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Localisation of shear fracture networks in anisotropic materials: influence of strain rate and material strength

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This contribution presents an experimental study of deformation localisation and the formation of fracture networks in elastoviscoplastic layered materials under pure shear boundary conditions. The mechanical properties of the analogue mixtures, which are made of plasticine, have been used to analyse the transition from models in which deformation is accommodated by homogeneous viscous flow to systems controlled by a few active faults. Two series of experiments have been studied: (a) the same material was deformed at different strain rates and (b) four materials with different mechanical properties were deformed at a fixed strain rate.

The results show that strain rate and viscous ductility define a change on the degree of deformation localisation and the geometry of fracture networks. The increase of deformation also produces changes on the mechanical behaviour of the systems and the type of deformation. Localisation of fracture networks is enhanced when strain rate is increased. Moreover, there is a progressive increment in the relationship between fracture displacement and fracture length related to the strain rate applied to the system. This experimental observation is also corroborated by a series of simple finite element linear elastoviscous simulations. In these models, a horizontal inclusion within a matrix simulates a pre-existing fracture. The displacement along this fracture is tracked at all times using some selected nodes located at the two walls. The results indicate that there is a dependency of fracture displacements on the strain rate. A deviation between shear strains registered by fractures and the one applied by the boundary conditions is also detected, especially at low strain.

The degree of localisation and the nucleation of shear fractures also depend strongly on the viscous ductility and strength of the analogue material. The raise of the material stiffness causes an increase of the length of fractures and displacements along them. This fact must be associated to the competition between the viscous stress relaxation of the material related to ductile flow and the brittle behaviour associated to the propagation of fractures. When the dominant process is ductile flow the material is able to relax the deviatoric stress at fault tips and the propagation of fractures is inhibited.

The presented models are illustrative examples of the transition between brittle and ductile behaviour.