EFFECT OF Al/AlH₃ AND Mg/MgH₂ COMPONENTS ON DETONATION PARAMETERS OF MIXED EXPLOSIVES

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A comparative calculation and experiments of Al/AlH₃ and Mg/MgH₂ components on the performance and detonation characteristics of mixed compositions on the basis of ammonium nitrate, RDX and HMX was carried out. The results of the comparative experiments and calculations have shown that the detonation velocity in the compositions with aluminum hydride is higher than in the compositions with aluminum powder under conditions of an equal mixture density and equal mass fractions of the components.

INTRODUCTION

The use of mixed high explosives (MHE) with aluminum powder with size of particles < 0.1 makes it actual the problem on correct thermodynamic calculation of aluminum oxidation degree effect on MHE detonation parameters[1]. For aluminum and other active metal powder with small particle size it is possible to expect a high oxidation degree of metal at a Chapman-Jouguet point. Therefore it is possible to expect increase of metal powder effect to the detonation parameters. The developed multiprocess model of detonation predicts a possibility of non-thermal decomposition of complex molecules inside a detonation wave front[2,3]. Therefore it is possible to expect the highly dispersed metal hydride powder will cause stronger effects to the detonation parameters of the mixed explosives in a comparison with metal powder.

In the given work the comparative calculations and experiments on study of aluminum and magnesium powders and just as aluminum and magnesium hydride powders effect on detonation parameters of the mixed explosives on the base of ammonium nitrate (AN), RDX and HMX were carried out. The calculations of the detonation parameters were carried out on three various techniques[4-6]. The numerical simulation of effects of mass fraction of the mentioned energetic components, MHE density, and metal oxidation degree on the detonation parameters of the considered compositions was carried out. The calculation results obtained on various techniques coincided and these results have shown noticeable a distinction in effect of metal powder and metal hydride powder on the MHE detonation parameters.

PHYSICAL MODEL FOR THE CALCULATION OF THE DETONATION PARAMETERS

In a used technique of thermodynamic calculations[4-6] the stoichiometric equation of decomposition reaction of energetic material is taken as a basis. The equations of conservation and selection rule for detonation velocity were used for calculation parameters of detonation

$$\sum_{i=1}^{N} \nu_i X_i \rightarrow \sum_{j=1}^{M} \nu_j Y_j,$$

$$\rho_0 \cdot D = \rho \cdot (D - U),$$

$$P = P_0 + \rho_0 \cdot D \cdot U,$$

$$H = H_0 + (P - P_0) \cdot (V + V_0) / 2,$$

$$D = D_{\min},$$

$$G_\Sigma = G_{\Sigma,\min},$$

where X_i, Y_j are refer to components of the initial composition and the detonation products (DP), ν_i, ν_j are stoichometric coefficients, ρ is the mass density, D, U are detonation velocity and particle velocity, P is the pressure, H is specific enthalpy, V is the specific volume, subscript 0 represents values under standard conditions. The total isobaric-isothermal potential per DP mass unit is calculated on the basis of the additivity condition

$$G_\Sigma = N_k G_k + N_g G_g,$$

where N_k is the moles number of a condensed phase per EP mass unit; G_k is the isobaric − isothermal potential of a condensed phase to one mole of a condensed phase; N_g is the moles number of a gas phase per DP mass unit; G_g is the isobaric − isothermal potential of gas phase to one mole of a gas phase. The equilibrium composition of DP is determined from the condition of total isobaric-isothermal potential minimum at the condition of elements mole number conservation. The calculations of DP pressure were carried out with the use of the BKW equation, with a set of parameters for RDX[4].

The detonation velocity was calculated on the basis of algorithm described by Mader[4].

CALCULATION AND EXPERIMENTAL RESULTS ON DETONATION PARAMETERS OF THE MIXED COMPOSITIONS

It is well known that finely dispersed metal or metal hydride powders are used, in order to increase the efficiency of HE compositions. In particular, the patents[7,8] propose compositions that contain ammonium nitrate (AN) or HE PETN, or HMX etc to be used as oxidizers, while metals (Al, Be, Li, Mg) or their hydrides are to be used as the combustible agents. A comparative quantitative analysis of the influence of a particular metal or metal hydride powder upon the detonation parameters and detonation products (DP) performance would be highly interesting. Previously obtained data[6,9] showed that DP potential is enhanced maximally as a result of using light metal hydrides (i.e. those of Al, Be, Mg). These data served as the basis for the investigation of mixtures containing Al or Mg, or their hydrides. The previously obtained computational and experimental results demonstrated that the introduction of active metal powders into HE compositions with a positive oxygen balance (i.e. into ammonium nitrate) might lead to the detonation parameters enhancement. That is why the comparative calculations of ammonium-nitrate-based compositions would be of interest at the initial stages.

