POST-YIELD AND FAILURE IN SEMI-CRYSTALLINE PLLA: THE ROLE OF PLASTICITY IN THE AMORPHOUS PHASE

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Introduction

Poly (PLLA) initially showed promise as a load-bearing material for medical device applications such as bioresorbable polymeric stents. However, poor performance in clinical trials has limited their use and providing sufficient stiffness and strength remains elusive. While many simulation approaches have been used to evaluate PLLA stents *in silico*, there is no consensus on the essential components of a material model for PLLA that captures both the initial response and that during degradation [1-2].

Here, a computational framework is presented that examines the post yield behaviour by considering a micromechanical model of a two-phase material. In particular, the role of plasticity in the amorphous phase in the post yield behaviour of the semi-crystalline polymer is explored.

Methods

A computational micromechanics model of semi-crystalline polymer using a representative volume element (RVE) approach is created (Fig.1A). Crystalline regions are anisotropic elastic, while amorphous regions are considered as isotropic elastic-plastic material and both are randomly assigned (Fig.1B). A remote strain is applied to the RVE, and periodic boundary conditions are enforced. In addition to the perfect plasticity of the amorphous phase, ductile damage (with element deletion) is introduced to prevent unrealistic local strains.

Results

Fig 1C. shows the predicted remote stress-remote strain response for the RVE (without ductile damage) compared with experimental data [3] with the model parameters (crystalline volume fraction, etc.) based on the experimental study. While the yield point is in general agreement, the post-yield behaviour is not in agreement. The local stress and strain distributions in the RVE are examined and localisations in strain are used to estimate the point of failure. Other criteria are considered based on post yield softening and all predictions are compared to previously published experimental data [3-4]. When ductile damage is included in simulations, stress concentrations in the RVE lead to a cascading failure of elements and ultimately the formation of a large void in the RVE as shown in Fig 1D for X_c =53%.

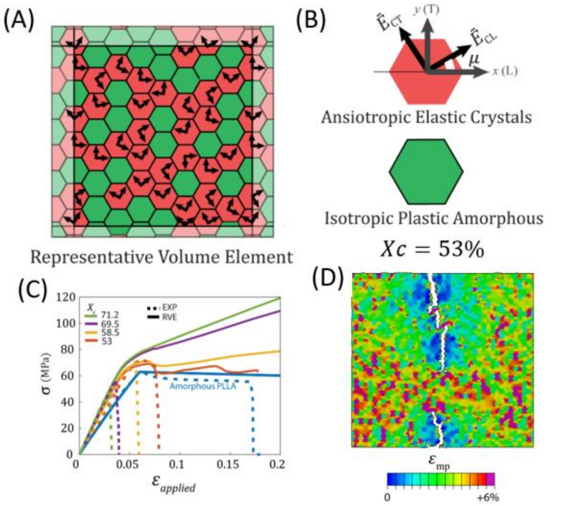

*Figure 1-**A.** 2D RVE of a semi-crystalline polymer **B.** Amorphous considered as isotropic elastic-plastic regions, while crystals remained as anisotropic elastic regions. **C.** Shows a comparison of provided stress-strain curves from computational RVE simulations (solid blue line) and experimental data (dash blue line). **D**. Contour plots of the distribution of ε_{mp}, where ductile damage implemented in the RVE.*

Discussion

The present work shows the capability of a micromechanics model to explain experimentally observed changes in evolution of ductility as the polymer physical properties change. The results shown suggest that at a minimum, a two-phase micromechanical model which considers plasticity and ductile damage in the amorphous phase is necessary to elucidate the experimental phenomena. These simulations can provide the basis of a constitutive relation that can be used in device level simulations.

References

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