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Prediction of viscoelastic and plastic properties of polymers using indentation

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ABSTRACT

Indentation methodologies are gaining popularity as they provide means of local property estimation, utilize smaller sample sizes, and do not destroy specimens. Classically, indentation has been used to measure hardness and Young's modulus [1], but researchers have also proposed ways of predicting stress–strain curves [2], yield strength [3], and fracture toughness [3]. Different indentation techniques are being used by researchers for different types of investigations. Nanoindentation is an indentation at very small scales to obtain local properties via single indent. Reference Point Indentation (RPI) is a technique wherein multiple indents are carried out at the same location and the material response with repeated loading is monitored. Researchers have shown that increase in indentation depth during loading cycles can be used to predict material's resistance to fracture [4]. Osteoprobe is a hand held indentation device which has been designed for in-situ bone quality measurements in clinical setting. In this study, we investigate the viscoelastic and plastic properties of polymers like PMMA using different microindentation techniques. Nine different polymers have been selected, which are commonly used for rapid prototyping applications. Some of the polymers exhibit very rubber like behavior, whereas others are stiffer and brittle. Indentation experiments are conducted on the nine polymers using the RPI equipment as well as the Osteoprobe. Similarities and differences in material behavior and predicted properties between these methods are of particular interest. Computational models can help in predicting material properties where analysis of experimental data becomes intricate. Load-deformation curves from experiments can be matched with results of finite element simulations, helping us to evaluate material properties via an inverse problem. Different substrate materials call for different material models and constitutive laws to be used. Material models can range from very simple elastic isotropic models to very complex viscoplastic models coupled with damage laws. Given such plethora of material models, it is important to select the right material model that reflects mechanical behavior of the material of interest. Uniaxial compressive and tensile testing can give us an estimate of elastic and plastic properties of material, whereas stress relaxation tests give us an estimate of viscous response. Coupling these responses together in an appropriate constitutive law meaningfully is still a challenge. Gaining better understanding of parameters obtained from these indentation experiments will not only help the engineering community but will also assist in prediction of material properties of biological tissue like bone for disease diagnosis.

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