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A GENERALIZED THREE-DIMENSIONAL COSSERAT POINT ELEMENT FOR NONLINEAR ORTHOTROPIC ELASTIC MATERIALS

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In the standard finite element procedure for hyperelastic materials the response of the element is determined by integrals over the element region which assume that the kinematic approximation is valid pointwise. This formulation may lead to a robust element, but it is known to exhibit unphysical locking for bending dominated structures, and for nearly incompressible materials. Special methods based on enhanced strains, reduced integration with hourglass control and other technologies have been developed to overcome these problems. However, it is also known that these improved formulations that are based on enhanced strains can exhibit unphysical hourglassing in regions experiencing combined high compression with bending.

The Cosserat point element (CPE) is a relatively new element technology that is based on the Cosserat point theory [5, 4]. It was observed in [3, 1] that the three-dimensional brick CPE is a robust, an accurate element that can be used to characterize the response of thin plates and shells with only one element through the thickness as well as complicated three-dimensional structures, and it does not exhibit unphysical locking or hourglassing for thin structures or nearly incompressible material response. Generally speaking, the CPE theory considers an element as a structure and introduces a strain energy function which characterizes the response of the structure, which is suitably restricted so that the element satisfies a nonlinear version of the patch test. The nodal positions are determined by balance laws of director momentum and hyperelastic constitutive equations for intrinsic director couples which specify the nodal forces. The nodal forces are related to derivatives of the strain energy function through algebraic relations in a similar manner to the relationship of the stress to derivatives of the strain energy function in the full three-dimensional theory of hyperelastic materials.

In this paper a generalized three-dimensional brick element for nonlinear orthotropic elastic materials with initially distorted meshes and general orientation of orthotropy is developed using the Cosserat point theory. In particular, in [2] the coefficients of the strain energy function, which controls the response to inhomogeneous deformations, were determined by limiting attention to a rectangular parallelepiped, and it was found that the formulation therein suffers from undesirable sensitivity to initially distorted meshes. Hence, the resulting three-dimensional CPE should have a wider range of applications, such as within realistic three-dimensional engineering problems.

In order to demonstrate the robustness of the developed CPE, a plane strain square block which is compressed between two smooth rigid parallel end plates with other two stress free edges is considered. The direction of the material orthotrorpy is given by the vectors $\{\mathbf{M}_1, \mathbf{M}_2\}$ with orientation angle $\theta = 60^o$ (see Fig. 1a). Figure 1b and c show the deformed shapes obtained by the CPE and the enhanced strains elements, respectively. It can be seen that the enhanced strains element exhibits an hourglass mode of deformation prior the physical instability point (limit point), while the CPE predicts the physical buckling mode.

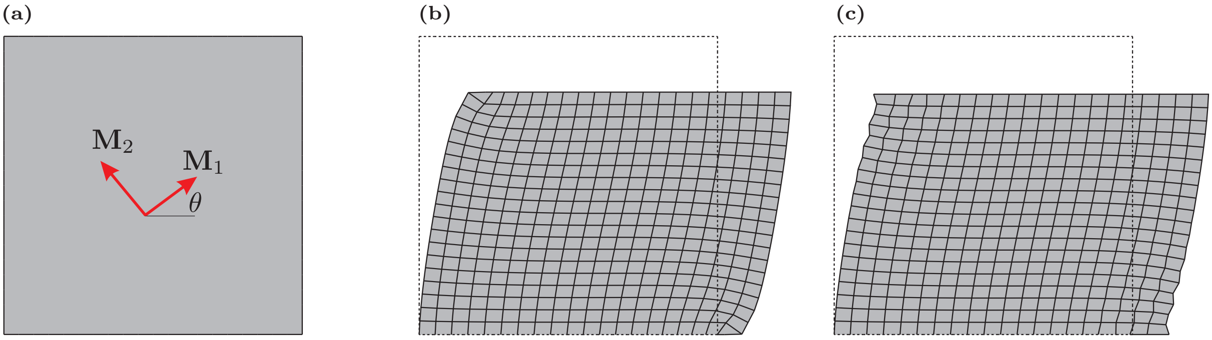

Figure 1: Plane strain compression of a block. **(a)** Geometry; **(b)** deformed shape predicated by CPE; **(c)** deformed shape predicated by enhanced strains element.

REFERENCES

[1] M. Jabareen, M.B. Rubin. A Generalized Cosserat point element (CPE) for isotropic nonlinear elastic materials including irregular 3-D brick and thin structural elements. *Journal of Mechanics of Materials and Structures*, Vol. **3:8**, 1465–1498, 2008.

[2] M. Jabareen, L. Sharipova, M.B. Rubin. Cosserat point element (CPE) for finite deformation of orthotropic elastic materials. *Comput. Mech.*, Vol. **49**, 525–54, 2012.

[3] S. Loehnert, E.F.I. Boerner, M.B. Rubin, P. Wriggers. Response of a nonlinear elastic general Cosserat brick element in simulations typically exhibiting locking and hourglassing. *Comput. Mech.*, Vol. **36:4**, 255-265, 2005.

[4] B. Nadler, M.B. Rubin. A new 3-D finite element for nonlinear elasticity using the theory of a Cosserat point. *Int. J. Solids Struct.*, Vol. **40**, 4585–4614, 2003.

[5] M.B. Rubin. *Cosserat Theories: Shells, Rods and Points., Solid Mechanics and its Applications*, Vol. 79, Kluwer, The Netherlands, 2000.