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NUMERICAL ANALYSIS OF EXPERIMENTALLY SIGNIFICANT MICROPOLAR PROBLEMS IN 3D

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The commonly used classical (Cauchy's) theory fails to correctly represent behaviour of materials in which a characteristic dimension representing microstructure size is large in comparison to a characteristic dimension of the specimen analysed. In such problems a size effect is eperimentally observed showing an increased stiffness in smaller specimens compared to that provided by the classical theory. In order to capture this phenomenon, a number of alternative continuum theories have been developed, including the micropolar (Cosserats') theory analysed here. In this theory, in addition to the displacement field, there also exists an independent microrotation field, representing the local rotation of a material point. Such a theoretical setting allows us to take into account the intrinsic material length-scale but, in order to completely describe such a material, six material parameters are needed, in contrast to only two in the classical theory. Experimental determination of the additional parameters, however, is not straightforward and the key to developing more precise experimental procedures could lie in inverse analysis involving highly efficient numerical procedures developed via a detailed analysis of specific micropolar boundary value problems for which closed-form solutions exist. Such experimentally significant boundary value problems involve pure cylindrical plate bending and pure torsion of a circular cylinder. These problems are analysed in detail and are shown to be highly useful in experimental determination of the micropolar material parameters. In the present contribution, they are solved using three-dimensional hexahedral finite elements interpolated using both the conventional Lagrange interpolation as well as the Lagrange interpolation enhanced with incompatible displacement modes. The element performance is assessed by comparing the numerical results against the available analytical solution and the existing experimental observations and the elements are shown to be be highly efficient. Furthermore, we extend the finite element formulation to a geometrically non-linear regime paying particular attention to proper geometric treatment of large rotations.

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