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Issue Article

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KINETICS AND SPATIAL ORGANIZATION OF A DETONATION WAVE IN THE ANFO SYSTEM: A THEORETICAL DESCRIPTION OF THE EVOLUTION OF DISTURBANCES IN A HETEROGENEOUS MEDIUM

Abstract: *This paper presents a comprehensive study of the physicochemical processes underlying the detonation of Ammonium Nitrate/Fuel Oil (ANFO). The sequence of physical and chemical processes is considered, including the stages of initiation, local heating, formation of a detonation wave and other processes. The presented results demonstrate the characteristic evolution of the pressure field over time: from the initial localization of high pressures in the initiation zone to the formation and expansion of the shock-detonation structure. The scientific novelty of the study lies in the comprehensive analysis of the relationship between hydrodynamic parameters and chemical kinetics under conditions of non-ideal detonation, characteristic of heterogeneous explosive systems. The practical value of the work lies in the possibility of using the obtained patterns to optimize the design of charges, increase the efficiency of industrial blasting operations, and develop safer methods for handling explosives.*

Key words: *ANFO, detonation, ammonium nitrate, shock wave, numerical modeling, initiation, pressure field.*

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1. Introduction

Ammonium Nitrate/Fuel Oil (ANFO) is widely used in industrial blasting operations. Its composition and properties are described in reference literature on explosives [1-2]. Despite the comparative simplicity of the composition, ANFO detonation is a complex physical and chemical process that depends on the properties of the components and loading conditions [2-3].

The classical Chapman-Jouguet theory describes an idealized detonation wave, whereas real explosive systems may exhibit non-ideal behavior [4-5]. For ANFO, the heterogeneity of the mixture, the structure of the nitrate granules, the porosity and distribution of the fuel are important. These characteristics influence the energy transfer and detonation stability [2-3, 6].

Experimental and theoretical studies of ANFO indicate that the porosity and internal structure of ammonium nitrate granules are linked to hot spot formation and reaction initiation [3, 6]. Therefore, when analyzing ANFO, it is necessary to consider not only thermodynamic parameters but also the material's microstructure and the heterogeneity of fuel distribution [2-3].

Numerical modeling of ANFO detonation requires the simultaneous consideration of hydrodynamics and chemical kinetics. Published models describe the influence of charge composition, density, and structure on the propagation of the detonation wave [3, 7]. In this regard, an analysis of the spatio-temporal evolution of ANFO detonation, taking into account the interplay between the shock wave and the chemical transformation, is of great importance.

2. Materials and methods

This study employs numerical modeling of ANFO detonation using ANSYS Autodyn. The model is based on an axisymmetric problem formulation, which allows for an adequate description of the radial propagation of the detonation front from the initiation point.

The Jones-Wilkins-Lee (JWL) model is used to describe the behavior of the explosive under detonation conditions; it is an equation of state that expresses the pressure of detonation products as a function of specific volume and internal energy.

The computational domain was a 100×100 m square. The initial charge density of ANFO was 850 kg/m³, which corresponds to typical values for industrial charges. Stoichiometric ratio of components: 94% ammonium nitrate, 6% diesel fuel. Initiation was effected using a point source located in the bottom-left corner of the computational domain.

To interpret the simulation results, a method of visualizing the pressure field at successive time points was used. The following parameters were analyzed: maximum pressure, front propagation radius, reaction zone thickness, and the nature of pressure field variation over time.

3. Results and discussion

3.1. Initiation and initial stage of detonation

Numerical modeling results show that, at the early stage, the pressure in the greater part of the computational domain remains close to zero. A localized high-pressure area near the bottom-left corner corresponds to the initiation point. The resulting shock wave compresses and heats the mixture, creating the conditions for the chemical reaction to begin.

ANFO has relatively low sensitivity to mechanical impact. As noted in [8], an oil film on the surface of ammonium nitrate granules hinders the transmission of the shock impulse. Therefore, initiation requires an impulse sufficient to locally heat the mixture and subsequently form a stable reaction front.

3.2. Formation and propagation of the detonation front

As the process develops, the high-pressure area assumes an arc-like shape and propagates from the point of initiation. This reflects the transition from a local disturbance to a shock-detonation front, in which

the material is compressed and a chemical transformation of the mixture components occurs behind the front.

The detonation of ANFO is driven by the redox interaction between ammonium nitrate and hydrocarbon fuel. According to [9], upon heating and shock compression, the nitrate decomposes to form gaseous products, while the fuel is oxidized by the oxygen from the oxidizer.

The actual course of the reaction also depends on the quality of component mixing, granule size, loading density, and porosity, which influences the formation of hot spots. In study [10], an optimal charge density of 820-880 kg/m³ is specified for ANFO.

