Detonation of Metalized Composite Explosives

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4.1 Introduction

From the end of the nineteenth century, readily oxidized ingredients and metals (Mg, Zn, and Al among them) came into use as a component of explosives to increase their fugacity. The first patent on Al incorporation into explosive formulations was given in 1899. Al came into wide use during the First World War as an ingredient of ammonals, in which its content varied from 7.5 to 23% [1]. The studies performed by Kast and actual practice showed that the enhanced properties of the explosives were not the same in all cases; moreover, the increase in fugacity was not observed for all explosives. At the same time, it was found that the addition of Al was accompanied by an increase in both mechanical sensitivity and the sensitivity to heating. According to Kast, grained Al powder, and in some cases Al flakes, offered advantages over fine powders. Reactions of Al with detonation products (DPs) were considered as secondary effects with respect to the explosive decomposition of the base high explosive (HE) [1].

A wealth of experimental data on the detonation performance of Al-containing formulations based on the different types of HE have been acquired over the course of the past century [1–27]. In general, the studies performed do not rule out the inferences of the pioneer works. The investigations are focused on formulations, conditions for their use, and various performance evaluations. The basic scientific questions are whether Al interacts with DPs and what reaction mechanisms occur at the different stages of the expanding products.

Metal-containing explosives are classified into two types. The compositions with a large amount of a HE having a high shock sensitivity and a small critical diameter ($d_{cr}$) are the first type. The second type are “fuel plus explosive oxidizer” mixtures [e.g., ammonium nitrate (AN) or ammonium perchlorate (AP) with a fuel]. The latter are characterized by relatively low detonation performance, low shock wave sensitivity, large infinite detonation diameter ($d_{inf}$), and large $d_{cr}$. Such “commercial” or “industrial” explosives are particularly
nonideal. Their performance has been collated and analyzed in a number of handbooks [10, 14, 22, 26]. Commercial explosives are widely used; however, the study of the macroscopic kinetics of their explosion decomposition is a rather complicated problem because the decomposition proceeds as a multi-phase process.

Binary and ternary metal-containing explosives are based, generally, on HE with low $d_{cr}$, which allows tests to be performed in a laboratory-scale explosion chamber and many experimental investigations of this type have been conducted. The studies usually include measurements of detonation velocity (DV), pressure history or particle velocity history, temperature, acceleration ability, and heat of explosion. Mechanical and shock wave sensitivity, critical diameter, brisance, and fugacity can also be measured. In doing so, the role of the factors controlling the effect produced by incorporating Al into explosives was discovered. The role of the following parameters was examined:

- Metal content
- Metal particle size and particle morphology
- Size of explosive grains
- Density and diameter of the charge
- The origin and oxygen balance (OB) of the base explosive

Progress is being made towards the numerical simulation of the detonation performance of Al-containing explosives. Advantages have been gained in understanding the mechanisms and regularities of the detonation in such materials.

On the basis of the results presented in a number of monographs and reviews [14,15,22,26], one can make some inferences on the Al effect. Incorporation of Al into the formulations (up to 20%) results in an increase in the heat of explosion and fugacity. Brisance is the same as it is for the base explosive (or slightly less). A moderate gain in acceleration ability is observed, while the DV reduces as the concentration of the metal particles decreases. The addition of Al involves a decrease of both pressures and particle velocities. Moreover, in some cases, detonation parameters are reduced more than that with the addition of inert ingredients such as LiF. Most of the aforementioned inferences are based on the data obtained for micrometric Al ingredients, while recently some new techniques for the production of energetic materials with uniformly distributed nanometric components, such as nanoscale Al in an explosive matrix, have been developed. Consequently, there is great motivation to investigate formulations of nanometric Al and HE.

This chapter mainly considers some results on the detonation performance of binary and ternary formulations, based on powerful HEs, including bis(2,2,2-trinitroethyl)nitramine (BTNEN) and ammonium dinitramide (ADN) – organic and inorganic oxidizers, with micrometric and nanometric Al powders. Particular attention has been given to nanocomposite explosives. Since the literature on the subject is quite voluminous, this review is mainly restricted to the results reported in Russia, which may not be available