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Numerical Simulation of Suspended RDX Dust Detonation in a Shock Tube

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Abstract: Dust detonation of RDX particles suspended in air is numerically studied with two-phase flow model. Behind the leading shock front of detonation, RDX particles are accelerated and heated by the gas flow. Melt of RDX occurrs in the surface of particles. It is assumed that melted part of particle is stripped by the gas flow and decomposition reaction happens instantaneously and energy release to support the propagation of detonation wave. Development and propagation of dust detonation with different concentration is numerically simulated and the parameters of detonation are obtained. Distribution of pressure, temperature, velocity behind leading shock front is calculated. Parameters of dust detonation are determined. At lower concentration of RDX dust, oscillating mode of the of peak pressure history of detonation front occurs. Numerical simulation results showed that as the concentration of RDX dust was more than 0.08kg/m^3 and less than 0.15kg/m^3, history of peak pressure of detonation wave front was regular oscillating. As the concentration was 0.07 kg/m^3, the oscillating was irregular.
Key words: two-phase detonation, RDX dust, ignition

1 Introduction

There are many works on two-phase detonation of gas-liquid fuel droplets and gas-solid metal. In this paper, suspended RDX dust detonation is studied. In two-phase detonation, particle ignition and energy release is the most important to support the propagation of in two-phase detonation. For detonation in gas-liquid system, liquid droplets are stripped and gasified by high velocity and high temperature gas flow behind shock front. Chemical reaction happens in gas phase. For detonation in gas-solid systems, chemical reaction happens as particle temperature reaches to ignition temperature. For RDX particle, because of its low melting point, melting occurs in high temperature gas flow behind shock front of detonation. In this paper, model of energy release of RDX particle behind shock front is suggested and Suspended RDX dust detonation wave is numerically studied.

2 Two-phase flow model for detonation in suspended RDX dust

Detonation in suspended RDX dust in shock wave tube is numerically simulated with two-phase flow model. The flow field is unsteady in one dimensional. The model assumes that RDX particles are uniformly distributed in air and their initial diameter is the same. Temperature in a single RDX particle is uniform. Energy released by Chemical reaction of RDX is only absorbed by gas phase. Following is the description of conservation law of gas and particles. Gas and solid satisfy the conservation laws respectively. There are mass, momentum and energy exchange between the gas phase and solid phase.

In high temperature static gas, temperature of explosive particles increases due to the effect of heat transfer and results in ignition. In detonation, explosive particles heated by convective heat transfer by gas of leading shock wave of detonation wave. As the temperature of particles rises to the melting point of RDX(477K), the surface of the explosive starts melting. In reference of liquid particles stripped by high velocity of gas flow, in calculation it is assumed that the liquefied part of explosive particles is stripped by air and instantaneously decomposed in high temperature gas environment.

3 Results of numerical simulation

RDX particles in shock wave tube are ignited by detonator. In numerical simulation, gas produced by detonator in shock wave tube is simulated by high speed and high temperature gas with the total energy to be equal to the total energy of detonator. Shock tube diameter is 8cm. Figure 1 and 2 is numerical simulation results of detonation of suspended RDX dust in air with 30 μm particle diameter and 750g/m^3 concentration. Figure 1a shows the pressure distribution of flow field behind detonation from 400μs to 2800μs with interval of 400μs. Figure 2 is a distribution of pressure, density, temperature and particle diameter distribution near the detonation wave front. Figure 2a is pressure distribution. In the suspended RDX dust detonation there is a compression wave after leading shock wave, in this region, the gas pressure rise. After the chemical reaction starts, the gas pressure drops. Figure 2b is velocity of gas and particles. The results showed that there is obvious difference between velocity and gas particle velocity. The particles are accelerated after lead shock. As the particle velocity displays to be zero in figure, it indicates that the particle has been completely consumed. Figure 2c is a diagram of temperature change. In the compression area after leading shock wave, temperature rise gradually. In energy release area, temperature rise rapidly. Figure 2d is a particle diameter variation. As the grain is consumed completely, gas pressure and velocity diagram corresponds to the inflection point, and the gas temperature reaches the maximum value.

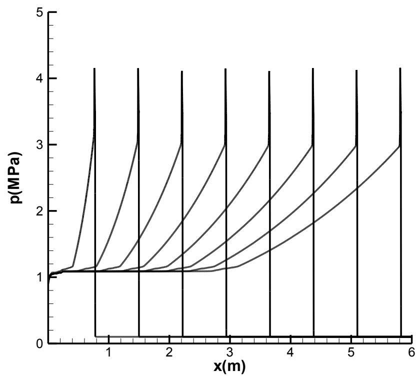
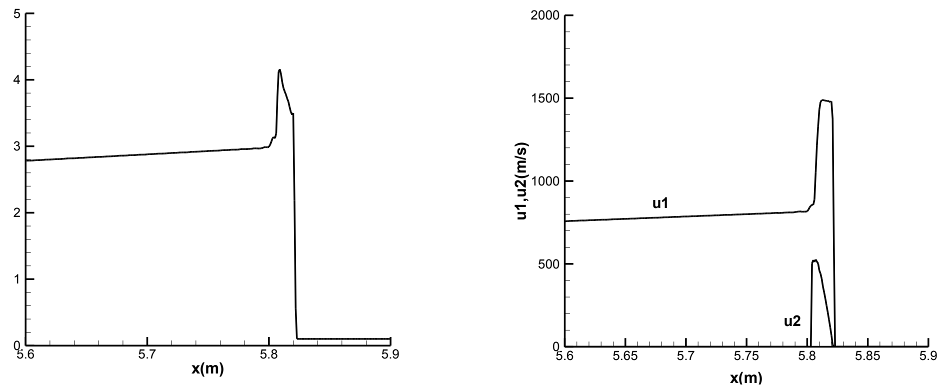
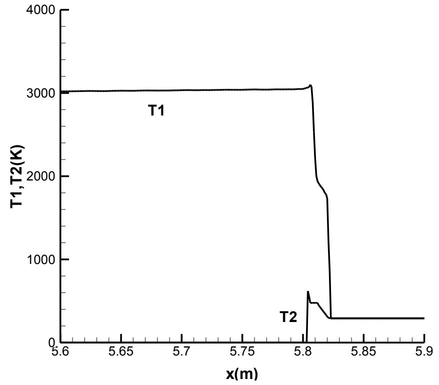


