Methods for System Identification in Mechanized Tunneling Considering Uncertain Model Parameters

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The ground model is central in computational tunneling, because it is crucial for predicting the distributions and magnitudes of the strains and, consequently, for reducing the surface settlements caused by the Tunnel Boring Machine (TBM) propagation. However, due to the complex interactions between the ground, the driving machine, the lining tube and the built environment, the accurate assignment of in-situ system parameters for numerical simulation in mechanized tunneling implicates tremendous difficulties. Nevertheless, the more accurate these parameters are, the more applicable the responses gained from computations will be. As a consequence, only the realization of the system identification approach provides improved and more sophisticated numerical predictions of the spatiotemporal ground behavior induced by driving the tunnel. In this context, we present methods of system identification for the adaptation of numerical simulation ground models considering both, deterministic and probabilistic approaches.

In the deterministic approach, measurements of the system responses obtained during the tunneling process (e.g. surface subsidence) are compared to their numerical counterparts computed from the numerical simulation (forward calculation). If there is no match, relevant deviations (defects or residuals) are iteratively minimized by applying appropriate derivative-free optimization algorithms, and by taking the parameters of the ground model used in the numerical simulation, as optimization parameters for the minimization problem (inverse problem). Hereby, the underlying optimization problem constitutes a highly nonlinear as well as non-smooth optimization problem associated with multiple optima (non-standard optimization problem).

Normally, geotechnical applications are associated with uncertainties. To capture such uncertainties it is advisable to take into account the significantly scattered material properties (e.g. stiffness, strength, permeability) of the soil. By that, the inherent randomness, i.e. aleatoric (objective) uncertainty, can be mapped. In addition to that, lack of data or information about events and processes, and misunderstanding the physical laws, can result in knowledge (epistemic/subjective) uncertainty. In order to assure realistic results, and to quantify the inherent uncertainties in the parameter estimation process, a probabilistic approach for the inverse problem is introduced. This approach is able to include the prior information about the parameters (the general trend of the parameters), which have been captured from bore holes sunken in the target area of the tunnel alignment. Also, uncertainties in the observed data as well as uncertainty of the ground model due to modeling approximations can be described. Furthermore, the results obtained provide most useful uncertainty measures for the identified parameters.

Due to the highly nonlinear problem nature of geotechnical applications with respect to both the physical and the geometrical characteristics, the numerical simulation is normally computationally expensive. To make the identification process as efficient and robust as possible, it is favorable to reduce the number of the parameters to be identified (i.e. the number of forward calculations) by performing sensitivity analysis. By that, the importance of each unknown model parameter with respect to the system response is evaluated such that an effective selection of the dominating parameters is enabled. Furthermore, an appropriate approximation for the forward model is being considered by different strategies (Response Surface Method, Proper Orthogonal Decomposition with Radial Basis Functions, and others) in order to reduce the computation time for each single forward computation.