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Coupling between 1D beam elements and 3D solid elements for the modelling of fiber-reinforced composites

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Fiber-reinforced composites are characterized by heterogeneous deformations at different scales. Because of the difference in stiffness between the fibers and the matrix, much larger deformations are expected in the matrix. Morever, in case of very thin layers between fibers, high deformation gradients are expected at a small scale. Discretizing the fibers and the matrix with conforming meshes to capture with a good accuracy the phenomena at such a small scale results in models with very large numbers of degrees of freedom.

Using overlapping non conforming meshes for the matrix and the fibers –1D beam element meshes for the fibers, and a coarse regular structured mesh for the matrix–, is a way to reduce the computational cost. Research work has been done on embedding 1D elements into a 3D mesh, for example using mortar coupling methods [1].

An alternative approach is proposed here, where the coupling between the fibers and the matrix is ensured by introducing discrete 1D spring type coupling elements, each of them associating a particle on the external surface of a beam element with the corresponding particle at the same position belonging to a matrix solid element. In addition, discrete 1D structural elements [2] are considered in the regions of thin layers between fibers to account for the behaviour of the matrix at small scale which cannot be captured by the coarse discretization of the matrix mesh.

In order to account for the strain energy related only to one component in overlapping regions, the contribution to the internal virtual work computed at integration points of the matrix solid elements located within the volume of a fiber is drastically reduced.

Simulation results involving a few dozen fibers embedded in a polymer matrix will be presented to illustrate the proposed approach.

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