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Computational Multi-scale Mechanics and Evolving Discontinuities

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Multi-scale methods are becoming a new paradigm in many branches of science. This also holds true for computational mechanics, where multi-scale approaches are among the most important strategies to further our understanding of the behavior of engineering and biomedical materials.

In multi-scale analyses a greater resolution is sought at ever smaller scales. In this manner it is possible to incorporate the physics more properly and therefore, to construct models that are more reliable and have a greater range of validity at the engineering scales. When resolving smaller and smaller scales, discontinuities become more and more prominent. Whereas at the macroscopic scales, one is used to think merely of cracks and shear bands, now also discontinuities like grain boundaries, solid-solid boundaries such as in phase transformations, and discrete dislocation movement come into consideration. Moreover, non-mechanical effects, like magneto-electro-chemical fields, humidity and temperature, can cause non-negligible effects, and have to be considered simultaneously.

In this lecture, we will start by a concise classification of multi-scale computational methods. We will concentrate on computational methods that allow for concurrent computing at multiple scales. Difficulties that relate to the efficient and accurate coupling between the various subdomains will be highlighted, with an emphasis on the coupling of domains that are modelled by dissimilar field equations. Next, we will focus on evolving discontinuities that arise at different scales and discuss methods that can describe them. Examples will be given at the macroscopic scale, at mesoscopic scales and within a multi-scale framework. Finally, some examples will be given of multi-scale analyses where coupling of evolving discontinuities is considered with non-mechanical fields.