Anisotropic Material Modeling in the FLAG Hydrocode

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Summary: When modeling mechanical behavior, material anisotropy is an important consideration that can also be computationally expensive. This presentation discusses an anisotropic elastic implementation in the FLAG Hydrodynamics code and its applications to a transverse isotropic dynamic sphere problem.

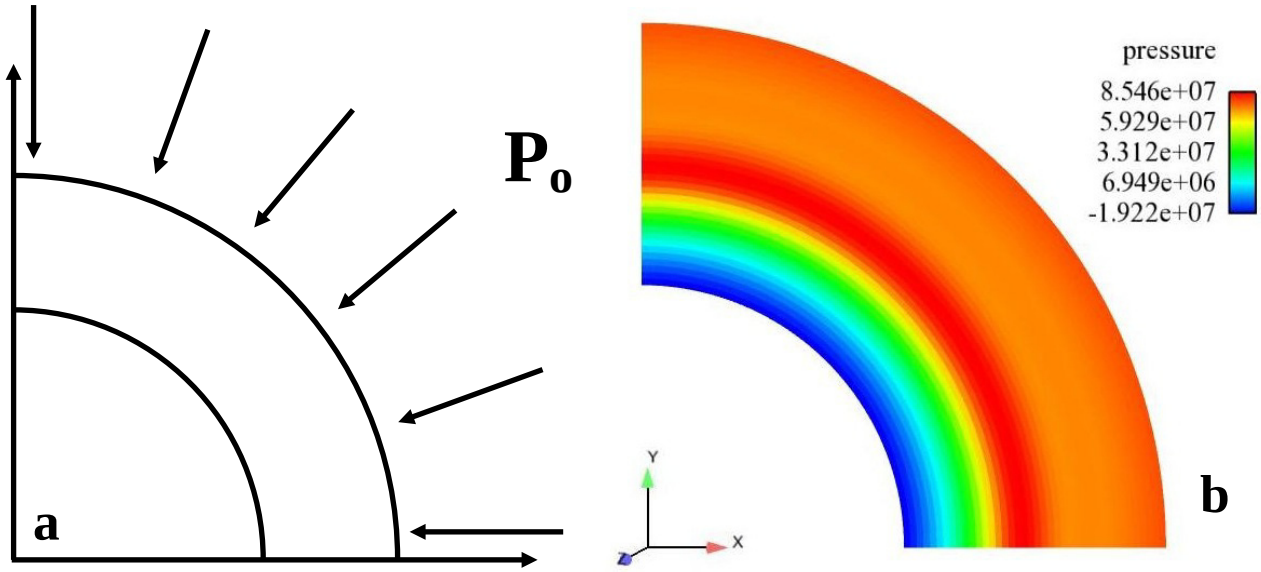
The relation between stress (s) and strain (e) for general anisotropy can be described with Hooke's Law:

$$s_{ij} = C_{ijkl} e_{kl} ,$$

where the stiffness matrix, C, has 21 independent constants. However, many materials have some elastic symmetry and can be defined with fewer than 21 constants. The different types of elastic symmetry defines a material's crystal classification (ex: monoclinic, orthotropic, tetragonal, etc.) with the simplest case being isotropy, which has a stiffness matrix with only 2 independent constants.

It is obvious that modeling highly anisotropic materials can be computationally expensive due to the increased number of independent equations and directional dependencies. Often, material isotropy is assumed in material deformation models because it simplifies the elastic-plastic implementation. However, most materials exhibit some level of anisotropic behavior during deformation. In many cases, such as in applications where large deformations occur in the plastic regime, the material anisotropy can greatly impact mechanical behavior. In order to accurately model material deformation behavior, it is essential to include anisotropic framework.
An elastic, anisotropic material model has been implemented in the FLAG Hydrodynamics code, which is currently in use at Los Alamos National Laboratory (LANL). In order to reduce tensor dimensionality and increase computational efficiency, we implement a tensor change-of –basis to transform the stress into an orthogonal coordinate system. Of the six orthonormal basis tensors, five are related to the deviatoric stress and one corresponds to the hydrostatic pressure.

A dynamic sphere problem has been simulation using both isotropic and transverse isotropic material classifications in order to validate and test the implementation. Results compare well to exact solution results. Future work includes extending the implementation to material anisotropy in the plastic regime, which reduces to an Eigenvalue problem.



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