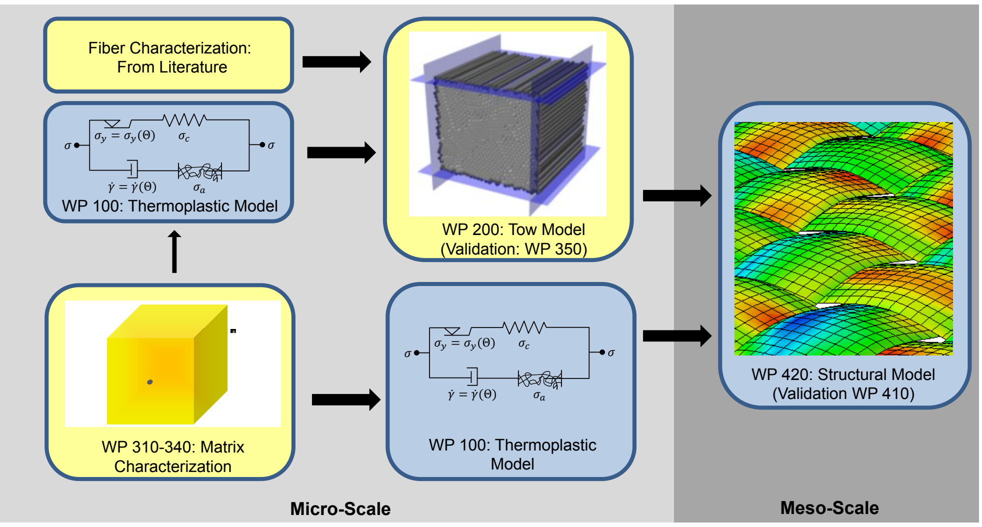


*Figure 1: Illustration of the work packages, interdependencies, and different scales.*


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