Fig. 1 shows the computational detonation velocity curves of (1) AN/AlH$_3$ and (2) AN/Al that are derived dependently upon the mass fraction of the addition AlH$_3$ or Al. The computations were performed using the method[6] (solid line) and method[5] (markers). Fig. 2 shows the computational detonation velocity curves of (1) AN/MgH$_2$ and (2) AN/Mg dependently upon the mass fraction of the addition MgH$_2$ or Mg. The computations were performed using the same aforementioned methods[5,6] The same relative density $\rho/\rho_{max} = 0.9$ was used in all the calculations. The calculations were based on the assumption that the oxidation of Al and Mg in the detonation wave's chemical reaction zone is complete (i.e. it occurs prior to the point of Chapman-Jouguet). The condensed phase of the detonation products was considered to be incompressible. Besides, the temperature and mass velocity of the gaseous and condensed phases was considered to be the same. As is obvious from the data obtained, provided that all other conditions are equal, aluminum and magnesium hydrides cause a stronger influence on the detonation parameters as compared to the respective metal powders (Al or Mg).
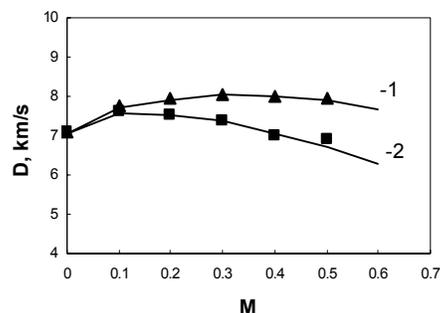

FIGURE 1. DETONATION VELOCITY VERSUS MASS FRACTION OF AlH$_3$ OR Al (1) AN/ AlH$_3$, (2) AN/Al.
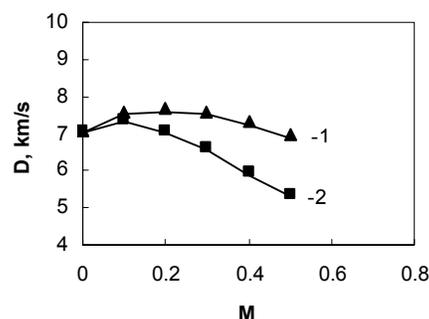

FIGURE 2. DETONATION VELOCITY VERSUS MASS FRACTION OF MgH$_2$ OR Mg (1) AN/MgH$_2$, (2) AN/Mg

Fig. 3 shows the computational detonation velocity curves of (1) RDX/AlH$_3$ and (2) RDX/Al. The computations were performed using the methods[6] (solid line) and method[5] (markers). Fig. 4 represents the computational detonation velocity curves of (1) RDX/MgH$_2$ and (2) RDX/Mg. The symbols at the curves are similar to those of fig. 3. The detonation velocities of the RDX-based compositions were calculated based on the same assumptions as mentioned above for the ammonium nitrate based compositions. As is obvious from the data obtained, provided that all other conditions are equal, aluminum and magnesium hydrides also cause a stronger influence on the detonation parameters as compared to the respective metal powders (Al or Mg). In distinction from the mixtures based on ammonium nitrate, the aluminum hydride or magnesium hydride powder addition do not increase the velocity of an ideal detonation as compared to pure RDX detonation

velocity. It should be noted that the aluminum hydride addition, as compared to magnesium hydride, decreases the detonation velocity to a less extent. The same relative density $\rho/\rho_{max} = 0.9$ was used in all the calculations concerning the RDX-based compositions.
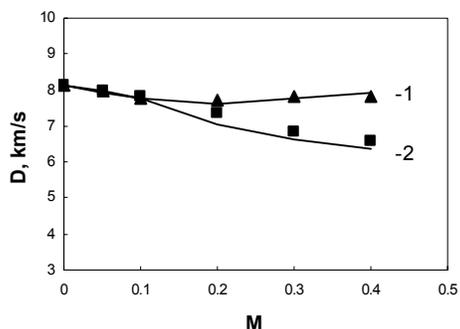

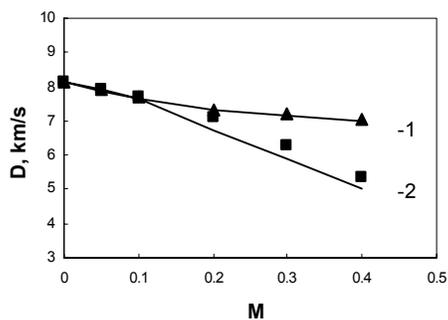**FIGURE 3. DETONATION VELOCITY VERSUS MASS FRACTION OF AlH$_3$ OR Al (1) RDX/AlH$_3$, (2) RDX/Al.**

