

Constitutive Modeling of Polymer Composites made from LBL Manufacturing Technique

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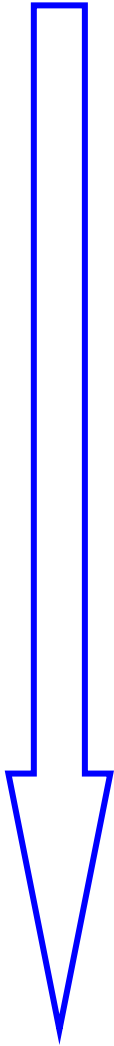
Outline

- **Introduction**
- **Overview**
- **Exponential- Layer-by-layer manufacturing**
- **Mechanical Behavior of Polymer Composites**
- **Constitutive Modeling of Polymer Composites**
- **Concluding Remarks**

Introduction

- **Goal of the project**
 - Development of a constitutive model for polymer composites and their application in computing fracture toughness
- **Advantages of using polymer composites**
 - Lightness
 - Resistance to corrosion
 - Ease in manufacturing
- **Applications**
 - **Military**
 - Light-weight body armor
 - Weapon systems
 - **Automobiles**
 - Body structures/components

Overview



**Understand the mechanical behavior
of polymer composites**

**Develop a constitutive model for
the material based on
experimental data**

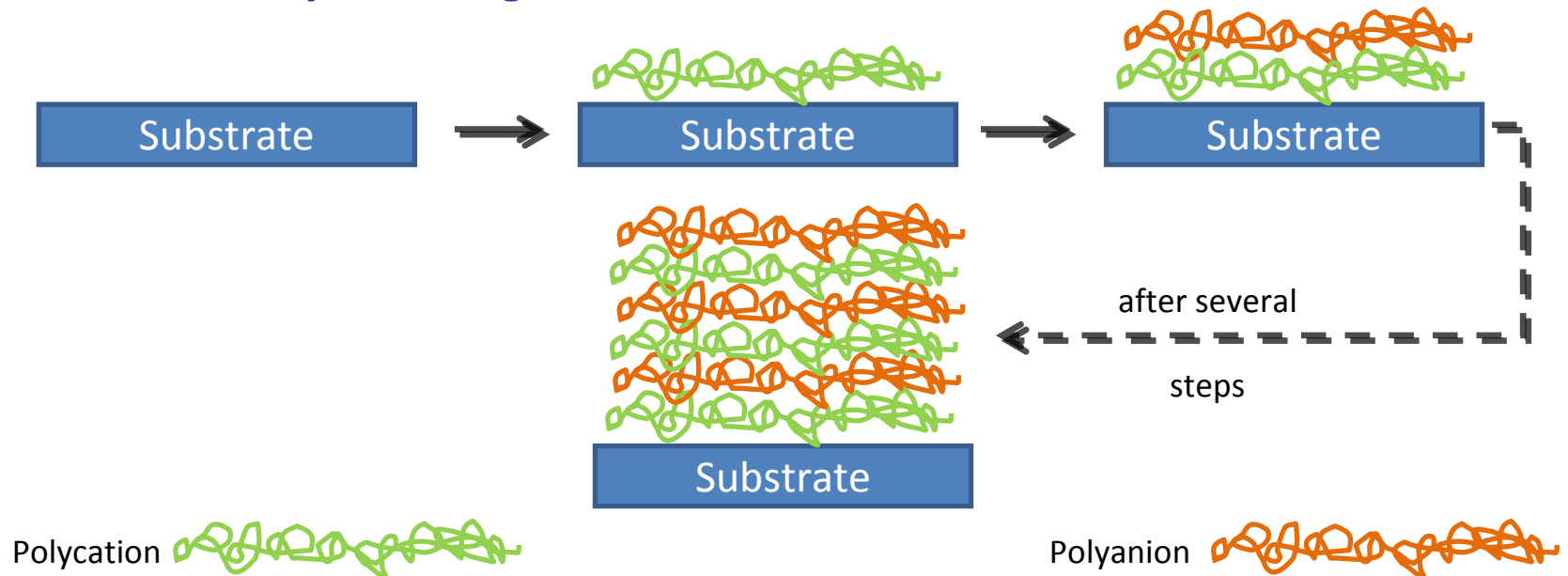
**Perform experiments with double
edged notch (DENT) specimens**