Fig. 1 Pressure profile in the flow field at different time

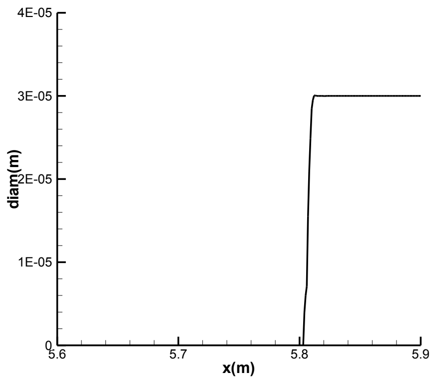


a. pressure distribution

b. velocity distribution



c. temperature distribution



d. particle diameter distribution

Fig.2 Parameters nearby detonation wave front

Table 1 lists the parameters of different concentrations of RDX dust detonation. Figure 3 is the peak pressure of detonation front at different position with different concentration. As the dust concentration with 600g/m^3, 450g/m^3, 300g/m^3, detonation wave tends to be steady quickly after ignited. As the dust concentration is 150g/m^3, oscillation occurs in Peak pressure of detonation front at different position. Figure 4 is peak pressure history with oscillation of detonation front as concentration is 100g/m^3. The periodic oscillation detonation velocity is 882 m/s.

Table 1 CJ parameters of detonation wave with different particle concentration

Concentration g/m^3	D m/s	p_{cj} MPa	ρ_{cj} kg/m^3	u_{cj} m/s	T_{cj} K	p_{max} MPa	Ignition distance mm	reaction zone mm
600	1739	2.53	3.24	769	2878	3.71	12	9
450	1650	2.08	2.94	722	2619	3.21	13	9
300	1508	1.57	2.63	646	2176	2.54	16	9
150	1059	0.72	2.45	428	1001	1.37	33	11

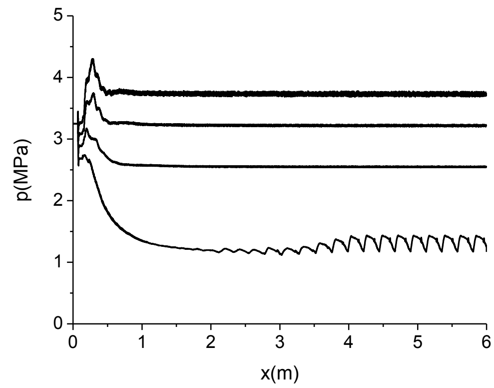


Fig. 3 Peak pressure history of front at different position with different concentration

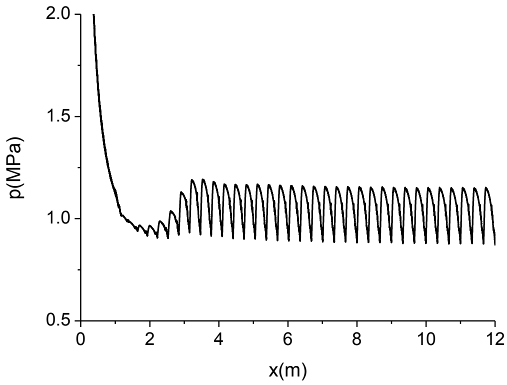


Fig. 4 Peak pressure history of detonation front with concentration of 100 g/m^3

Detonation of suspended RDX dust with low concentration 60g/m^3, 70g/m^3, 80g/m^3 is numerically simulated. It is periodic oscillation as concentration of 80g/m^3. As the concentration of 70g/m^3 oscillation is irregular, but it can form the detonation wave. As the concentration is 60g/m^3, as the leading shock wave propagates to 4m, maximum pressure decreased significantly, it fails to form a detonation wave. This results show that lower limit of detonability of RDX dust is between 60-70 g/m^3.

4 Conclusion

Detonation in suspended RDX explosive dust was numerically simulated by using two phase flow model. In the detonation, explosive particles are heated by convective heat transfer by gas behind leading shock wave of detonation and then melt. In reference of liquid particles stripped by high velocity of gas flow, in numerical simulation it is assumed that the liquefied part of explosive particles is stripped by air and instantaneously decomposed in high temperature gas environment.

The development and propagation process of detonation suspended RDX dust are obtained by numerical simulation with distribution of pressure, density, velocity, temperature in the flow field behind shock waves. As the suspended RDX dust concentration is 0.08-0.15kg/m3, the numerical simulation of detonation wave pressure peak curve appeared to have regular oscillations in the detonation wave. As the RDX concentration was 70 g/cm3, detonation pressure peak curve appeared irregular oscillation detonation wave.

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