3D Isogeometric Simulation of Mechanized Tunnelling: Application for Excavation Analysis in Partially Saturated Ground

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Numerical simulations in mechanized tunnelling is subject of long-term research due to the highly complex interactions between the various components involved in the construction process, namely the ground, the tunnel lining, the grouting medium and the tunnel boring machine (TBM). Solutions based on standard FEM- and Cut-FEM techniques have already been developed to predict the excavation-induced response [1], but are lacking in terms of computational costs and numerical robustness. Thus, to address the challenge of performing efficient and accurate large-scale three-dimensional analysis, we developed a fully IGA-based simulation framework, able to capture the strongly non-linear and coupled-field behavior arrising during the excavation process. The computational model inherits multiphase formulations for fully and partially saturated soils, as well as the contact between the TBM and the ground. To account for the process-oriented analysis, the pressure boundary conditions are also included.

By employing trivariate Non-Uniform Rational B-Spline (NURBS) shape functions together with combining Isogeometric Analysis (IGA) with Bézier decomposition, circular tunnel profiles can be precisely described in the numerical simulation, directly. This eliminates the need for conventional mesh generation and, thus, the corresponding geometric error often seen in FEM, allowing the presented framework to be integrated within an automated BIM-FEM design-to-analyis workflow in the future [3]. Furthermore, the smoothness and continuity of NURBS-based surface representations improves the robustness and accuracy of the contact algorithm. The computational model comprises only several patches and connecting interfaces, therefore constructing it is done fast and easily during preprocessing stage. On top of that, the higher-order discretization capabilities, enabled by hpk-refinement, improves computational efficiency of the simulation [4]. The results show that the convergence rate is faster than with traditional finite element analysis (FEM) using Lagrange shape functions.

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