**Finite element simulation of DENT
experiments with constitutive model
and discrete cohesive zone elements**

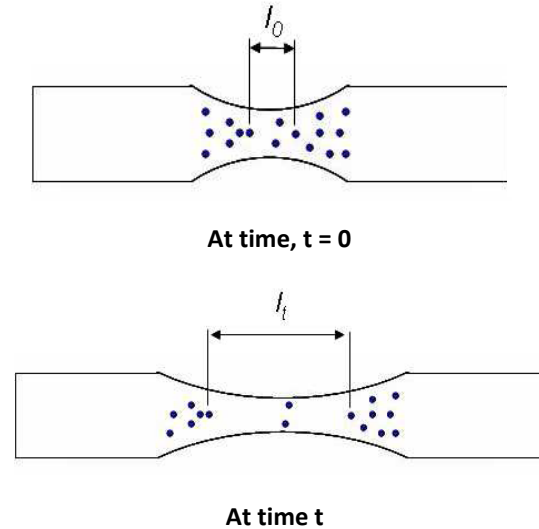
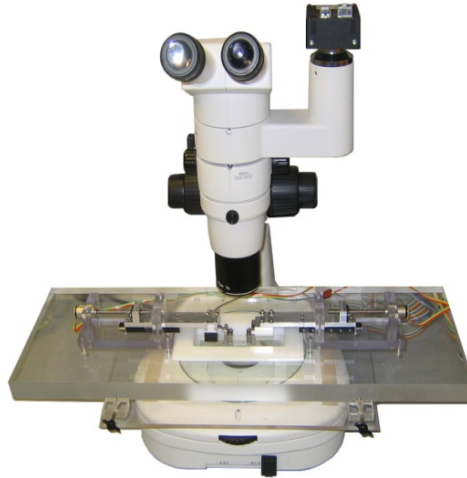
**Extract amount of energy dissipated
through fracture**

Layer-By-Layer Manufacturing

- **Composition of Polymer composite**
 - Cationic Polyurethane (PU) / Polyacrylic acid (PAA)
- **Layer-by-layer (LBL) technique**
 - Sequential deposition of mono-layers of oppositely charged polyelectrolytes on a glass substrate



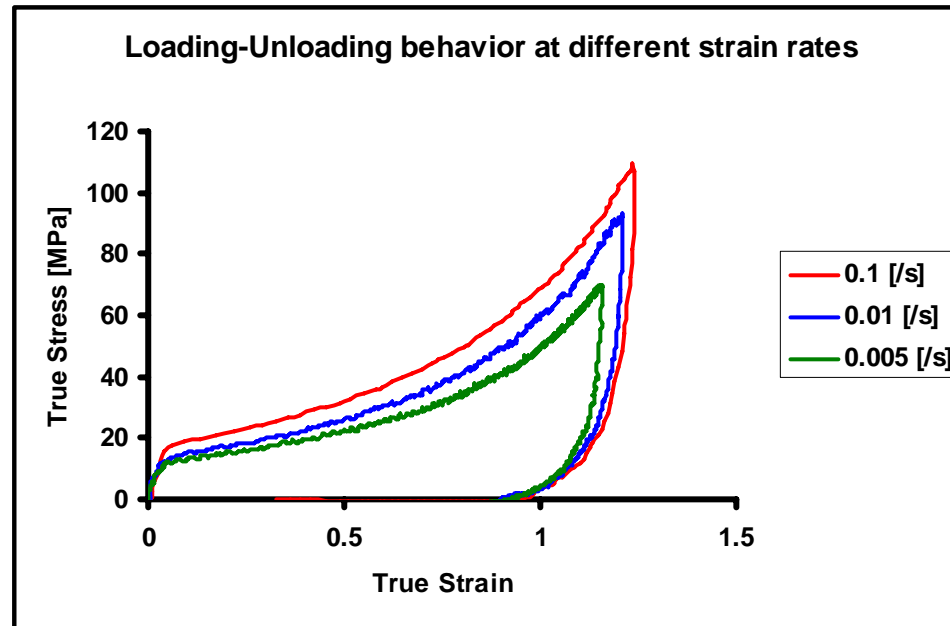
Mechanical Behavior of Polymer composites



- **Uniaxial Tensile Tests at Low Strain Rates**
 - In-house tensile testing set-up
 - Non-contact strain measurement
 - Tracking of 25 mm spheres adhered to the surface
 - Displacement of gage marks on the surface

