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Plenary Lecture

BEHAVIOUR OF SOFT MATERIALS UNDER TRIAXIAL LOADING

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Summary: Materials are usually tested uniaxially, but in many real life situations they are subjected to multiaxial loading. For example, cartilage in a joint is loaded in triaxial compression, as is a seal or an o-ring in a hydraulic system. Tissues such as blood vessels are loaded in biaxial tension, and triaxial tension occurs at notches and crack tips.

Models of soft materials usually separate their behaviour into volumetric and deviatoric components, for numerical reasons, and we usually make crude assumptions about the volumetric part. It is common to say that the material was assumed to be nearly incompressible, and then to use a relatively low bulk modulus in order to ensure a stable solution. In reality many soft tissues undergo large volume changes associated with fluid flow, which have not generally been measured or well understood. Models that separate volumetric and deviatoric stresses have been shown by Ni Annaidh et al to be incorrect, at least for anisotropic materials, and are probably also wrong for isotropic materials. In other areas of mechanics it is well known that high triaxial stresses cause significant changes in deviatoric stiffness, for example in rock mechanics where high triaxial stresses increase the velocity of seismic waves. There is some theory that predicts this but it does not work for soft tissues.

We have modelled deformation of the brain under gravitational loading in different positions, and measured it using MRI. A parametric study shows that the deviatoric stiffness has little effect on the displacement, but the bulk modulus is critically important, and must be quite low to match the behaviour that is observed in real life. It seems that not only are there large changes in volume but that they are critical in determining how the material actually deforms.

We have developed a system for testing soft materials under triaxial loading. Initial results show that there is significant coupling between volumetric and deviatoric deformation and the conventional assumption that they are independent is incorrect. This has important implications for predicting the behaviour of soft materials under triaxial loading.