IMPLICATIONS OF SHEAR BAND MICROMECHANICS ON THE MATHEMATICAL STRUCTURE OF CONSTITUTIVE RELATIONSHIPS

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In a companion paper [1], an analysis of shear banding is presented based on a micropolar constitutive law, from which several conclusion can be made about the post-bifurcation evolution of shear bands. It is noted that while many of these conclusions do not depend on details of the constitutive law, a key advantage of micropolar theory is its tie to micromechanically based constitutive laws [2,3]. In this paper the analysis is continued with more emphasis on micromechanical issues. Specifically, limitations are noted with formulations where relative deformations between particle pairs are projected from continuum strain. It is shown that in principle such binary contact laws cannot capture important features observed at both micromechanical level and in bulk behavior. At the micromechanical level, binary laws fail to capture the non-uniform loss of contacts thus overestimating the stability of the material. The bulk behavior lacks the peak in the stress-strain curve expected in a biaxial test. Both deficiencies are removed by introducing a mesoscale law that ties the micromechanical motions to continuum strain through multiple projections. In particular, the mesoscale law display strain softening behavior stemming from dilatancy and produce realistic shear bands in finite element simulations of biaxial tests. While the mesoscale law is in effect a phenomenological constitutive law, the resulting model gives good predictions for evolution of microscale variables. On closer inspection, it is noted that the multiple projection scheme is a means to capture non-affine deformations that are absent in models based on binary contacts. Thus, constitutive relationships can be developed that take advantage of particle-scale observations in experiments and simulations using the Discrete Element Method.

References

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