A Finite Element Tearing and Interconnecting-based Algorithm for Hybrid Fire Testing

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ABSTRACT

Large-scale structural fire tests are rare because of the need of expensive specialized facilities. As a result, most of the research regarding the behaviour of structures in fire has been carried out on single components subjected to standard heating curves. Although they offer significant information for the understanding of fire performance of specific structural elements, they do not account for force redistribution owing to the interaction with the remaining part of the structural assembly. In order to overcome such limitations, Hybrid Simulation (HS) represents a viable approach.

HS is an online dynamic simulation paradigm that computes the time history response of a prototype structure to an earthquake excitation using a hybrid model that combines Numerical Substructures (NSs) and Physical Substructures (PSs), as comprehensively reviewed in [1]. Hybrid simulation of the response of a structure to a fire load was also investigated [2,3].

On these premises, this work presents the development of a novel methodology based on Finite Element Tearing and Interconnecting (FETI) algorithms [4] to improve Hybrid Fire Testing (HFT). In particular, the Gravouil and Combescure (GC) algorithm and the Localized Lagrange Multipliers (LLM) method to couple multiple Physical Substructures (PS) and Numerical Substructures (NS) by imposing compatibility and balance at the interface degrees-of-freedom (DoF) were exploited. Thus, the proposed partition algorithm allows to overcome the shortcomings of standard fire tests by imposing realistic boundary conditions to the physical structure to be tested experimentally. Since a fire test is typically static, but highly nonlinear behaviour with possible occurrences of limit points and/or local instabilities can be experienced by the structure, a Dynamic Relaxation (DR) algorithm was implemented. Moreover, the DR algorithm was combined with Component-Mode Synthesis (CMS) to maximize the convergence rate of DR. Simple validation examples, that also include noise and measuring errors, along with the HFT of a virtual steel frame case study, are thoroughly reported in the paper to show the effectiveness of the methodology to be used in future experimental tests.

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