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Mechanical characterization and Finite Element Implementation of the Soft Materials used in a Novel Anthropometric Test Device for Simulating Underbody Blast Loading

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Abstract

Soft materials (e.g. polymers) are widely used in biomechanical devices to represent the nonlinear viscoelastic properties inherent in biological soft tissues. Knowledge of their mechanical properties is used to inform design choices and develop accurate finite element (FE) models of human surrogates. The goal of this study was to characterize the behavior of eight polymeric materials used in the design of a novel anthropomorphic test device (ATD) and implement these materials in an FE model of the ATD.

Tensile and compressive tests at strain rates ranging from 0.01 s^{-1} to 1000 s^{-1} were conducted on specimens from each material. Stress-strain relationships at discrete strain rates were used to define strain rate-dependent hyper-elastic material models in a commercial finite element solver. Then, the material models were implemented into an FE model of the ATD. The performance of the material models in the FE model was evaluated by simulating experiments that were conducted on the ATD lower limb.

The material characterization tests revealed viscoelastic strain rate-dependent properties in the flesh and compliant elements of the ATD. Higher modulus polymers exhibited rate-dependent, strain-hardening properties. A strong agreement was seen between the material model simulations and corresponding experiments. In component simulations, the materials performed well and the model reasonably predicted the forces observed in experiments.

1. Introduction

Anthropomorphic test devices (ATDs) have been used in automotive safety research since the 1970s to predict injuries (Crandall et al., 2011). ATDs must repeatedly perform under a dynamic range of loading rates and reliably distinguish between injuries ranging from minor to severe. Biofidelity is an assessment of a devices' ability to replicate the kinetics and kinematics of a human subjected to identical loads (Mertz and Irwin, 2015). Automotive ATDs are suitable for impacts where the principle direction of force comes from the front, side or rear (Davidsson et al., 1998; Eppinger et al., 1984; Foster et al., 1977). However, during the recent military conflicts in Iraq and Afghanistan, improvised explosive devices (IEDs) accounted for the most death and injury to Coalition troops (Ramasamy et al., 2008). Military vehicles were common