Partitioned coupling of discrete elements with large deformation structural finite elements to model rockfall impact on flexible protection structures

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ABSTRACT

This contribution presents a coupled simulation approach for the modeling and simulation of very flexible protection structures under rock impact. For this purpose, an algorithm is presented that couples the Finite Element Method (FEM) and the Discrete Element Method (DEM) [1]. The coupling is done in a partitioned manner, which allows to combine the respective best-suited solution strategies for each sub-problem and transfer information in-between. Results of a weak coupling algorithm are discussed and additionally an outlook for a strong coupling algorithm is given, where an additional inner loop is added which checks for convergence at the coupling interface. The simulation of this interaction can especially be used to simulate impacting objects on arbitrary flexible structures. This requires the possibility to model the load on the structure caused by the impacting object on the one hand and the possibility to analyze the structural response on the other hand. As various load scenarios caused by natural hazards and general impacting objects can be modeled as single spheres or clusters of spheres the simulation with the DEM is a promising choice for the loading side. Moreover, a special focus is put on falling rock impact in this work. To analyze the response of structures exposed to these loading scenarios a time dependent dynamic analysis must be performed where attention is directed to the detailed modeling and simulation of the impact and the resulting interaction of the structure and the impacting object. While the DEM analysis is always using an explicit time integration scheme the possibility of different schemes is given on the FEM side. Both, an explicit central difference scheme as well as an implicit scheme are used and compared.

Due to the big amount of energy brought into the system by the impacting objects, protection structures are built to allow large deformations, achieving a smooth and slow load transmission [2]. This effect reduces the peak loads and thus the maximum stresses in the system. To enable the simulation of these structures, finite elements are implemented and used which allow for large deformation analysis using non-linear strain and non-linear stress measures, not being restricted to small strains by the fact of using non-linear constitutive laws as plasticity and Neo-hook hyper-elasticity. To allow for even larger deformations in this process, a sliding-cable algorithm (using master-slave constraints) is presented which is able to simulate the so called "curtain-effect" of protection structures as they are normally constructed in mountainous regions.

REFERENCES

[1] Santasusana, Miquel *Numerical Techniques for non-linear analysis of structures combining Discrete Element and Finite Element Methods*, CIMNE, (2016).

[2] Volkwein, Axel *Numerische Simulation von flexiblen Steinschlagschutzsystemen*, ETH, (2004).