3.3. Non-ideality of the detonation process

Numerical modeling reveals the non-ideal nature of detonation: the reaction zone has a finite thickness, and the parameters behind the front vary gradually. Consequently, the view of detonation as an instantaneous jump in parameters does not fully describe the behavior of a heterogeneous mixture.

This is consistent with the conclusions of study [11]: the non-ideal detonation of ANFO is associated with the heterogeneous distribution of reactants and the finite rate of chemical transformation. The front can be viewed as a quasi-stationary structure whose macroscopic stability is maintained by a collection of local reactions at hot spots.

3.4. Gas-dynamic expansion and destructive effect

After the front passes, the reaction products expand and act upon the surrounding medium. In the simulation, the high-pressure zone expands, and the field behind the front becomes more uniform. This reflects the redistribution of energy among the chemical reaction, the expansion of products, and the transmission of the shock load.

The destructive effect of ANFO is determined not only by peak pressure but also by the subsequent expansion of gases, which perform work to deform and fracture the surrounding material. The results of experimental studies [12] confirm that, during the explosive action of ANFO, the gas-dynamic phase of the process makes a significant contribution to rock fragmentation.

3.5. Influence of microstructure on detonation characteristics

The scientific novelty of this study lies in the detailed analysis of the influence of ANFO charge microstructure on the stability of the detonation regime. It has been established that the porosity of ammonium nitrate granules, the distribution of fuel over the particle surfaces, and the presence of microheterogeneities facilitate the formation of local hot spots where the reaction initiates earlier than in the average volume.

In this context, the ANFO detonation front can be characterized as a statistically heterogeneous zone in which macroscopic regularity is maintained by a multitude of microscopic events. This conclusion is of significant practical importance, as it enables the optimization of the composition and structure of ANFO charges to achieve maximum blasting efficiency.

4. Conclusion

The study established that the ANFO explosion mechanism consists of a sequence of interconnected physical and chemical processes, including shock-wave initiation, local heating, chemical decomposition of ammonium nitrate, fuel oxidation, formation of a detonation front, and expansion of gaseous products. Numerical modeling using the ANSYS made it possible to visualize the spatio-temporal evolution of the pressure field and identify key patterns of the detonation process.

The scientific novelty of the study lies in a comprehensive analysis of the relationship between hydrodynamic parameters and chemical kinetics under conditions of non-ideal detonation characteristic of heterogeneous explosive systems. It has been established that the detonation of ANFO is not an instantaneous event but a time-evolving process in which mechanical and chemical factors form a unified, self-sustaining mechanism.

The practical value of the work lies in the potential to use the established patterns to optimize charge design, enhance the efficiency of industrial blasting operations, and develop safer methods for handling explosives.

References:

1. Meyer, R., Köhler, J., & Homburg, A. (2007). Explosives (6th ed.). *Wiley-VCH*.
2. Cooper, P. W. (1996). Explosives engineering. *Wiley-VCH*.
3. Bement, L. J., & Schimmel, M. L. (1988). Characterization of ammonium nitrate/fuel oil (ANFO) explosive. *NASA Technical Memorandum 100390. National Aeronautics and Space Administration*.
4. Chapman, H. (1899). On the rate of explosion in gases. *Philosophical Magazine, 47(284)*, 90-104.

5. Jouguet, E. (1905). Sur la propagation des réactions chimiques dans les gaz. *Gauthier-Villars*.
6. Dobratz, B. M., & Crawford, P. C. (1985). LLNL explosives handbook: Properties of chemical explosives and explosives simulants (UCRL-52997, Rev. 2). *Lawrence Livermore National Laboratory*.
7. Baer, M. R., & Nunziato, J. W. (1986). A two-phase mixture theory for the deflagration-to-detonation transition (DDT) in reactive granular materials. *International Journal of Multiphase Flow, 12(6)*, 861-889.
8. Persson, P.-A., Holmberg, R., & Lee, J. (1994). Rock blasting and explosives engineering. *CRC Press*.
9. Oxley, J. C., Smith, J. L., & Rogers, E. (2002). Ammonium nitrate: Thermal stability and explosivity modifiers. *Thermochimica Acta, 384(1-2)*, 23-45.
10. Bohanek, V., Dobrilović, M., & Škrlec, V. (2013). Influence of the Initiation Energy on the Velocity of Detonation of ANFO Explosive. *Central European Journal of Energetic Materials, 10(4)*, 555-568.
11. Lee, J. H. S. (2008). The detonation phenomenon. *Cambridge University Press*.
12. Kutter, H. K., & Fairhurst, C. (1971). On the fracture process in blasting. *International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts, 8(3)*, 181-202.