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Computational Fracture Mechanics: Towards Multi-∗ Analysis

Methods of Computational Fracture Mechanics (CFM) are designed for numerical analysis and simulation of the propagation of cracks in solid products. CFM results are crucial in improving the mechanical performance of industrial products. Physical models for CFM are being steadily developed since the very end of XIX century, routinely based on energy balance analysis of crack propagation by means of simplified elasticity theory for homogeneous materials. However, contemporary approach to highly-automated digital industry challenges CFM problems to advance far beyond this paradigm, stipulating the following features:

- Multicriteria (involving comparative analysis of different crack propagation criteria basing on different conceptual and physical models of fracture)
- Multiscale (requiring coherent modeling of crack initiation and impact across all scales of the product ranging from each smallest mechanical part up to the large organizational-technical system that includes the product as a functional element)
- Multiphysical (examining wrecking effects jointly caused by mechanical forces, gravitation, heat, electromagnetic fields, and chemical reactions)
- Multimaterial (being applied to products made from composite materials or highly heterogeneous structures produced by additive 3D-printing technologies)

All these features are collectively addressed as “multi-∗” in the present report. Traditional Finite Element Method (FEM) used more than 40 years as a major computational physics device is known to fail to provide satisfactory simulation results for real-life multi-∗ CFM problems even when the most powerful supercomputers in the world are utilized. A number of alternative methods are being intensely developed recently, such as:

- Strong Discontinuity Method
- Extended Finite Element Method
- R-adaptive methods, such as those based on Configurational Forces or Universal Meshes
- Meshfree methods, such as Scan&Solve™, or methods based on Peridynamics
- Phase-field models in brittle fracture
- Discontinuous Galerkin and Polytopal Finite Element Methods
- Methods for Cohesive Fracture Models
- Methods based on Functional-Voxel geometrical models
- Moving Cellular Automatons Method
- Fractal Fracture Mechanics methods

A number of these CFM methods are surveyed in the report.