

OPEN MATRIX VERY LOW DENSITY EXPLOSIVE FORMULATIONS

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INTRODUCTION

The detonation velocity of an explosive is a function of the chemical energy released in the detonation, the rate at which this energy is released, the initial density of the explosive, the explosive charge diameter, and the degree of charge confinement. Provided that the extrinsic parameters of explosive charge diameter and/or confinement and initiation strength are adequate, then the detonation characteristics become a function of only two intrinsic variables; e.g., chemical energy release of the particular explosive and its loading density. Hence, for a specific explosive the detonation velocity becomes a near-linear function of its loading density.

Nitroquanidine, for example, has been determined (ref. 1) to have the following empirical relationship between detonation velocity and loading density:

$$D = 1.440 + 4.015 \rho \text{ mm}/\mu\text{sec} \quad (1)$$

with ρ in g/cc. This explosive has been reported to be detonable at bulk densities from 1.7 to as low as 0.11 g/cc (ref. 2). In general, however, it is not physically possible to test and evaluate most explosives at densities below about 0.4 g/cc. Furthermore, even if these explosives would be desirable candidates for various applications at these low densities, they could not practically be utilized in such manner; normal handling and storage would cause settling of the loose-pack powder, resulting in malfunction of any device or operation that would be dependent on such low-explosive-density detonation.

Nevertheless, there exist many uses for the low detonation velocities and associated low detonation pressures resulting from the reliable and ideal detonation of low-density explosives. The objective is to reduce the explosive density yet retain integrity of the formulation. To some extent simple dilution of the explosive with an inert material is expedient, but limited in that excessive dilution will preclude detonation of the explosive component. The limit of this technique is reduction of density by a factor of 4 or 5 at most and will affect the critical size and booster-requirements extensively.

There are a number of viable techniques for obtaining low density explosive systems that can be reliably detonated. Some of these have been previously investigated and others are under current investigation. In this paper we will describe

some of these techniques, particularly those we have reported upon in the past, and will then describe another technique under current investigation which has not been exploited to any extent to date but which we believe to be a viable technique.

BACKGROUND

Sadwin (ref. 3) employed low density nitroguanidine for explosive welding. In a somewhat different approach Abegg et al. (ref. 4) utilized low density explosives by dispersing the explosive in an inert plastic. Cook (ref. 5) and Davis (ref. 6) utilized granular ammonium nitrate which was thinly coated with explosives such as nitroglycerine, TNT, tetryl, or HMX. Thus, in Sadwin's work simple reduction of bulk explosive loading, e.g., 0.6 g/cc, resulted in reduced detonation pressures on the order of 28 kbars. In the case of Abegg et al., where low explosive density was achieved by dilution with a plastic inert, detonation pressures as low as 25 kbars were obtained from 10 percent PETN mixed with 90 percent nitropolyurethane. Finally, in the case of Cook and Davis, their postulation was the sensitization of ammonium nitrate into sympathetic detonation with the explosive sensitizers described. The resulting detonation velocities were as low as 1.1 mm/ μ sec, considerably lower than the detonation velocity of ammonium nitrate if such had detonated at the detonation velocity characteristic of its density. Here, again, the reduced detonation velocities resulted in much reduced detonation pressures.

The IIT Research Institute has been conducting investigations into the area of low explosive density detonation for over a dozen years. In general, we have taken diversified approaches. A very successful technique followed the approach of Shackleton (ref. 7) who investigated the use of expanded materials for the attainment of low explosive densities. In our work (ref. 8) various explosives were admixed to polyurethane foams so that upon expanding and curing the final effective loading density of the explosive component was as low as 0.05 g/cc, yet dilution in the polyurethane was only 30 to 70 percent. This technique, however, results in closed cells containing a blowing agent--either carbon dioxide or Freon, depending on the system being used. The explosive component, as particles of explosive, becomes separated from particle to particle by the polyurethane component as well as by the separation caused by the closed cell structure. The difficulty imposed because of this produces a very insensitive explosive formulation and rheological limits on explosive content.

As a result of these limitations we investigated the formulation of explosive systems wherein the explosive component would be deposited upon an open matrix structure; i.e., no closed cells. In this manner the explosive component could be deposited in a continuous layer, or surface, so that initiation and propagation of detonation would be much more readily, and reliably, achieved. A simple example of this technique is a glass wool upon which a surface of explosive is deposited, either by precipitation from a solvent or by vapor deposition. For practical purposes, how-

ever, we also investigated another technique of achieving an open matrix structure which would ultimately allow a processing method conducive to extrusion forming.

PREPARATION TECHNIQUE

Two basic techniques were utilized to prepare open matrix explosive formulations--the first based on an ethyl cellulose matrix, and the second on the glass wool matrix mentioned above.

