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STRUCTURAL STUDY OF AP-HTPB COMPOSITE UNDER IMPACT LOADING

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Abstract
The impact response of a composite material is dependent on its microstructure. This study examines the effect of particle size and impact velocity on the temperature rise and strain rate in a composite material containing Ammonium Perchlorate (AP) crystals and Hydroxyl-terminated polybutadiene (HTPB) binder by combining computational and experimental work. Samples of AP-HTPB composite, with AP crystal sizes of 200 and 400 µm, respectively, are impacted at velocities ranging between 5-10 m/s. A volume fraction of 70-80% AP is maintained in each sample.

1. Introduction

Microstructure of a solid propellant composite material exhibits a variety of complex mechanical interactions under impact loading, which can potentially cause the propellant to detonate. The fracture mechanisms are trans-granular fracture through the crystals and the binder, and intergranular fracture at the interfaces between the crystal and the binder[1]. Previous work has shown that the propagation of debonding at the material interfaces is the primary failure mechanism [2]. Understanding the differences in strain rate and temperature rise rate in bulk materials under impact is important for characterizing impact sensitivity of a solid propellant. Areas in the microstructure with large differences in strain rate releases thermal energy from friction, which causes an increase in temperature and can potentially start the chemical reactions required for detonation. These 'hot spots' are the areas where propellant composite material failures are initiated. Interfacial strength of the composite is an important determinant of intergranular failure and has been measured experimentally in solid composite propellants through methods including scanning electron microscope monitoring and digital image correlation [2,3]. In this study, a drop hammer test is used for experimental testing to find temperature and a cohesive finite element method (CFEM) program is used for computational analysis of both strain and temperature.

2. Materials and Methods

CFEM is used to numerically analyze impact due to its ability to model the interfaces between materials and to model stochastic fracture paths. In this work, cohesive traction-separation law parameters, viscoplasticity parameters, and material shock parameters for AP and HTPB have been obtained through previous experimental work [4] and are input into the CFEM code. The drop hammer test is considered to be one of the most efficient methods for determining the impact sensitivity of a material, [5] The drop hammer test, shown in in Fig. 1., is conducted by dropping a hammer from a specified height to induce the desired impact velocity on a striker that impacts the test material, which is placed on a transparent glass disc that allows a camera to observe the impact in real time. At a point during the fall of the drop hammer, a camera is triggered and multiple high-speed images are captured within a specified timeframe. When the drop hammer is paired with an infrared camera, hot spots can be detected in examined material, and the temperature evolution can be observed in real-time. [6]

For infrared measurements, a mid-wavelength infrared camera (MWIR) is used in the current drop hammer experiment. This MWIR camera has a single-color pyrometry and an infrared range of 3.7-4.8 micrometers in wavelength to observe temperature changes that the samples exhibit upon impact. The sensors in medium wave infrared cameras capture photons within the infrared energy range, allowing them to observe the heat signatures of the sample during impact.

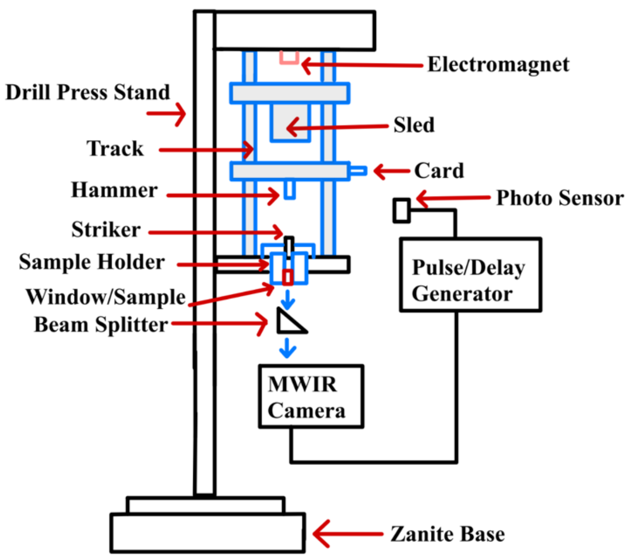

Fig. 1. Experimental Setup

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