

**TITLE:** Modelling FSI test cases using a CEL approach in the context of overmoulding fibre skeleton structures

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**ABSTRACT:**

Overmoulding of three-dimensional continuous fibre skeletons is an advanced manufacturing process for producing high-performance structural components with exceptional mechanical properties and design flexibility. The process enables components to be adapted to specific load conditions and facilitates the creation of high-performance lightweight structures with novel geometries. A schematic illustration of the 3D Skeleton winding process chain at Fraunhofer ICT is shown in Figure 1. Despite significant advancements in process technologies [1]-[2], the material behaviour and interaction mechanisms during overmoulding are not yet fully understood. To address this gap, numerical process simulation is used to deepen understanding of the process and create a basis for virtual process design and reliable prediction of component properties.

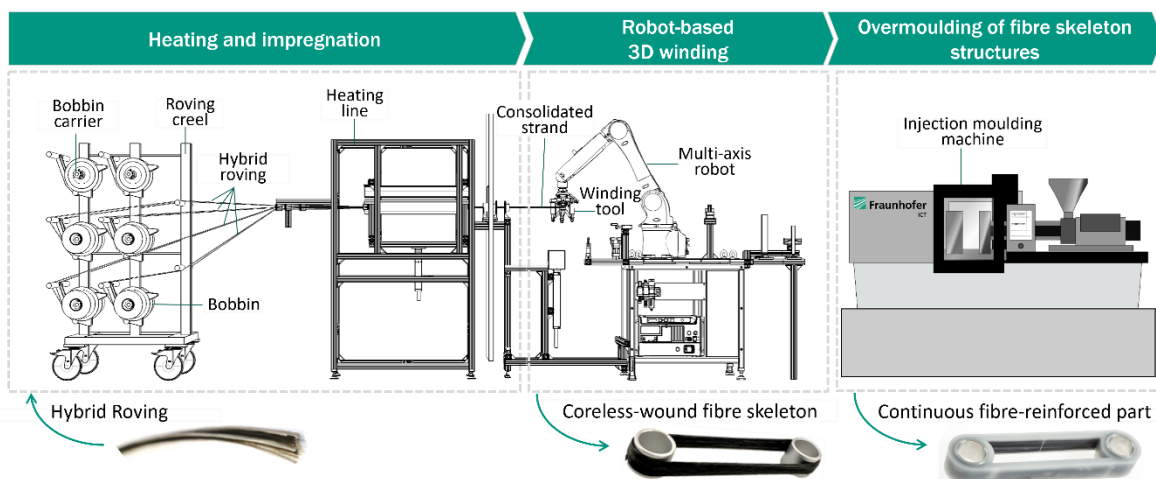


Figure 1: Schematic illustration of the 3D Skeleton Winding (3DSW) process chain at Fraunhofer ICT, based on [3]. In the first process step, a hybrid roving is pulled through a heating and impregnation unit. The continuous thermoplastic and reinforced filaments are then wound around inserts to form a skeleton structure after cooling. In the third process step, the skeleton structure is overmoulded with a thermoplastic matrix to obtain the final part [3].

Since the polymer melt flow interacts with the deformation of the fibre skeletons during overmoulding, the fluid phase is modelled with a Coupled Eulerian-Lagrangian (CEL) formulation in Abaqus/Explicit. In CEL, the phase is deformed in a Lagrangian step for each time step and then projected back to an Eulerian mesh, accounting for the transport equations [4]. This framework is well suited to problems involving large deformations and fluid motion simultaneously, and has been successfully used for the simulation of fibre bundles in compression moulding processes [5].

In the present work, a fluid-structure interaction (FSI) between a polymer melt modelled as fluid phase in CEL and a solid fibre part modelled as Lagrangian body is investigated. In the literature, FSI test cases often exist only for  $Re \gg 1$  [6]. To verify the suitability of the CEL approach in the context of overmoulding, where  $Re \ll 1$  applies, two test cases are examined, which are shown in Figure 2. In the first case, the fluid flow impacts the structure primarily perpendicularly, resulting in a deformation of the structure due to bending. The deformation of a circular clamped plate in a channel filled with fluid is compared to an analytical solution. In the second

FSI case, the flow moves parallel to the structure, resulting in a deformation of the structure, that is dominated by shear.

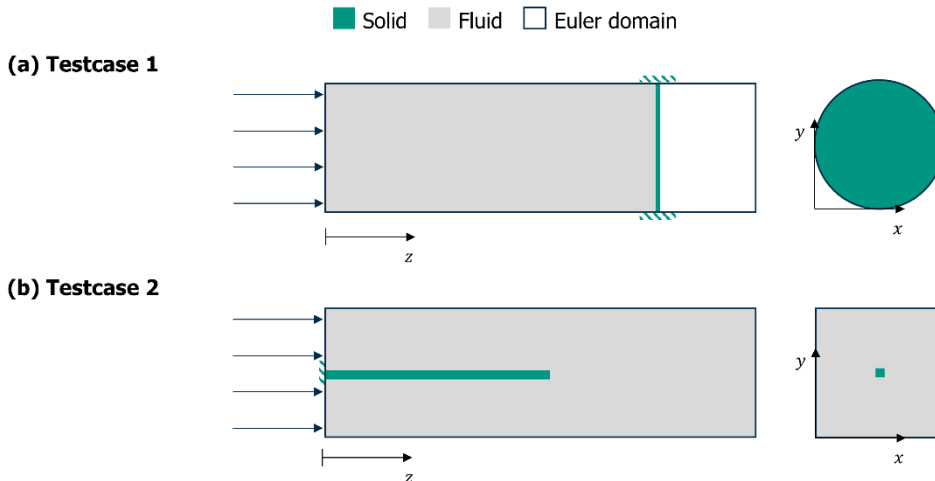


Figure 2: Schematic illustration of two FSI test cases. The solid structure is shown in green, the fluid phase in grey and the surrounding Euler domain in blue. In the first test case (a), the fluid impacts the structure primarily perpendicular and in the second test case (b) the flow moves parallel to the structure.

The numerical results form the basis for a correct prediction of the interaction between fluid and fibre skeleton during overmoulding and verify the suitability of the CEL approach in the context of overmoulding skeleton structures.

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