The ethyl cellulose matrix system is based on the use of acetone as a solvent for ethyl cellulose and the explosive, into which a water soluble salt is admixed and subsequently leached out to provide the open-cell low-bulk density material. Several approaches were tried, and the one that yielded the best results was the following. First of all, the final product was to be an unconfined 2.54-cm square by 27.9-cm long charge, which is equivalent to a volume of 179.8 cc. The final explosive density was to be 0.10 g/cc, and the ethyl cellulose density 0.15 g/cc; from the work reported in Ref. 8 on foamed explosives, we know that a system with these proportions is potentially detonable. Accordingly, 27 g of ethyl cellulose was mixed with 70 cc of acetone and stirred vigorously until a filmy consistency was achieved, whereupon the explosive--18 g of PETN--was blended in. Finally, a sufficient quantity of sodium nitrate crystals, viz. 164 g, to bring the mixture to the desired volume was added; after thorough mixing the entire slurry was spooned into a mold having the desired charge dimensions. The acetone was allowed to evaporate overnight, and at this point the product was a rigid solid material with a firm definite structure. The final step was to leach out the sodium nitrate, a procedure that required no more than several hours. Following this, the resultant matrix was dried in the sun for several hours. The final product was a very light but firm explosive matrix system containing only PETN and ethyl cellulose at densities of 0.10 and 0.15 g/cc, respectively. Weighings of the charge in various stages of the above process verified that none of the explosive and ethyl cellulose was lost and that all of the sodium nitrate had been leached out of the system.

The second technique, based on use of glass wool as a matrix structure, was somewhat more simple. For this we utilized the same mold as before. Glass wool has a bulk density of 0.07 g/cc, which we measured before proceeding. Accordingly, to fill the mold volume at this density required 11.8 g of glass wool, which was cut from the roll and placed in the mold. Next a solution of 18 g of PETN in 120 cc of acetone was prepared (almost a saturated solution), and then poured into the mold over the glass wool. It appeared that the solution distributed itself fairly uniformly in the glass wool. Again, the acetone was allowed to evaporate overnight, whereupon the matrix was removed from the mold. Again we achieved a fairly rigid system, held firm by the continuous PETN crystals that were precipitated upon the glass wool structure. The final weight was approximately 28 g, which was in good agreement with the weight

of materials that went into the system, viz. 28.8 g.

Figure 1 shows a photograph of the two matrix explosive charges prepared by each of the techniques described above. The wires emanating from the ethyl cellulose system are for a continuous detonation velocity probe which was incorporated into the mold before the charge was added.

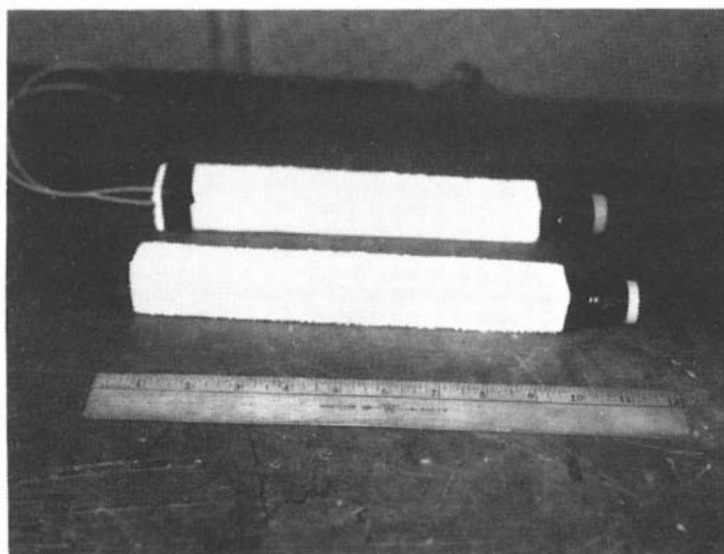


Fig. 1. Photograph of the Two Open-Cell Matrix Explosives (Lower Charge: Ethyl Cellulose Matrix; Upper Charge: Glass Wool Matrix).

EXPERIMENTAL CHARACTERIZATION

Following preparation of the two matrix charges described above, attempts to detonate the charges were made. In each case the booster was 3 g of loose tetryl initiated with a No. 6 electric blasting cap. The loose tetryl was held in place by a cup formed out of black electrical tape. The instrumentation for the ethyl cellulose matrix system was a continuous resistance type probe (ref. 9), and for the glass wool matrix system light pipe probes (ref. 10). The response of these probes was recorded on oscilloscopes equipped with Polaroid cameras.

Neither of these matrix charges detonated, and subsequent inspection of the firing area revealed that significant portions of charge had not even reacted. This however, is not necessarily a discouraging trend. These charges were fired in a completely unconfined condition at a charge size which is probably subcritical for the amount of explosive present, which was at 0.10 g/cc. Reliable performance will be achieved by the proper combination of explosive density, diameter, and degree of confinement.

SUMMARY

In this paper, we have established the feasibility of preparing open-cell matrix explosive charges by two entirely different techniques, one based on a low-density ethyl cellulose matrix and the other on a low-density glass wool matrix. Subsequent attempts to detonate these charges failed, because of a lack of confinement and too small a charge size (diameter). But the intent of this work was to mainly establish the feasibility of the charge preparation techniques, and as such the sizes were deliberately kept small and the confinement minimal until the problems associated with the former could be worked out. Hence, it is not surprising that the two charges as described in this paper, did not detonate. But as a result of the present work, we are now in a position to prepare quality open-cell matrix charges, and the next effort will involve solution of the problems associated with adequate diameter and confinement.

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