FIGURE 4. DETONATION VELOCITY VERSUS MASS FRACTION OF MgH$_2$ OR Mg (1) RDX/MgH$_2$, (2) RDX/Mg

Additionally, we have performed a series of computations to define the detonation velocity dependence upon the mass fraction of Al or AlH$_3$ in the mixture with HMX. We used three computational techniques[4,5,6]. These computations were based on the assumption that the density of the compositions was the same, while the mass fraction of such addition as Al or AlH$_3$ was different. The same density $\rho = 1.4$ g/cm^3 was preset for all these compositions. However, it is obvious that the composition porosities differed from one another. The computational results (Fig. 5,6) also revealed that aluminum hydride

decreases the detonation velocities to a much less extent as compared to aluminum, while the mass fraction of Al and AlH$_3$ and composition densities are similar. The following symbols are used in Fig. 5,6, namely: a solid line represents the method[6]; the squares represent the method[5]; and triangulars represent the method[4]. The data obtained as a result of using the aforementioned three computational methods are in a satisfactory agreement.
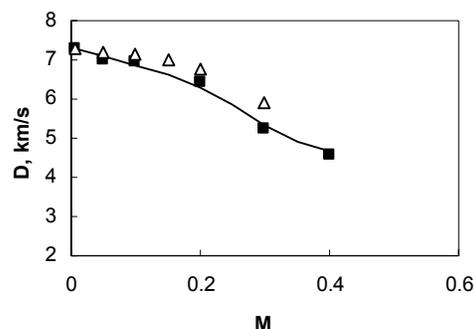

FIGURE 5. DETONATION VELOCITY VERSUS MASS FRACTION OF ALUMINUM IN HMX/Al COMPOSITION.
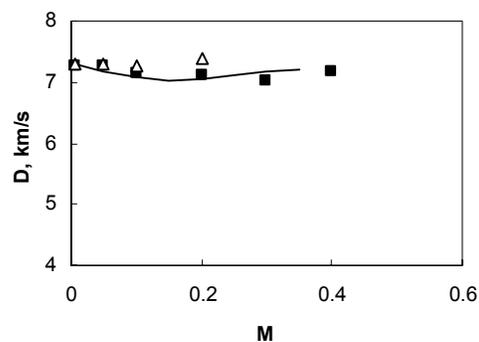

FIGURE 6. DETONATION VELOCITY VERSUS MASS FRACTION OF ALUMINUM HYDRIDE IN HMX/AlH$_3$ COMPOSITION.

In order to verify the computational, results, we have carried out several experiments on determination of the detonation characteristics of the compositions under consideration. We have measured directly the detonation velocities of the HMX-based HE mixtures, in order to define experimentally the influence of aluminum or aluminum hydride on the detonation parameters. The

charges with the density of 1.5 g/cm3 were used in the experiments. The charge diameter and height were 11mm and 33 mm respectively. The content of aluminum or aluminum hydride was varied within the limits of ~ 0 – 25% (of mass). The detonation velocity was measured using electric contact sensors that were installed at the base of 22 mm. Fig. 7 shows the experimental detonation velocity curves versus mass fraction of Al or AlH_3 in the mixture with HMX. The experimental results do not contradict to the computational data. According to the experiments, the aluminum hydride addition reduces the detonation parameters to a less extent than aluminum.
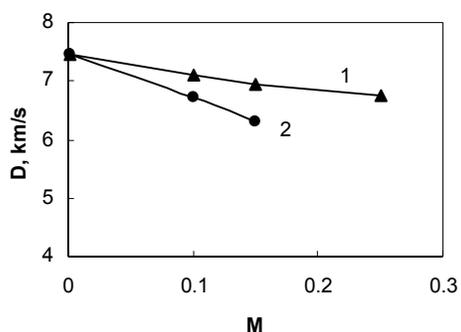

FIGURE 7. EXPERIMENTAL DETONATION VELOCITY VERSUS MASS FRACTION OF AlH_3 OR Al IN COMPOSITIONS (1) HMX/AlH_3 AND (2) HMX/Al.

With respect to the assumptions made for the detonation parameters calculations (i.e. a complete oxidation of aluminum in the point of Chapman-Jouguet), probably, it would be possible to conclude that chemical decomposition of aluminum hydride occurs inside the detonation front (i. e. before a Chapman-Jouguet plane). The developed multiprocess model of detonation predicts a possibility of non-thermal decomposition of complex molecules inside the detonation front[2,3] . That is why it could be expected that a highly dispersed aluminum hydride powder in the HE mixtures would cause a more influential effect upon the detonation parameters than aluminum powder. With allowance for a small duration of shock front effect on aluminum hydride particles the hypothesis about the non-thermal decomposition mechanism of aluminum hydride in detonation wave is represented to be rather probable.

CONCLUSION

We have considered the influence of aluminum, magnesium and their hydride powders on the detonation characteristics of the compositions based on ammonium nitrate; RDX and HMX. The comparative computational and experimental data show that the addition of aluminum hydride, if added to the aforementioned HE compositions, decreases the detonation velocity to a less extent than the aluminum powder, provided that the composition relative or absolute densities and the added mass fraction are similar.

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