THE VISCOUS RELATION FOR THE INITIAL ISOTROPIC RESPONSE OF ICE IN ICE-SHEET FLOW

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Abstract

On the large time-scales of ice-sheet ow, the ice is assumed to be incompressible and commonly to obey a non-linearly viscous fluid constitutive law for the shear response, neglecting the shorter time-scale viscoelastic effects. That is, at constant temperature, the deviatoric stress depends only on the strain-rate. The pressure is a workless constraint, not given by any constitutive law, but determined by the momentum balances and boundary conditions. Such a viscous law, necessarily isotropic by material frame indifference, has a general quadratic representation, with alternative, but equivalent, stress and strain-rate formulations. However, it is still common practice to ignore the quadratic term and adopt a simple relation in which the deviatoric stress is co-axial with the strain-rate, and which depends on only one of the two stress (or strain-rate) invariants. Standard single stress component tests, uniaxial compression or simple shear, are not sufficient to determine the general form, but either can determine the response coefficient dependence on one invariant in the simple co-axial form. Early experiments showed that uniaxial compression and combined compression and shear data yielded different response coefficient dependences, but this has been ignored and the uniaxial correlation has been adopted. Here we show that it is necessary to include a quadratic term to correlate with independent uniaxial and shear data, but dependence on one invariant is sufficient. The stress and strain-rate configurations in combined uniaxial stress and simple shear experiments is analysed to derive a universal relation independent of the actual response coefficients in a general viscous relation, which is examined for the data determined by a set of such experiments, showing inconsistencies. Such data cannot then be applied to test the consistency of any viscous relation.