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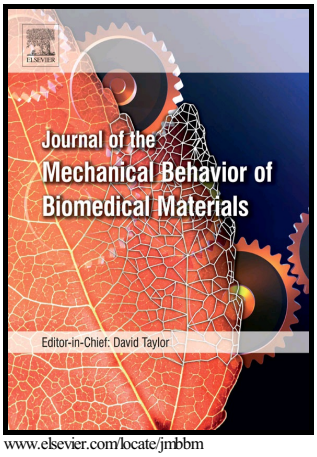


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# Experimental study of the strain rate dependence of a synthetic gel for ballistic blunt trauma assessment

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**Abstract**

The mechanical characterization of a polymer gel used as reference backing material for blunt ballistic impact interpretation is performed at room temperature from quasi-static (0.002 $s^{-1}$) up to high strain rates (1500 $s^{-1}$). As very high strain tensile tests (350%) are conducted, an appropriate gripping device and particular strain measurement techniques are used, as well as high strain compressive tests (80%) based on retro lighting imaging. One major challenge is to carry out reliable compressive tests at high strain rates with polymeric split Hopkinson pressure bars using high-speed imaging and specific signal processing software. These mechanical tests provide a primary response to the strain rate dependence of the hyperelastic material behavior. Indeed, the material exhibits a higher stress response when the strain rate increases. Moreover, dynamic compression tests highlight a larger radial strain propagating along specimen axis with higher strain rates. This preliminary study on the characterization of the gel's mechanical behavior, constitutes an interesting step for an evaluation of human surrogate material. The extensive constitutive law can therefore be implemented for numerical simulations, with an aim of impact biomechanics analysis and body armor assessment.

*Keywords:* Soft materials, Mechanical characterization, Hopkinson bars, High strain rate, High-speed imaging



## 1. Introduction

Over the last few years, numerous studies have been carried out on human body soft tissue behavior. Various soft materials are used as average physical human tissue simulant. They can be classified into four categories: ballistic gelatin, polymer, rubbers and clay (Jussila et al., 2005; Mukasey et al., 2008; Payne et al., 2015; Sparks et al., 2015). Actually, these materials may contribute to a better understanding of human body tissue response in many research fields: defense, safety, crashworthiness and medicine (Bresson et al., 2012; Fontenier et al., 2016; Swain et al., 2014). In the framework of defense and safety, experiments are conducted to better understand the behavior of the human body subjected to high-speed dynamic loadings, such as ballistic impacts. In this context, the French Ministry of the Interior has to evaluate the risk of non-penetrating ballistic trauma which can occur during direct impact of Less-Lethal Kinetic Energy projectiles (LLKE) used by law enforcement officers. These trauma may also be due to the armor deformation and are called Behind Armor Blunt Trauma (BABT). Indeed, this concern has seen a growing interest with a consequent number of studies about blunt ballistic trauma caused by LLKE projectiles and armor deformation on human cadavers and anesthetized animals (Bir and Viano, 2004; Gryth et al., 2007; Pavier et al., 2015; Prat et al., 2010, 2012). For practical and ethical reasons, researchers have developed and employed homogeneous materials as human body substitute.

The two typical soft materials used in this research scope are generally the ballistic gelatin containing 10% or 20% in mass of gelatin with the remaining percentage being water. BABT has been recently studied to evaluate transient cavity formation and transient pressure inside ballistic gelatin (Luo et al., 2016). However, previous studies

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