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Pressure and friction dependent mechanical strength – cracks and plastic flow

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ABSTRACT

The mechanical properties of a polymer composite plastic bonded explosive, EDC37, have been investigated as a function of hydrostatic confining pressure between 0.1 and 138 MPa. The results indicate different failure processes in two pressure ranges, a low pressure range between about 0.1 and 7 MPa and a higher pressure range between about 7 and 138 MPa. In the low pressure range slow crack processes are important in failure while in the higher pressure range plastic flow dominates. The pressure dependence of the compressive strength in the low pressure range is attributed to coulomb friction between surfaces of closed shear cracks and from the observed linear increase of the strength with pressure and the angle of the fracture plane a friction coefficient is obtained. Friction coefficients can also be obtained from the ratio of the compressive to tensile strength and directly from the above angle. The friction coefficients obtained from these separate observations are in agreement and this is taken as strong evidence for the importance of this friction in determining strength and mechanical failure. These results clearly establish experimentally the role of friction in determining strength with or without applied pressure. An empirical relationship between strength, pressure and strain rate is also obtained for this pressure range and the failure strength of EDC37 is more sensitive to pressure than strain rate.

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1. Introduction

Explosives and propellants are often used under conditions of confinement and pressurization. Explosives are confined in projectile cases and are pressurized, during launch by set back forces and during impact by set forward forces. Propellants are confined by the breech and are pressurized by hot gasses during burning. Because of these pressurizations the properties of explosives and propellants under confinement are of interest. The mechanical properties under pressure are needed for both prediction of energetic material behavior through modeling and specifically for safety considerations. Engineering models require material properties data with changing strain rate and pressure for their parameterization and validation. From a safety standpoint, under some circumstances, fracture or yield during the use of explosives can lead to unwanted and hazardous ignitions (Howe et al., 1985; Frey, 1985; Coffee, 1985; Heavens and Fields, 1972). The fracture of propellants during burning can lead to hazardous burning conditions (See Nicolaides et al., 1982). Understanding cracking and yield in explosives is therefore fundamental to their engineering performance and safe use. Because of these considerations a program has been initiated to study the mechanical properties of these materials under hydrostatic pressure (Wiegand, 2000a,b; Wiegand and Reddingius, 2003, 2005a,b) for quasi-static conditions.

The results presented here indicate two pressure ranges in which the mechanical failure properties differ, a low pressure range between about 0.1 and 7.0 MPa and a higher pressure range between about 7.0 and 138 MPa. The damage processes which occur in both pressure ranges are considered, with greater emphasis on the low pressure range.

2. Material and methods

A high pressure chamber designed to contain pressures up to 138 MPa was used to study the compressive mechanical properties as a function of confining pressure (Wiegand, 2000b). Hydraulic oil was used as the confining medium and the sample in the form of a right circular cylinder was protected from the oil by a tight fitting tubular gum rubber or neoprene shroud. A sketch of the sample, shroud and sensors is given in Fig. 1. The ends of the sample were against steel platens and O-ring seals were used to prevent oil from reaching the sample. The confining pressure is taken here as the chamber hydrostatic pressure before the start of and/or during axial compression. In all cases the pressures referred to here are this hydrostatic pressure. The chamber pressure was determined using a SENSOTEC pressure gauge, model JTE/1108-03, calibrated by the manufacturer and mounted at the base of the chamber. In addition, a McDaniel Controls dial pressure gauge was mounted at the

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