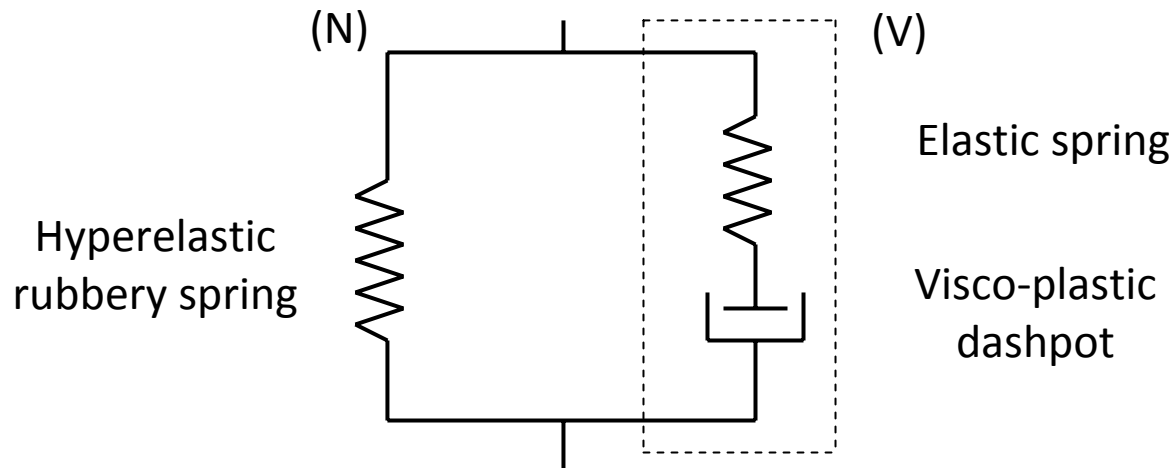
Mechanical Behavior of Polymer composites

- The deformation of the gage section is mostly homogeneous
- Strain rate dependent response of the material
 - Increase in yield strength with increase in strain rate
 - Minor change in amount of hardening with increased strain rate
 - No effect of strain rate on the amount of unloading



Constitutive Model of Polymer Composite

- Schematic representation of the constitutive model



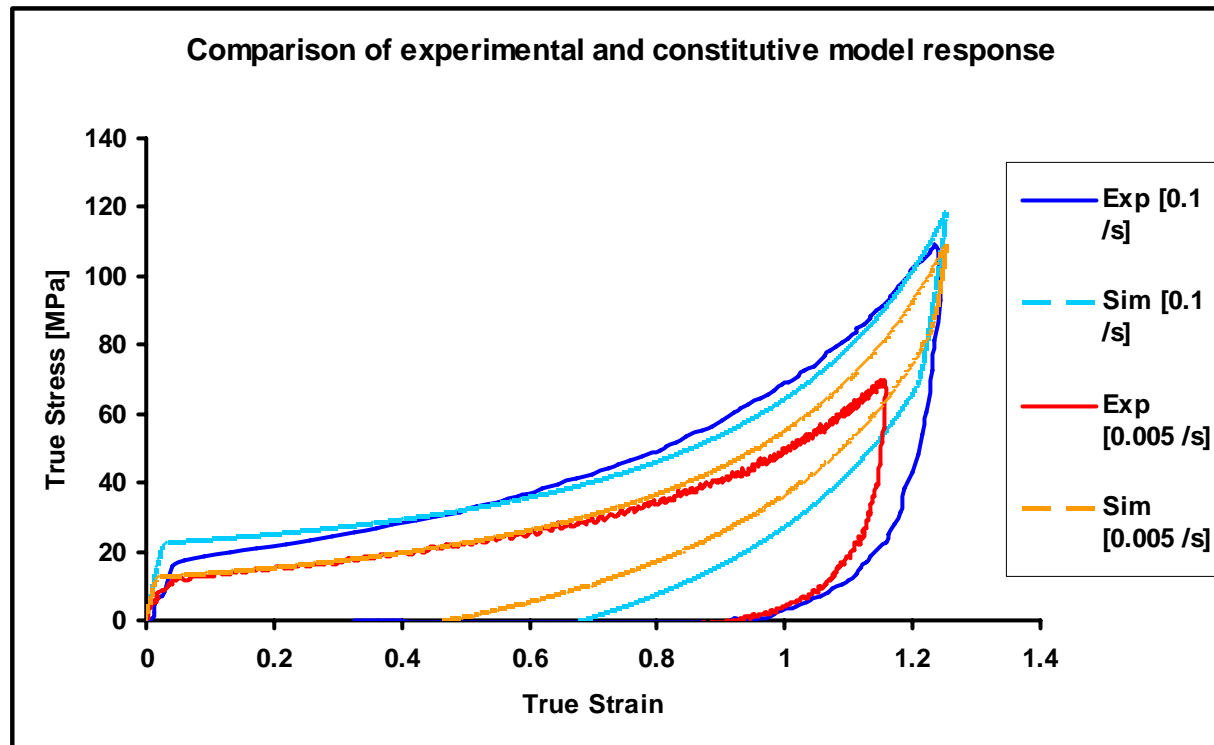
$$F = F^N = F^V$$

$$T = T^N + T^V$$

- Elasto-Viscoplastic response of the polymer composite

Constitutive Model of Polymer Composite

- Identification of material parameters for the model
- Implementation of user material routine in Abaqus 6.5



Concluding Remarks

- The model is successful in capturing the loading part of the response
- The amount of unloading in the constitutive model is greater than that observed in the material
- Strain rate dependent effects are taken into account in the design of the constitutive model